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Initial Nutritive Value and Utilization Affect Apparent Diet Quality of Grazed Forage

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Abstract

An on-farm study was conducted to measure the effect of forage nutrive value and utilization on diet quality selected by cattle grazing rotationally stocked pastures. In New York 20 paddocks on three farms were grazed by lactating dairy cows or heifers, and in West Virginia 47 paddocks on four farms were grazed by lactating beef cows and calves or yearlings. Most pastures were grazed for one to three days. For each nutritive value component — crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), non structural carbohydrates (NSC), and total digestible nutrients (TDN) — apparent diet quality was calculated as the components calculated mass in the pregrazing forage mass minus the calculated mass in the postgrazing forage mass divided by the forage mass disappearing during grazing. Forage utilization was calculated as pregrazing forage mass minus postgrazing forage mass divided by pregrazing forage mass. Cattle grazed selectively increasing CP, NSC, and TDN and decreasing ADF and NDF in the apparent diet compared to the pregrazing forage. Initial pasture nutritive value had the major effect on apparent diet quality. Forage utilization modified apparent intake by reducing the magnitude of selective grazing.

Nutritive Value of Forage and Selectivity of Grazing Animals

When producing livestock on pasture it is important to know the nutritive value of the forage being consumed by the animals. Following the animals and sampling what they are eating is one option for estimating the quality of the feed being consumed (4). However, random plucking or clipping a pasture prior to grazing may not be adequate because livestock graze selectively. Selective grazing is the ability of animals to consume forage of a quality different than the average forage in the pasture and is dependent on the botanical state of the sward and the physiological state and learning experience of the animal (10,11,14). Mechanisms that account for animals' grazing preferences appear to be related chemical factors such as readily fermentable carbohydrates, crude protein, and anti-quality components that provide feedback to animals when grazing (6,9,10,11).

Other methods for measuring the characteristics of forage consumed during grazing include: the use of esophageal fistulated animals to collect samples for analysis (1,2,3); the use of internal markers such as alkanes, indigestible NDF; or external markers such as ytterbium, chromium oxide, chromium-straw, and chromium mordanted fibrous material. These methods are suited to research station but not for on-farm research.

Macoon et al. (5) used three methods (the pulse-dose marker, animal performance, and forage disappearance) to estimate pasture dry matter intake of grazing lactating cows. They found that clipping before and after grazing provided dry matter intake estimates similar to the animal performance method. However, the pulse dose marker method generally gave estimates greater than animal performance and was not correlated with either of the other two methods. The pre- and postgrazing clipping method can be used relatively easily in either experiment station or on-farm research.

Producers using rotational stocking often take or have advisors take pregrazing forage samples to monitor forage nutritive quality in pastures. These producers need information that relates pregrazing forage nutritive value to diet quality consumed by the grazing herd so that they can develop supplementation strategies and predict the effect of management changes on animal performance. This study was conducted to quantify the effect of pregrazing forage nutritive value and forage utilization on the apparent diet quality of forage consumed by cattle on rotationally stocked cool-season pastures.

