Diet and forage quality of intermediate wheatgrass managed under continuous and short-duration grazing

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Abstract

Diet quality and forage quality were determined under short-duration and continuous grazing of intermediate wheatgrass (*Agropyron intermedium*) in 72-day grazing trials in 1985 and 1986. The short-duration unit was divided into 8 subunits grazed sequentially for 3 days each. Six crossbred heifers and 2 esophageally fistulated steers were randomly assigned to each grazing treatment. Animals were weighed and fecal samples, pasture samples, and diet (esophageal masticate) samples were collected in each of the three 24-day periods. In vitro organic matter disappearance (IVOMD) of steer diets under short-duration grazing declined linearly across periods of both years and across days within periods in 1986. Crude protein content of steer diets under short-duration grazing declined quadratically across periods in 1986. Crude protein and IVOMD content of steer diets under continuous grazing declined linearly in 1985. The effects of 4 maturities of intermediate wheatgrass on digestibility and ruminal kinetics were compared in a 4×4 Latin square design with 4 ruminally and abomasally fistulated crossbred wethers. Organic matter intake and digestibility, in situ rate and extent of NDF digestion, liquid passage rate and particulate mass flowing from the rumen decreased linearly with increased forage maturity. These data suggested that effects of forage maturity or period of grazing had similar effects on diet quality and forage quality. However, diet quality under short-duration grazing also declined across days within subunits.

Key Words: *Agropyron intermedium*, forage, beef cattle, wethers, digestibility, passage rates

Because the demand for grazing is projected to increase (Reid and Klopfenstein 1983), management systems must be developed to increase range and pasture productivity and efficiency. Maturity of forage plants (Brady 1973) and type of grazing system (Pitt 1986) affect the chemical composition of forage. As forage plants mature, crude protein content and digestibility decrease and fiber fraction concentration increases. Dietary chemical composition and increased forage maturity alter rate of passage (Bull et al. 1979) and fermentation kinetics (Mertens 1977).

Short duration grazing (SDG) may allow greater stocking rates than continuous grazing (Heitschmidt et al. 1982b, Jung et al. 1985). This could be due to increased forage quality and quantity or efficiency of harvest (Heitschmidt et al. 1982b). However, SDG has, in some studies, been shown to have no effect on animal weight gain (Heitschmidt et al. 1982a, Jung et al. 1985). Chemical composition of diet (esophageal masticate) may be the most sensitive measure of change due to grazing management. However, composition of forage selected by animals grazing a cool-season forage under continuous and SDG systems as forage matures has not been reported. These data are needed to adequately evaluate the grazing system by forage maturity interactions and to be used in manage-

ment models to predict animal, plant, and economic performance of alternative grazing systems. Therefore, objectives of these trials were to determine seasonal changes in diet composition and in vivo organic matter digestibility under short duration and continuous grazing and determine effects of intermediate wheatgrass maturity on intake, digestibility, in situ rate of digestion and fluid and particulate passage rates.

Materials and Methods

Grazing Trials

Two 72-day grazing trials were conducted on part of a 48-ha intermediate wheatgrass (*Agropyron intermedium*) pasture in central Washington. The study area was described in detail by Pierson and Scarnecchia (1987). The area was divided by ocular and stratigraphic estimates of equivalent standing crop into 2 units, 1 for SDG and 1 for continuous grazing. The SDG unit was further subdivided into 8 subunits. Short duration grazed subunits averaged .35 ha in both years and the continuously grazed unit was 3.76 and 3.54 ha in 1985 and 1986, respectively.

