Effects of Chemical Composition on Forage Intake of Heifers Fed Hays of Different Species

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Summary

Alfalfa, smooth bromegrass, and big bluestem hays harvested at two maturities differing by four weeks were fed at mature-to-immature hay ratios of 1:0, 2:1, 1:2, and 0:1 to yearling heifers in an experiment with a three 4 x 4 Latin square design with 14 day periods. Concentrations of in vitro digestible dry matter and crude protein were greater and concentrations of neutral detergent fiber, acid detergent fiber, and indigestible neutral detergent fiber (determined by either a manual method with a 96 hour incubation or an automated method with a 48 hour incubation) were less in alfalfa hay than in the two grass hays and in smooth bromegrass hay than in big bluestem hay. Concentrations of in vitro digestible dry matter and crude protein decreased whereas those of neutral detergent fiber, acid detergent fiber and indigestible neutral detergent fiber increased with increasing forage maturity. Consumptions of dry matter, digestible dry matter, in vitro digestible dry matter, and crude protein were greater for heifers fed alfalfa hay diets than those fed the two grasses. Consumptions of total neutral detergent fiber and indigestible neutral detergent fiber, determined by the automated method with a 48 hour incubation, were greater by heifers fed diets containing big bluestem than those fed alfalfa or smooth bromegrass diets. Consumptions of acid detergent fiber and indigestible neutral detergent fiber, determined by a manual method with a 96 hour incubation, were greater for heifers fed alfalfa or big bluestem hay diets than those of heifers fed smooth bromegrass diets. Consumption of dry matter, in vivo or in vitro digestible dry matter, crude protein, neutral detergent fiber, acid detergent fiber and automated indigestible neutral detergent fiber decreased as the mature-to-immature hay ratio decreased. Diet digestibility was not affected by forage species, but increased as the mature-to-immature hay ratio decreased. Fecal excretion of dry matter and neutral detergent fiber did not differ between forage species or mature-to-immature hay ratios. Forage dry matter intake expressed as a percentage of body weight was significantly related to the concentrations of in vitro digestible dry matter (r^2=.14), crude protein (r^2=.17), neutral detergent fiber (r^2=.20), and manual indigestible neutral detergent fiber (r^2=.18) of the hays and the concentration of digestible dry matter of the diets (r^2=.43).

Introduction

Because intake accounts for approximately two-thirds of the variation in the productive performance of cattle fed forages, the ability to predict forage intake is essential to predict animal performance and develop balanced supplementation programs. Because of its relationship to the volume occupied by forage cell walls in the rumen, neutral detergent fiber (NDF) concentration, a measure of forage cell walls, has been used to predict forage intake by ruminant animals. This approach has been particularly effective in ruminant animals fed stored forages of a single species harvested at different maturities. However, because of the different cell wall structure of different forage species, the rate and extent of cell wall digestion in different forage species may vary. Therefore, the relationship between forage total NDF concentration in mixed species forages, as would occur in most pastures, is weak and of little value in prediction equations.

Although rates and extents of cell wall digestion vary widely between different forage species, the relationship between the amount of lignin and the amount of cell wall that is truly indigestible is relatively constant between many forage species. Because this indigestible cell wall occupies volume within the rumen until removed by digesta passage, it should be highly related to forage intake, across species.

Therefore, the objective of this project was to evaluate the relationship between the concentration of indigestible NDF and other cell wall components and dry matter intake by growing heifers fed hays of different legume, cool season grass and warm season grass species.

Materials and Methods

In the summer of 1997, second harvest alfalfa, smooth bromegrass and big bluestem forages were mowed, sun-cured, and baled as large round bales at two maturities. Immature alfalfa was harvested at the one-tenth bloom stage and immature smooth bromegrass and big bluestem were harvested at seedhead emergence. Mature forages of each species were harvested four weeks after immature forages were harvested. Bales were stored outside on tires until initiation of the feeding experiment in February. Prior to initiation of the feeding experiment, the rotted outer layer of hay on each bale was removed, and the hay in the unweathered core of each bale was ground through a two inch by three inch screen of a tubgrinder and stored in a barn.