On-Farm Experimental Procedures, Design, and Analysis

This study was conducted on 67 paddocks across three farms in New York (Allegany, Cattaraugus, and Wyoming counties in 1989 and 1990) and four farms in West Virginia (Preston, Grant, and Pendleton counties in 1997, 1998, and 1999). In New York 20 rotationally stocked paddocks were grazed by lactating dairy cows or growing beef heifers during midsummer. In West Virginia, 47 rotationally stocked paddocks were grazed by lactating beef cows and their calves or growing yearlings across the growing season from May to October. Paddocks were rotationally stocked for one to three days except for four paddocks that were grazed for four to seven days. Forage samples were taken at uniform intervals along established line transects run across each paddock. Samples were taken at 15 (in West Virginia) or 30 (in New York) points per paddock, from a 1-ft^2 (0.0929-m^2) area clipped to ground level. These samples were composited by paddock and frozen. After grazing another 15 or 30 samples were clipped in the same manner in the near vicinity of the previously clipped samples and frozen. Sward height was measured as compressed forage height using a falling plate meter (12) at 30 (West Virginia) and 60 (New York) points in each paddock. Clipped samples were thawed and forced ambient air-dried (New York) or oven-dried at 55°C and allowed to air equilibrate (West Virginia), then weighted for a preliminary air-dry weight. Samples were packaged in plastic bags and sent to a commercial forage testing laboratory (Dairy-One, Ithaca, NY) for NIR forage analysis for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), non structural carbohydrates (NSC), and total digestible nutrients (TDN). The New York dataset was used as part of the laboratory's calibration or validation data for NIR analysis of forage samples (r^2 and standard error of calibration were: CP 0.98, 0.72; ADF 0.96, 1.35; NDF 0.97, 2.31). The laboratory oven-dry weight was used to adjust the air-dry weight to dry weight for estimating pasture forage mass.

The apparent diet quality for CP, ADF, NDF, NSC, and TDN was calculated as the quality of forage disappearing during grazing. For quality component X, the apparent diet quality (DQ) of X (X_{DQ}) is the calculated mass of X in the pregrazing initial forage mass [initial forage mass (Y_{IFM}) times concentration of X in the initial forage mass (X_{IFM})] minus the mass of X in the postgrazing residual forage mass [residual forage mass (Y_{RFM}) times concentration of X in the residual forage mass (X_{RFM})] divided by initial forage mass minus the residual forage mass as follows:

$$X_{DQ} = \left[(Y_{IFM} * X_{IFM}) - (Y_{RFM} * X_{RFM})\right] / (Y_{IFM} - Y_{RFM})$$

Forage utilization (FU) was calculated as forage disappearance during graze expressed as a fraction of the pregrazing forage mass:

$$FU = (Y_{IFM} - Y_{RFM}) / Y_{IFM}$$

Paddock sampling was conducted under weather conditions and in a manner to reduce dry matter losses from treading damage. However, some loss probably occurred causing some error in estimates. In addition to the 67 paddocks listed four other paddocks were excluded from analysis due to sampling error that resulted in their being extreme outliers in apparent intake.

Statistical analysis was conducted using multiple regression (8) to measure the effect of initial forage mass concentration of the respective chemical component (CP, ADF, NDF, NSC, and TNC), forage utilization, pregrazing forage mass, postgrazing forage mass, pregrazing sward compressed height, and postgrazing sward compressed height on apparent diet quality concentration of the respective component in the forage removed during grazing. When a regression coefficient, including the intercept, was not significantly different from zero ($P < 0.05$) the coefficient was removed from the regression.

Nutritive Value of Pastures and Effect on Apparent Diet Quality

Plant species present in the paddocks represented the range of species present in rotationally stocked pastures in the region. These included orchardgrass (*Dactylis glomerata* L.), bluegrass (*Poa* sp.), bentgrass (*Agrostis* sp. L.), timothy (*Phleum pratense* L.), quackgrass [*Elymus repens* (L.) Gould], smooth bromegrass (*Bromus inermis* Leyss.), tall fescue [*Lolium arundinaceum* (Schreb) S.J. Darbyshire.], white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.), alfalfa (*Medicago sativa* L.), birdsfoot trefoil (*Lotus corniculatus* L.), plantains (*Plantago* sp.), and dandelions (*Taraxacum officinale* F.H. Wigg.). Individual paddocks differed in the predominant grass and usually contained two to three grasses and one or two legumes.

