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A STUDY OF ALFALFA AND SOME OTHER HAYS.

Approved by the Station Council,
ALSTON ELLIS, President.

FORT COLLINS, COLORADO.

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A STUDY OF ALFALFA AND SOME OTHER HAYS.

WM. P. HEADDEN. A.M., PH.D.

The following pages are not intended as a continuation of Bulletin No. 35, although in a certain sense they form a part of that study. The work done on Bulletin No. 35, was undertaken with the view of examining the changes produced in the soil by continuous cropping to alfalfa, and, as published, claims to be a record of the work done on the plant—a study preliminary to that of the soil proper. We have been compelled, so far, to content ourselves with that work as published. There arose some questions in connection with that study which could not be discussed at the time, because our observations had not been extended enough, and we could not draw upon the results of observations still to be made. We shall, therefore, be compelled to connect portions of this bulletin rather closely with portions of Bulletin No. 35. The object of this bulletin, however, is to present a study of hays, more especially, hays made from leguminous plants—alfalfa, clover, and pease—though we shall discuss other hays to some extent.

We have attempted in this study to go beyond the routine methods of such investigations and to contribute to a better interpretation of the data obtained by the old methods in terms of much narrower and more definitely studied groups whose chemical composition, at least, if not their feeding value, is either already better known or susceptible of determination. In regard to their feeding value, too, we gain a more rational basis for evaluation than has been possible under our old methods and conventionalities.

There are many things in this bulletin which are only tentative, but they are the best results which we have obtained, and we give them as such without any apology except that we regret that our investigations have not been pushed so far as we have desired to push them.

I have no doubt but that some intelligent critic, with strongly utilitarian proclivities, will ask what value such work may be to the farmer; and possibly add, to any one else? There may also be a goodly number, other than the farmers and critics, who have but little sympathy with the class of effort recorded in these pages. I am aware that cattle will feed upon hay just as in the past and that the feeders will probably pay little heed to questions of composition as given in the fuller analyses; possibly but little more than the average man does to the same questions expressed in the terms of the analyses now in vogue. In spite of this, there is a satisfaction in finding out, with some degree of definiteness, what we mean by the old terms, such as nitrogen-free extract, crude fiber, etc. These have been useful terms, very convenient ones, under which to include much that we did not know about a fodder. If this line of work has no other commendation, it is an attempt to find out how much we do not know, and to which we have made no pretense of knowledge, and also some of our misconceptions.

In the closing paragraphs of Bulletin No. 35, I called attention to the variations in the composition of alfalfa hay grown in different localities, and the analyses given cover a period of about ten years—1886-1896. It would seem that the analyses recorded in this period ought to represent with a fair degree of accuracy the composition of the plant as grown in this country; but there is such a wide range in its composition that the suggestion is near at hand that the variation in composition is due to climatic conditions, and not to differences in the soils. We have extended our observations to observe these effects, and not simply to increase the number of analyses of alfalfa, which seems to us altogether useless.

It is true that there are variations in the climate of a locality from year to year; still the climatic conditions of a given locality are, in the main, quite constant in their general character, and we reduce the climatic effects to this minimum by making observations upon the plant grown in the same locality, and, contrariwise, we gain information on this very point by taking our samples from the same plot of ground.

Our samples of alfalfa hay showed, in comparison with samples from other states, a great uniformity in composition. The crude protein in the first cutting hay had a range of less than two per cent.—from 14 to 15.9 per cent. These samples represented hay made from alfalfa grown with and also without irrigation; also such as had been grown upon high land as well as that which had been grown upon low land. The crude fiber in these samples had a very much greater range in percentage—from 32 to 40 per cent.—than the crude proteids. This may have been partly due to a less degree of sharpness in the method of determination, but we judge it to be due to an actual difference in the samples. These are narrow limits when compared with those shown by analyses representing different states, in which we have, for the crude protein, a range of 14.6 per cent.—from 11.1 to 25.7 per cent.; and for the crude fiber, a range of 24.5 per cent., or from 15.4 to 39.97 per cent.

In the second cutting again we find a narrow range, but wider than in the first cutting. The extreme range for the crude protein is 5.6 per cent., and, excluding an exceptional sample with 18.47 per cent., this range becomes 3.5 per cent. The crude fiber for this cutting has a range of about 12 per cent.—from 26.16 to 38.08 per cent.

The range for the proteids in the third cutting is 3.5 per cent., and for the crude fiber, 10 per cent. These samples were all of hay as put into the mow or stack.

A study of the analyses published up to 1896, fails to furnish any general composition for this fodder, and we cannot discern any patent and adequate reason for this. In the New Jersey Experiment Station Report, for 1886, the lowest amount given for crude protein was 16 per cent., and the highest for crude fiber was 35 per cent.; as given in the Report for 1888, eight samples are recorded; the lowest of these in proteids has 15.24 per cent., and the highest in crude fiber has only 24.34 per cent. The same observations are true of the Texas samples, except that we find a greater difference between the highest and lowest in the case of both of these constituents; for the proteids, from 15.31 to 25.75 per cent., and for the crude fiber, from 16.64 to 34.23 per cent. If we take the published analyses of Colorado samples we shall find a like variation.