Twelve yearling crossbred heifers (initial weight, 744 lb) were allotted to three groups of four. Each group of heifers was fed one of the three forage species at four mature-to-immature forage ratios (100:0, 67:33, 33:67, and 0:100) in a 4 x 4 Latin square design experiment with 14 day periods. Forages were individually fed twice daily at a level allowing a 10% weighback of uneaten feed with four pounds of a soybean meal-based supplement per day (Table 1) to ensure that crude protein was not limiting intake. The first seven days of each period were used to adjust heifers to the diets and the last seven days were used for recording of intake data. Feed samples were collected from day 10 to 12 of each period. To estimate fecal output, 1 gm of chromic sesquioxide was added to the soybean supplement at each feeding during day 8 to 14. Rectal fecal samples were collected twice daily before feeding on days 12 through 14 in each period.

Hay, supplement, uneaten feed and fecal samples were dried at 60°C for 48 hours and analyzed for in vitro digestible dry matter, crude protein, neutral detergent fiber and acid detergent fiber. Indigestible fiber concentrations of the hay, supplement and uneaten feed samples were determined by two methods. In one method (manual method), samples were weighed into 50 ml centrifuge tubes and incubated with McDougall's buffer solution and rumen fluid in sealed tubes for 96 hours. The digestion mixture was washed into a 600 ml Berzelius beaker with neutral detergent solution, refluxed for one hour and filtered onto filter paper. After drying, paper and undigested residues were weighed. In the automated procedure, samples were weighed into fiber bags and incubated for 48 hours in rumen fluid in a rotating incubator. After incubation, bags were placed in an Ankom fiber analysis apparatus and washed in neutral detergent. After drying, bags and undigested residues were weighed. To estimate fecal output, the chromium concentration of fecal samples was determined by atomic absorption spectrophotometry of phosphoric acid extracts of ashed samples. All differences observed in the results and discussion section were significant at a probability level of .05.

Results and Discussion

As expected, the concentrations of in vitro digestible dry matter and crude protein were higher and the concentrations of neutral detergent fiber, and acid detergent fiber were lower in alfalfa hay than in the hays of the two grass species across maturity mixtures (Table 2). Similarly, the concentrations of in vitro digestible dry matter and crude protein were higher and the concentrations of neutral detergent fiber and acid detergent fiber were lower in smooth bromegrass hays than in big bluestem hay. Hay species did not affect the indigestible neutral detergent fiber concentration determined by the manual method using a 96 hour incubation, but the concentrations of indigestible neutral detergent fiber determined in an automated method using a 48 hour incubation were lower in alfalfa than in the two grasses and were lower in smooth bromegrass than big bluestem. The differences between the concentrations of indigestible neutral detergent fiber determined by the two methods may have resulted from the different lengths of incubation, particularly for the two grasses, which likely had a higher concentration of slowly digestible fiber still available for digestion after 48 hours than alfalfa.

The proportions of in vitro digestible dry matter and crude protein increased and those of neutral detergent fiber, acid detergent fiber, and indigestible neutral detergent fiber determined by either method decreased as the ratio of mature hay to immature hay fed decreased. The magnitude of these differences for in vitro digestible dry matter, crude protein, acid detergent fiber and automated indigestible neutral detergent fiber, however, differed between forage species resulting in significant species by hay ratio interactions. Although the difference in the in vitro digestible dry matter concentration of mature and immature alfalfas was .2%, differences in mature and immature smooth bromegrass and big bluestem were 9.2 and 8%. Whereas the difference in crude protein concentration of mature and immature alfalfa was 4%, differences in mature and immature smooth bromegrass and big bluestem were 2.5 and 2%. Although the difference in acid detergent fiber concentration of mature and immature alfalfa was 1.3%, differences in mature and immature smooth bromegrass and big bluestem were 7.2 and 5%. And although the difference in automated indigestible neutral detergent fiber concentration of mature and immature alfalfa was .2%, differences in mature and immature smooth bromegrass and big bluestem were 10.9 and 10%, respectively.