Six crossbred pregnant heifers (average weight 356 kg) and 2 crossbred steers with esophageal fistulas (average weight 326 kg in 1985, 273 kg in 1986) were randomly assigned to each of the 2 grazing systems. Animals in the continuous grazing treatment grazed the entire unit for 72 days. Initial stocking density on the continuous unit was .8 and .9 AU/ha and on the SDG unit was 1.1 and 1.1 AU/ha for 1985 and 1986, respectively. Animals in the SDG treatment grazed each subunit for 3 days; then, all animals were moved into the next subunit. Therefore, subunits were grazed for 3 days followed by 21 days of rest in each of the 3 periods. Initial stocking density for the SDG subunits ranged from 6.9 to 9.9 AU/ha in 1985 and 6.2 to 11.7 AU/ha in 1986. Stocking variable terminology was according to Scarnecchia and Kothmann (1982) and animal-unit-equivalents were based on the model of Scarnecchia and Gaskins (1987). The 72-day studies were conducted from 18 May to 29 July 1985 and 23 May to 3 Aug. 1986. Mineral supplement (50% dicalcium phosphate and 50% trace mineralized salt[1]) was provided ad libitum.

Twenty-five randomly distributed .5 m² plots were clipped to ground level before and after grazing in each subunit through the 3 rotations to estimate standing crop. In the continuously grazed unit, standing crop was estimated by clipping, to ground level, 40 randomly distributed .5 m² plots at 7-day intervals in 1985 and 24-day intervals in 1986.

In 1985, heifers were weighed on day 1, 2, 7, 8, 9, 31, 32, 33, 55, 56, 57, 71, and 72. Esophageal masticate samples were collected on day 7 to 12 in each period alternating between a.m. and p.m. times of grazing without a previous fast to avoid fasting-induced, selective grazing (Sidahmed et al. 1977). Esophageal masticate samples were frozen (–20° C) until they were lyophilized. Esophageal masticate samples were composited (w/w) by steer, within day 7 to 9 and within day 10 to 12, representing subunits 3 and 4 under SDG,

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[1]97% NaCl, .002% Se, .014% Co, .015% I, .032% Cu, .24% Fe, .31% Mn, .66% Zn.

in each period. Fecal grab samples from heifers were collected on day 7 and 8 in each period, and frozen until subsequent analyses. Subsamples were taken from pasture plots.

In 1986, heifers were weighed on day 1, 2, 7, 8, 31, 32, 55, 56, 71, and 72. Esophageal masticate samples were collected on day 7, 8, and 9 representing subunit 3 under SDG, in each period alternating between a.m. and p.m. collections. Esophageal masticate samples were frozen (−20° C) until they were lyophilized. Fecal grab samples from heifers were collected on day 7 and 8 in each period, and frozen until subsequent analyses. Subsamples were taken from pasture plots.

Fecal grab samples were oven-dried at 50° C and composited (w/w) by animal. Pasture samples were oven-dried at 50° C. All samples were ground through a 1-mm screen in a Wiley mill. Chemical analyses of pasture samples and esophageal masticate samples included crude protein (CP) by macro-Kjeldahl (AOAC 1984), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) according to Goering and Van Soest (1970) and in vitro organic matter digestibility (IVOMD) by the Moore modification (Harris 1970) of Tilley and Terry (1963). Crude protein contents of esophageal masticate were corrected for urea-N content. Urea-N in esophageal masticate was measured by extracting soluble N in 10% Burrough's buffer (Burroughs et al. 1950) at 37° C for 1 hour and measuring ammonia-N by the phenol-hypochlorite method (Weatherburn 1967). All chemical analyses are reported as a percentage of organic matter. Ash-free indigestible acid detergent fiber (IADF) was measured in fecal and esophageal samples according to Nelson et al. (1985). A preliminary study (M.L. Nelson, unpublished data) showed no effect (P>.1) of sampling day within collection period on fecal IADF content of grazing animals. Therefore, animals were assumed to be in steady state conditions. In vivo forage organic matter digestibility (in vivo OMD) was calculated using IADF as the internal marker (Harris 1970).

Digestion Trial

Intermediate wheatgrass was harvested from an adjacent ungrazed portion of the 48-ha seeded field used for the grazing studies. Forage was harvested with a rotary mower and sun-cured at 4 stages of maturity (late boot stage, full head, mature and post ripe) on 26 May, 19 June, 13 July, and 6 Aug. 1985.