Even the most unfriendly critic of the methods or the operators using them, cannot possibly explain these differences by the weaknesses of either or both of these. In order to obtain light upon this point, we have studied the three cuttings of 1894, the first cutting of 1895, and the three cuttings of 1896. The methods employed in the analyses and the operators during the period of these experiments were the same, so the results are comparable, and are free from divers personal equations. There is, it is evident, much even in these results which would be more satisfactory if more uniform; still they show that this fodder, as grown in this State, has a pretty uniform value. The season of 1896 was not a very favorable one, and we judge that we have as great a variation, due to seasonal differences, as we have reason to expect. The samples for 1896 were all taken from the same piece of land with one exception, and this one differs so slightly from the others in composition that it is fortunate, rather than otherwise, that it was obtained from another locality.

Some of the samples of previous years were taken from nearly the same ground as those of 1896, so that they also have value indicative of how much alfalfa hay cut from the same land may vary in chemical qualities from year to year.

Three samples of each cutting were taken, representing different stages of maturity, regard being had to their respective influences upon the quality of hay produced.

The results of the analyses are as follows:

Cutting.	Condition of the Plants.	Air Dried Hay.							Thoroughly Dried Hay.					
		Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-Free Extract.	Total Nitrogen.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-Free Extract.	Total Nitrogen.
1	Coming in bloom.	7.22	9.81	1.15	15.16	36.49	30.17	2.426	10.57	1.24	16.47	39.43	32.29	2.6[illegible]
1	In half bloom	7.92	11.89	1.26	14.46	32.80	31.67	2.310	12.92	1.36	15.70	35.62	34.41	2.5[illegible]
1	In full bloom....	6.38	10.57	1.31	15.73	34.91	31.11	2.516	11.29	1.40	16.80	37.29	33.23	2.6[illegible]
	Average..	**7.17**	**10.76**	**1.24**	**15.12**	**34.73**	**30.98**	**2.417**	**11.44**	**1.33**	**16.32**	**37.44**	33.31	2.6[illegible]
2	Coming in bloom.	4.43	12.70	1.71	17.68	27.47	36.01	2.858	13.28	1.78	18.50	28.75	37.69	2.9[illegible]
2	In half bloom....	9.48	11.34	1.50	17.14	24.27	36.27	2.743	12.53	1.65	18.94	26.81	40.08	3.0[illegible]
2	In full bloom....	8.56	9.91	1.78	16.41	27.11	36.24	2.625	10.84	1.95	17.94	29.64	39.64	[illegible]
	Average..	**7.49**	**11.32**	**1.66**	**17.08**	**26.28**	**36.17**	**2.742**	**12.22**	**1.79**	**18.46**	**28.38**	39.13	2.9[illegible]
3	Coming in bloom.	8.64	12.24	1.72	16.53	24.30	36.57	2.645	13.39	1.88	18.09	26.59	40.04	2.8[illegible]
3	In half bloom....	7.43	11.07	1.52	15.51	30.55	33.92	2.482	11,96	1.64	16.76	33.00	36.65	2.6[illegible]
3	In full bloom	8.36	10.66	1.83	15.59	30.18	33.38	2.495	11.63	2.00	17.01	32.94	36.42	2.7[illegible]
	Average..	**8.14**	**11.32**	**1.69**	**15.88**	**28.34**	**34.62**	**2.540**	**12.33**	**1.84**	**17.29**	**30.84**	37.70	2.7[illegible]

The analyses of the first cutting agree with those of preceding years, but the series representing the second cutting is not concordant with previously obtained results. The most marked deviations are in the higher amounts of crude protein and in the lower percentages of crude fiber. The third cutting is far more representative of the plants than the samples of the previous years, because this set of samples of the third cutting is complete in itself. The samples, too, represent the whole plant, without loss of leaves and stems, cut in the very best condition. The third cutting of 1894, the only previous year in which samples of this cutting were analyzed, was represented by samples of hay as it was taken from the field.

There is, in the 1896 samples, a superiority in quality over the samples of 1894. This is most marked in the third cutting, but, as has just been stated, a portion of this difference may be attributed to the fact that the samples were more nearly comparable to those of the other cuttings. The crude protein is higher for each of the three cuttings and the crude fiber is lower, while the nitrogen-free extract is slightly higher, though not so much so as one, at first glance, would think.

The season of 1894 was favorable for the making of heavy crops. The first cutting was very heavy, the stems were exceptionally stout, and the growing period was long. These conditions were reversed in 1896, and I am inclined to attribute the differences observed almost wholly to this cause. The second crop of 1896 grew quickly and resembles in composition samples of the first cutting, cut on May 5th, 1895, rather than the other second cutting samples. Both samples matured rapidly; they were both high in ash, high in crude protein, and low in crude fiber. The first cutting of 1895 (May 5th), is even higher in protein than the second cutting of 1896, and quite as low in crude fiber. This seems to me to indicate that the rate of maturing which, of course, depends upon the seasonal influences, determines, very largely, the composition of the hay produced. It is quite evident that a quickly maturing crop will probably be less in quantity than a more slowly maturing one of the same kind. In 1894 we collected samples from a variety of soils to see whether any differences in the quality of the hay were to be attributed to this cause. The results are in favor of an affirmative answer, but in no very marked degree. I speak of soils which have received no fertilizers. It is a demonstrated fact that these have an effect upon the quality of the hay, and I have elsewhere noted the susceptibility of the alfalfa plant to the direct application of manures. A fertilized soil, or one naturally rich, which, under ordinary conditions, is equivalent to a vigorous growth extended over a longer period, tends to increase the percentages of ash, protein, and crude fiber. In the second cutting of 1896, the ash and protein are high, but the crude fiber is low and the crop was light.