There was a large range in quality component concentration, pre- and postgrazing forage mass and height, and forage utilization across paddocks (Table 1). There were high correlations between nutritive value components in the pregrazing and postgrazing forage mass (Table 2). The correlation between pregrazing forage mass and postgrazing forage mass (0.82) and pregrazing forage mass and utilized forage mass (0.88) were high. Regressions run using utilized forage mass gave r^2 and regression SD values equivalent to regressions using forage utilization. Regressions run using residual forage mass were similar for CP but were not significant for TDN, ADF, or NDF. Only regressions using forage utilization are presented because forage utilization had a lower correlation with pregrazing forage mass than did postgrazing forage mass or utilized forage mass and was not significantly correlated with pregrazing concentration of CP or ADF and only slightly correlated with pregrazing concentration of NDF, TDN, and NSC.

Table 1. Mean, standard deviation (SD), minimum (Min), and maximum (Max) values for pregrazing initial forage mass (IFM), postgrazing residual forage mass (RFM), IFM compressed height (IFM_{HT}), RFM compressed height (RFM_{HT}), utilized forage mass (FM_{UTIL}), forage utilization (FU), IFM quality and apparent diet quality (DQ) across pastures in New York and West Virginia (N = 67).

Measure	**Mean**	**SD**	**Min**	**Max**
	Pre- and postgrazing pasture characteristics			
IFM	2800	1259	1271	6127
RFM	1615	668	427	3486
IFM_{HT}	5.43	1.63	2.49	11.61
RFM_{HT}	2.51	0.59	1.52	4.01
FM_{UTIL}	1184	806	205	3536
FU	0.40	0.15	0.11	0.80
	Pregrazing forage quality			
ADF_{IFM}	34.1	4.4	25.8	43.0
CP_{IFM}	14.2	3.7	7.7	23.9
NDF_{IFM}	56.2	6.5	38.8	66.3
NSC_{IFM}	17.3	4.4	4.7	26.4
TDN_{IFM}	60.3	4.2	51.7	69.0
	Apparent intake diet quality			
ADF_{DQ}	28.7	8.8	-1.5	42.6
CP_{DQ}	17.0	5.9	4.7	31.5
NDF_{DQ}	50.6	15.2	-18.7	73.5
NSC_{DQ}	20.8	14.2	-3.9	89.5
TDN_{DQ}	65.7	8.7	52.3	91.5

ADF = acid detergent fiber.
CP = crude protein.
NDF = neutral detergent fiber.
NSC = non structural carbohydrates.
TDN = total digestible nutrients.

Table 2. Correlation matrix of forage chemical components and physical measurements. Only correlation coefficients that were significant at the $P < 0.01$ level are shown.

	IFM_{HT}	IFM	CP_{IFM}	ADF_{IFM}	NDF_{IFM}	TDN_{IFM}	NSC_{IFM}	RFM_{HT}	RFM	FU	FM_{UTIL}	CP_{DQ}	ADF_{DQ}	NDF_{DQ}	TDN_{DQ}	NSC_{DQ}
IFM_{HT}																
IFM																
CP_{IFM}		-0.50														
ADF_{IFM}		0.58	-0.79													
NDF_{IFM}		0.37	-0.82	0.82												
TDN_{IFM}		-0.53	0.55	-0.69	-0.65											
NSC_{IFM}			0.44	-0.67	-0.82	0.58										
RFM_{HT}	0.60					0.43										
RFM		0.82	-0.39	0.45		-0.33										
FU		0.32			0.36	-0.35	-0.34	-0.37								
FM_{UTIL}		0.88	-0.46	0.54	0.41	-0.56			0.45	0.70						
CP_{DQ}		-0.51	0.83	-0.69	-0.71	0.50	0.41		-0.35	-0.33	-0.51					
ADF_{DQ}		0.43	-0.33	0.60	0.50	-0.44	-0.53			0.38	0.47	-0.50				
NDF_{DQ}		0.33	-0.34	0.46	0.59	-0.44	-0.60			0.39	0.38	-0.51	0.80			
TDN_{DQ}		-0.38		-0.46	-0.40	0.56	0.42			-0.44	-0.47	0.39	-0.85	-0.64		
NSC_{DQ}					-0.34		0.55			-0.31			-0.74	-0.86	0.65	

