IN VITRO DIGESTIBILITY OF RANGE FORAGE PLANTS OF THE *FESTUCA SCABRELLA* ASSOCIATION[1]

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ABSTRACT

The *in vitro* digestibility of cellulose was determined for 20 grasses, 6 forbs, and 6 miscellaneous browse species of the *Festuca scabrella* association of southwestern Alberta. From this was calculated the "Nutritive Value Index" (N.V.I.) and percentage of digestible protein. The mean N.V.I. and the mean digestible protein of the four cultivated grasses, *Bromus inermis, Elymus junceus, Festuca rubra,* and *Phleum pratense,* at each stage of growth, was higher than the respective mean of the native species of grasses. However, *Bromus pumpellianus,* a native species, had a higher mean N.V.I. for all stages of growth than any of the other grasses studied. The forbs as a class were equal or superior to the grasses in N.V.I. and percentage of digestible protein. It is suggested that other factors such as palatability, toxicity, and regional adaptation should be considered before a species is adequately evaluated as a range forage.

INTRODUCTION

In a previous paper (9) the chemical composition of a number of the principal range forage species of the *Festuca scabrella* association, which were collected at five stages of growth, was reported. It was found that the protein and phosphorus content of all species under study declined with advancing maturity, while calcium and crude fiber increased. Carotene content of the grasses also decreased with maturity but that of the forbs and shrubs showed no regular pattern. Forbs and shrubs were higher in protein, phosphorus, and carotene than the grasses at all stages of growth. Seasonal declines in protein and phosphorus were closely paralleled by a decline in live weight gains of cows although ample feed supplies were available. It was concluded that, at least on marginal land, the destruction of forbs and shrubs was of questionable value and that quality of forage rather than quantity was the important factor. In view of this, *in vitro* digestibilities were determined on the same species at five stages of growth to obtain an additional measure of their relative nutritive values.

METHODS

The usefulness of the artificial rumen as a tool in determining the digestibility of a forage has been shown by Brown (2), Hershberger *et al.* (8), Pigden (11), and others. Baker and Harris (1), Cook and Stoddart (3), and Morrison (10) reported that the digestibility of cellulose was directly proportional to the over-all nutritive value of a forage and so cellulose was the analysis chosen for this study.

The *in vitro* technique was that described by Donefer *et al.* (6). This technique was standardized, using two standard forage samples from Macdonald College on which *in vivo* and *in vitro* digestibilities were available. When *in vitro* trials on the "Standard Forage Samples" were carried out at the Research Station, Lethbridge, Alberta, it was found that an 18-hour digestion period produced results most closely resembling the 12-hour figures reported on the Macdonald College data sheets. Hence, an 18-hour digestion period was used for the *in vitro* trials reported in this

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TABLE 1. — PERCENTAGE OF CELLULOSE, DIGESTIBILITY COEFFICIENT OF CELLULOSE, AND "NUTRITIVE VALUE INDEX" OF 32 SPECIES OF FORAGE PLANTS

