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The Apparent Digestibility by Sheep of Prairie Hay Harvested at Three Stages of Maturity

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THE APPARENT DIGESTIBILITY BY SHEEP OF PRAIRIE HAY HARVESTED AT THREE STAGES OF MATURITY

By

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This is to certify that, in accordance with the requirements of South Dakota State College for the Master of Science Degree, Mr. Robert M. Jordan has presented to this committee three bound copies of an acceptable thesis, done in the major field; and has satisfactorily passed a two-hour oral examination on the thesis, the major field, Animal Husbandry, and the minor field, Biochemistry.

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Introduction

Grass is the greatest asset of the Northern Great Plains. Grass does and must serve as the basic feed for the flocks and herds of this area. Without grass, much of the Northern Great Plains would be waste land with little or no value.

In the states of North and South Dakota, Nebraska, Colorado, Wyoming, and Montana, about 67 per cent of the total land is in pasture and hay[1]. Seventy-five to 95 per cent of the total feed needed by cattle and sheep in the Northern Plains states is furnished by Pasture and roughage[1]. With an ever-increasing demand for food and the need for greater efficiency of production, it is imperative that more complete and more accurate information be secured on the actual nutritive value of the native grasses of this area if maximum results are to be obtained in the utilization of these grasses.

Efficient range management and range livestock production necessitates cutting and storing of prairie hay for use during severe winters and in time of drought. In 1948, 2,893,000 acres of prairie hay were harvested in South Dakota[1]. Chemical analysis and limited digestibility studies of grasses of other areas have indicated that the feeding value and cash value of much of this hay is greatly

1. 1948 South Dakota Crop and Livestock Reporting Service, Sioux Falls, South Dakota.

affected by the stage of maturity at which it is harvested and the care that is taken in storing it.

Chemical analysis made on South Dakota range grasses shows striking differences in chemical composition, particularly in regards to decreases in protein, as the stage of maturity progresses. However, the chemical composition does not give a reliable index of the nutritive value of the hay, partly because of differences in coefficients of apparent digestibility of the various organic nutrients and partly because of other differences such as palatability, vitamins, and possibly reduction in mineral availability.

This study was undertaken with the objective of gaining information on the comparative nutritive value of prairie hay cut at three stages of maturity as indicated by the apparent digestibility determined with lambs.

Review of Literature

Seasonal Variation in Chemical Composition

It has been demonstrated that the chemical composition of growing grasses changes as the plants mature. Gastler and Moxon (1943-44) reported decreases in protein, calcium, and phosphorus in western wheatgrass and blue gramma grass as maturity increased. Samples were cut at the shooting, seed-ripe, and mature and weathered stages from eleven different locations in South Dakota. At the shooting stage, western wheatgrass contained over 9 per cent protein, whereas at the mature and weathered stage it contained less than 4 per cent at most locations. The phosphorous content declined from 0.26 per cent to 0.09 per cent during the same period.

McMillan and co-workers (1943) reported upon the chemical composition and grazing values of typical plains pastures in the Panhandle region of Oklahoma. Samples of buffalo grass, blue gramma grass, and Russian thistle were studied over a four year period. Moisture, crude protein, carotene, and phosphorous were high in each of the forages during the early stages of development, but declined as maturity advanced. Yearling Hereford steers, grazed on these pastures, made an average daily gain of 1.47 pounds in June as compared to 0.53 pounds in August.

Baker and co-workers (1947) found that early cut hay was higher in protein and phosphorous than late cut hay. In a feeding trial with steers, the steers made a greater total gain per acre on early cut hay than on late cut hay.

Savage and Heller (1947) completed a comprehensive study of the nutritional qualities of range forage plants growing on the range at the United States Southern Plains Experimental Range Station, Woodward, Oklahoma. Samples were collected at monthly intervals from different locations on the range. This study included 29 different species of grasses, forbs, and browse plants. Included in the study was western wheatgrass, a grass very common on South Dakota ranges. The protein content of western wheatgrass declined from a high of 22.12 per cent protein (oven dry basis) in April to a low of 5.74 per cent protein (oven dry basis) in September. This same trend was evident in all of the other grasses studied. Calcium, phosphorous, and fat content also declined as the maturity of the plant progressed. Crude fiber and nitrogen-free extract increased as the stage of maturity advanced. In April western wheatgrass contained 34.76 per cent nitrogen-free extract (oven dry basis) and 28.25 per cent fiber, whereas in September it contained 47.89 per cent nitrogen-free extract and 34.25 per cent crude fiber.

Morrison (1948) gives average values for timothy hay

when cut at various stages of maturity. Timothy hay cut at the early bloom stage contained 7.5 per cent protein, and 51.6 per cent total digestible nutrients, whereas timothy cut at late seed stage contained 5.3 per cent protein and 42.8 per cent total digestible nutrients. This same trend was evident for all the grasses listed in his tables of average composition of various feeds.

Digestion Trials

Digestion trials offer research workers a more accurate means of determining the fundamental nutritional value of a feed than does an ordinary feeding trial. Two feeds may have similar chemical composition, yet one of the feeds may be digested and utilized more completely than another. A digestion trial will determine these differences and give a "nutritive value" of a feed based on digestibility and chemical composition of the feed fed.

Fraps (1930) studied the digestibility by sheep of the constituents of the nitrogen-free extract of feeds. He concluded that feeds known to be of high feeding value, such as corn, barley or linseed meal, for example, are characterized by a high content of starch or sugar and starch combined, or, if the starch content is not high, by a high content of protein. Further, roughages as a group were rather low in starch content and consequently of much lower value than feeds high in this component. He stated that the nitrogen-free extract in corn was of greater value than the nitrogen-free extract value in hay, since it existed, for the most part, in the form of starch rather than pentosans which tend to lower digestion coefficients of the feed.