Four ruminally and abomasally fistulated crossbred wethers (average weight 82 kg) were randomly allotted to a 4 × 4 Latin square design. Dietary treatments were the 4 stages of maturity of intermediate wheatgrass. Two cells of maturity 1 forage were miss-

ing because we did not harvest enough forage. Wethers were fed, in amounts to allow 20% feed refusals (orts), twice daily at 0700 and 1900. Mineral supplement (50% dicalcium phosphate and 50% trace mineralized salt[1]) was provided ad libitum.

Animals were housed in a temperature-controlled, continuously lighted room. Periods were 11 days in duration, which included day 1 through 7 for diet adaptations and day 8 through 11 for collection of ruminal, abomasal, and fecal samples. Feed intake was determined as feed offered, corrected for orts from day 6 through 9.

Rate and extent of digestion of neutral detergent fiber (NDF) of the 4 diets was determined using 5 × 10 cm dacron bags[2] (pore size $52 \pm 16 \mu$ m). About 2 g of forage, which was previously ground through a 1-mm screen in a Wiley Mill, was placed in each dacron bag. Bags containing the same forage that each sheep was fed were suspended in the rumen at 0700 on day 8. Duplicate bags were removed from each sheep at 4, 8, 12, 24, 48, 72, and 96 hours of incubation. Bags, after removal from the rumen, were frozen (−20° C) until subsequent analysis. Bags were thawed, rinsed with water, and the residue remaining in each bag was quantitatively transferred for NDF analysis.

Rate of liquid passage was determined using a 5-g dose of cobalt lithium ethylenediaminetetraacetic acid (CoLiEDTA) synthesized according to Uden et al. (1980). Rate of particulate passage was determined using a 15-g dose of ytterbium (Yb) labeled forage prepared according to Goetsch and Galyean (1983). Ytterbium-labeled forage contained an average of 8.4 mg Yb/g. An aliquot of forage of each maturity was ytterbium labeled so that labeled forage and the diet of each sheep within a period were the same. Markers in gelatin capsules were administered into the rumen simultaneously with the insertion of dacron bags. Ruminal contents, samples at 0, 4, 8, 12, 24, 48, 72, and 96 hours after dosing, were obtained using a 15-mm diameter rubber tube with a wire running through the center which was attached to a rubber stopper. The tube was inserted through the ruminal strata and then sealed. Each collection was a composite of samples from different sites (ventral sac, dorsal sac, and reticulum) in the reticulo-rumen. Composite samples were strained through cheesecloth to separate liquid from particulate fractions. Contents of the abomasum were sampled at 1000, 1300, 1600, and 1900 on days 8, 9, 10, and 11 in each period, respectively.

[2]R102 Marvelaire White, Erlanger, Blumgart & Co., Inc., New York, NY.

Table 1. Quantity and quality of intermediate wheatgrass under short-duration and continuous grazing.

| | 1985; Period | | | 1986; Period | | | |
Item	1 24–29 May	2 17–22 Jun	3 11–16 Jul	1 29–31 May	2 22–24 Jun	3 16–18 Jul	SEM[a]
Short-duration grazing							
Crude protein, % of organic matter (OM)[c]	8.3	6.3	4.3	9.2	6.2	3.9	0.4
In vitro OM digestibility, %[c,d]	77.6	72.8	65.2	70.3	65.3	60.3	1.0
Standing crop, kg/unit[b]	3503	2847	1732	3240	3184	2026	237
Standing crop, g/m[2b]	125.6	102.1	62.1	116.1	114.1	72.6	8.5
Continuous grazing							
Crude protein, % of OM[c]	9.1	6.2	3.9	9.6	5.6	3.7	0.4
In vitro OM digestibility, %[b,d]	75.8	74.3	68.6	66.7	63.8	61.5	1.1
Standing crop, kg/unit	3504	2460	1352	3199	3397	3005	700
Standing crop, g/m[2b]	93.2	65.4	36.0	90.3	95.9	84.5	18.4

[a]Standard error of the mean.
[b]Linear effect of period (P<.05).
[c]Linear effect of period (P<.01).
[d]Effect of year (P<.01).

