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Nutritional Characteristics of Some Mountain Meadow Hay Plants of Colorado

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GRADUAL depletion of native prairie meadows in favor of cultivated crops in the Plains Area has all but replaced this former source of winter roughage for livestock. Of the native meadows remaining, those found in the numerous mountain valleys in the Rocky Mountain States are assuming a rather important position from the viewpoint of the stock grower.

Colorado mountain meadow hays have for a period of years found a ready market in eastern states and have acquired a reputation for their quality among local stock growers as well. It is said that cattle will subsist over winter satisfactorily on this roughage alone, although numerous ranchers have adopted the expedient of sowing alsike clover in the bottom-land meadows to raise the protein content, which practice does materially improve the nutrient quality of the hays produced.

Nutritional characteristics of alfalfa and of some of the more common tame grasses, such as timothy, have been studied rather intensively in recent years. Some of these have also been studied with respect to their vitamin content, in addition to their chemical composition.

In Colorado a rather cursory study of many native grasses was made in 1889 by Cassidy and O'Brine (1). This study was largely taxonomic in nature, although fodder analyses were made. Since no attention was given in this work to the mineral nutrients in the ash, and since it antedated the discovery of vitamins as accessory food factors, it was thought advisable to briefly review this subject in the light of present-day concepts of nutrient values and to make an effort to determine wherein lies the reputed excellence of these hays.

This work represents a cooperative project between the staff of the Chemistry Section of the Colorado Experiment Station and Melvin Morris, formerly of the Botany Section and later of the Range and Pasture Management Section.

The hay samples discussed in this paper were composed of 10 of the most common individual species of hay plants, namely, the grasses timothy *(Phleum pratense)*, tufted hairgrass *(Deschampsia caespitosa)*, and red top *(Agrostis alba)*, the grasslike plants *(Carex* spp. and *Juncus* spp.), and herb, alsike clover *(Trifolium hybridum)*. In addition, three samples of mixed plants were investigated to determine whether or not any material differences in nutrient quality exist among the hays of upper benches, those occupying median benches, and those in the creek bottoms. These are our samples nos. 3295, 3296, and 3297, respectively.

TABLE 1.—*Fodder analyses, North Park hays, 1933.*

Sample no.	Scientific name	Common name	Moisture, air-dry	Moisture, 100° C.	Ether extract	Crude fiber	Protein	Crude ash	N-free extract
3294	*Agrostis alba*	....	42.39	6.44	1.43	33.10	6.27	8.60	44.14
3292	*Phleum pratense*	....	58.44	6.46	1.32	37.29	6.15	5.81	42.97
3287	*Deschampsia caespitosa*	....	50.33	6.54	1.29	36.10	6.57	7.69	41.80
3286	*Carex aquatalis*	....	65.58	6.42	1.65	32.10	8.98	7.69	43.21
3289	*Carex athrostachya*	....	62.34	6.50	1.39	30.00	9.64	7.93	44.54
3290	*Carex rostrata*	....	67.20	6.48	1.47	31.61	9.88	8.55	42.01
3293	*Carex praegracilis*	....	61.04	6.90	1.33	32.43	10.62	6.45	42.27
3284	*Eleocharis ovata*	....	62.34	6.59	1.21	29.64	11.08	10.46	41.02
3291	*Juncus ater*	....	57.47	6.19	1.04	31.67	11.01	5.30	44.77
3288	*Juncus longistylis*	....	53.57	6.73	1.15	32.23	9.08	7.06	43.73
3285	*Trifolium hybridum*	....	66.88	7.85	1.21	26.00	15.35	7.16	42.43
3295	Timothy (high bench) mixture	....	....	6.51	1.47	34.68	7.08	6.70	44.54
3296	Sedges (medium bench) mixture	....	....	6.95	1.72	30.81	8.86	8.52	44.14
3297	Sedges (creek bottoms) mixture	....	....	5.53	1.56	32.25	8.88	7.00	44.77
					Recalculated to moisture-free basis				
3294	*Agrostis alba*	(red top)	....	...	1.53	35.38	6.70	9.19	47.20
3292	*Phleum pratense*	(timothy)	....	...	1.41	39.88	6.57	6.21	45.93
3287	*Deschampsia caespitosa*	(hairgrass)	....	...	1.38	38.63	7.03	8.23	44.73
3286	*Carex aquatalis*	(meadow sedge)	....	...	1.76	34.31	9.60	8.22	46.11
3289	*Carex athrostachya*	(sedge)	....	...	1.49	32.09	10.31	8.48	47.63
3290	*Carex rostrata*	(sedge)	....	...	1.57	33.80	10.57	9.14	44.92
3293	*Carex praegracilis*	(sedge)	....	...	1.43	34.83	11.41	6.93	45.40
3284	*Eleocharis ovata*	(spikerush)	....	...	1.30	31.73	11.86	11.20	43.91
3291	*Juncus ater*	(wiregrass-rush)	....	...	1.11	33.76	11.74	5.65	47.74
3288	*Juncus longistylis*	(rush)	....	...	1.23	34.56	9.74	7.57	46.90
3285	*Trifolium hybridum*	(alsike clover)	....	...	1.31	28.22	16.66	7.77	46.04
3295	Timothy (high bench) mixture	(largely timothy)	....	...	1.56	36.70	7.49	7.09	47.16
3296	Sedges (medium bench) mixture	(mostly sedges and timothy)	....	...	1.83	32.76	9.42	9.06	46.93
3297	Sedges (low bench) mixture	(hairgrass, foxtail, and spikerush)	....	...	1.65	34.14	9.40	7.41	47.40

These samples were collected by Melvin Morris in the meadows of North Park (Jackson County), Colo., during two consecutive summers, 1933 and 1934. They were taken at the time of haying operations in this area, which is usually about August 20, although the harvesting date fluctuates with the years, dependent upon seasonal conditions.

ANALYTICAL DATA

The fodder analyses in table 1, constituting the 1933 crop, exhibit some interesting differences as between species and also as compared with similar values for alfalfa hays. The average amount of dry matter derived from many samples of irrigated alfalfa is about 24 percent. From this table it is apparent that the average air-dry weight for native meadow hays is about 39.2 percent. The average crude protein in alfalfa hays of our section is about 18 percent, whereas these native meadow species carry an average of 8.9 percent protein, with extremes of 6.1 percent to 11.0 percent. The total ash also fluctuates rather widely among the species, ranging between 5.3 percent and 10.4 percent, with an average of 7.5 percent to 9.0 percent. The nitrogen-free extract averages about 43 percent for these mountain hays as against 34 percent for alfalfas, whereas the crude fibers are about on a par at 32.5 percent. The ether extracts average about 1.38 percent, which is lower than that for average alfalfa hays.