Burkitt (1940) fed beardless wheatgrass cut at the early stage (3 to 5 inches), a medium stage (7 to 10 inches)

and a late stage (anther falling) to yearling sheep. The seasonal decline in digestibility of total nutrients ranged from 72.10 to 62.85 per cent when determined on a dry matter basis. The digestibility of the crude protein decreased from 79.3 to 64.2 per cent with increased maturity. The nutritive ratios of the early, medium, and late hays were 1:3.39, 1:4.57, and 1:10.10, respectively.

Digestion trials conducted with sheep by Sotola (1940) revealed that standard crested wheat grass loses much of its nutritive value as it matures. When the grass was 4 inches high it contained 66.73 per cent total digestible nutrients; when 10 inches high, 66.68 per cent; and at the anther falling stage, 48.00 per cent. The digestible protein content declined from 10.15 per cent (4 inch stage) to 1.94 per cent (anther falling stage) during the same period. Smooth brome was found by Sotola (1941) to contain 80.14, 79.50, and 54.92 per cent total digestible nutrients at the 4 inch, 10 inch and anther falling stages, respectively.

Crampton, and Jackson (1944) found a steady decline in the digestibility of pasture herbage dry matter from 75 per cent for early spring grass to 60 per cent for grass cut six weeks later. They believed that the digestibility of mixed pasture herbage by sheep and steers was correlated with the leaf-stem ratio existing in the plants at each stage.

Hobbs and co-workers (1945), in studying the chemical composition of native grasses, found that the protein and

calcium and phosphorous content in the grasses decreased as the season advanced. This decrease was extremely rapid after September and the protein content reached a low of 2.56 per cent during the winter. The fiber content went up rapidly after September and the digestibility of dry matter, protein and nitrogen-free extract decreased correspondingly. The digestibility of the grasses was determined with steers fed in dry lot and steers allowed to graze on pasture. The apparent digestibility of dry matter, crude protein and crude fiber of the grass in June was lower than in the period from July through September. During the period from July through September, there was very little change in the digestibility of the nutrients with the exception of ether extract and crude protein. However, the apparent digestibility of dry matter varied from 58 per cent in September to 41 per cent in November. Digestibility of crude protein decreased from 54 per cent to 19 per cent during this same period. It is apparent from this that lower protein content and lower digestibility of crude protein in the grasses as the season advances reduces considerably the value of hays harvested in the late periods.

Drapala, Raymond and Crampton (1947) investigated the effects of maturity of the plant, its lignification and subsequent digestibility. Red clover plants were cut at 5 stages of maturity, the degree of lignification was

determined for each stage and the findings related to cell digestibility as observed microscopically in the feed residues. It was shown that lignification proceeds regularly with advancing maturity of the plant. In general, the increase in the number of undigested bits of tissue and their increase in particle size is correlated with the increase in maturity of the plant and its increase in lignification.

A study by Swift and associates (1947) was made of the effect of various supplements on the digestibility of a mixed ration for sheep. Using five sheep on each treatment, 2 levels of crude fiber, ether extract, protein, carbohydrates and urea were added to the ration. The addition of crude fiber reduced the total amount of protein and ether extract digested, while the most prominent effect of added carbohydrates was to reduce the digestibility of the crude fiber and protein. Protein supplement in the form of casein increased the digestibility of protein, ether extract and energy, and decreased the digestibility of the crude fiber and nitrogen-free extract slightly. Urea caused a prominent increase in the digestibility of protein while addition of corn oil to the ration in the smaller of the amounts fed increased the digestibility of each feed constituent, the larger amount of corn oil having the reverse effect. This indicates that there is an optimum level of fat and any over that amount causes a depressing effect on digestibility.

Gallup and Briggs (1948) in studying the apparent

digestibility of prairie hays of variable protein content with steers, found that total digestible nutrients of the hay increased in a fairly uniform manner from 41 per cent to 56 per cent as the protein content of the hay increased from about 3 per cent to 6 per cent. Likewise, crude fiber digestibility increased from 56 per cent to 69 per cent, while the apparent digestibility of protein increased from reported negative values to 41 per cent. They further found that when cottonseed meal in amounts varying from 0.5 pound to 3 pounds daily was fed as a supplement to 10 pounds of hay, differences in digestibility correlated the protein content of the hay. The digestibility of dry matter in the high protein hay was equal to that in rations made up of average or low protein hay supplemented with 2 pounds of cottonseed meal.

Forbes and Garrigus (1948) investigated the relationship between chemical composition, digestibility and palatability of pasture forages, and found that the palatability of pasture forage declined as the maturity increased. They noted an increase in lignin content with an increase in maturity. As the lignin content increased the apparent digestibility of the dry matter and total digestible nutrients decreased.

Burroughs and co-workers (1949a) found that the protein requirement for efficient digestibility was lower when the

forages fed were low in starch content. In further studies (1949b) they noted an increased digestibility of dry matter in ground corn cobs and timothy by 14 and 17 per cent, respectively, as a result of adding soybean oil meal to the ration.

Experimental Procedure

The hays used in this experiment were native prairie hay grown near the North Central Substation at Eureka, South Dakota.

The grass was cut and harvested when the western wheatgrass was in the shooting stage, July 19; the seed-ripe stage, August 21; and the mature stage, September 20, 1947. The hay was stacked in the field and later baled and brought to the Agricultural Experiment Station at Brookings, South Dakota for the digestion trials. These trials were conducted from May 3 until June 29, 1948. Hereafter, the hay harvested at the shooting stage will be designated as "early", that cut at the seed-ripe stage as "medium", and that cut when the grass was mature as "late".