Table 1. Composition of supplement fed with mixtures of hays of different forage species.

Ingredient	%, as-fed
Soybean meal	95.91
Salt	2.47
Trace mineral premix	.25
Vitamin A premix	1.37

Table 2. Effects of forage species and mature-to-immature hay ratio on the chemical composition of the hays and diets.

	Forage species (sp) and mature:immature hay ratio (r)														
	Alfalfa				Smooth bromegrass				Big bluestem				Significance[a]		
Item	1:0	2:1	1:2	0:1	1:0	2:1	1:2	0:1	1:0	2:1	1:2	0:1	sp	r	sp*r
	----------% DM----------														
Hay															
IVDDM[b]	56.4	56.4	56.5	56.6	43.3	46.4	49.5	52.5	39.1	41.7	44.4	47.1	**	**	**
CP	15.9	17.1	18.3	19.5	7.4	8.5	9.8	10.9	3.7	4.4	5.0	5.7	**	**	*
NDF	51.4	51.2	51.0	50.8	62.8	60.8	58.8	56.9	71.4	70.4	69.3	68.2	**	**	N
ADF	33.9	33.5	33.1	32.6	35.9	33.5	31.1	28.7	39.8	38.1	36.4	34.8	**	**	*
iNDF															
Manual	34.8	32.2	29.5	26.9	37.4	32.7	27.9	23.2	38.7	35.6	32.4	29.4	N	**	N
Auto	30.6	30.6	30.5	30.4	46.7	43.1	39.4	35.8	55.1	51.8	48.1	45.1	**	**	**
Diet															
IVDDM	62.2	62.3	62.1	61.4	54.7	55.9	57.1	59.9	50.5	50.9	52.3	54.2	**	**	**
CP	22.1	23.1	23.9	24.1	18.0	17.9	17.6	19.0	14.4	13.3	13.0	13.3	**	N	N
NDF	45.5	45.2	44.9	45.7	51.7	51.1	50.5	48.2	58.6	59.6	59.7	59.2	**	N	N
ADF	29.9	29.4	29.0	29.1	29.9	28.4	26.9	24.8	32.8	32.6	31.6	30.6	**	**	N
iNDF															
Manual	29.3	26.8	24.1	22.9	28.1	25.3	22.0	18.2	29.1	27.8	26.0	24.1	N	*	N
Auto	24.9	25.0	25.1	25.8	34.8	33.3	31.6	28.4	42.3	41.6	39.7	37.2	**	**	N

[a] Significance levels: N, Not significant; *, P<.05; **, P<.01.

[b] Abbreviations: IVDDM=In vitro digestible dry matter; CP=Crude protein; NDF=Neutral detergent fiber; ADF=Acid detergent fiber; and iNDF=Indigestible neutral detergent fiber.

After adjustment for the composition of supplements and uneaten feed, diets containing alfalfa hay had higher concentrations of in vitro digestible dry matter and crude protein and lower concentrations of neutral detergent fiber, acid detergent fiber and automated indigestible neutral detergent fiber than diets containing hays from the two grasses. Similarly, diets containing smooth bromegrass hay had higher concentrations of in vitro digestible dry matter and crude protein and lower concentrations of neutral detergent fiber, acid detergent fiber and automated indigestible neutral detergent fiber than diets containing big bluestem hay. The concentration of in vitro digestible dry matter increased and the concentrations of acid detergent fiber, manual indigestible neutral detergent fiber and automated indigestible neutral detergent fiber decreased as the ratio of mature hay to immature hay decreased. Although the concentration of in vitro digestible dry matter in the immature alfalfa hay diet was actually .8% lower than mature alfalfa hay diet, in vitro digestible dry matter concentrations of diets containing immature smooth bromegrass and big bluestem hays were 2.2 and 3.7% greater than diets containing their respective mature hays. Concentrations of crude protein and neutral detergent fiber in the diets were not affected by the ratio of mature-to-immature hay.