It has been found by comparison of results with various laboratories over the country that because of altitude differences the boiling point of water differs quite widely in Colorado from that in states of lower altitude. This always gives higher results for crude fibers determined in our laboratory. The altitude of our laboratory is about 5,000 feet above sea level. Consequently our results for crude fiber should be multiplied by the factor .859 to be consonant with determinations in states whose altitude does not exceed 1,000 feet.

Table 2 represents the hay plants of the 1934 crop. Before considering them it should be noted that the growing season of 1934 was perhaps the driest season in North Park, and in fact in most of Colorado, within the memory of the inhabitants. During this summer, and for the first time in many years, the snowbanks in the mountains almost disappeared. There was a scarcity of water, even in the lowland meadows, which are usually somewhat marshy during the vegetative season. These conditions are reflected in the character of the hay grasses of this season, which show an average of 56.95 percent of air-dry matter in 1934 against 39.22 percent for those of the 1933 crop. The significant differences in the fodder analyses for the two seasons appear to be a higher ether extract in the dry season, a lower crude fiber content, a lower protein content, a slightly higher ash content, and a slightly higher nitrogen-free extract.

The individual species show some anomalous characteristics under these conditions, especially in the case of hairgrass *(Deschampsia*

TABLE 2.—*Fodder analyses, North Park hays, 1934.*

Sample no.	Scientific name	Common name	Moisture, air-dry	Moisture, 100° C.	Ether extract	Crude fiber	Protein	Crude ash	N-free extract
3403	*Agrostis alba*	....	35.94	8.66	1.71	32.03	6.75	8.78	42.07
3401	*Phleum pratense*	....	56.26	7.85	1.95	33.40	5.88	6.36	44.56
3397	*Deschampsia caespitosa*	....	27.82	8.30	1.70	35.48	5.31	3.79	45.42
3396	*Carex aquatalis*	....	44.24	8.24	2.93	28.27	9.44	9.45	41.67
3398	*Carex athrostachya**	....	....	8.47	2.52	27.22	8.69	9.97	43.13
3399	*Carex rostrata*	....	....	8.44	1.98	30.65	8.81	9.21	40.91
3402	*Carex praegracilis*	....	23.76	8.63	2.18	30.22	7.69	6.68	44.60
3394	*Eleocharis ovata*	....	43.12	9.41	2.13	24.38	9.19	10.63	44.26
3400	*Juncus ater*	....	33.76	8.70	1.85	30.08	9.94	5.22	44.21
3395	*Trifolium hybridum*	....	....	9.39	1.46	25.21	12.38	8.21	43.35
3404	Upland hay	....	....	8.40	2.18	27.89	7.56	7.56	46.32
3405	Midland hay	....	....	8.15	2.37	28.99	8.00	7.58	44.91
3406	Lowland hay	....	....	8.04	2.22	29.13	7.31	8.11	45.19
					Recalculated to moisture-free basis				
3403	*Agrostis alba*	(red top)	....	...	1.87	35.07	7.39	9.61	46.06
3401	*Phleum pratense*	(timothy)	....	...	2.12	36.25	6.38	6.90	48.35
3397	*Deschampsia caespitosa*	(hairgrass)	....	...	1.86	38.69	5.79	4.13	49.53
3396	*Carex aquatalis*	(sedge)	....	...	3.19	30.81	10.29	10.30	45.41
3398	*Carex athrostachya**	(sedge)	....	...	2.75	29.74	9.49	10.89	47.13
3399	*Carex rostrata*	(sedge)	....	...	2.16	33.48	9.62	10.06	44.68
3402	*Carex praegracilis*	(sedge)	....	...	2.39	33.07	8.42	7.31	48.81
3394	*Eleocharis ovata*	(spikerush)	....	...	2.35	26.91	10.14	11.73	48.87
3400	*Juncus ater*	(wiregrass)	....	...	2.03	32.95	10.87	5.72	48.41
3395	*Trifolium hybridum*	(alsike clover)	....	...	1.61	27.82	13.66	9.06	47.85
3404	Upland hay	(largely timothy)	....	...	2.38	30.45	8.25	8.35	50.57
3405	Midland hay	(mostly sedges and timothy)	....	...	2.58	31.56	8.71	8.25	48.90
3406	Lowland hay	(hairgrass, foxtail, and spikerush)	....	...	2.40	31.68	7.95	8.82	49.15

*Contains *Carex festivella*.

TABLE 3.—*Fodder analyses of sedges, rushes, and miscellaneous hays.*

No. of samples	Location	Genera	Ether extract	Crude fiber	Protein	Crude ash	N-free extract
7	Miscellaneous	*Juncus* (rushes)	2.16	31.69	8.78	7.35	50.02
1	Miscellaneous	*Deschampsia* (hairgrass)	1.57	35.75	7.63	7.21	47.84
5	Miscellaneous	*Eleocharis* (rushes)	2.56	28.19	8.59	12.43	48.23
9	Miscellaneous	*Phleum* (timothy)	2.91	33.29	8.16	6.74	48.90
10	Miscellaneous	*Agrostis* (red top)	2.58	30.58	9.60	7.92	49.32
4	Miscellaneous	*Trifolium* (alsike)	2.81	26.50	16.96	9.82	43.91
20	Miscellaneous	*Carex* (sedges)	2.58	28.58	10.99	8.92	48.93
5	Colorado (1930)	*Medicago* (alfalfa)	2.08	34.38	18.93	8.64	35.97
7	Colorado (1895)	*Medicago* (alfalfa)	1.42	37.75	15.79	10.56	34.47
250	Henry & Morrison	*Medicago* (alfalfa)	2.52	30.96	16.30	9.41	40.81
42	Henry & Morrison	Western prairie hays	2.78	32.62	8.56	8.24	47.80
		Comparison of North Park hays with hays from other sources					
7	Miscellaneous	*Juncus*	2.16	31.69	8.78	7.35	50.02
3	North Park hay	*Juncus*	1.47	33.76	10.78	6.31	47.68
1	Miscellaneous	*Deschampsia*	1.57	35.75	7.63	7.21	47.84
2	North Park hay	*Deschampsia*	1.62	38.66	6.41	6.18	47.13
5	Miscellaneous	*Eleocharis*	2.56	28.19	8.59	12.43	48.23
2	North Park hay	*Eleocharis*	1.83	29.32	11.00	11.46	46.39
9	Miscellaneous	*Phleum*	2.91	33.29	8.16	6.74	48.90
2	North Park hay	*Phleum*	1.77	38.07	6.47	6.55	47.14
10	Miscellaneous	*Agrostis*	2.58	30.58	9.60	7.92	49.32
2	North Park hay	*Agrostis*	1.70	35.23	7.04	9.40	48.88
4	Miscellaneous	*Trifolium*	2.81	26.50	16.96	9.82	43.91
2	North Park hay	*Trifolium*	1.46	28.02	15.16	8.41	46.95
20	Miscellaneous	*Carex*	2.58	28.58	10.99	8.92	48.93
2	North Park hay	*Carex*	2.47	32.56	9.95	9.26	45.76

caespitosa), where the ash content is lower in the dry season. A two-season comparison is not sufficient to warrant the drawing of broad conclusions, but the differences indicate that if studied over a period of several years some very illuminating data would be collected regarding the responses of individual species to moisture conditions.