	Stage of growth[1]															Mean N.V.I.
	1			2			3			4			5			
	Cellulose	Dig. coeff.	N.V.I.	Cellulose	Dig. coeff.	N.V.I.	Cellulose	Dig. coeff.	N.V.I.	Cellulose	Dig. coeff.	N.V.I.	Cellulose	Dig. coeff.	N.V.I.	
GRASSES	(%)	(%)		(%)	(%)		(%)	(%)		(%)	(%)		(%)	(%)		
Native species:																
Agropyron dasystachyum	34.2	46.2	52.9	36.1	38.1	42.3	35.8	37.6	41.6	36.8	34.3	37.3	41.6	29.9	31.5	41.0
Agropyron smithii	25.4	65.0	77.6	32.1	55.5	65.1	30.9	24.0	23.7	31.9	24.5	24.4	35.9	30.2	31.9	44.5
Agropyron subsecundum	34.6	54.5	63.8	34.0	32.1	34.4	40.8	22.7	22.0	39.8	22.9	22.3	46.1	21.2	20.1	32.5
Bromis pumpellianus	28.6	70.3	84.6	36.1	50.5	58.6	33.8	48.5	55.9	39.9	38.6	42.9	43.1	43.7	49.6	58.3
Calamagrostis inexpansa	33.7	46.5	53.3	36.9	38.4	42.7	33.8	22.8	22.2	37.5	24.7	24.7	39.5	23.4	22.9	33.2
Calamagrostis rubescens	32.0	66.3	79.3	35.4	32.5	34.9	32.8	46.8	53.7	33.0	23.3	22.8	39.1	25.7	26.0	43.3
Danthonia intermedia	33.8	41.7	47.0	30.1	35.5	38.8	32.6	34.9	38.1	36.7	34.7	37.8	39.0	37.2	41.1	40.6
Danthonia parryi	31.7	37.0	40.8	34.9	35.3	38.6	35.1	27.3	28.1	38.0	25.2	25.3	38.9	26.0	26.4	31.8
Deschampsia caespitosa	30.0	44.6	50.8	34.5	31.1	33.1	33.9	25.7	26.0	34.7	13.4	9.8	34.2	6.2	0.3	24.0
Elymus condensatus	29.9	47.0	54.0	35.8	15.7	12.8	34.2	12.7	8.9	40.6	7.0	1.4	44.5	9.2	4.3	16.3
Elymus innovatus	32.7	47.1	54.1	36.1	24.8	24.8	34.9	20.7	19.4	37.0	17.1	14.7	47.4	18.3	16.2	25.8
Festuca idahoensis	35.8	41.7	47.0	38.4	51.8	60.3	35.0	27.0	27.7	35.9	18.8	16.9	38.8	14.6	11.4	32.7
Festuca scabrella	33.2	48.5	55.9	33.4	53.0	61.8	36.6	36.3	39.9	38.4	32.1	34.4	39.5	24.0	23.7	43.1
Stipa richardsonii	31.3	51.6	60.0	34.6	34.8	37.9	35.8	23.8	23.5	34.8	29.0	30.3	40.5	22.8	22.2	34.8
Stipa spartea var. *curtiseta*	32.6	54.1	63.3	33.1	43.7	49.6	31.9	43.6	49.5	35.8	36.5	40.2	35.4	37.0	40.8	48.7
Stipa viridula	30.2	51.5	59.9	35.7	48.4	55.8	25.4	43.0	48.7	34.6	37.8	41.9	36.3	26.0	26.4	46.5
Mean	31.9	50.8	59.0	34.8	38.8	43.2	34.0	31.1	33.1	36.6	26.2	26.7	40.0	24.7	24.7	37.3
Cultivated species:																
Bromus inermis	28.2	63.5	75.6	34.5	53.2	62.1	29.5	35.2	38.5	35.6	39.2	43.7	39.4	34.8	37.9	51.6
Elymus junceus	25.5	63.3	75.4	34.7	37.1	40.9	33.3	55.8	65.5	33.5	48.8	56.3	31.9	32.6	35.0	54.6
Festuca rubra	27.9	55.3	64.9	28.9	49.0	56.6	22.8	44.6	50.8	25.9	42.8	48.4	29.6	11.7	7.6	45.7
Phleum pratense	26.9	51.6	60.0	30.5	46.5	53.3	30.5	32.9	35.4	35.2	28.8	30.0	40.3	22.3	21.5	40.0
Mean	27.1	58.4	69.0	32.2	46.4	53.2	29.0	42.1	47.6	32.6	39.9	44.6	35.3	25.4	25.5	48.0
Mean of all grasses	30.9	52.4	61.1	34.3	40.4	45.3	33.0	33.3	36.0	35.8	29.0	30.3	39.0	24.8	24.8	39.5
FORBS																
Artemisia gnaphalodes	35.4	69.4	83.4	34.1	55.2	64.7	33.4	46.7	53.6	—	—	—	—	—	—	67.2
Aster laevis	27.2	77.1	93.5	28.8	55.2	64.7	31.2	61.8	73.4	—	—	—	—	—	—	77.2
Hedysarum americanum	22.8	19.2	17.4	25.9	15.5	12.6	29.8	11.3	7.0	—	—	—	—	—	—	12.3
Lathyrus ochroleucus	27.8	47.7	54.9	28.1	43.7	49.6	28.7	42.0	47.4	—	—	—	—	—	—	50.6
Lupinus argenteus	29.7	43.1	48.8	30.4	54.5	63.8	26.8	48.7	56.2	—	—	—	—	—	—	56.3
Vicia americana	28.4	54.1	63.3	26.9	40.9	45.9	28.9	40.5	45.4	—	—	—	—	—	—	51.5
Mean	28.6	51.8	60.3	29.0	44.2	50.3	29.8	41.8	47.1							52.6
MISCELLANEOUS																
Carex atherodes	30.1	27.0	27.7	34.7	26.1	26.5	30.1	20.2	18.7	34.7	12.6	8.8	34.4	11.7	7.6	
Potentilla fruticosa	22.3	1.0	−6.5	22.4	8.9	3.9	24.2	9.0	4.0	—	—	—	—	—	—	
Symphoricarpos occidentalis	15.5	23.8	23.5	19.2	21.0	19.8	15.5	11.3	7.0	—	—	—	—	—	—	
Populus tremuloides	18.4[2]	39.7	44.4	—	—	—	—	—	—	—	—	—	25.3[3]	20.3	18.9	
Rosa woodsii	—	—	—	—	—	—	—	—	—	—	—	—	26.6[4]	25.7	26.0	
Salix species	21.1[2]	25.2	25.3	—	—	—	—	—	—	—	—	—	25.3[3]	13.2	9.5	