IFM_{HT} = pregrazing initial forage mass compressed height
IFM = pregrazing initial forage mass
CP_{IFM} = crude protein in the pregrazing initial forage mass
ADF_{IFM} = acid detergent fiber in the pregrazing initial forage mass
NDF_{IFM} = neutral detergent fiber in the pregrazing initial forage mass
TDN_{IFM} = total digestible nutrients in the pregrazing initial forage mass
NSC_{IFM} = non structural carbohydrates in the pregrazing initial forage mass
RFM_{HT} = postgrazing residual forage mass compressed height
RFM = postgrazing residual forage mass
FU = forage utilization
FM_{UTIL} = utilized forage mass
CP_{DQ} = apparent diet quality CP
ADF_{DQ} = apparent diet quality ADF
NDF_{DQ} = apparent diet quality NDF
TDN_{DQ} = apparent diet quality TDN
NSC_{DQ} = apparent diet quality NSC

The diet quality selected by rotationally stocked cattle increased the apparent intake of CP, NSC, and TDN and decreased the apparent intake of ADF and NDF compared to the concentration of these components in the pregrazing forage mass. The factors that produced significant regression coefficients were concentration of the nutritive value component in the pregrazing forage mass ($P < 0.001$ for all components) and forage utilization ($P = 0.031$, 0.017, and 0.035 for CP, TDN, and ADF, respectively) (Table 3). The regression intercept was only significant for the apparent intake of ADF ($P = 0.007$).

Table 3. The effect of pregrazing initial forage mass (IFM) concentration of CP, TDN, NSC, ADF, NDF, and forage utilization (FU) on apparent diet quality (DQ) of the forage components.

Component	Regression			R^2	SD_{reg}
CP_{DQ} =		1.32 CP_{IFM}	– 4.37 FU	0.97	3.2
TDN_{DQ} =		1.17 TDN_{IFM}	– 12.8 FU	0.99	7.0
NSC_{DQ} =		1.54 NSC_{IFM}	– 14.7 FU	0.78	11.8
ADF_{DQ} =	– 14.2	+ 1.09 ADF_{IFM}	+ 14.4 FU	0.42	6.8
ADF_{DQ} =		0.69 ADF_{IFM}	+ 13.3 FU	0.95	7.0
NDF_{DQ} =		0.75 NDF_{IFM}	+ 22.4 FU	0.95	12.4

CP = crude protein.
TDN = total digestible nutrients.
NSC = non structural carbohydrates.
ADF = acid detergent fiber.
NDF = neutral detergent fiber.

Regressions for CP, TDN, and NSC imply that the apparent diet quality intake for these components was proportionally greater than the pregrazing concentration (component regression coefficient > 1). But, as forage utilization increased there was less selectivity (FU regression coefficient < 0) probably because the animals choices were reduced. This is in keeping with previous research where cattle diets were higher in CP and lower in ADF than the standing crop with animals taking more bites from preferred forages; and as stocking rate increased selection pressure increased most on more desirable species (2,3,7,9,15).

The regression for diet quality ADF implies a constant selection against forage with high ADF (negative intercept), a proportional effect of pregrazing forage ADF concentration (component regression coefficient > 1), and reduced selection as forage utilization increased (FU regression coefficient > 0). When the intercept value for the ADF regression was removed there was little change in the regression SD and the regression coefficients were similar in magnitude to those for NDF. The regression for NDF implies a proportional selection against forage with high NDF (component regression coefficient < 1) with a positive effect of forage utilization (FU regression coefficient > 0); implying that the animals selected for forage lower in ADF and NDF but as forage utilization increased there is less ability to be selective due to less choice.