Botanical analysis[1] of the hay indicated that it contained approximately 62 per cent western wheat grass (Agropyron smithii), 22 per cent green needle grass (Stipa viridula), 3 per cent needle and thread (Stipa comata), 9 per cent other grasses, consisting mainly of Kentucky bluegrass (Poa pratensis), June grass (Koeleria cristata), and red top (Agrostis alba), and 4 per cent weeds.

The hay was described[1] as upland prairie hay, with the official hay grade of U. S. Grade 2 for that cut at the early stage of maturity, the medium hay was U. S. Grade 3,

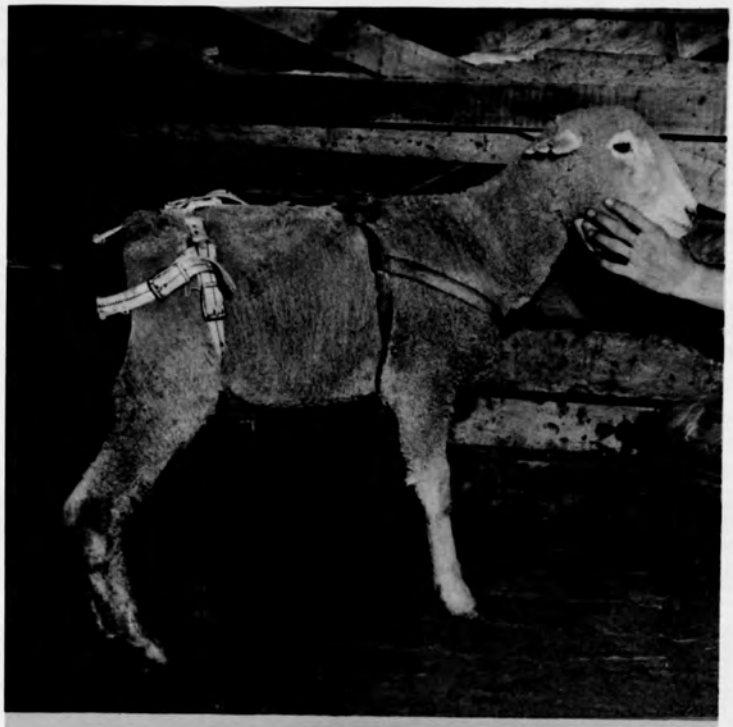
1. Agronomy Department, South Dakota State College, Brookings, South Dakota.

and the late hay was U. S. Sample Grade, being coarse and over-ripe.

Lambs were used as experimental animals to determine the digestibility and nutritive value of the prairie hays. The hay was fed without grain supplement.

The lambs used were western lambs, largely of Rambouillet breeding. They were purchased from a local lamb feeder and weighed approximately 90 pounds at the start of the experiment. Upon arrival at Brookings, each lamb was treated to reduce parasitism, since internal parasites are known to affect the digestive efficiency and capacity of animals (Forbes, et. al., 1946). They were put on a prairie hay ration similar to the ration that they would receive in the trial and were kept on this ration for three weeks prior to the commencement of the digestion trial.

During the experiment the lambs were stanchioned and fed hay in a feeding crate as described by Erickson (1947). The lambs were fed twice daily, at 7:00 a.m. and at 4:30 p.m., and were allowed to eat for two hours at each feeding period, after which they were turned into a concrete pen for the remainder of the day. No fecal loss was noted from the collection sacks at that time. Water and a mixture of salt and bonemeal in equal parts were available in the enclosure at all times. Preliminary periods were of 10 days duration, followed by collection periods of 10 days duration.



Side view of individual lamb showing sack for feces collection.

Fig. 1

Front view of digestion crate showing removable drawer.

Fig. 2

Rear view of digestion crate showing crate construction and sack for feces collection.

Fig. 3

It was desired that all lambs be offered equal amounts of hay, since it is known that the plane of nutrition affects digestibility. The amount of the hay consumed by those lambs receiving the least palatable hay was used as a basis for feeding all the lambs during a period. In this investigation the late hay was the least palatable, thus the consumption of this hay governed the level of feeding for the other two hays. During each period of the investigation, three lambs were fed early, medium, and late cut hay, respectively.

Nine lambs were used in this experiment. Each type of hay was fed to three lambs during each period. The hays were rotated each period; thus, during the entire trial, each lamb received each type of hay once, making a total of 27 fecal collections of the three types of hays.

The feces were collected by means of a canvas harness and canvas sack similar to those used by Forbes (1937), with adaptations made by McCall, et. al. (1943). The size of the individual canvas bags was increased from those used by McCall so the collections would have to be made only once a day (Figure 1). The feces collected were weighed to the nearest gram and one-fortieth aliquotes of the feces were taken and preserved with thymol in tightly covered gallon glass jars and stored in an electric refrigerator maintained at 0° Centigrade. Refused feed for each lamb was collected

and stored separately in covered metal containers and weighed at the end of each trial. Hay samples for each type of hay were taken daily and placed in a covered metal container from which a composite sample for each hay was made for chemical analysis. Proximate chemical analyses[1] (A.O.A.C. 1945) were made at the close of each trial on composite aliquoted samples of feed offered, refused feed, and the feces. The nitrogen of the feces was determined previous to drying so as to minimize any discrepancy in chemical analysis that may occur due to loss of nitrogen when the feces were dried (Cockren, Fries, and Bramar, 1925), (French, 1930), (Gallup and Hobbs, 1944).