Table 2. Composition of steer diets (esophageal masticate) under short-duration and continuous grazing, 1985.

| Item | Period 1 | | Period 2 | | Period 3 | | SEM[b] |
	24–26[a] May	27–29 May	17–19 Jun	20–22 Jun	11–13 Jul	14–16 Jul	
			% of Organic Matter				
Short-duration grazing							
Crude protein[f]	13.4	12.3	12.0	10.9	8.5	7.5	0.5
In vitro OM digestibility[d]	72.1	72.5	70.2	70.9	61.0	60.1	2.3
Neutral detergent fiber[e]	52.2	55.6	52.2	53.5	59.1	58.8	1.6
Acid detergent fiber[e]	30.9	31.6	29.6	30.9	38.0	36.5	1.7
Acid detergent lignin	6.9	5.9	4.5	6.6	9.6	9.1	0.8
Continuous grazing							
Crude protein[f]	13.4	13.0	10.3	8.9	7.3	6.3	1.0
In vitro OM digestibility[f]	69.3	74.6	66.4	61.7	55.5	58.0	2.7
Neutral detergent fiber	53.9	52.4	60.1	57.7	60.1	60.9	6.2
Acid detergent fiber[e]	30.8	29.6	33.8	32.9	37.5	38.6	2.7
Acid detergent lignin	8.3	7.3	6.8	7.6	9.6	12.1	1.2

[a]Under short-duration grazing, first dates under each period were on subunit 3 and second dates on subunit 4.
[b]Standard error of the mean calculated from steer by period by day; n=2.
[c]Linear effect of period ($P<.05$).
[d]Linear effect of period ($P<.05$).
[e]Quadratic effect of period ($P<.10$).
[f]Quadratic effect of period ($P<.05$).

Samples of feed, orts, feces, abomasal contents, and ruminal contents were dried at 50° C in a forced-air oven. Samples of feed, orts, feces, and abomasal contents were ground through a Wiley Mill (1-mm screen). Samples were composited (w/w) by wether within period. Chemical composition of feed, orts, abomasal contents and feces were determined by methods described for the grazing studies.

Samples of ruminal liquid were thawed and centrifuged at $30,000 \times g$ for 20 min. The supernatant was decanted for subsequent Co analysis. Samples of ruminal particulates were prepared for Yb analysis according to the methods described by Ellis et al. (1980). Concentrations of Co and Yb were determined using a Perkin-Elmer model 2380 atomic absorption spectro-photometer (Perkin-Elmer 1971). The natural log of Co or Yb concentration was regressed on hour post-dosing to determine rates of fluid or particulate outflow from the rumen (Grovum and Williams 1973). Ruminal liquid volume was calculated from predicted initial concentration of Co and amount of Co pulse-dosed into the rumen. Ruminal particulate mass was calculated from predicted initial Yb concentration and actual Yb dosage. Particulate mass flowing from the rumen was calculated as the product of ruminal particulate passage rate and ruminal particulate mass (Grovum and Williams 1973). Content of IADF in feed, abomasal, and fecal samples was used as an internal marker to determine digestibility coefficients. Digestibilities in the rumen, lower tract, and total tract were calculated according to Harris (1970). In situ rate and extent of NDF digestion, and discrete lag time were determined by fitting the model of Mertens and Loften (1980).

Statistical Analysis

Grazing Trials

Esophageal masticate composition and in vivo organic matter digestibility were analyzed with split block or repeated measures designs (Gill and Hafs 1971, Steel and Torrie 1980). The model included effects of animal, period, day, and the 2 and 3 way interactions. Animal by period was the error term for animal and period. Animal by period by day was the error term for day and the 2 way interactions with day. Linear and quadratic orthogonal contrasts were calculated for period. Standing crop mass and composition were analyzed with the previously described repeated measures designs. Linear and quadratic orthogonal contrasts were calculated for period. Regression equations were calculated to relate diet quality and in vivo OMD with day of grazing. Additional

equations were calculated to relate diet quality with standing crop composition.

Digestion Trial

Data were analyzed as a 4×4 Latin square (Steel and Torrie 1980). Linear and quadratic orthogonal contrasts for forage maturity were calculated.