The conditions obtaining later in the season of 1896, were more nearly normal for our locality and the third cutting grew for a longer period, matured more slowly, and, while the proteids are high, we have an increase of about six per cent. in the crude fiber of the later sample. There is no such increase in the other series for this or for preceding years. While there is in general an increase in the percentage of woody fiber, with the development of the plant, we have found it neither so great nor so regular as is shown in Bulletin No. 8, of this station, and also by others. We speak of the plant during the period in which it is fit for making hay. In this instance, however, we have a decided increase which, I believe, is fully accounted for by the explanation offered, i. e., the season conditions which determine the rate at which the plant matures. If this view be correct, it follows that the same piece of ground will produce hays of different qualities in different years even when we take hays of the same cutting, and the total of these seasonal influences is correctly indicated by the differences in the composition of the respective samples. This influence seems to be large enough to determine the relative desirableness of the different cuttings which, under ordinary conditions, stand pretty close together. In speaking of the crop of 1894, we state that the first and second cuttings are about equal in value, so far as the proteids are concerned, and subsequently we call attention to the fact that, if we reject an entirely green sample because of its immaturity, the results are then in favor of the second cutting. The seasonal effects do not have to be very great to determine which of the cuttings shall have the more desirable composition.

The following table, presenting the averages for the respective cuttings for the years 1894, 1895, and 1896, will serve to make these differences plain and show that for a given district there is a comparative constancy in the composition of this fodder.

These averages, to which is appended averages for the usual three cuttings, taken from Bulletin No. 48 of the Utah Agricultural Experiment Station, which I have recalculated to a common water content of 7.5 per cent., instead of 12 per cent., to facilitate their comparison with our Colorado samples, are as follows:

Cutting.	Year Collected.	Source of Sample.	Number of Samples.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-free Extract.
1	1894	Laboratory samples.........	9	6.21	10.03	1.55	14.85	36.28	31.08
1	1894	Farm department................	3	7.59	11.19	*3.59	14.92	28.10	34.61
1	1895	Laboratory samples	4	6.49	10.61	1.50	15.13	34.03	32.24
1	1896	Laboratory samples..............	3	7.17	10.76	1.57	15.12	34.73	30.65
1	1896(?)	Utah †..........................	3	7.50	9.78	2.59	14.29	28.41	37.43
		Average	**22**	**6.99**	**10.47**	**1.80**	**14.86**	**32.31**	**33.57**
2	1894	Laboratory samples	5	5.94	10.24	1.41	14.43	34.15	33.73
2	1894	Farm department................	3	8.05	10.48	1.53	13.99	31.97	33.98
2	1896	Laboratory samples..............	3	7.49	11.32	1.66	17.08	26.28	35.25
2	1896(?)	Utah	3	7.50	8.78	2.13	15.23	31.18	35.28
		Average	**14**	**7.24**	**10.21**	**1.68**	**15.18**	**30.90**	**34.79**
3	1894	Laboratory samples..............	2	5.93	9.83	1.46	13.01	37.01	32.74
3	1894	Farm department................	3	5.63	10.07	1.43	13.47	33.70	35.70
3	1896	Laboratory samples....	3	8.14	11.32	1.69	15.88	28.34	34.62
3	1896(?)	Utah.......................... ...	3	7.50	8.58	1.73	11.95	32.79	37.45
		Average	**11**	**6.80**	**9.95**	**1.58**	**13.81**	**32.98**	**34.90**

* Not included in the average.
† Taken from Bulletin No. 48, Utah Expt. Sta., and recalculated to a basis of 7.5 per cent. moisture.

We see from the preceding table that, for the first cutting, representing three years and four soils, the composition is practically constant, the greatest variation being in the percentage of crude fiber. This difference, however, is no greater than may be found in different samples collected from the same field on the same date. The results for the second cuttings are not so uniform, and I think that we have here exhibited the maximum variation, which may reasonably be attributed to differences in the seasons, amounting to three per cent. for the protein, and eight per cent. for the crude fiber.

The averages for the third cuttings show the same irregularities that are observed in the second cuttings. My samples for the season for 1896 are consonant with the general results in showing the second cutting to be, in point of composition, the preferable one. While these samples are the farthest removed from the general averages, they differ from these less than samples of the same cutting in any year may differ from one another. I am convinced that the variation in the different cuttings from year to year is dependent mostly upon the seasons, and is in no case very large, very much smaller in fact, than I had supposed.

CHANGES IN COMPOSITION OF OLD HAY.