Heifers fed diets containing alfalfa hay consumed greater quantities of dry matter, digestible dry matter, in vitro digestible dry matter, and crude protein than heifers fed diets containing either of the grass hays (Table 3). Heifers fed diets containing big bluestem hay consumed more dry matter and in vivo digestible dry matter than heifers fed diets containing smooth bromegrass hay. Furthermore, heifers fed the diets containing big bluestem consumed more neutral detergent fiber than heifers fed the other two diets, and heifers fed diets containing alfalfa consumed more neutral detergent fiber than heifers fed diets containing smooth bromegrass. Therefore, between species, neutral detergent fiber does not seem to control feed intake. Intake of acid detergent fiber and manual neutral detergent fiber did not differ between heifers fed diets containing alfalfa or big bluestem hay, but intakes of these constituents in heifers fed diets containing alfalfa or big bluestem hay were greater than those of heifers fed diets containing smooth bromegrass hay. In contrast, intakes of automated indigestible neutral detergent fiber did not differ between heifers fed diets containing alfalfa or smooth bromegrass hay, but were greater in heifers fed diets containing big bluestem hay.

Intakes of dry matter, digestible dry matter, in vitro digestible dry matter, crude protein, and neutral detergent fiber increased as the ratio of mature hay to immature hay in the diets decreased across species. Because neutral detergent fiber intake increased across mature hay to immature hay ratios within species, it seems that total neutral detergent fiber may not control forage consumption even within forage species. In contrast, intake of acid detergent fiber, manual indigestible neutral detergent fiber, and automated indigestible neutral detergent fiber did not differ across the ratios of mature hay to immature hay in the diets, implying that these constituents may be associated with control of forage consumption at least within species.

Table 3. Effects of forage species and mature-to-immature hay ratio on intake of dry matter and its components in diets by heifers.

	Forage species (sp) and mature:immature hay ratio (r)														
	Alfalfa				Smooth bromegrass				Big bluestem				Significance[a]		
Item	1:0	2:1	1:2	0:1	1:0	2:1	1:2	0:1	1:0	2:1	1:2	0:1	sp	r	sp*r
	----------kg/d----------														
DM[b]	8.1	8.3	9.0	9.8	6.1	7.2	8.1	7.6	6.9	8.0	8.6	8.8	**	**	N
DDM	4.8	5.2	5.8	6.3	3.4	3.8	5.1	4.7	3.7	4.6	5.4	5.5	**	**	N
IVDDM	5.0	5.1	5.5	6.0	3.3	3.9	4.6	4.5	3.4	4.0	4.5	4.7	**	**	N
CP	1.8	1.9	2.1	2.4	1.1	1.2	1.4	1.4	1.0	1.0	1.1	1.2	**	**	N
NDF	3.7	3.7	4.1	4.5	3.2	3.7	4.1	3.7	4.1	4.8	5.2	5.2	**	**	N
ADF	2.4	2.4	2.6	2.9	1.8	2.1	2.2	1.9	2.3	2.6	2.7	2.7	**	N	N
iNDF															
Manual	2.4	2.2	2.2	2.2	1.7	1.8	1.8	1.4	2.0	2.2	2.2	2.1	*	N	N
Auto	2.0	2.1	2.3	2.5	2.1	2.4	2.6	2.2	3.0	2.2	3.5	3.3	**	N	N
	----------% BW----------														
DM	2.22	2.23	2.40	2.54	1.66	1.95	2.16	2.06	1.85	2.10	2.31	2.37	**	**	N
DDM	1.33	1.38	1.54	1.71	.92	1.04	1.36	1.29	.99	1.22	1.43	1.48	**	**	N
IVDDM	1.38	1.38	1.48	1.62	.90	1.07	1.22	1.23	.93	1.07	1.20	1.28	**	**	N
CP	.49	.51	.56	.64	.30	.33	.37	.39	.26	.28	.30	.32	**	**	N
NDF	1.01	1.01	1.08	1.21	.85	1.00	1.09	1.00	1.09	1.25	1.38	1.40	**	*	N
ADF	.66	.65	.70	.77	.50	.56	.59	.51	.61	.69	.73	.72	**	N	N
iNDF															
Manual	.65	.60	.58	.60	.47	.50	.47	.38	.54	.59	.60	.57	**	N	N
Auto	.55	.56	.61	.68	.58	.67	.69	.59	.79	.88	.92	.88	**	N	N