All of the data were tested for significance by analysis of variance, as outlined by Snedecor (1946). In the discussion of these results, the word "significant" or a single asterisk has been used to indicate a difference that would occur by chance in not more than 5 per cent and not less than 1 per cent of such trials when no such differences existed in the population from which the data were taken. "Highly significant" or a double asterisk has been used to indicate a difference that would occur by chance in less than 1 per cent of such trials.

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1. Experiment Station Chemistry Department, South Dakota Agricultural Experiment Station, Brookings, South Dakota.

The coefficients of digestibility were determined in the manner explained by Maynard (1947) and Morrison (1948). In order to obtain data for the intake of nutrients, the weight of the hay offered was multiplied by the percentage of each nutrient contained in the hay, and the weight of the hay refused was multiplied by the percentage of each nutrient in the hay refused. The figures for the intake of a particular nutrient were calculated by subtracting the amount of that nutrient in the refused hay from the amount of that nutrient in the hay offered. The figures for excreted nutrients were calculated by multiplying the percentage of each nutrient in the feces voided by the amount of feces voided. The amount of each nutrient apparently digested was obtained by subtraction of the amount of each nutrient excreted in the feces from the amount of each nutrient consumed. The coefficients of digestibility are expressed as percentages obtained by dividing the quantity of a nutrient apparently digested by the quantity of that nutrient consumed. Analysis of variance was calculated on the percentage of digestibility of each of the classes of nutrients studied.

Results and Discussion

Table I shows the chemical composition of the three hays fed.

Table I
Chemical Composition of Hays Fed

Hay	Period	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract	Ash
		%	%	%	%	%	%
Early	I	89.55	8.50	2.58	27.75	41.37	9.35
(Cut	II	89.67	8.31	1.97	29.77	40.42	9.20
July 19)	III	89.03	7.59	2.21	28.61	39.02	11.60
	Av.	89.42	8.13	2.25	28.71	40.27	10.05
Medium	I	88.07	5.91	3.11	28.84	41.28	8.93
(Cut	II	89.34	6.56	2.70	30.52	41.50	8.06
Aug. 21)	III	89.44	5.25	2.23	30.51	40.95	10.50
	Av.	88.95	5.91	2.68	29.96	41.24	9.16
Late	I	88.81	4.61	3.15	30.08	41.43	9.54
(Cut	II	88.13	4.70	2.75	31.54	41.10	8.04
Sept.20)	III	87.93	5.06	2.18	27.27	41.72	11.70
	Av.	88.29	4.79	2.69	29.63	41.42	9.76

The largest difference found in the three hays was the crude protein content. The crude protein ranged from 8.13 per cent for the early hay to 4.79 per cent for the late cut.

Early cut hay contained 2.25 per cent ether extract, 2.68 per cent was found in the medium cut hay, while the late hay contained 2.69 per cent ether extract. However, the chemical analysis of ether extract includes many things other than fat and is not considered highly important in evaluating feedstuffs of low fat content (Moxon 1948). Ward and Reid (1948) concluded that estimates of crude fat are misleading in experiments involving the analysis of dairy cow feces.

The crude fiber content of 28.71 per cent, 29.96 per cent, and 29.63 per cent for early, medium, and late hay, respectively, did not show as great an increase as might be expected on the basis of other experiments reviewed. Anderson (1948) and Wilcox (1949) find that 80 to 90 per cent of the lignin is found in the nitrogen-free extract fraction rather than in the fiber.

The dry matter content and the nitrogen-free extract content was very similar for the three hays during the three periods.

Analysis of variance of the chemical composition of the three hays fed is given in Table 2.

Table 2
Analysis of Variance of Chemical Composition of Hays Fed

Source of Variation	Degrees of Freedom	Mean Squares				
		Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.
Total	8	.47	2.35	.178	1.98	.68
Between Hay	2	.96	8.69**	.185**	1.26	1.15
Between Periods	2	.55	.24	.42	3.13	.48
Error	4	.43	.24	.05	1.77	.54

** Highly significant differences
* Significant differences

There was a highly significant difference in the amount of crude protein that the three types of hay contained. This

clearly shows that the time at which the hay is cut has a definite bearing on the amount of crude protein the hay will contain.

The difference in the amount of ether extract that the three types of hay contain is highly significant and the difference between periods was significant. There were no significant differences in dry matter content, crude fiber or nitrogen-free extract.

During the first trial the lambs were offered 2 pounds of hay per day. The hay weighed back during this period was very small and the lambs showed evidence of needing more hay. During the second and third trial the hay offered was increased to 2.5 pounds per day. The data on hay consumption, hay refusal, and feces voided are in Table 3.

Table 3
Total Hay Consumed and Feces
Voided in 10 Day Periods

Hay	Period	Lamb	Hay Offered	Hay Refused	Hay Consumed	Feces Voided Fresh	Feces Voided Dry Basis
			Grams	Grams	Grams	Grams	Grams
Early	I	1	9080	283	8797	7971	4258.91
		4	9080	164	8916	8085	4272.11
		7	9080	559	8521	7612	4059.48
	Av.		9080	335.3	8744.6	7889.3	4196.83
	II	2	11350	763	10587	11363	6429.18
		6	11350	938	10412	8892	4674.52
		8	11350	604	10746	9716	5111.58
	Av.		11350	768.2	10581.6	9990.3	5405.09
	III	3	11350	278	11072	9150	4106.52
		5	11350	215	11135	9009	4761.26
		9	11350	615	10735	14671	5218.47
	Av.		11350	369.3	10980.6	10943.3	4695.42
Av. for early hay			10593.3	491.0	10102.3	9607.6	4765.78
Medium	I	2	9080	578	8502	8957	4392.51
		5	9080	113	8967	9130	4668.17
		8	9080	728	8352	9885	4413.65
	Av.		9080	473	8607	9324	4491.44
	II	3	11350	661	10689	12544	6354.79
		4	11350	693	10657	12296	6687.79
		9	11350	1235	10115	15497	6153.86
	Av.		11350	863	10487	13445.6	6398.81
	III	1	11350	1201	10149	8033	4138.60
		6	11350	688	10662	9154	4944.99
		7	11350	620	10720	9544	4350.16
	Av.		11350	836.3	10513.6	8910.3	4477.88
Av. for medium hay			10593.3	724.1	9869.2	10560.0	5122.71