In table 3 have been brought together the averages of some miscellaneous published data of fodder analyses for several species of plants. A comparison of these with North Park plants is given which brings out some interesting differences. The North Park hays appear to carry lower quantities of ether extract and higher quantities of crude fiber. There is an interesting relationship observable between the crude fiber and the ash content of these grasses. In connection with the present study, and also in some unpublished data regarding other plant species, it appears that an increased ash content tends to suppress the crude-fiber content, and consequently to increase the nitrogen-free extract, which is generally considered to be carbohydrates.

Table 4 is presented to show the effects of a dry growing season upon the nutritional value of individual species. The fact that 1933 was a fair growing season as regards moisture, while 1934 was an unusually dry season, is reflected in these fodder analyses. Further study would doubtless reveal whether or not plants absorb more mineral constituents in dry growing seasons which in turn tend to suppress crude fiber and produce a more digestible or a better quality hay.

FODDER ANALYSES

In any discussion of the feed value of hays it must be borne in mind that roughage of any kind serves in part a physical and physiological purpose of supplying bulk and dilution within the animal rumen. Ordinarily, these things are brought home to the feeder only when alimentary difficulties arise as a result of feeding too concentrated a diet. From the purely nutritional viewpoint, the value of hay plants lies in the proteins, carbohydrates, mineral ash, and fat constituents, and in the vitamins they furnish.

In table 3 an attempt has been made to compare individual species from miscellaneous sources with some similar species of Colorado mountain meadow plants. The stage of growth of a plant at time of harvest is of primary importance to its nutrient qualities. The Colorado mountain meadow plants cited in the tables were harvested during the latter part of August, and most of them had well developed seed stocks. Obviously, since the miscellaneous analyses collected from the published accounts of other authors do not specify their stage of growth, the direct comparison is unfair except as it shows a general likeness or any major differences. The comparison is made with this in mind.

Alfalfa, a cultivated hay plant in general use, has long been esteemed as a roughage, because it approaches more nearly a balanced

TABLE 4.—*Comparison of fodder analyses for 1933 and 1934, North Park hays.*

Season	1933	1934	1933	1934	1933	1934	1933	1934
Species	*Eleocharis ovata*		*Trifolium hybridum*		*Carex aquatalis*		*Carex athrostachya*	
Ether extract	1.30	2.35	1.31	1.61	1.76	3.19	1.49	2.75
Crude fiber	31.73	26.91	28.22	27.82	34.31	30.81	32.09	29.74
Protein	11.86	10.14	16.66	13.66	9.60	10.29	10.31	9.49
Ash	11.20	11.73	7.77	9.06	8.22	10.30	8.48	10.89
N-free extract	43.91	48.87	46.04	47.85	46.11	45.41	47.63	47.13
Species	*Carex rostrata*		*Carex praegracilis*		*Deschampsia caespitosa*		*Juncus ater*	
Ether extract	1.57	2.16	1.43	2.39	1.38	1.86	1.11	2.03
Crude fiber	33.80	33.48	34.83	33.07	38.63	38.69	33.76	32.95
Protein	10.57	9.62	11.41	8.42	7.03	5.79	11.74	10.87
Ash	9.14	10.06	6.93	7.31	8.23	4.13	5.65	5.72
N-free extract	44.92	44.68	45.40	48.81	44.73	49.53	47.74	48.41
Species	*Juncus longistylis*		*Phleum pratense*		*Agrostis alba*			
Ether extract	1.23	....	1.41	2.12	1.53	1.87		
Crude fiber	34.56	....	39.88	36.25	33.38	35.07		
Protein	9.74	....	6.57	6.38	6.70	7.39		
Ash	7.57	....	6.21	6.90	9.19	9.61		
N-free extract	46.90	....	45.93	48.35	47.20	46.06		
Mixed species	Upland (timothy)		Midland (sedges)		Lowland (sedges)			
Ether extract	1.56	2.38	1.83	2.58	1.66	2.40		
Crude fiber	36.70	30.45	32.76	31.56	34.14	31.68		
Protein	7.49	8.25	8.42	8.71	9.40	7.05		
Ash	7.09	8.35	9.06	8.25	7.41	8.82		
N-free extract	47.16	50.57	46.93	48.90	47.40	49.15		

ration than other known hay plants. Therefore, some analyses of Colorado alfalfa hays are presented in table 6, as well as a few other published reports, found in table 3, in order to evaluate better the special merits of two distinctly different families of plants. A more comprehensive treatment of the feed value of alfalfa hays may be found in technical bulletin 4 of this station.

From the data at hand it appears that the more striking differences in nutrient value lie in the proteins, carbohydrates (N-free extract), and to a lesser extent, the minerals. Alfalfa appears to carry nearly twice the quantity of proteins and also more mineral than is found in the hay plants. On the other hand, the soluble carbohydrates in the hay plants exceed those present in alfalfas by relative percentages of the order of 43 percent to 34 percent.

Table 3 is anomalous and incomprehensible to the authors of this paper. It appears that the evident palatability and excellence of these mountain meadow hays as compared with those of similar species grown largely in draws and creek bottoms of the prairie states cannot be explained on the basis of fodder analyses. The rushes and sedges of the prairie states grow taller and coarser and naturally are refused by cattle in favor of the better upland grasses. Because of their coarseness, they have been used as thatching to top off haystacks or, in many instances, were burned as waste. A possible and plausible reason for the difference in palatability lies in the shorter growing season and the cooler climate under which these mountain hay plants are grown, which is not favorable to the formation of great quantities of woody tissue. The miscellaneous hays in table 3 do not bear out this statement, since in most cases the crude fiber in our mountain hays is higher than that in other published analyses. These miscellaneous analyses are unreliable for comparison and may be discounted because of lack of specific information as to the stage of maturity of the plants and method of determination of the crude fiber. Crude fiber determinations in high altitudes require corrections downward because of the lower boiling points prevailing there. We have found by comparison that our crude fiber determinations should be multiplied by a factor of .859, as previously mentioned in this bulletin. A few fodder analyses of miscellaneous alfalfa hays, when compared with Colorado alfalfas, appear to show similar relations.