[a] Significance levels: N, Not significant; *, P<.05; **, P<.01.

[b] Abbreviations: DM=dry matter; DDM=in vivo digestible dry matter; IVDDM=In vitro digestible dry matter; CP=Crude protein; NDF=Neutral detergent fiber; ADF=Acid detergent fiber; and iNDF=Indigestible neutral detergent fiber.

The in vivo digestion coefficient of diets containing alfalfa hay tended (P<.07) to be higher than diets containing the two grasses (Table 4). However, the digestibilities of the diets containing either of the two grass hays did not differ. As expected, the digestibilities of the diets increased as the ratio of mature hay to immature hay decreased. The amounts of dry matter and neutral detergent fiber excreted in the feces were not different between species or mature to immature hay ratios. This response may imply the use of the indigestible fraction of neutral detergent fiber in controlling forage intake across species. Although the amount of acid detergent fiber consumed did not differ between heifers fed diets containing alfalfa or big bluestem hay, the amounts of acid detergent fiber excreted by heifers fed diets containing alfalfa hay were greater than those fed smooth bromegrass or big bluestem diets.

Regression equations predicting dietary dry matter intake, expressed as kilograms per day or as a percentage of body weight, from the chemical composition of the hays was most highly significant for total neutral detergent fiber concentration (Table 5). Dietary dry matter intake was also significantly related to the manual indigestible neutral detergent fiber and crude protein concentrations of the hays. However, the acid detergent fiber and the automated indigestible neutral detergent fiber concentrations were not significantly related to dietary dry matter intake. The in vivo digestible dry matter concentration of the diet (or the digestibility) was significantly related to dietary dry intake. The regression equations predicting dry matter intake from the concentration of any other constituent of the diet, however, were not significant.

Because fecal output of dry matter and neutral detergent fiber did not differ between heifers fed diets containing hays of greatly varying composition (Table 4), it seems that fecal output of total dry matter and/or neutral detergent fiber may control forage intake. To determine whether consumption of total or indigestible neutral detergent fiber could be used to predict fecal dry matter or neutral detergent fiber excretion, regressions were calculated (Table 6). Total neutral detergent fiber intake was more closely related to fecal dry matter excretion than intake of indigestible neutral detergent fiber determined by either the manual method with a 96 hour incubation or the automated method with a 48 hour incubation. Intake of total neutral detergent fiber and automated indigestible neutral detergent fiber equally predicted fecal neutral detergent fiber excretion. However, although these regressions were significant, they accounted

Table 4. Effects of forage species and mature-to-immature hay ratio on the dry matter digestibility and output of fecal dry matter, neutral detergent fiber and acid detergent fiber in heifers fed hay-based diets

	Forage species (sp) and mature:immature hay ratio (r)														
	Alfalfa				Smooth bromegrass				Big bluestem				Significance[a]		
Item	1:0	2:1	1:2	0:1	1:0	2:1	1:2	0:1	1:0	2:1	1:2	0:1	sp	r	sp*r
DM digestion, %	59.8	61.2	63.2	64.5	55.2	53.5	63.0	62.5	52.9	57.8	62.1	62.6	N	**	N
Fecal output DM,															
kg/d	3.3	3.1	3.2	3.5	2.7	3.4	3.0	2.8	3.2	3.3	3.3	3.3	N	N	N
%BW	.89	.85	.86	.93	.74	.91	.80	.77	.85	.88	.88	.89	N	N	N
NDF,															
kg/d	1.9	1.7	1.7	1.8	1.7	2.0	1.7	1.6	1.8	1.9	1.8	1.8	N	N	N
%BW	.50	.46	.45	.49	.45	.54	.46	.42	.49	.50	.48	.49	N	N	N
ADF,															
kg/d	1.3	1.1	1.2	1.3	1.0	1.2	1.0	.9	1.0	1.0	1.0	1.1	**	N	N
%BW	.36	.31	.32	.36	.27	.31	.26	.23	.26	.27	.26	.28	**	N	N