Table 3
Total Hay Consumed and Feces Voided in
10 Day Periods (Cont'd)

Hay	Period	Lamb	Hay Offered	Hay Refused	Hay Consumed	Feces Voided Fresh	Feces Voided Dry Basis
			Grams	Grams	Grams	Grams	Grams
Late	I	3	9080	868	8212	9528	4584.87
		6	9080	1047	8033	8604	4375.99
		9	9080	695	8385	13434	4590.40
	Av.		9080	870	8210	10522	4517.09
	II	1	11350	1033	10317	10871	5052.84
		5	11350	360	10990	11401	6100.68
		7	11350	1832	9518	10832	5358.59
	Av.		11350	1075	10275	11034.6	5504.04
	III	2	11350	1038	10312	10587	4908.13
		4	11350	854	10496	10063	4823.20
		8	11350	1469	9881	10009	4843.36
	Av.		11350	1120.3	10229.6	10219.6	4858.23
Av. for late hay			10593.3	1021.8	9571.5	10592.1	4959.79

There were many individual variations in hay consumption, with lambs 6 and 9 being the most erratic. Hay refusal usually was the greatest when late hay was fed. The average quantity of hays refused was 491.0 grams, 724.1 grams and 1021.8 grams in a 10 day period for the early, medium, and late cut hay, respectively.

The chemical composition of the hay refused is given in Table 4. The refused hay consisted largely of dust and coarse, stemmy weeds. The composition of the hay refused varies considerably among lambs for crude protein, ether extract, nitrogen-free extract, crude fiber, and ash. However,

the per cent of dry matter is quite constant throughout the entire experiment.

Table 4
Chemical Composition of Hay Refused

			Composition					
Hay	Period	Lamb	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	N.F.E. %	Ash %
Early	I	1	85.13	5.55	.96	28.06	33.37	17.19
		4	86.34	3.53	.73	45.21	31.23	5.64
		7	84.94	5.66	1.27	30.69	36.04	11.08
	Av.		85.47	4.91	.99	34.72	33.55	11.30
	II	2	90.51	6.03	1.43	36.45	38.60	8.00
		6	87.35	6.01	.93	35.81	37.78	6.82
		8	88.48	5.00	1.29	38.31	37.00	6.88
	Av.		88.78	5.68	1.22	36.86	37.79	7.23
	III	3	82.88	3.61	.46	39.85	34.21	4.75
		5	85.16	3.40	.60	38.83	38.06	4.27
		9	86.17	4.84	.71	29.52	45.98	15.12
	Av.		84.74	3.95	.59	36.07	39.42	8.05
Av. Early Hay			86.33	4.85	.93	35.88	36.92	8.86
Medium	I	2	84.78	3.29	1.14	40.64	33.97	5.74
		5	87.79	3.66	1.00	45.29	33.65	4.19
		8	86.17	3.21	1.12	39.61	35.63	6.60
	Av.		86.25	3.39	1.09	41.85	34.42	5.51
	II	3	91.41	3.31	1.30	43.63	38.48	4.69
		4	89.74	3.94	2.19	42.26	36.51	4.84
		9	90.68	7.00	4.23	24.17	40.35	14.93
	Av.		90.61	4.75	2.57	36.69	38.45	8.15
	III	1	83.55	2.83	1.07	34.94	39.70	5.01
		6	81.84	3.09	.91	34.26	38.56	5.02
		7	84.48	4.44	1.15	32.59	37.07	9.23
	Av.		83.29	3.45	1.04	33.93	38.44	6.42
Av. Medium Hay			86.72	3.86	1.57	37.49	37.10	6.69

Table 4
Chemical Composition of Hay
Refused (Cont'd)

Hay	Period	Lamb	Composition					
			Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.	Ash
			%	%	%	%	%	%
Late	I	3	84.55	3.18	1.66	39.56	34.72	5.43
		6	84.00	3.19	1.57	39.31	33.09	6.84
		9	86.31	3.08	1.31	41.48	35.82	4.62
	Av.		84.95	3.15	1.51	40.12	34.54	5.63
	II	1	91.18	2.59	1.53	43.26	39.72	4.08
		5	90.94	2.69	.74	45.99	38.36	3.16
		7	91.87	3.38	2.12	39.22	41.08	6.07
	Av.		91.33	2.89	1.46	42.82	39.72	4.44
	III	2	80.12	4.28	1.68	31.14	35.71	7.31
		4	80.61	4.31	1.66	37.64	37.51	9.49
		8	73.93	4.64	2.13	20.13	35.62	11.41
	Av.		78.22	4.41	1.82	26.30	36.28	9.40
Av. Late Hay			84.83	3.48	1.60	36.41	36.85	6.49

The chemical composition of feces voided is given in Table 5. The total feces (fresh basis) voided over a period of 10 days appears to be in an inverse relationship to the amount of hay consumed (Table 3). Lamb number 9 had very wet feces during the entire three trials, and consequently, influenced the averages. Since all the lambs had free access to a mineral mixture of salt and bone meal, no significance can be put on the values for ash as given in Table 5.