Results and Discussion

Grazing Trials

Numbers of animal-units (AU) per grazing treatment calculated according to Scarnecchia and Gaskins (1987) were 2.9 and 3.2 for the beginning and end of the 1985 study and 3.1 and 3.4 for the beginning and end of the 1986 study. Grazing pressures for the SDG subunits ranged from 5.5 to 20 and 6.7 to 19 AU/ton for 1985 and 1986, respectively. Grazing pressures for the continuous unit ranged from .9 to 3.5 and 1.0 to 1.63 AU/ton for 1985 and 1986, respectively. Mean stocking density, calculated from mean animal weight, for SDG subunits ranged from 7.4 to 10.5 and 6.6 to 10.6 AU/ha for 1985 and 1986, respectively. Stocking density for the continuous unit ranged from .8 to .85 and .9 to .96 AU/ha for 1985 and 1986, respectively. System stocking levels were 2.7, 2.8, 2.0, 2.2 AUM/ha for the SDG unit in 1985 and 1986 and the continuous unit in 1985 and 1986, respectively.

Pasture forage (Table 1) under both grazing systems contained similar crude protein (CP) content both years. However, in vitro organic matter disappearance (IVOMD) was greater in 1986 than 1985 for both grazing systems. Pasture forage CP and IVOMD under both grazing systems and standing crop under SDG declined linearly across period.

A primary objective was to identify interactions of period with subunits or days within period. These interactions were expected due to reduced selective grazing across days within an SDG subunit and the possibility of differential effects of a grazing system across period on plant regrowth. Diet chemical composition of steers under SDG in 1985 (Table 2) was not affected by subunit within period. Therefore, no differences due to subunit were detected. Diet CP and IVOMD declined; NDF and ADF increased across period as the plants matured.

In 1986, diet IVOMD of steers under SDG (Table 3) decreased across day within subunit and period. Diet NDF and ADF increased across day within subunit. This indicated that degree of selective grazing was altered across day within subunit as grazing

Table 3. Composition of steer diets (esophageal masticate) under short-duration and continuous grazing, 1986.

Item	Period 1			Period 2			Period 3			SEM[a]
	29 May	30 May	31 May	22 Jun	23 Jun	24 Jun	16 Jul	17 Jul	18 Jul	
	—————————————————— % of Organic Matter ——————————————————									
Short-duration grazing										
Crude protein	18.6	18.0	17.4	13.7	20.8	11.0	16.9	9.1	11.6	4.2
In vitro OM digestibility[b,c]	74.5	71.1	69.5	73.0	67.2	65.1	60.7	65.8	52.4	5.7
Neutral detergent fiber[c]	63.7	72.1	66.3	55.7	65.2	79.9	66.0	76.3	74.2	9.8
Acid detergent fiber[d]	35.3	39.2	36.0	30.6	30.2	43.5	33.0	40.2	41.7	3.7
Acid detergent lignin	5.6	5.3	5.0	4.0	6.4	6.2	6.4	7.0	5.8	.9
Continuous grazing										
Crude protein	17.2	15.3	16.3	13.2	18.0	15.5	11.5	9.8	9.4	3.9
In vitro OM digestibility[e]	75.9	77.8	75.7	73.5	57.0	60.2	58.6	66.3	62.1	2.9
Neutral detergent fiber	60.5	59.7	64.6	60.8	61.7	65.8	71.8	59.7	66.2	5.2
Acid detergent fiber	32.8	33.4	35.5	34.1	37.1	38.4	40.9	34.0	35.5	2.5
Acid detergent lignin[b]	3.3	3.3	4.0	5.0	6.3	5.5	6.5	5.5	5.1	1.1

[a]Standard error of the mean calculated from steer by period by day; n = 2.
[b]Linear effect of period ($P<.10$).
[c]Linear effect of day ($P<.10$).
[d]Linear effect of day ($P<.05$).
[e]Period by day interaction ($P<.05$).

under SDG reduced the availability of the preferred plant parts.