In table 5 the data of the ash analyses are presented side by side for the two growing seasons. This facilitates a comparison of the mineral content of the individual species, as well as any sharp differences in composition which may have occurred from season to season.

Except for the ash of alsike clover *(Trifolium hybridum)*, which approaches the composition of alfalfa ashes, the hay plants, which are largely rushes, sedges, and timothy, are characterized by a very high silica content in the ash. This also varies quite widely between species, as shown by a range of between 34 percent and 63 percent of the total ash composition. The second highest ingredient is potash, which also

TABLE 5—*Pure ash and its composition in Colorado mountain meadow plants.*

Season	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934
Species	*Eleocharis ovata*		*Trifolium hybridum*		*Carex aquatalis*		*Carex athrostachya*		*Carex rostrata*	
Sample no.	3284	3394	3285	3395	3286	3396	3289	3398*	3290	3399
% pure ash	10.380	10.229	7.690	8.120	7.380	9.070	8.320	9.672	8.620	8.749
SiO_2	45.724	51.194	5.045	3.106	34.320	49.081	43.583	57.676	47.339	63.975
SO_3	4.913	9.227	3.328	3.445	4.182	5.236	5.215	5.099	3.734	2.785
Cl	2.371	1.378	1.004	1.907	2.602	4.698	1.296	4.310	.557	.703
CO_2	.970	.104	22.924	26.410	2.401	.733	2.153	1.113	1.326	1.350
P_2O_5	6.725	4.459	6.016	4.194	6.400	4.699	5.215	3.867	5.552	3.957
Al_2O_3	.213	....	.094	.044	.078	....	.166	....	.653	....
Fe_2O_3	1.405	.249	.299	.381	.460	.456	.512	.358	1.356	.727
Mn_3O_4	.407	.458	.712	.196	.864	.482	.512	.449	.484	.438
CaO	6.894	7.806	27.911	25.585	9.354	8.571	8.616	9.012	5.064	9.246
MgO	2.111	1.590	7.331	5.166	3.578	3.583	2.798	4.341	3.189	3.059
K_2O	27.801	21.953	24.830	29.070	36.185	23.493	26.802	14.521	30.674	13.639
Na_2O	1.000	1.896	.733	.926	.118	.058	3.425	.226	.198	.279
Sum	100.534	100.314	100.227	100.430	100.542	101.060	100.293	100.972	100.126	100.158
O = Cl	.534	.314	.227	.430	.542	1.060	.293	.972	.126	.158

*Contains *Carex festivella*.

TABLE 5, continued.—*Pure ash and its composition in Colorado mountain meadow plants.*

Season	1933	1934	1933	1934	1933	1934	1933	1933	1934
Species	*Carex praegracilis*		*Deschampsia caespitosa*		*Juncus ater*		*Juncus longistylis*	*Phleum pratense*	
Sample no.	3293	3402	3287	3397	3291	3400	3288	3292	3401
% pure ash	6.230	6.372	6.960	3.697	5.600	5.147	6.820	6.03	5.835
SiO_2	37.810	41.528	57.061	32.011	14.608	16.680	15.851	47.316	53.794
SO_3	4.713	6.358	3.590	5.128	11.470	13.966	5.492	2.710	4.215
Cl	1.264	1.640	2.389	1.363	4.271	5.300	4.818	2.774	1.417
CO_2	2.937	2.345	.857	6.477	5.966	4.343	7.791	1.957	.962
P_2O_5	5.331	4.752	5.415	6.379	6.046	6.199	8.421	6.745	5.212
Al_2O_3	.220	.132	.034	.324	.197	.100	.189	....	....
Fe_2O_3	.300	.742	.300	1.150	.622	.648	.571	.260	.468
Mn_3O_4	.404	.353	.012	.671	.611	.361	.925	.005	.171
CaO	9.232	9.460	6.634	9.915	8.314	8.273	5.306	5.940	5.363
MgO	3.351	3.070	2.206	4.034	3.958	4.323	3.961	2.309	2.078
K_2O	34.725	29.463	21.692	31.440	43.193	40.598	45.896	30.168	25.950
Na_2O	....	.527	.350	1.416	1.708	.405	1.868	.441	.690
Sum	100.287	100.370	100.540	100.308	100.964	101.196	101.089	100.625	100.320
O = Cl	.287	.370	.540	.308	.964	1.196	1.089	.625	.320

Season	1933	1934	1933	1934	1933	1934	1933	1934
Species	*Agrostis alba*		Upland (timothy)		Midland (sedges)		Lowland (sedges)	
Sample no.	3294	3403	3295	3404	3296	3405	3297	3406
% pure ash	8.020	8.265	6.900	7.355	8.350	7.212	7.220	7.513
SiO_2	61.612	62.068	45.445	43.967	46.266	43.748	43.142	51.052
SO_3	3.564	3.684	4.373	4.200	5.044	4.453	5.460	3.840
Cl	2.311	2.919	1.938	3.208	1.838	1.818	.752	1.393
CO_2	.497	.157	1.284	1.557	.583	2.205	1.210	2.243
P_2O_5	4.202	4.272	5.797	5.420	5.668	5.908	5.717	4.842
Al_2O_3	.203	....	.155	.098	.482	....	.205	.106
Fe_2O_3	.227	.214	.186	.377	.216	.240	.330	.311
Mn_3O_4	.159	.155	.303	.325	.412	.495	.570	.534
CaO	5.413	4.712	7.597	10.901	8.825	10.801	9.532	8.785
MgO	2.798	2.342	2.991	2.837	2.750	2.215	2.978	2.459
K_2O	18.382	19.789	30.369	27.402	28.330	28.198	30.275	24.477
Na_2O	1.153	.348	....	.433	....	.329	....	.272
Sum	100.521	100.660	100.438	100.725	100.414	100.410	100.171	100.314
O = Cl	.521	.660	.438	.725	.414	.410	.171	.314

fluctuates quite widely between species. A curious thing observed in the course of analysis was the fact that the ashes in many instances contained sufficient manganese to impart a blue-green color to the crude ash. The hay plants were almost uniformly high in content of this element. It is also interesting to note in connection with the mixed hays that the manganese content increases in passing from the upland, through the midland, down to the swamp-land meadows. With the relatively high manganese content in the plants of the poorly aerated marsh lands, it is an interesting speculation whether or not this ingredient is instrumental in the oxygen exchange within the plant in unaerated or water-logged soils.

As noted, table 6 introduces analytical data on alfalfa hays made at this laboratory at different times from the year 1896 to that of 1933. These hays were all collected in the vicinity of Fort Collins and were irrigated alfalfas.