Table 5
Chemical Composition of Feces Voided

Hay	Period	Lamb	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract	Ash
			%	%	%	%	%	%
Early	I	1	53.43	4.16	1.67	15.40	23.04	9.16
		4	52.84	4.08	1.63	14.71	21.21	9.21
		7	53.33	4.13	1.65	14.50	23.70	9.35
	Av.		53.20	4.12	1.65	14.87	22.65	9.24
	II	2	56.58	4.26	1.94	14.86	25.38	10.14
		6	52.57	3.83	1.67	13.69	23.38	10.00
		8	46.64	4.37	1.96	12.77	19.25	7.29
	Av.		51.93	4.15	1.86	13.77	22.67	9.14
	III	3	44.88	3.89	1.12	10.81	20.31	8.75
		5	52.85	4.70	1.23	13.32	17.31	10.59
		9	35.57	4.42	.56	5.51	11.21	13.87
	Av.		44.43	4.34	.97	9.88	16.28	11.07
Av. Early Hay			49.85	4.20	1.49	12.84	20.53	9.82
Medium	I	2	49.04	3.74	1.97	14.66	20.79	7.88
		5	51.13	3.62	2.09	15.56	22.07	7.79
		8	44.65	3.39	1.67	13.21	19.90	6.48
	Av.		48.27	3.58	1.91	14.48	20.92	7.38
	II	3	50.66	3.53	1.95	14.90	21.67	8.61
		4	54.39	4.58	1.97	15.54	22.08	9.22
		9	39.71	3.99	1.85	10.58	14.75	6.54
	Av.		48.25	4.03	1.92	13.67	19.50	8.12
	III	1	51.52	3.77	2.20	13.51	23.68	8.26
		6	54.02	4.41	1.80	13.74	23.00	11.07
		7	45.58	3.79	1.54	12.04	19.75	8.46
	Av.		50.37	3.99	1.85	13.10	22.14	9.26
Av. Medium Hay			48.97	3.87	1.89	13.75	20.85	8.26

Table 5
Chemical Composition of Feces Voided (Cont'd)

Hay	Period	Lamb	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	N-Free Extract %	Ash %
Late	I	3	48.12	3.11	2.33	13.93	21.46	7.29
		6	50.86	3.70	2.46	15.19	21.53	7.98
		9	34.17	2.61	1.43	9.90	15.13	5.10
	Av.		44.38	3.14	2.07	13.01	19.37	6.79
	II	1	46.48	3.33	2.01	11.76	22.22	7.16
		5	53.51	3.77	2.22	14.67	24.26	8.59
		7	49.47	3.62	2.42	12.35	21.48	9.60
	Av.		49.82	3.57	2.22	12.93	22.65	8.45
	III	2	46.36	3.47	1.75	11.70	21.84	7.60
		4	47.93	3.77	1.81	12.16	20.90	9.29
		8	48.39	3.40	1.89	12.51	21.50	9.09
	Av.		47.56	3.55	1.82	12.12	21.41	8.66
Av. Late Hay			47.25	3.42	2.04	12.69	21.15	7.97

The average apparent digestion coefficients are presented in Table 6 and are summarized in Table 7. The analysis of variance for each nutrient is given in Tables 8 through 12.

Table 6
Coefficients of Apparent
Digestibility of Hays Fed

Hay	Period	Lamb	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	N-Free Extract %
Early	I	1	46.02	56.14	42.51	49.70	49.85
		4	46.53	56.94	43.46	51.37	53.72
		7	46.98	57.53	44.71	52.97	49.25
	Av.		46.51	56.87	43.56	51.35	50.94
	II	2	32.23	46.05	3.64	45.54	32.82
		6	50.05	61.60	30.89	60.00	50.89
		8	53.01	53.49	11.76	60.58	57.14
	Av.		45.10	53.71	13.00	55.37	46.95
	III	3	58.41	58.19	58.94	68.55	57.12
		5	52.01	50.42	55.60	62.07	64.13
		9	45.50	22.03	.994	73.63	60.33
	Av.		51.97	43.55	38.51	68.08	60.53
Av. Early Hay			47.86	51.38	31.69	58.27	52.81
Medium	I	2	41.49	35.28	36.02	44.91	47.57
		5	40.89	37.93	42.16	44.67	45.69
		8	40.11	34.71	39.80	43.96	43.62
	Av.		40.83	35.97	39.33	44.51	45.63
	II	3	33.36	38.73	17.88	41.14	39.00
		4	29.74	21.48	16.84	39.74	39.09
		9	31.66	11.59	19.43	45.55	44.97
	Av.		31.59	23.93	18.05	42.14	41.02
	III	1	54.76	46.10	26.44	64.34	54.39
		6	48.43	29.75	33.25	61.03	51.96
		7	55.92	36.75	39.65	66.08	58.35
	Av.		53.04	37.53	33.11	63.82	54.90
Av. Medium Hay			41.82	32.48	30.16	50.16	47.18

Table 6
Coefficients of Apparent
Digestibility of Hays Fed (Cont'd)

Hay	Period	Lamb	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract
			%	%	%	%	%
Late	I	3	37.45	24.21	18.26	44.42	40.91
		6	39.09	17.35	21.49	43.66	45.75
		9	38.50	11.72	30.63	45.56	42.14
	Av.		38.23	17.76	23.46	44.55	42.93
	II	1	44.23	26.47	26.26	59.19	43.22
		5	36.95	17.94	18.21	51.01	38.90
		7	35.59	16.84	40.80	53.25	40.53
	Av.		38.92	20.42	28.42	54.48	40.88
	III	2	46.35	30.67	19.44	55.31	47.02
		4	48.09	29.42	21.91	57.20	52.36
		8	45.54	32.76	12.48	55.27	48.90
	Av.		46.66	30.95	17.94	56.93	49.43
Av. Late Hay			41.27	23.04	23.27	51.99	44.41