Chemical composition of steer diets under continuous grazing in 1985 (Table 2) was not affected by day within period similar to steers under SDG. Esophageal masticate CP and IVOMD declined and ADF increased across period as the plants matured.

In 1986, diet ADL of steers under continuous grazing (Table 3) increased across period. An exception to the general trend was an increase in IVOMD on day 2 of period 3. No effects of day within period were detected for diet CP, NDF, or ADF, which indicated that degree of selective grazing was not altered across the 3 sampling days in a period under continuous grazing.

A quadratic period by year interaction was detected for in vivo organic matter digestibility by heifers under SDG (Table 4). This

Table 4. In vivo organic matter digestibility of intermediate wheatgrass by heifers under short duration or continuous grazing.

	Year						
	1985			1986			
	Period			Period			
Grazing Management	1 24–25 May	2 17–18 Jun	3 11–12 Jul	1 29–30 May	2 22–23 Jun	3 16–17 Jul	SE[a]
	——In vivo organic matter digestibility, %——						
Short duration[b]	66.4	71.0	58.8	70.0	61.0	54.3	2.0
Continuous[c]	63.5	60.5	51.7	64.9	59.0	51.0	1.3

[a]Standard error of the mean calculated from period by heifer (year) for n = 5.
[b]Quadratic period by year interaction ($P<.05$).
[c]Linear effect of period ($P<.001$).

interaction was apparently due to increased digestibility in period 2 of 1985. However, standing crop IVOMD in 1985 showed only a small reduction from period 1 to 2, which may indicate that standing crop measurements were not good single point predictors of in vivo measurements. In vivo organic matter digestibility (OMD) of heifers under continuous grazing decreased across period from 64.2 to 51.4% similar to standing crop and esophageal masticate IVOMD.

Chemical composition of esophageal masticate is a result of the interaction between chemical composition of forage and selection by the animal. The quantity of forage present can affect diet selection and intake by animals (Hodgson 1981). In 1985, total

herbage available per treatment in period 2 (Table 1) was similar between grazing units. However, standing crop (g/m²) appeared greater in the SDG subunits, which may have provided a greater chance for selectivity.

Significant differences across days in period 1 would not be expected since animals in both grazing systems were grazing homogeneous new pastures. By period 2, regrowth effects allowed expression of differences in plant parts and chemical composition of forage caused by differences in grazing. By period 3, standing crop averaged only 1,540 kg/treatment in 1985 (Table 1); mostly stem remained in both grazing treatments and the homogeneous forage offered little opportunity for selective grazing.

The decline in CP content of esophageal masticate across periods was consistent with reported values (Sims et al. 1971, Kamstra 1973, Rauzi 1975, Svejcar and Vavra 1985). There is wide variation reported for IVOMD of forage varying in maturity, although values reported by Svejcar and Vavra (1985) and White (1983) were similar to the IVOMD of esophageal masticate collected in the present study. Further, Pitts and Bryant (1987) and Taylor et al. (1980) in Texas reported similar rates of change in esophageal masticate contents of CP and IVOMD across collection date under SDG, continuous, or Merrill grazing systems, as in the present study. Greatest differences between in vivo OM digestibilities and IVOMD occurred in periods 1 and 3 with IVOMD being higher in both periods. The lower in vivo OM digestibility in period 1 could have been due to a faster rate of particulate passage which would have reduced in vivo OM digestibility. Increased NDF, ADF, and ADL in esophageal masticate across periods was consistent with reported values (Kamstra 1973, Cogwell and Kamstra 1976, Hart et al. 1983).

Heifer average daily gain under SDG averaged .68 and .89 kg/d in 1985 and 1986, respectively. Heifer average daily gain under continuous grazing averaged .63 and .83 kg/d in 1985 and 1986, respectively.

Digestion Trial

Forage crude protein content declined and forage NDF and ADF content increased with increased forage maturity (Table 5). Forage ADL was not affected by forage maturity. The decline of CP with increased maturity of forage was greater for this study than the CP decline reported by Sims et al. (1971), Kamstra (1973), and Svejcar and Vavra (1985).