[1]Stages of growth: (1) Leaf stage, (2) Heading, (3) Seed ripe, (4) Cured, (5) Weathered

[2]Leaves [3]Bark and winter buds [4]Rose hips

paper. Digestible protein was calculated from the percentage of protein (9) and the coefficient of digestibility of cellulose, on the assumption that the latter is indicative of the digestibility of the protein. The replicates reported in (9) for each stage of growth of each species were composited for the *in vitro* determinations. Duncan's multiple range test (7) was used to determine the significance of differences between stages of growth and between groups of forages.

Cellulose was determined by the method of Crampton and Maynard (5) with modifications suggested by Donefer *et al.* (6). The "Nutritive Value Index" (N.V.I.) was calculated from the *in vitro* data using the equation: N.V.I. = 1.314y—7.8 as proposed by Donefer, 'y' being the *in vitro* digestibility coefficient of the cellulose. The N.V.I. as proposed by Crampton, Donefer, and Lloyd (4) is based on a standard forage of early-cut, chopped, dehydrated legume hay that was given the N.V.I. of 100 when fed to sheep.

RESULTS AND DISCUSSION

The data on percentage and digestibility of cellulose, Nutritive Value Indexes, and percentage of digestible protein were divided into three groups representing grasses, forbs, and miscellaneous (one sedge, two shrubs, two trees, and the winter seed pod of *Rosa woodsii*) and are presented in Tables 1 and 2. The grasses have been further divided into cultivated and native species. It has been well established by other workers that the nutritive value of forages decreases as they mature and this same trend was evident in the mean N.V.I. and digestible protein of the grasses and forbs (Tables 1 and 2).

The mean cellulose content of the grasses increased by 26 per cent from the first to the last stage of growth, and the mean digestibility coefficient decreased by 53 per cent, while in the forbs the figures are only 4 per cent and 19 per cent, respectively (Table 1). In the grass group, the mean N.V.I.'s of stages 1 and 2 were significantly greater ($P < .01$) than those of stages 3, 4, and 5. Of the grasses, *Bromus pumpellianus* had the highest N.V.I. in the leaf stage of growth with an index of 84.6 and when weathered had an index of 49.6. *Agropyron smithii* was highest during the heading stage with an N.V.I. of 65.1, while *Elymus junceus* exceeded the others during the seed ripe stage with 65.5 and the cured stage with 56.3. *Danthonia parryi* and *Festuca scabrella*, which made up 35 per cent of the range forage in the area sampled (9), had a mean N.V.I. for all stages of 37.5, which was slightly lower than the over-all mean of 39.5 for all species of grasses studied. *Festuca rubra*, which maintained a relatively high protein content throughout the year (9), had a very low N.V.I. of 7.6 at the weathered stage of growth, while *Stipa spartea* var. *curtiseta* with a relatively low protein content had an above-average N.V.I. at all stages of growth. The mean N.V.I. for all stages of the cultivated species of grasses was 28.7 per cent higher than the comparable figure for the native species.

Although the mean N.V.I.'s of the forbs decreased with maturity, this reduction was so small that the differences between stages of growth were not significant. *Aster laevis* at the leaf stage of growth had the highest N.V.I. (93.5) of all the samples tested, which placed it very close to the

TABLE 2. — PERCENTAGE OF DIGESTIBLE PROTEIN (CALCULATED) OF 32 SPECIES OF GRASSES, FORBS, AND MISCELLANEOUS FORAGE PLANTS