[a] Significance levels: N, Not significant; *, P<.05; **, P<.01.

[b] Abbreviations: DM=dry matter; CP=Crude protein; NDF=Neutral detergent fiber; and ADF=Acid detergent fiber.

for at most, 53 and 40% of the amount of total dry matter and neutral detergent fiber excreted by the heifers. Therefore, it is apparent that there are factors other than total or indigestible neutral detergent fiber influencing forage intake through fecal excretion.

Implications

Although the digestibility of diets containing alfalfa, smooth bromegrass, or big bluestem hay harvested at comparable maturities did not differ, consumption of dry matter and digestible dry matter by heifers fed diets containing alfalfa were 19.8 and 29.6% higher than heifers fed diets containing smooth bromegrass and 9.3 and 16.4% higher than heifers fed big bluestem. Furthermore although increasing the maturity of alfalfa by four weeks reduced consumption of dietary dry matter and digestible dry matter decreased by 13.0 and 22.2%, increasing maturity of smooth bromegrass and big bluestem for a similar period reduced dry matter consumption by 19.8 and 21.9% and reduced digestible dry matter consumption by 28.7 and 33.1%, respectively. Therefore, although harvesting forages at an immature state will improve utilization of all forages, it is more important for grass species than alfalfa. Dietary intake can be predicted from either the digestible dry matter content of the diet or the concentrations of neutral detergent fiber, 96-hour indigestible neutral detergent fiber, crude protein or in vitro digestible dry matter in the hays.

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Table 5. Quadratic regression equations predicting dietary dry matter intake of hay-based diets by yearling heifers from the composition of the hay and total diets.

	Dependent variables							
	Dry matter intake, kg/d				Dry matter intake, % BW			
Independent variable	Intercept	Slope x	Slope x^2	r^2	Intercept	Slope x	Slope x^2	r^2
Hay composition, % of DM								
IVDDM[a]		N[b]			-.75	.096	-0007	.14
CP	9.2	-.40	.021	.15	2.38	-.084	.0047	.17
NDF	61.1	-1.72	.014	.23	12.78	-.340	.0027	.20
ADF		N				N		
iNDF,								
Manual	19.3	-.59	.007	.23	4.24	-.104	.0012	.18
Auto		N				N		
Diet composition, % of DM								
DDM	16.4	-.48	.006	.33	8.191	-.261	.0026	.43
IVDDM		N				N		
CP		N				N		
NDF		N				N		
ADF		N				N		
iNDF,								
Manual		N				N		
Auto		N				N		

[a] Abbreviations: DM=dry matter; DDM=in vivo digestible dry matter; IVDDM=In vitro digestible dry matter; CP=Crude protein; NDF=Neutral detergent fiber; ADF=Acid detergent fiber; and iNDF=Indigestible neutral detergent fiber.
[b] Not significant.

Table 6. Linear regressions predicting the amount of fecal dry matter and neutral detergent fiber excreted from the amounts of total and indigestible neutral detergent fiber consumed by heifers fed diets containing different hays.

	Dependent variables					
	Fecal dry matter excretion, kg/d			Fecal NDF excretion, kg/d		
Independent variable	Intercept	Slope	r^2	Intercept	Slope	r^2
NDF intake, kg/d	1.43	.419	.53	.87	.217	.40
iNDF intake, kg/d						
Manual	2.11	.523	.31	1.25	.255	.21
Auto	1.91	.48	.43	1.06	.27	.38