Organic matter intake by wethers and digestion coefficients for

Table 5. Effect of maturity of intermediate wheatgrass (harvest date) on composition of organic matter and voluntary intake, digestibility, neutral detergent fiber kinetics, and ruminal passage kinetics of wethers.

Item	Harvest date				SEM[a]
	26 May	19 Jun	13 Jul	6 Aug	
Composition, % of organic matter					
Crude protein[f]	10.5	7.1	4.9	3.8	0.22
Neutral detergent fiber (NDF)[e]	70.1	72.5	74.4	72.9	0.73
Acid detergent fiber (ADF)[e]	41.4	42.2	44.4	43.0	0.43
Acid detergent lignin (ADL)	4.2	5.3	6.3	6.4	1.03
Intake and digestibility by wethers					
Organic matter (OM) intake, g/day[d]	973.2	747.2	563.2	447.0	55.9
OM digestibility, %[b]	70.5	64.2	60.7	58.5	2.5
NDF digestibility, %[c]	75.4	69.8	65.5	62.7	2.0
ADF digestibility, %[c]	76.2	71.0	66.7	65.0	2.0
Nitrogen digestibility, %	83.2	80.1	81.8	83.8	2.0
In situ forage NDF kinetics in wethers					
Digestion lag, hours	−0.1	0.07	1.3	1.2	1.8
Rate of NDF disappearance, %/hour[c]	4.7	4.4	3.4	2.9	0.4
Extent of NDF disappearance, %[c]	82.8	75.5	69.0	64.5	0.9
Ruminal passage rate kinetics of wethers					
Ruminal liquid volume, liters	2.8	3.3	3.3	3.2	0.2
Ruminal liquid passage, rate, %/hour[b]	8.2	7.5	5.9	5.2	0.7
Ruminal particulate mass, kg	1.5	1.7	1.2	1.5	0.2
Ruminal particulate passage rate, %/hour	4.8	4.1	3.9	2.7	1.1
Particulate mass outflow, g/hour[b]	65.8	57.7	45.8	39.8	11.5

[a]Standard error of the mean for n=4.
[b]Linear effect of harvest date ($P<.10$).
[c]Linear effect of harvest date ($P<.05$).
[d]Linear effect of harvest date ($P<.01$).
[e]Quadratic effect of harvest date ($P<.10$).

Table 6. Regression equations predicting composition of esophageal masticate of steers under short-duration and continuous grazing from day of grazing.

Item[a]	Year							
	1985				1986			
	Equation	r^2	Root MSE	P	Equation	r^2	Root MSE	P
Short-duration grazing								
CP	= 14.52 −.10 Day	.89	.84	.004	CP = 18.87 − .11 Day	.61	2.17	.066
IVOMD	= 75.18 − .23 Day	.65	4.06	.053	IVOMD = 74.62 − .25 Day	.72	3.74	.032
NDF	= 49.88 + .14 Day	.60	2.85	.071	NDF = 65.64 + .10 Day	.19	4.98	.392
ADF	= 28.09 + .15 Day	.49	3.59	.120	ADF = 35.66 + .03 Day	.03	4.0	.732
ADL	= 5.24 + .06 Day	.20	2.67	.380	ADL = 5.01 + .02 Day	.23	1.0	.334
Continuous grazing								
CP	= 14.42 −.13 Day	.90	1.02	.004	CP = 18.02 −.12 Day	.52	2.87	.105
IVOMD	= 72.94 − .29 Day	.74	4.07	.028	IVOMD = 76.89 − .30 Day	.69	4.76	.041
NDF	= 53.95 + .13 Day	.11	8.88	.526	NDF = 60.53 + .09 Day	.04	10.46	.701
ADF	= 29.52 + .14 Day	.48	3.49	.125	ADF = 33.79 + .06 Day	.04	6.85	.692
ADL	= 7.40 + .03 Day	.16	1.50	.434	ADL = 3.49 + .05 Day	.63	.83	.058

[a]CP = crude protein, IVOMD = in vitro organic matter disappearance, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin.