TABLE 6.—*Miscellaneous fodder analyses of Colorado alfalfa.*

Sample no.	Legend	Location	Year	Ether extract	Crude fiber	Protein	Crude ash	N-free extract
......	First and second cuttings (3)	Fort Collins	1896*	1.38	39.09	15.61	10.42	33.50
3185	3d cutting (1)	Inverness	1928	2.44	24.47	21.37	9.91	41.89
3279-80-81	2d cutting (3)	Windsor	1933	1.28	32.58	19.54	10.09	36.50

Ash analyses, Colorado alfalfas

Number of samples	3	1	3
Season	1896*	1928	1933
Sample number	.....	3185	3279-80-81
Pure ash	10.420	10.052	9.250
SiO_2	1.655	6.228	5.066
SO_3	6.081	7.517	6.994
Cl	6.340	3.301	4.640
CO_2	24.226	20.323	18.083
P_2O_5	4.436	5.009	5.110
Al_2O_3	.115	.860	.284
Fe_2O_3	.295	1.229	.467
Mn_3O_4	.115	.100	.188
CaO	25.468	19.691	20.157
MgO	3.625	4.045	5.173
K_2O	27.357	31.258	32.917
Na_2O	1.754	1.184	1.969
Sum	101.507	100.745	101.048
O = Cl	1.507	.745	1.048

*Colo. Exp. Sta. bul. 35.

In connection with the ash it is noteworthy that the high ingredients in mountain hay plants are silica, potassium, and calcium, while in alfalfa they are potassium, calcium, and carbon dioxide. Manganese values are sufficiently higher in the meadow hay plants to be noteworthy. The phosphorus values for the mountain meadow hay plants would average slightly higher than for alfalfa, but considering that alfalfa carries a higher percentage of ash, this seeming advantage for the hay plants vanishes completely.

ASH ANALYSES

The percentages of mineral ingredients given in table 5 are based on the carbon-free ash, which is believed to be the proper basis for comparison. There was little available literature dealing with ash constituents of similar plants from other sources, hence the discussion is based on differences between Colorado species, as well as a comparison of these with the ash of alfalfa hays.

First of all, it may be noted that a great difference exists in the amount of air-dry matter between individual species, and a still greater difference between these plants and alfalfa.

Colorado alfalfa, depending upon the age of the plant at harvest, yields from 20 to 24 percent of air-dry matter. The hay plants of 1933, an average growing season, yielded an average of 39.2 percent, while those of the extremely dry season of 1934 yielded about 56.9 percent of air-dry hay.

On the moisture-free basis, six samples of mixed native grass hays gave 7.43 percent of ash constituents, whereas seven alfalfas gave 9.86 percent of ash. If the ash content were calculated on the basis of freshly cut green plants, the above ratio would be changed to about 2.18 percent for alfalfa and 3.55 percent for the native meadow hay plants, but the silica content of the native plants is very high (43 to 51 percent). As a mineral ingredient this silica is practically valueless in animal metabolism and is largely eliminated.

In the light of the rather voluminous literature published during recent years dealing with mineral deficiencies in animal metabolism, the entire question of qualitative and quantitative mineral composition of plants assumes considerable importance. Also, for the same reason, it would be interesting to know whether, under conditions of irrigated agriculture, the available mineral soil constituents can change materially within a period of 30 or 40 years. Table 6, while very fragmentary, gives the only available data of that nature in this laboratory. These are too meager to warrant any conclusions, but they appear to indicate that between the years 1896 and 1933 the ashes of some alfalfa hays show an increase in silica, a decrease in lime, and an increase in magnesium and potassium. There is also a very slight increase in phosphoric acid. Periodic investigations with several economic plants of the region over a rather extended period of years should cast some interesting sidelights upon the longevity and future productiveness of our irrigated soils.

Returning again to a discussion of the mountain meadow hay plants, the principal constituents of the ashes are found to be silica, potassium, calcium, phosphoric anhydrid, and sulfates, in order of their descent, while for alfalfa and its kindred species, alsike clover, there are present potassium, calcium, carbonic acid, sulfates, and phosphates, in the descending order. Undoubtedly the carbonates, or at least a major portion of them, pre-existed in the plant in the form of some organic combination. The same may be said of the phosphates.

In the case of the hay plants, the carefully ashed leaves and stems showed beautiful silica skeletons under the microscope.

Interesting are the changes in ash composition of the different genera as affected by a normal or by a very dry growing season. Most of the hay plants cited show an increase in SiO_2 during a dry season. Hairgrass *(Deschampsia)* and the upland composite (largely timothy) are exceptions. Alsike clover *(Trifolium hybridum)*, a widely different genus which normally contains much less SiO_2 than the hay plants, shows a decrease in this constituent for a dry season.

These hay plants during a dry growing season show a marked decrease in K_2O content with few exceptions, notably hairgrass. Alsike clover, again, a widely different genus, shows a marked increase in this component during a dry year.

The lime (CaO), a minor constituent in most of the hay plants but a major one in alfalfa and alsike, does not show much fluctuation between wet and dry years. More of the hay plant species show a slight increase, while alsike clover shows a decrease for a dry season.

Magnesia (MgO) shows even less fluctuation under unequal moisture conditions. It is a minor constituent and shows a very slight average decrease for the dry season of 1934. In this case the same is true for alsike clover as for most of the hay plants.

There seems to be no regularity in the sodium content of these ashes. Percentages range from zero to more than 3 percent. Apparently no correlation with chlorine or sulfates exists in these data.

Iron and alumina are among the smallest components in quantity in all the ashes, and our limited data do not warrant more comment than that iron is usually the major of these two constituents.

Manganese, another minor constituent of ashes, is remarkable because of its abnormally high content in these hay plants. It is far above the usual content in alfalfa hays (0.1 to 0.15 percent) and in 8 out of 13 samples it is suppressed by a dry season (1934). Whether the high manganese content is peculiar to these hay plants or is due to its high content in the soil cannot be concluded from the limited data. Suffice it to say that top soil from the location yielded .0048 percent Mn_3O_4 to a CO_2 solution.

In general, the phosphoric acid content is slightly depressed by a dry season. It is significant, however, that these hay plant species compare very favorably with alfalfa and alsike in P_2O_5 content.