Table 7

Summary of Coefficients of Apparent
Digestibility of Hays Fed

Hay	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract
	%	%	%	%	%
Early	47.86	51.38	31.69	58.27	52.81
Medium	41.82	32.48	30.16	50.16	47.18
Late	41.27	23.04	23.27	51.99	44.41

The average coefficients of digestibility for the dry matter of the hays were 47.86 per cent for the early hay,

41.83 per cent for the medium hay and 41.27 per cent for the late cut hay. When subjected to analysis of variance (Table 8) this decrease in dry matter digestibility was not significant. The difference between periods did reach the level of significance, but the reason for this was not evident. The coefficient of digestibility of dry matter between hays does not agree with Nelson (1948) who obtained digestion coefficients for dry matter of 47.61 per cent, 44.25 per cent, and 38.38 per cent for early, medium, and late cut hays, respectively, when run on the same type of hay with steers. These differences were significant.

Table 8
Analysis of Variance of Dry Matter
Coefficients of Digestibility

Source of Variation	D/F	S of S	M S	F
Total	26	1568.53		
Between Hay	2	280.72	140.36	3.30-
Between Periods	2	693.46	346.73*	8.15
Hay x Periods	4	170.22	42.56	1.80-
Error	18	424.13	23.56	

*Significant differences

The average coefficient of apparent digestibility of crude protein declined sharply as the maturity of the hay increased. This decline from 51.38 per cent for early hay to 32.48 per cent for medium hay, to 23.04 per cent for late hay was significant (Table 9).

Table 9
Analysis of Variance of Crude Protein
Coefficients of Digestibility

Source of Variation	D/F	S of S	M S	F
Total	26	6166.44		
Between Hay	2	3747.36	1873.68*	9.41
Between Periods	2	118.49	59.242	
Hay x Periods	4	796.68	199.17	2.38-
Error	18	1503.91	83.55	

*Significant differences

The large and persistent decrease in the digestibility of the protein in later cut hays may be the main factor in decreased feeding value for hays cut at later stages of maturity when the value of such hays are measured by gains in weight in feeding trials (Baker and Arthand, 1947), (Nelson, 1948), (Jordan, 1948).

Many investigators feel that protein digestibility is low due to the fact that the bacteria fail to break down the lignin and fiber in which the protein is encased. Maynard (1947) points out that differences in crude fiber digestibility have an influence on the digestibility of all nutrients because intact fiber hinders the action of the digestive enzymes on the other nutrients. Patton and Giescher (1942) concluded that lignin decreases the availability of other constituents by any of three ways: "(1) the lignin may incrust the other digestible nutrients, putting them in a nutshell which the animal cannot crack;

(2) lignin may combine chemically with other constituents, forming unavailable compounds; and (3) it seems possible that digestion may be retarded through local inhibitions of digestive enzymes due to the toxic action of phenolic groups resulting in partial decomposition of lignin."

Table 10 shows the analysis of variance of ether extract.

Table 10
Analysis of Variance of Ether Extract
Coefficient of Digestibility

Source of Variation	D/F	S of S	M S	F
Total	26	6075.01		
Between Hay	2	829.10	414.55	1.84-
Between Periods	2	1127.92	563.96	2.50-
Hay x Periods	4	902.68	225.67	1.26-
Error	18	3215.31	178.63	

There were no significant differences in the analysis of variance for ether extract (Table 10). The ether extract decreased in digestibility from 31.69 per cent to 30.16 per cent, to 28.27 per cent for the early, medium, and late cut hays, respectively. The fact that there was so much variation between lambs, particularly the low values received for lambs 2 and 9 when on early hay, may account for this lack of significance.

Table 11
Analysis of Variance of Nitrogen-Free Extract Coefficients of Digestibility

Source of Variation	D/F	Sums of Squares	Mean Square	F
Total	26	1484.74		
Between Hay	2	339.64	169.82**	40.50
Between Periods	2	684.04	342.02**	81.63
Hay x Periods	2	16.77	4.19	
Error	18	444.29	24.68	

The analysis of variance showed highly significant differences between hays in the digestibility of nitrogen-free extract (Table 11). There was considerable variation in digestion coefficients between lambs but a definite decrease from 52.81 per cent to 47.18 per cent to 44.41 per cent was apparent as the plants increased in maturity before cutting. This decrease may be due to the fact that the late cut hays which are low in protein exert a depressing effect on digestibility of the nitrogen-free extract, (Morrison, 1948). A highly significant difference was noted when analysis of variance was used to test for between periods. This indicates that some lambs digested the nitrogen-free extract better than others. There was no significant difference in hays times periods.

Digestibility of crude fiber decreased from 58.27 per cent to 50.16 per cent and then increased slightly to 51.99 per cent for the early, medium, and late cut hay, respectively. When subjected to an analysis of variance these differences were not significant (Table 12).

Table 12
Analysis of Variance of Crude Fiber
Coefficients of Digestibility

Source of Variation	D/F	Sums of Squares	Mean Square	F
Total	26	2161.23		
Between Hay	2	335.31	167.66	1.32-
Between Periods	2	806.37	403.19	3.17-
Hay x Periods	4	508.15	127.04*	4.47*
Error	18	411.50	28.41	

Significant differences

The average digestion coefficients for fiber are higher than for any other nutrient, including nitrogen-free extract. It is a popular belief that lignin is a part of fiber, however, Anderson (1948) found 80 to 90 per cent of the lignin present in the nitrogen-free extract fraction when an improved system of lignin determination was used. Thus, it appears that the crude fiber fraction consists largely of cellulose, starches, and sugars that are quite digestible, instead of undigestible lignin. This may explain why the digestion coefficient for fiber was higher than nitrogen-free extract. There was a significant difference in the hays times period. This is explainable since the late hay in the second and third period was more digestible than the early hay in period one and medium hay in all three periods. Lamb number 9, whose coefficients were very low for protein on all three hays and for ether extract on early hay, has a higher coefficient of digestion for fiber than any other

lamb.