That fresh hay, i. e., hay which has been in the mow o[r] stack from one to nine months, is preferable to hay which has been there for a longer time, is generally conceded; whether there is any good ground for the general belief o[r] not. The samples which we have used to study this question were prepared for analysis, put in glass bottles, and from one to two years allowed to elapse between the two determinations. These samples were stored in a dark cupboard in a dry room which was as close an imitation of the conditions prevailing in a mow as we could produce. The samples were air dried when put away, but they evidently changed in the amount of moisture present, as it was found necessary to redetermine the moisture in all of the samples. I expected that the crude protein would be most susceptible to changes, and therefore determined upon making a series of nitrogen determinations from which to judge of the amount of deterioration. We found that we were wholly wrong in our idea that the nitrogen would be the most sensitive measure of any changes, at least for the conditions under which our samples were preserved. It may be noticed here that every sample had increased in the amount of moisture contained; only one remained unchanged and this was the only sample which showed a diminution in the amount of nitrogen present. The changes, with this one exception, were all in the same direction—to an increase in the percentage of nitrogen. We examined seventeen samples and found but one exception to this rule. The bottles containing these samples were stoppered and sealed with paraffin, so it would seem very improbable that the whole seventeen should fail to keep out the atmospheric moisture. We give the moisture determinations to show how marked this increase was and how general the rule, there being only one pronounced exception to it. The first column contains the figures representing the hay in 1894, and the second in 1896.

	1894. Per cent.	1896. Per cent.
1	4.49	8.68
2	4.17	8.12
3	7.86	7.81
4	6.29	8.84
5	6.30	8.54
6	5.29	6.91
7	4.70	7.27
8	4.31	6.68
9	4.40	7.61
10	6.61	7.17
11	5.81	7.94
12	6.06	6.52
13	8.87	8.26
14	7.14	8.17
15	7.46	8.72
16	3.77	4.41
17	7.60	8.62

If this increase of moisture had not been accompanied by an increase in the percentage of nitrogen in the dry matter, I would have attributed it, in spite of the fact that the bottles were sealed, to the absorption of moisture.

NITROGEN IN NEW AND OLD HAY.

	1894. Per cent.	1896. Per cent.
1	2.422	2.989
2	2.604	2.878
3	2.740	2.132
4	2.459	2.514
5	2.181	2.770
6	2.205	2.382
7	2.037	2.500
8	2.149	2.627
9	3.013	3.037
10	2.572	2.657
11	2.005	2.912
12	2.401	3.051
13	2.366	2.588
14	2.047	2.426
15	2.522	2.702
16	2.562	2.680
17	2.638	2.657

In the above table the percentages are calculated on the dry material. The two series, of course, represent the same samples. There is no regularity in the amount of the increase in case of either the water or the nitrogen. This study is not sufficiently extended to justify fuller discussion, but a study of my notes indicates that the samples cut in early bloom have suffered the least change; also that the change is less in one year than in two years. The last three samples were only one year old at the time the analyses were made.

The increase in the percentage of water in the sample and the increased percentage of nitrogen in the dry matter seem to me to point to a transformation in the constituents included under the term nitrogen-free extract. It is certainly beyond question that the nitrogen cannot be increased by absorption, and it is improbable that the material which we class as crude fiber will break down rapidly enough to account for the formation of so much water, in some instances four per cent., especially when we remember its ability to resist the action of dilute acids and alkalies.

Our experiments indicate that there is no loss of the proteids, but that chemical changes take place to a considerable extent in some of the other constituents, probably in those complex and less stable compounds grouped under the head of nitrogen-free extract and frequently spoken of as carbohydrates. The apparent increase of nitrogen is easily accounted for by the elimination of water and probably of other compounds also, as oxides or hydrides of carbon.

We have in the above explanation of our facts, I think, a full and satisfactory explanation of such facts as have been observed relative to the saving of hay, for instance, by putting it in a mow, in which case the loss of weight is much less than when the hay is kept in the stack. Our application of the observed facts would be, that, other things being equal, hay preserved in the stack is more freely exposed to influences which promote these changes in the less stable constituents of the hay; and the loss due to these changes becomes noticeable.

I understand that it is found almost impossible, in practice, to feed out anywhere near the amount of hay for a ton put in a stack, that is usual to feed out when the same weight is put into a mow. It is evident that some hays may age very much faster than others, due to kind of hay—alfalfa, clover, timothy, etc.—also due to development at time of cutting, manner of storing, and other conditions.

There is, perhaps, a suggestion in the figures representing the percentages of water found in 1896, that the samples in 1894 did not really represent air dried hay and that in the course of the intervening year and a half, or more, they had really become such. This receives support from those samples prepared in 1896, which have about the same percentage of water. But this compels us to assert that the sealing of the bottles was of no avail at all and disregards the increase in the percentage of nitrogen in the dry matter, which seems to us fully established. The differences cannot be attributed to the different methods of determination, nor yet to the operator, as the same person, my assistant, Mr. Ryan, made the two series of determinations by the same method and always in duplicate.

While this subject may be more interesting to the investigator in the domain of agricultural science than to the practical agriculturist, we regret having been unable to pursue it to no greater extent.

ARTIFICIAL DIGESTION OF ALFALFA HAY.