The sulfates and chlorides in the ash did not seem to correlate uniformly with the other ingredients of the ash. With respect to the proteins in some species there is a lineal relation, and in others the relation is inverse. The yearly differences in content are small, indicating the same trend in most instances as the total ash content, namely, an increase during a dry growing season. There are exceptions to the foregoing statement, however, and the chlorides appear to fluctuate more widely than the sulfates. A part of the sulfur may exist within the plant in the form of proteins or other organic com-

TABLE 7.—*Ionic balance in pure ash composition for various plants.*

	Solanum tuberosum (Potato tuber*)		*Trifolium hybridum* (Alsike)		*Carex rostrata* (Sedge)		*Juncus ater* (Rush)		*Medicago sativa* (Alfalfa)		*Phleum pratense* (Timothy)	
No. samples	6		2		2		2		3		2	
H_2O on plant @ 100° C.	77.83		69.46		69.33		49.65		75.53		60.40	
% ash on dry matter	4.197		7.905		8.684		5.373		9.250		5.932	
	Ash	Milli. Equiv.	Ash	Milli. Equiv.	Ash	Milli. Equiv.	Ash	Milli. Equiv.	Ash	Milli. Equiv.	Ash	Milli. Equiv.
SiO_2	1.014	33.6	4.075	135.2	55.657	1846.0	15.644	518.9	5.066	168.1	50.555	1676.9
SO_3	5.720	143.0	3.386	84.6	3.259	81.4	12.718	317.7	6.994	174.7	3.462	86.5
Cl	2.342	66.1	1.455	41.0	.630	17.8	4.785	134.9	4.640	130.8	2.095	59.0
CO_2	15.429	701.2	24.667	1121.1	1.338	60.8	5.154	234.2	18.083	822.1	1.459	66.3
P_2O_5	12.388	523.2	5.105	215.6	4.754	200.8	6.122	258.6	5.110	215.8	5.978	252.3
Al_2O_3	.141	8.3	.069	4.1	.326	19.1	.148	8.7	.284	16.7	.000	....
Fe_2O_3	.658	24.8	.340	12.8	1.041	39.2	.635	23.9	.467	17.5	.364	13.7
Mn_3O_4	.025	0.7	.454	11.9	.466	12.2	.486	12.7	.188	4.9	.088	2.3
CaO	1.376	49.1	26.748	954.3	7.155	255.3	8.293	295.8	20.157	719.2	5.651	201.6
MgO	4.886	242.4	6.248	309.9	3.124	155.0	4.140	205.4	5.173	256.6	2.193	108.8
K_2O	56.241	1194.1	26.950	572.2	22.156	470.4	41.895	889.5	32.917	698.9	28.059	595.7
Na_2O	.358	11.57	.829	26.7	.238	7.7	1.056	34.0	1.969	63.5	.565	18.3
Sum	100.528		100.328		100.142		101.080		101.048		100.472	
O = Cl	.528		.328		.142		1.080		1.048		.472	
Total anions		1467.1		1597.5		2206.8		1464.3		1511.5		2141.0
Total cations		1530.97		1891.9		958.9		1471.0		1777.3		940.4
Total		2998.0		3489.4		3165.7		2935.3		3288.8		3081.4
Anions		765.9		476.4		2146.0		1230.1		689.4		2074.7
Cations		1530.9		1891.9		958.9		1471.0		1777.3		940.4
Total, minus CO_2		2296.8		2368.3		3104.9		2801.1		2466.7		3015.1

*Bliss Triumph.

pounds, but it is logical to assume that most of the chlorine and sulfur are either linked up as esters or inorganic salts of the respective acids. Within its analytical experience this laboratory has found certain plants highly tolerant of chlorides and sulfates, which are often found in the plants in higher amounts than can be accounted for by their physiological and biochemical needs.

With respect to the total of anions and cations in plant ashes, curiosity prompted us to set up a table of analyses (table 7) representing as wide a variety of plants or plant parts as was available in our laboratory.

In addition to roughage plants, an analysis of potato tubers is included, since potato culls are sometimes used as stock food in this region. The stage of growth of all is more comparable because the samples represent these plants or plant parts at maturity. The real purpose in presenting this table is the fact that the ash composition of different families of the plant kingdom shows wide differences. It has often been observed in this laboratory, during the course of years, that the ionic balance in plant ashes varies quite widely. The authors have been curious to know whether or not certain ratios of anions to cations maintain any degree of constancy for given families, genera, or species of plants. If this should prove to be the case, then such analyses should prove valuable to the botanist and the plant physiologist, and even to the biochemist, as an aid in unraveling some of the complexities of nature. The data presented here are too scanty to prove the point, but are nevertheless interesting.

The analyses show a wide variation in ionic balance, and as far as they go seem to indicate that the ions occur in simple numerical ratios. Whether these would bear any relation to the pH of the plant juices is problematical, because organic bases and acids, and buffers in the sap, might mask the results.

In the table ionic balances are struck, first by including the carbonates, and secondly by ignoring the CO_2 as an ion formed in the process of combustion. Insofar as our limited data show, if carbonates be included it is apparent that the ratio of anions to cations is approximately equality for most plants cited, although cations are usually in slight excess. There are two notable exceptions in the cases of *Carex rostrata* and *Phleum pratense*, in which the ratio of anions to cations is approximately as 2:1.

If we eliminate from these data the item of CO_2 as representing an artificial anion produced in the act of oxidation of organic matter, we have a second set of relations expressed. In this case the two plants mentioned still carry the ionic ratio of 2:1 in favor of anions. In the case of the remaining analyses, however, the ratio changes from equality in the case of potato tubers and alfalfa to an approximate 2:1 ratio in favor of cations, while in the case of *Juncus ater* the ratio still remains approximate equality. In one instance, that of alsike clover, which is a hybrid as its Latin name implies, the ratio now becomes approximately as 4:1 in favor of cations. These relations we cannot attempt to explain upon the basis of such meager data as are here presented, but one is intrigued with the possibilities of more extensive studies.

The entire question of the qualitative and quantitative relation between the readily available minerals in the soil and the composition of ashes of plants grown in them appears to be a fertile field for study from both its physical and biochemical aspects. One may find all manner of views expressed in the literature, but it appears that up to the present the amount of well-planned research directed at a specific and categorical answer to this question is sadly inadequate. Much data is available, but this is usually very fragmentary and scattered geographically, both as to method of study and as to the ends sought. The underlying reason for this dearth of conclusive material may be the vast amount of painstaking work that would be required, together with the fact that little professional glory would attach thereto. Three principal factors—soil, climate, and moisture—together with many minor factors, are involved. It is very probable, however, that a systematic study of the leading plant families under acid (unsaturated-podzolic) soil conditions and alkaline (saturated-solonchak) soil conditions would yield a volume of useful information to the botanist in the fields of physiology and ecology, and probably also from the aspects of taxonomy and genetics.

VITAMIN STUDIES

Table 8 shows the vitamin-A content of several species of hay plants of the 1933 crop, as well as of three mixtures of these hay plants.