	Digestible protein					
	Stage of growth[1]					Mean
	1	2	3	4	5	
	(%)	(%)	(%)	(%)	(%)	(%)
GRASSES						
Native species:						
Agropyron dasystachyum	5.3	3.2	3.6	2.3	1.3	3.1
Agropyron smithii	10.9	8.1	1.3	0.7	1.1	4.4
Agropyron subsecundum	6.3	2.6	1.2	0.8	0.4	2.3
Bromus pumpellianus	12.7	3.9	4.0	1.5	1.9	4.8
Calamagrostis inexpansa	5.5	3.5	1.6	0.9	0.7	2.4
Calamagrostis rubescens	9.9	2.6	3.9	0.8	1.1	3.7
Danthonia intermedia	3.9	2.8	2.4	1.8	1.3	2.4
Danthonia parryi	4.1	3.1	1.9	0.9	1.0	2.2
Deschampsia caespitosa	5.0	2.1	1.6	0.7	0.3	1.9
Elymus condensatus	7.7	1.0	0.8	0.2	0.2	2.0
Elymus innovatus	5.8	1.9	1.3	0.6	0.5	2.0
Festuca idahoensis	5.1	4.3	2.1	0.9	0.6	2.6
Festuca scabrella	6.6	5.4	2.4	1.5	1.0	3.4
Stipa richardsonii	5.3	2.3	1.2	1.2	0.6	2.1
Stipa spartea var. *curtiseta*	4.9	2.7	3.1	1.6	1.7	2.8
Stipa viridula	6.4	4.2	2.5	1.4	0.9	3.1
Mean	6.6	3.4	2.2	1.1	0.9	2.8
Cultivated species:						
Bromus inermis	10.4	6.1	1.8	2.3	0.7	4.3
Elymus junceus	8.9	2.9	4.6	4.5	2.2	4.6
Festuca rubra	9.6	5.9	4.3	4.2	1.0	5.0
Phleum pratense	6.9	3.3	1.9	0.8	0.5	2.7
Mean	9.0	4.6	3.2	3.0	1.1	4.2
Mean of all grasses	7.1	3.6	2.4	1.5	1.0	3.5
FORBS						
Artemisia gnaphalodes	7.2	5.9	4.2	—	—	5.8
Aster laevis	11.6	5.9	5.2	—	—	7.6
Hedysarum americanum	3.7	2.7	0.9	—	—	2.4
Lathyrus ochroleucus	9.7	8.8	5.7	—	—	8.1
Lupinus argenteus	7.5	7.6	5.2	—	—	6.8
Vicia americana	13.0	7.2	5.4	—	—	8.5
Mean	8.8	6.4	4.4			6.5
MISCELLANEOUS						
Carex atherodes	2.5	2.2	1.2	0.5	0.6	
Potentilla fruticosa	0.1	0.8	0.9	—	—	
Symphoricarpos occidentalis	4.0	1.8	1.1	—	—	
Populus tremuloides	6.2[2]	—	—	—	0.8[3]	
Rosa woodsii	—	—	—	—	1.7[4]	
Salix species	4.0[2]	—	—	—	1.0[3]	

[1]Stages of growth: (1) Leaf stage
(2) Heading
(3) Seed ripe
(4) Cured
(5) Weathered

[2]Leaves
[3]Bark and winter buds
[4]Rose hips

standard forage sample on which the N.V.I. is based. The mean N.V.I. of stage 3 in the forbs group was greater than that of stages 2, 3, 4, or 5 of the grasses. The importance of this was indicated in the first paper (9) when it was stated that "chronologically, the seed-ripe stage in forbs is roughly comparable to the cured stage in the grasses, and thus a desirable nutritive level is maintained by the forbs for a longer period of time than by the grasses". The mean N.V.I. of the three stages of *Hedysarum americanum* was quite low, being 80 per cent lower than the over-all mean of the other five forbs.

The N.V.I.'s of the miscellaneous group were quite variable. However, the N.V.I. of 44.4 for poplar leaves, 25.3 for willow leaves, and 18.9 for poplar bark and stems are worthy of note. *Potentilla fruticosa*, which had a relatively high protein content of 9.5 to 13.0 per cent (9), had a surprisingly low N.V.I., it being −6.5 to 4.0. In Table 2 there were no significant differences in digestible protein between stages in either the grass or forbs group. *Bromus pumpellianus*, with 12.7 per cent protein, was highest of all grasses during the leaf stage of growth, but decreased rapidly as the season progressed. *Elymus junceus*, although not as high in digestible protein as *Bromus pumpellianus* during the leaf stage, maintained a relatively high digestible protein content and was highest of all the grasses during stages 3, 4, and 5.

The forbs were high in digestible protein when compared to the grasses, *Vicia americana* and *Lathyrus ochroleucus* being the top two species, with 8.5 and 8.1 per cent digestible protein, respectively. The mean digestible protein content of the forbs during the seed-ripe stage (4.4 per cent), like the mean N.V.I. of the forbs, was higher than that of the grasses during stages 2, 3, 4, and 5. The species in the miscellaneous group were all low in digestible protein and quite variable. The only sample of any importance was the poplar leaves, which contained 6.2 per cent digestible protein.

These results indicate that the superior grasses were *Bromus pumpellianus*, *Elymus junceus*, and *Bromus inermis*, the first being a native species while the last two are cultivated ones. Of the forbs, *Aster laevis* and *Artemisia gnaphalodes* were outstanding. However, before fully evaluating any species, other factors must be considered, such as palatability, presence or absence of toxic factors, yield in competition with other forage plants, and recuperative ability after grazing.

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