Pregrazing quality component concentration and forage utilization had different magnitudes of effect on the ability of cattle to select diets of higher quality than initially present in the paddock (Table 4). For CP, TDN, and NSC apparent diet quality was 2 to 9 units higher than pregrazing concentrations when utilization was low (0.20). As forage utilization increased to 0.60 apparent diet quality for these components was only -2.6 to 3.8 units higher than pregrazing concentrations. This indicates that when pastures are grazed to a shorter height the animal’s ability to selectively graze decreases. At low levels of forage utilization selection for diets low in ADF did not vary much between pastures differing in pregrazing ADF concentrations while the magnitude of selection for diets low in NDF where greater as NDF concentration increased (Table 4). This would be expected because grasses are higher in NDF than legumes but somewhat similar in ADF at a given maturity (13). This allows for a greater selectivity for NDF than ADF in a paddock where the age of forage growth is controlled through rotational stocking. As forage utilization increased the ability to select diets low in these fiber types decreased.

Table 4. Apparent diet quality (DQ) of forage nutritive value components due to selective grazing calculated from regressions using different levels of pregrazing initial forage mass (IFM) nutritive value and levels of forage utilization; values represent the 10, 25, 50, 75, and 90 percentile rankings of the measures.

IFM nutritive value measure	**Concentration**	**Forage utilization**				
		0.20	0.27	0.41	0.49	0.60
		CP_{DQ}				
CP	9.1	11.1	10.8	10.2	9.9	9.4
	11.2	13.9	13.6	13.0	12.6	12.2
	14.2	17.9	17.6	17.0	16.6	16.1
	17.1	21.7	21.4	20.8	20.4	20.0
	19.2	24.5	24.2	23.6	23.2	22.7
		TDN_{DQ}				
TDN	54.5	61.2	60.3	58.5	57.5	56.1
	56.4	63.4	62.5	60.7	59.7	58.3
	61.2	69.0	68.1	66.4	65.3	63.9
	63.3	71.5	70.6	68.8	67.8	66.4
	65.2	73.7	72.8	71.0	70.0	68.6
		NSC_{DQ}				
NSC	11.5	14.8	13.7	11.7	10.5	8.9
	14.5	19.4	18.4	16.3	15.1	13.5
	17.6	24.2	23.1	21.1	19.9	18.3
	20.1	28.0	27.0	24.9	23.8	22.1
	23.3	32.9	31.9	29.9	28.7	27.1
		ADF_{DQ}				
ADF	28.1	19.3	20.3	22.3	23.5	25.1
	31.4	22.9	23.9	25.9	27.1	28.7
	34.0	25.7	26.7	28.8	29.9	31.5
	37.3	29.3	30.3	32.4	33.5	35.1
	39.8	32.1	33.1	35.1	36.2	37.8
		NDF_{DQ}				
NDF	47.2	39.9	41.4	44.6	46.4	48.8
	52.6	43.9	45.5	48.6	50.4	52.9
	56.2	46.6	48.2	51.3	53.1	55.6
	62.1	51.1	52.6	55.8	57.6	60.0
	64.8	53.1	54.6	57.8	59.6	62.0

CP = crude protein.
TDN = total digestible nutrients.
NSC = non structural carbohydrates.
ADF = acid detergent fiber.
NDF = neutral detergent fiber.

Summary and Implications

Apparent intake of forage CP, NSC, and TDN is highly related to their concentration in the pregrazing forage mass, with apparent diet quality of these nutrients being higher than that in the pregrazing forage mass. As forage utilization increased selective grazing for CP and TDN decreased and apparent intake came more in line with their concentration in the pregrazing forage mass. The apparent intake of NDF was likewise affected by pregrazing forage mass concentration and forage utilization. In paddocks high in NDF there was a strong dietary selection against NDF, whereas in paddocks low in NDF there was less selection against NDF. In all cases selection against NDF declined with increasing forage utilization. The use of low forage utilization to allow for selective grazing has some merit but does not appear to be a practical method to compensate for low forage nutritive value. When forage nutritive value is low the manager may best meet grazing animal needs by removing the low quality forage by close grazing with livestock that do not require high forage quality or by harvesting the area for conserved feed, allowing the forage to regrow; grazing it when it is young and of higher nutritive value.

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