TABLE 8.—*Vitamin A in North Park hays, 1933.*

Hay no.	Species	No. rats	Level fed, g.	Depleted weight	Final weight	Weekly gain	Units A per g. hay	Life (days)
3294	*Agrostis alba*	5	.05	108.5	144.0	4.5	30.0	50
3292	*Phleum pratense*	5	.05	107.9	137.6	3.9	26.0	50
3287	*Deschampsia caespitosa*	5	.05	114.1	142.7	3.6	24.0	56
3286	*Carex aquatalis*	5	.05	115.8	152.2	4.8	32.0	55
3289	*Carex athrostachya*	5	.05	111.2	158.4	5.9	38.0	56
3290	*Carex rostrata*	5	.05	108.1	143.4	4.4	32.0	55
3293	*Carex praegracilis*	5	.05	109.0	150.8	5.5	36.0	56
3284	*Eleocharis ovata*	5	.05	109.4	151.4	5.3	36.0	56
3291	*Juncus ater*	4	.05	108.4	147.2	4.9	32.0	56
3288	*Juncus longistylis*	5	.05	112.9	147.2	4.3	28.0	56
3285	*Trifolium hybridum*	5	.05	106.3	157.7	6.4	42.0	56
3295	Timothy (high bench)	3	.10	118.2	154.5	4.6	15.0	56
3296	Sedges (medium bench)	6	.05	120.3	156.7	4.6	30.0	56
3297	Sedges (creek bottoms)	5	.05	118.2	163.9	5.7	38.0	56
Positive controls		1	..	101.0	202.5	12.7	...	56
Negative controls		2	..	136.3	102.0	–4.3	...	26

In a previous bulletin of this station dealing with vitamin studies on alfalfa hays (4), it was found that well-cured alfalfas carry a median value of about 30 to 40 units per gram of vitamin A, with extremes varying from 9 to 60 units. The technique of the present study was identical with that followed in the previous publication. Albino rats 28 days old were used, and all animals were depleted of body store of vitamins before the tests were begun. It is observable that sample 3285 (alsike clover) carries the highest value for vitamin A in this table. It is comparable to a good grade of alfalfa hay in this respect. The advantage of an admixture of this plant with meadow hay plants is quite apparent.

The average vitamin-A content for 10 individual species of hay plants in the same table is 31.4 units per gram of hay—only slightly below the values for good alfalfa hay. The extremes for these hay plants are 24 and 36 units per gram, respectively, showing greater uniformity of vitamin-A content than alfalfa hays, although this quantity is usually less for the hay plants.

With respect to the vitamin-B content of these mountain meadow hays, table 9 is self-explanatory. Omitting the value of sample 3285, which is alsike clover, the average for the 10 individual species is 2.81 units of vitamin B per gram of hay, with extremes of 1.6 to 3.9 units. The three hay plant mixtures, nos. 3295-6-7, carry an average of 2.56 units; samples 3313-14-15 in the table represent alfalfa hays and their vitamin-B content. Studies on alfalfa hays reported in technical bulletin 4 of this station were carried out without previous depletion of the test animals. The results cannot be used for com-

TABLE 9.—*Vitamin B in North Park hays, 1933.*

Hay no.	Species	No. rats	Level fed, g.	Depleted weight	Final weight	Weekly gain	Units B per g. hay	Life (days)
3294	*Agrostis alba*	5	.75	84.2	127.8	6.7	3.0	56
3292	*Phleum pratense*	5	.75	92.1	101.1	3.6	1.6	56
3287	*Deschampsia caespitosa*	5	.75	80.9	129.0	6.0	2.5	56
3286	*Carex aquatalis*	5	.75	81.1	151.2	8.7	3.9	56
3289	*Carex athrostachya*	5	.75	79.6	128.9	6.2	2.7	56
3290	*Carex rostrata*	5	.75	84.3	113.8	3.7	1.7	56
3293	*Carex praegracilis*	5	.75	86.0	131.0	5.6	2.5	56
3284	*Eleocharis ovata*	5	.75	77.3	130.8	6.7	2.9	56
3291	*Juncus ater*	7	.50	79.8	121.4	6.1	4.0	56
3288	*Juncus longistylis*	5	.75	81.1	138.8	7.2	3.2	56
3285	*Trifolium hybridum*	5	.75	76.2	117.0	5.1	2.5	49
3295	Timothy (high bench)	5	.75	86.4	134.6	5.9	2.6	56
3296	Sedges (medium bench)	6	.75	60.5	128.3	5.9	2.7	56
3297	Sedges (creek bottoms)	4	.75	81.2	125.5	5.5	2.4	56
3313	Alfalfa	4	.75	84.0	110.1	3.3	1.5	56
3314	Alfalfa	5	.75	81.4	125.3	5.5	2.4	56
3315	Alfalfa	5	.75	83.0	118.2	4.4	1.9	56
Negative controls		4	Initial weight 47.5	85.6	49.5	..	..	20.2 (All died)

parison here. However, from the three samples here represented and some unpublished data at our disposal, it appears that Colorado alfalfa hays carry from 1.5 to as high as 3.5 units of vitamin B per gram. The method of curing is very important to the vitamin content. Considering the method of field curing as practiced in this section, it would appear safe to place vitamin-B value for alfalfa hay at 2.0 to 2.2 units per gram, which would give the mountain meadow hay plants a very slight advantage in this accessory food factor.

As presented in table 10, the content of the vitamin-G factor for 10 individual species of mountain hay plants ranges from 4.1 to 6.6 units per gram of hay, with an average of 5.41 units. The three mixed hays show an average value of 6.1 units of vitamin G per gram, with the midland hay plants having a distinct advantage over the marshland and highland hays. Again, comparing these values with similar ones for alfalfa hays (technical bulletin 4), we find a slight advantage in favor of the mountain meadow hays. This is of the order of 5.41 units to 6.1 units of vitamin G as compared with 4 units to 4.5 units for alfalfa hays.