The data in Table 13 have been calculated to show the total digestible nutrients and chemical composition of each of the three hays studied. It may be noted that there is a decline in total digestible nutrient content with increased maturity of the grass.

Digestible crude protein content decreased by the greatest amount. Early cut hay contained 4.18 per cent digestible protein, medium cut hay contained 1.92 per cent digestible protein, whereas the late cut hay contained only 1.10 per cent digestible protein.

Table 13
Total Nutrients and Digestible Nutrients Based on Chemical Analysis and Digestion Coefficients on Prairie Hay Harvested at Three Stages of Maturity

Hay		Dry Matter	Crude protein	N-Free Extract	Crude Fiber	Ether Extract	Total Dig. Nut.
Early	Total	89.42	8.13	40.27	28.71	2.25	43.77
	Dig.	42.80	4.18	21.27	16.73	.71	
Med.	Total	88.95	5.91	41.24	29.96	2.68	38.22
	Dig.	37.20	1.92	19.46	15.03	.81	
Late	Total	88.29	4.79	41.42	29.63	2.69	36.31
	Dig.	36.44	1.10	18.39	15.40	.63	

* Includes ether extract x 2.25.

The total protein content of 8.13 per cent in the early hay was 169 per cent more than the 4.79 per cent protein contained in the late hay; further the digestible protein, as measured by digestion trials, of 4.18 per cent in the early

hay was 380 per cent more than the 1.10 per cent digestible protein contained in the late cut hay. This demonstrates the importance of going a step beyond the chemical determinations and conducting digestion trials to determine how well the animal utilizes the feed. As an example, the crude protein content of the early hay was 8.13 per cent, of which 51.38 per cent was digestible, whereas the late hay contained 4.79 per cent protein of which 23.04 per cent was digestible. Thus it is apparent that there are two factors that lower the value of late cut or mature hay. These two factors are: (1) less total nutrient content, and (2) reduction of apparent digestibility of the nutrients.

The nutritive ratio of the early cut hay was 1:9.47. The nutritive ratio for the medium cut hay was 1:18.91 and that for the late cut hay was 1:32.01. Maynard (1947) states "As the nutritive ratio becomes wider the digestibility of all nutrients tends to be lower." The results of this experiment substantiate this statement.

Morrison (1948) recommends a nutritive ratio of 1:8.5 for 130 pound pregnant ewes up to 4 to 6 weeks before lambing and 1:7.6 to 1:7.8 for fattening a 90 pound lamb. Using these standards as a guide, none of these classes of sheep would be supplied a satisfactory ration if fed any of these prairie hays without supplements.

Summary

The results are presented of 27 individual trials with lambs fed prairie hay at the early (shooting) stage, medium (seed-ripe) stage, and late (mature) stage. The prairie hay consisted of about 62 per cent western wheatgrass, 22 per cent needle grass, 3 per cent needle and thread, 9 per cent other grasses consisting mainly of Kentucky bluegrass, June grass, and red top, and 4 per cent weeds. The crude protein content of the hay decreased as the plants matured, as follows: early hay, 8.13 per cent; medium hay, 5.91 per cent; and late hay, 4.79 per cent. These differences were statistically significant. Ether extract, fiber, and nitrogen-free extract increased slightly with maturity. With the exception of ether extract, none of these differences were significant, however.

Coefficients of digestibility of the various nutrients decreased as the grass matured. The differences in apparent digestibility of the crude protein of the three hays were statistically significant and the differences in apparent digestibility of nitrogen-free extract were highly significant. The apparent digestibility of protein was 51.38 per cent for the early cut hay, 32.48 per cent for the medium cut hay and 23.04 per cent for the late cut hay. The nitrogen-free extract coefficients of digestibility were 58.27 per cent, 50.16 per cent, and 51.99 per cent for the early, medium, and late cut hay, respectively.

Digestibility coefficients for ether extract were somewhat variable between lambs and between periods. There were no significant differences among the hays in digestibilities of dry matter, ether extract, or fiber.

The early cut hay contained 43.77 per cent total digestible nutrients while that at the medium stage contained 38.22 per cent total digestible nutrients, and the late cut hay contained 36.31 per cent total digestible nutrients. The total protein content of 8.13 per cent in the early hay was 169 per cent more than the 4.79 per cent in the late hay. Furthermore, the digestible protein in early hays of 4.18 is 380 per cent more than in late hay which contained 1.10 per cent. The nutritive ratios were 1:9.47 for the early cut hay, 1:18.91 for the medium cut hay, and 1:32.01 for the late cut hay. These nutritive ratios are all too wide for optimum production of any type of sheep, as given in Morrison's Feeding Standards. The hay cut at the late stage was less palatable than that cut at the early stages. The digestibility of all the nutrients decreased and the nutritive ratio became wider with increased maturity.

Thus, this study indicates that the nutritive value of prairie hay decreases as the stage of maturity increases and that protein varies the most in content and its digestibility was affected the most by the time at which the hay was cut. The harvesting of native hay at an early stage of maturity can save farmers and ranchers a great deal by reducing the amount of protein supplement that is needed to balance the rations of cattle and sheep.

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