It is not our purpose to discuss the relative merits of artificial compared with animal digestion, but if we confine ourselves to the question of the pepsin digestion of the albuminoids, it is certainly more agreeable, more satisfactory in that it can readily be applied to a much larger range of samples in a short time, and has the further advantage that the different samples can be subjected to the same conditions. The commercial pepsin preparations may vary in quality very greatly, but the pepsin can be tested before it is used quite as easily as any other chemical reagent.

We undertook the investigation to discover whether there is any difference in the digestibility of the three cuttings of alfalfa hay or in alfalfa hay of different ages. The samples employed in this work were new hay, one-year-old hay, and two-year-old hay. These terms, new hay, one-year-old hay, and two-year-old hay, are to be understood in their ordinary sense, and not that a sample of alfalfa was made into hay and its digestibility determined forthwith, for such was not the case. The samples were taken in the years of 1894, 1895, and 1896, and the determinations were made in the last year.

THE METHOD.

We followed the method in general use—digestion with a dilute hydric chlorid solution of pepsin. After an extended series of experiments with coagulated egg albumen, we adopted the following method as giving the best results. We dissolved five grams of scale pepsin in one litre of two-tenths per cent. hydric chlorid and to five grams of alfalfa, ground as fine as possible, we added 150 cc. of the pepsin solution, and digested it for eight hours at forty degrees C., adding, during the eight hours, .7 grams of hydric chlorid.

After the digestion was completed, the alfalfa remaining was filtered off, washed free from chlorid, and the residual nitrogen determined by Kjeldahl's method.

The period of eight hours was decided upon, because we found in experimenting with the egg albumen that we obtained a complete solution in this time and seldom in a shorter period, and if we allowed it to stand longer a precipitate began to form which was not very readily gotten into solution again. This method contains an error in that it shows any soluble amids which may not be assimilated by the animal as digestible. As the amount of amids is quite large in some of the samples, this may give rise to comparatively large errors. This error is not wholly eliminated in the case of animal digestion. The amount of amids had been previously determined in the samples of 1894 and 1895. They amounted to 10.85 per cent., for the first cutting, 19.93 per cent., for the second cutting, and 5.03 per cent. (one sample only) for the third cutting. The amids were not determined in the samples for 1896. The co-efficients of digestion obtained do not show any variation corresponding with the amids found. The sample of second cutting in half bloom shows a lower digestion co-efficient than the one following it in full bloom, and still lower than the one preceding it in half bloom, and yet it contains amid nitrogen corresponding to 29.47 per cent. of its crude protein. The others contained much less nitrogen in this form, the amount corresponding to 18.84 per cent., and 17.82 per cent. of the crude protein in the respective samples.

The co-efficients of digestion for the proteids in alfalfa, as determined by animal digestion, are as follows:

In green alfalfa, 78-83; mean of six trials, 81.

Carefully dried alfalfa, 70-83; mean of six trials, 80.

Alfalfa hay, early bloom, best quality, 71-83; mean of twenty-six trials, 76.

Alfalfa hay, full bloom, 66-73; mean of ten trials, 68.

Alfalfa hay, carefully dried, 78; mean of two trials, 78.

Alfalfa hay as given in Colorado Bulletin No. 8, 77.

Alfalfa hay as given by N. Y. Exp. Sta., 69.

Considering these seven averages, we observe that five of them fall between 76 and 81 per cent.

The only statements that I recall to have seen concerning the relative efficiency of animal and pepsin digestion is to the effect that the pepsin is rather higher, usually dissolving from 2 to 6 per cent. more of the crude protein than is taken up by the animal. If we take the average of the five most nearly agreeing means, given above, we obtain 78.4

for the co-efficient of digestibility for crude protein in alfalfa hay, or 75.6, if we include all the means given. It seems probable that the five closely agreeing ones are nearer to the truth than the two whose average is ten per cent. below the average of the five, and I take it that the 75.6 is a less representative co-efficient than the 78.4.

We record in the following table the results obtained by pepsin, or artificial digestion, of the first, second, and third cuttings of the year 1894; the first cutting of 1895, and the three cuttings of 1896.

ARTIFICIAL DIGESTION OF PROTEIDS IN ALFALFA HAY.