OM, NDF, and ADF decreased with increased forage maturity. Post-ruminal digestion coefficients (calculated by difference) were not affected by forage maturity and averaged .8, 1.5, and 3.1% for OM, NDF, and ADF, respectively. Additionally, in situ rate and extent of NDF digestion, rate of liquid passage and particulate mass outflow from the rumen decreased with increased forage maturity. Rate of particulate passage tended to decrease with increased forage maturity.

Regression Relationships

In the grazing trials, rate of decline (Table 6) in diet CP across days of grazing ranged from .10 to .13 percentage units/d. Diet IVOMD declined from .23 to .30 percentage units/d across days of grazing. Regression equations predicting forage CP and OM digestibility by wethers from harvest day after initiation of the grazing trial were Forage CP, % = 10.23 − .08 Day (r^2 = .88, $P<.001$) and

OM digestibility, % = 69.75 − .15 Day (r^2 =, $P<.05$). Forage NDF, ADF, and ADL regressions were not significant and no regressions were improved by fitting quadratic regression lines. In vivo OMD relationships, under SDG, were OMD, % = 61.14 + .78 Day − .02 Day^2 (r^2 = .72, $P<.001$) and OMD, % = 71.91 − .32 Day (r^2 = .64, $P<.001$) for 1985 and 1986, respectively. Under continuous grazing the relationships derived were OMD, % = 66.41 − .24 Day (r^2 = .72, $P<.0001$) and OMD, % = 67.61 − .29 Day (r^2 = .77, $P<.0001$). Differences in potential prediction equations between studies are likely due to differences in animal species, amount of diet selectivity allowed, and forage conservation.

Diet CP and IVOMD content could be adequately predicted from pasture composition. In 1985 under SDG, the relationships derived were Diet CP, % = 3.65 + 1.21 Pasture CP (r^2 = .89, $P<.01$) and Diet IVOMD, % = 1.51 + .92 Pasture IVOMD (r^2 = .70, $P<.05$).

In 1986, relationships under SDG were Diet CP, $\% = 8.45 + 1.04$ Pasture CP ($r^2 = .61$, $P<.1$) and Diet IVOMD, $\% = 1.21$ Pasture CP $- 12.09$ ($r^2 = .72$, $P<.05$). In 1985 under continuous grazing, the relationships derived were Diet CP, $\% = 2.80 + 1.18$ Pasture CP ($r^2 = .90$, $P<.01$) and Diet IVOMD, $\% = 1.91$ Pasture IVOMD $- 75.53$ ($r^2 = .82$, $P<.01$). In 1986, relationships under continuous grazing were Diet CP, $\% = 8.44 + .89$ Pasture CP ($r^2 = .41$, $P<.2$) and Diet IVOMD, $\% = 2.89$ Pasture IVOMD $- 111.88$ ($r^2 = .73$, $P<.05$).

Summary

This study involved 3 trials designed to assess the effects of grazing system and plant maturity on animal and plant responses. In this study, forage quality declined with increased maturity as evidenced by decreased CP and increased fiber fraction contents. In the grazing trials, this decrease in forage quality resulted in decreased quality of forage consumed by animals. In vivo and in vitro digestibility also decreased with increased forage maturity. In the digestion trial, rate and extent of ruminal NDF digestion declined with increased forage maturity. Poppi (1980) suggested that decreased extent of digestion led to decreased rate of passage and a subsequent decrease in intake. This suggestion is supported by data from the digestion trial in which intake and particulate mass flowing from the rumen declined significantly with increased forage maturity.

Grazing systems have been used in attempts to alter chemical composition of plants and, ultimately, intake by ruminants. Although statistical comparisons were not appropriate, these data suggest that effects of maturity were similar under SDG or continuous grazing. It is likely that variables more fundamental than the choice of grazing system are more important in determining seasonal change in forage and diet quality and animal production. Therefore, numerous field studies are needed to develop and validate sound empirical and/or theoretical models of the effects of grazing management on seasonal changes in forage and diet quality and animal production.

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