TABLE 10.—*Vitamin G in North Park hays, 1933.*

Hay no.	Species	No. rats	Level fed, g.	Depleted weight	Final weight	Weekly gain	Units G per g. hay	Life (days)
3294	*Agrostis alba*	5	.5	54.8	118.2	7.9	5.2	56
3292	*Phleum pratense*	6	.5	55.5	105.2	6.3	4.2	56
3287	*Deschampsia caespitosa*	6	.5	53.7	107.2	6.7	4.4	56
3286	*Carex aquatalis*	6	.5	56.7	139.3	9.5	6.4	56
3289	*Carex athrostachya*	6	.5	54.8	121.3	8.3	5.6	56
3290	*Carex rostrata*	5	.5	54.9	124.1	8.7	5.8	56
3293	*Carex praegracilis*	6	.5	55.1	127.5	9.1	6.0	56
3284	*Eleocharis ovata*	5	.5	55.8	136.2	9.9	6.6	56
3291	*Juncus ater*	6	.5	55.6	125.5	8.7	5.8	56
3288	*Juncus longistylis*	5	.75	57.4	133.0	9.4	4.1	56
3285	*Trifolium hybridum*	5	.5	56.4	110.9	6.8	4.4	56
3295	Timothy (high bench)	5	.5	54.0	112.2	7.3	4.8	56
3296	Sedges (medium bench)	5	.3	51.1	112.4	7.3	8.3	56
3297	Sedges (creek bottoms)	5	.5	53.4	116.4	7.9	5.2	56
Positive controls		2	..	55.0	192.5	17.2	..	56
Negative controls		2	..	58.3	50.5	–1.0	..	56

CONCLUSIONS

FODDER ANALYSES

1. Fodder analyses do not appear to show material differences between Colorado mountain meadow hay plants, rushes, and sedges, and those grown in other regions.

2. These mountain meadow plants differ quite widely from alfalfas in the following respects:
   - (a) Alfalfa hays carry approximately twice as much crude protein as is found in mountain meadow plants. These values are about as 18 percent is to 9 percent.
   - (b) Mountain meadow hays carry more nitrogen-free extract (carbohydrates) than alfalfas. This approximately is as 43 percent is to 34 percent.
   - (c) In mineral content, alfalfa hays are superior to mountain meadow hays of the proximate order of 10 percent to 7.5 percent.
   - (d) The crude-fiber content of the two types of hays is about equal and is of the order of 32.5 percent.
   - (e) Ether extracts of mountain meadow hays average about 1.38 percent, which is slightly less than similar values for alfalfa.
   - (f) *Trifolium hybridum* materially improves the quality of mountain meadow hays and approaches alfalfa in composition. It is high in protein.
   - (g) A wide difference exists among these hay-plant species as to the amount of air-dry hay obtained from a given weight of fresh-cut, green material. This difference is even greater as between hay plants and the alfalfa plant.

ASH ANALYSES

1. In most of the hay-plant species, silica is the predominating ingredient of the ash, while in alfalfa and alsike clover the predominating acid ingredient is carbon dioxide.
2. The descending order of mineral ingredients in hay plants is $SiO_2 >$, $K_2O >$, $CaO >$, $P_2O_5 >$, $SO_3 >$, $MgO >$, $CO_2 >$, $Cl >$, $Na_2O >$, $Fe_2O_3 >$, $Mn_3O_4 >$, Al_2O_3, while for alfalfa and alsike clover the order is $K_2O >$, $CaO >$, $CO_2 >$, $SO_3 >$, $P_2O_5 >$, $MgO >$, $SiO_2 >$, $Cl >$, $Na_2O >$, $Fe_2O_3 >$, $Al_2O_3 >$, Mn_3O_4.
3. The effect of lack of moisture or of a dry growing season seems to be an increase in mineral constituents of the rushes, sedges, and hay plants.
4. Ashes of mountain meadow hay plants of North Park, Colo., carry as high a percentage of P_2O_5 as do alfalfas of the irrigated section.

5. North Park meadow hays have an inordinately high content of Mn_3O_4—much more than do alfalfa hays.
6. Both these North Park hay plants and Colorado alfalfas carry adequate amounts of mineral for animal subsistence.
7. A wide variation in the anion and cation balance is shown in the ashes of some genera of Colorado plants.

VITAMIN-A CONTENT

Alsike clover is comparable to alfalfas in the vitamin-A content. Alfalfa hays, depending upon method of curing, carry from 9 to 60 units of this factor with an average of about 40 units for good alfalfa hay. Mountain meadow hay plants carry from 15 to more than 30 units per gram of vitamin A, with an average approximating 30 units. Thus, while these hay plants carry less vitamin A than alfalfas, that amount seems to be sufficient for the nutritional needs of animals.

VITAMIN-B CONTENT

Neither alfalfa hays nor mountain meadow hay plants appear to carry an adequate amount of this factor for prosperous subsistence of animals. Alfalfas which carry from 1 to 3 units per gram of vitamin B, with an average of about 2 units per gram, are slightly at a disadvantage when compared with mountain meadow hay plants which carry from 1.5 to 4.0 units with an average of about 2.6 units per gram of hay. Timothy appears to be the poorest of the hay plants with respect to content of vitamins A, B, and G.

VITAMIN-G CONTENT

The vitamin-G content of both alfalfas and mountain meadow hay plants is slightly higher than that of B vitamin. Here, again, the hay plants show up to advantage over the alfalfa hays. The hay plants studied range from 4.1 to 6.6 units per gram of vitamin G, with an average approximating 5.4 units, whereas, for alfalfa hays these values range from 3 to 5 units. A conservatively estimated average for alfalfa hays, based on a previous study, would be from 4 to 4.5 units per gram of the vitamin-G factor. It is inadvisable to conclude whether or not these values are adequate for prosperous subsistence of animals without the use of supplementary feeds.

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REFERENCES CLASSIFIED

Fodder Analyses
- Timothy: 10, 11, 18, 20.
- Hay plants: 1, 2, 10, 16.
- Alfalfa: 4, 9, 10, 21.

Chemical Analyses
- Timothy: 5, 8, 12, 15, 18.
- Hay plants: 2, 7, 19.
- Alfalfa: 4, 9.

Vitamins
- Timothy: A, 3, 13, 14.
  B, 12, 13, 14.
  C, 22.
  G, 11, 12.
- Hay plants: A, 6, 13, 17.
  B, 17.
- Alfalfa: A, B, G, 4, 21.
  B, 14.

BULLETIN SERVICE

The following technical publications of the Colorado Experiment Station are available upon request:

Number	Title	Authors
11	Critical Period for Irrigating Wheat	D. W. Robertson and others
12	The Use of Electrodialysis for Estimating Phosphate Availability in Calcareous Soils	James B. Goodwin
14	The Use of Sugar Beet Petioles as Indicators of Soil Fertility Needs	Robert Gardner, D. W. Robertson
15	The Influence of Various Factors, Including Altitude, in the Production of Angel Food Cake	Mark A. Barmore
16	A Study of Some Abnormalities Occurring in Certain Potato Varieties in Colorado	Rudolph Daniel Anderson
17	Notes on *Cryptolestes Ferrugineus* Steph	Elwood H. Sheppard
18	Further Studies on Vitamins in Alfalfa Hay	C. E. Vail, J. W. Tobiska, Earl Douglass
19	Protein Content of Corn as Influenced by Laboratory Analyses and Field Replication	Warren H. Leonard, Andrew Clark
20	Slick Spots in Western Colorado Soils	Robert Gardner, Robert Whitney, Alvin Kezer