Number of Cutting.	Condition at Time of Cutting.	Total Nitrogen.	Nitrogen not Digested.	Nitrogen Digested.	Co-efficient of Digestion.
	Samples gathered in 1894—				
1	Plants not in bloom	2.878	0.574	2.304	80.07
1	Plants not in bloom	2.132	0.420	1.712	80.30
1	Plants in half bloom	2.514	0.520	1.994	79.30
1	Plants in full bloom	2.989	0.590	2.399	80.26
1	Plants in full bloom	2.770	0.522	2.248	81.15
1	Plants in early seed	3.051	0.643	2.408	78.92
1	Plants in full seed	2.500	0.595	1.905	76.02
2	Plants coming in bloom	3.037	0.522	2.515	82.81
2	Plants in half bloom	2.657	0.542	2.115	79.60
2	Plants in full bloom	2.627	0.502	2.125	80.89
2	Plants in full bloom	2.382	0.495	1.887	79.18
3	Hay, College farm	2.912	0.514	2.398	82.69
	Samples gathered in 1895—				
1	Plants in full bloom	2.588	0.499	2.089	80.72
1	Plants in full bloom	2.702	0.508	2.194	81.20
1	Plants in full bloom	2.680	0.510	2.170	80.97
1	Plants in full bloom	2.657	0.540	2.117	79.68
	Samples gathered in 1896—				
1	Plants coming in bloom	2.624	0.580	2.044	77.89
1	Plants in half bloom	2.514	0.512	2.002	79.60
1	Plants in full bloom	2.687	0.498	2.189	81.69
2	Plants coming in bloom	2.990	0.664	2.326	77.79
2	Plants in half bloom	3.032	0.664	2.368	78.10
2	Plants in full bloom	2.870	0.559	2.311	80.87
3	Plants coming in bloom	2.894	0.635	2.259	78.06
3	Plants in half bloom	2.681	0.567	2.114	78.85
3	Plants in full bloom	2.722	0.596	2.126	78.15

It is observable throughout the series that the sample in full bloom have a slightly higher co-efficient than the other cuttings with only one exception, which is in favor of a very early cutting. The third cutting hay (No. 12) is no an exception, as the plants were near or at full bloom when cut.

We have already given the average co-efficient of alfalfa hay of all kinds, determined by animal digestion, as 78.4. The highest and lowest individual results in the experiments which we have accepted as most representative are far apart, ranging from 70 to 83, a maximum difference of 13 per cent. of the proteids. The maximum difference in our series, debarring No. 7, because it was too ripe for hay is five per cent. of the proteids, or, including all samples, it is approximately ten per cent. of the proteids. The co-efficients given by cuttings are as follows: For 1894, first cutting, 79.43; second cutting, 80.62; third cutting, 82.69; for 1895, first cutting, 80.64; for 1896, first cutting, 80.14; second cutting, 78.81; third cutting, 78.85. The average for all the cuttings, made in the three years, is 79.79, which is in excellent agreement with the results obtained by animal digestion.

The results taken by years are as follows: For 1894, hay two years old, 80.91; for 1895, hay one year old, 80.64; for 1896, new hay, 79.27, from which it is clearly apparent that the proteids have not lost any of their digestibility, and from this standpoint hay which is one or even two years old, is quite as good as new hay. The nitrogen determinations given on page 11 show a relative increase of nitrogen, so that whatever changes take place in hay in the mow, during the course of one or two years, they do not cause any deterioration in either the amount or digestibility of the proteids. The importance of this will be more apparent to the average feeder when he considers that the proteids make up between 1-7 and 1-6 of the total weight of the hay, and that in value it is equal to over one-third of the hay. This is based upon two and three-tenths cents per pound for proteids, one and fourteen-hundreths cents per pound for fats, and ninety-four hundreths cent per pound for crude fiber and nitrogen-free extract. (Conn. Exp. Sta., 1893.)

PENTOSANS.

It has been customary until very recently, and is still the general practice, to divide the food elements of plants into the four groups, fats, crude fiber, nitrogen-free extract and crude protein. We have known how to divide the protein into two classes of nitrogen compounds, which are probably of very unequal value as food constituents, and, while we have been accustomed to speak of nitrogen-free extract, as though it had some definite individual character, we have done so with the understanding that it included gums, starch, sugar, etc., etc., and the same has been the case with the term crude fiber. We know that it contains cellulose and other allied compounds which differ from one another in composition, and probably to even a greater extent in their physiological value. Several of these compounds give, under similar treatment, a characteristic product which becomes the measure of the amount of them present. While it is exceedingly improbable that there is in the hays, to be mentioned later, only one furfurol-yielding complex, I have, for the sake of greater simplicity, calculated the results obtained in terms of xylan, as this is probably the predominating group yielding the furfurol. These substances are given in the present prevailing method of stating fodder analyses, partly as crude fiber and partly as nitrogen-free extract. The former, according to our results, contains from one-half to three-fourths of them and the latter the rest. We frequently speak of the nitrogen-free extract as almost equivalent to carbohydrates soluble in water; this custom has the merit of easy expression and convenience. It is not our province to determine the relation of these constituents to the economy of the plant, and it does not effect our object in the least to determine this, but simply to determine the quantity of them present. It seems highly probable that, as they are more reactive than the celluloses proper, they play a more important part in the nutrition of animals than these, but are inferior to the carbohydrates proper.

We have followed in our furfurol determinations the method as laid down by the Association of Official Agricultural Chemists, except that we dissolved the hydrazone in ether alcohol.

The samples of alfalfa hay used in these determinations were the same samples of which fodder analyses have been given in Bulletin No. 35 and in the early part of this bulletin. The results in the following table are calculated on dry matter. The crude fiber found in these samples is also given.

XYLAN IN ALFALFA HAY.

No.	Cutting.	Condition of Plants.	Xylan.	Crude Fiber.
		Samples gathered in 1894—		
1	1	Plants not in bloom	9.44	37.04
2	1	Plants in full bloom	9.86	38.50
3	1	Plants in full bloom	10.94	42.77
4	1	Plants in early seed	13.77	40.13
5	1	Plants in full seed	14.42	48.38
6	2	Plants coming in bloom	14.03	34.13
7	2	Plants in half bloom	12.43	39.19
8	2	Plants in half bloom	14.50	39.88
9	2	Plants in full bloom	12.48	39.64
10	3	Hay, from College farm	10.54	39.36
11	3	Hay, from Rocky Ford	12.34	34.27
		Samples gathered in 1896—		
12	1	Plants coming in bloom	14.24	39.43
13	1	Plants in half bloom	11 09	35.61
14	1	Plants in full bloom	9.12	37.29
15	2	Plants coming in bloom	8.88	28.75
16	2	Plants in half bloom	9 10	26.81
17	2	Plants in full bloom	11.01	29.64
18	3	Plants coming in bloom	10.11	26.59
19	3	Plants in half bloom	11.76	33.00
20	3	Plants in full bloom	12.91	32.94
		Parts of Plants—		
21	3	Leaves	9 29	13.00
22	3	Upper part of stems	13.32	....
23	3	Lower part of stems	11.25	....
		Crude Fiber—		
24	3	From the leaves	12.73	....
25	3	From the upper part of the stems	13.46	....
26	3	From the lower part of the stems	15.41	33.07

The percentage of crude fiber is given in the first twenty analyses to show that there is no constant relation between it and the xylan in the whole hay. This becomes more apparent when we examine the results of 24, 25, and 26. If we calculate the xylan found in 24, to percentage of the total xylan in the original sample, assuming thirteen per cent., as the average for crude fiber in leaves, we find it corresponding to 17.69 per cent. And in like manner for 25 and 26, assuming 33.07 per cent., as the percentage of crude fiber in the stems, we find the xylan in 25 corresponding to 33.33 per cent. of the xylan in their original sample, and in 26 it amounts to 45.29 per cent. The method of preparation of the crude fiber was not the same in each case and these samples are not strictly comparable as far as the method affects the question.

If we express these results in the more direct manner of stating the percentage of the total xylan removed by the successive digestions with sulphuric acid and caustic soda, we find that in the case of the leaves 82.31 per cent. of the xylan was removed; in the upper part of the stems, the small ends, we have 66.66 per cent. removed, and in the lower and more woody part we find that 54.71 per cent. has been removed. While it may not be rigorously correct that the amount of those substances which yield the furfurol are proportional to the furfurol obtained, it may be assumed to be true for the aggregate which we have in hay, and an examination of the percentages of xylan shows that they, like the proteids, depend probably not so much upon differences of soil, as upon seasonal differences. Taking the three cuttings of 1896, the second and third show an increase in the xylan as the plant matures, but the first cutting shows the opposite. The samples collected in 1894 are equally indefinite. We are, however, justified by analyses 21 to 26, in concluding that there are several complexes present which yield furfurol, and they offer different degrees of resistance to the alternate action of acids and alkalies. The complexes yielding more readily to the action of these agents predominate in the leaves, forming nearly nine-tenths of the whole amount, whereas in the stems they form only about one-half.

Analyses to be given subsequently indicate that there is still another distinction, for some of them are removed by extraction with alcohol and water, while others are not. The conditions, under which the work recorded in these paragraphs was made, were as uniform as possible, for it is evident that this is necessary in order that our results shall have the same significance.

COMPARISON OF LEGUMINOUS HAYS BY NEW METHODS.

It has long been felt that our methods of fodder analysis leave much to be desired, and, while they are very helpful in forming a judgment of the value of a hay, they have not been conclusive. I do not claim that the present effort leads to much more satisfactory conclusions, but it is an effort to get a more definite and detailed view of the components of hay. Heretofore we have been accustomed to speak of carbohydrates and water soluble substances as though starch, sugar, etc., were present in abundance. We may not be able to show what the substances are which we have been calling by these names, but we can show how much sugar and starch are present and that we must find some other names for the rest. As an example of the inadequacy of a fodder analysis to enable us to judge of the value of a grass as a fodder plant, I may cite the case of *Stipa viridula var. robusta.* My attention was called to this grass by Professor C. S. Crandall, who requested me to analyze it. The grass is one familiar to people of the West, growing in bunches among the foothills. For comparison we give an analysis of a hay taken from the Year Book of the Department of Agriculture for 1894:

	Hay, mixed grasses, and clover. Per cent.	Stipa viridula. Per cent.
Water	13.20	5.53
Ash	4.40	5.76
Protein	5.90	8.91
Fiber	29.00	39.60
Nitrogen-free extract	45.00	38.24
Fat	2.50	1.96

The analysis of the hay is an average analysis, while that of the Stipa is a single analysis of a small sample; but it suffices to show that hay made from this grass ought to be preferable to a mixed hay, that is the average article, but cattle will not eat the Stipa, and horses feed on it with great moderation. The analysis is correct in regard to the composition of the fodder, but stock do not like it, and hay which animals will not eat, except when driven to it by excessive hunger, does not answer the purposes of a first-class fodder, however good an analysis may show it to be. We have a parallel in the composition of our native hays and of alfalfa. All stock, so far as I know, eat alfalfa greedily, and its analysis shows it to be an excellent fodder for general purposes, and yet it possesses qualities which make it, in general estimation, a poor fodder for work or road horses, and it sells in the market at about one-half the price of native hay.

It is not probable that chemical analyses will ever be able to discover these properties which are, partly at least, physiological; still we may yet learn more about the subject and become able to form a better judgment than we can at present.

In the following I have endeavored to obtain a better knowledge of the hays made from alfalfa, clover, the field pea, and native hay.

For the methods followed I am indebted mostly to the work of Cross and Bevan, but I have also drawn upon whatever literature has been accessible to me.

The process of analysis is almost identical with that proposed by Professor Stone, i. e., successive extraction with boiling alcohol, cold water, diastase, boiling dilute acid, boiling dilute alkali, and treatment of the residual fiber with chlorin. The reducing power of the products of hydrolysis were determined by means of Fehling's solution and estimation of the copper by means of potassic cyanid solution. The chief difficulties arose from the large amounts of coloring compounds presents in some of the extracts. The reducing power of some of these solutions was diminished by treating them with basic lead acetate, though I could find no sugar in the precipitate.

The preparation of the sample of hay for this process is of considerable importance. If there are larger pieces of stems, it is difficult to free the cellulose from lignones and the cellulose will give the phloroglucin-hydrochloric acid reaction. I found this markedly the case with alfalfa, clover, and the pea vines, but not so with the native hay. If the sample is ground to a uniformly fine powder this is not the case, and the cellulose will not react with the phloroglucin solution. That this is the correct explanation of the cause of the reaction, and that it is not due to the inability of the chlorin to remove the lignone groups, is clearly observable when the reaction is watched under the microscope. The small pieces will remain uncolored, and the large ones will be observed to have an outer uncolored portion inclosing a colored nucleus.

The alfalfa selected for this analysis was a sample of new hay made from plants coming into bloom.

The following are the results obtained:

	Per cent.
Invert sugar	none
Sugar	trace
Dextrin	trace
Starch	1.11
Xylan, inverted by dilute acid	3.76
Xylan, soluble in alkali solution	0.15
Lignones, rendered soluble by chlorin	6.66
Cellulose	25.59
Moisture	7.21
Ash	9.81
Ether extract	1.15
Proteids	15.16
Soluble in alcohol	13.87
Soluble in water (starch, etc., deducted)	11.88
Not determined	3.65
	100.00

The substances dissolved by water are only partly precipitated upon the addition of a large excess of alcohol. The amount precipitated was 8.2 per cent. of the sample. It did not prove to be dextrin. This caused me some trouble and I increased the amount of hydric chlorid used in inverting and increased the time of heating, at the temperature of boiling water, to one and a half and even to two hours. I did the same with the starch solution.

A portion of the sample was extracted successively with 95 per cent. alcohol and cold water—two grams of the sample, 24 c. c. alcohol, and subsequently 40 c. c. cold water—the residue was washed with cold water and the remaining nitrogen determined. We found 1.554 per cent., calculated on the air dried substance; whereas the total nitrogen was equal to 2.426 per cent., a difference of .672 per cent., which is over 27 per cent. of the total nitrogen. This is rather more than we have found in any sample in the form of amid nitrogen; but inasmuch as some samples have furnished nearly as much as this, we are led to believe that it is the amids, principally if not wholly, which are soluble in water. There is in this no oxidation and fermentation such as take place in the weathering of hay, and the two processes are not equivalent, though they may be similar to some extent.

The crude fiber contained, in this instance, .33 per cent. nitrogen, or, roughly calculated on air dried hay, about .11 per cent. This was neglected in the further calculations. Of the crude fiber itself 78.96 per cent. was cellulose, and 21.04 per cent. was lignones.

The sample of clover hay was two years old. The plants were cut when the heads were half turned, and the whole plant was cured without the loss of any leaves or stems. The sample, as judged by physical properties, is somewhat above the average of clover hay in quality. The ordinary fodder analysis of this sample was, for the dry matter:

	Per cent.
Ash	10.63
Ether extract	2.07
Crude protein	14.18
Crude fiber	30.52
Nitrogen-free extract	42.60
Total	100.00

The average percentage of nitrogen, as determined in the fresh sample, was 2.268, and two years later it was 2.287. There is no apparent change in the nitrogen content caused by its aging.

The co-efficient of digestion, as determined by pepsin solution, was found to be 76.43 per cent., which is rather higher than the maximum for red clover hay, 71, and even higher than that of the green clover, 76. This hay was going on three years old at the time the determination was made.

The amount of xylan found was 16.54 per cent., which is materially more than the maximum found in alfalfa hay. The average nitrogen-free extract in alfalfa hay is close to 32 per cent., while the clover has 43 per cent.; and it seems probable that the excessive xylan found in the clover, owes its origin to the non-fibrous celluloses included in the nitrogen free extract. The fuller analysis of the sample was as follows:

	Per cent.
Invert sugar	1.33
Sugar	0.21
Dextrin	4.03
Starch	0.76
Xylan, inverted by dilute acid	4.03
Xylan, soluble in alkali solution	0.72
Lignones, soluble by chlorin	4.99
Cellulose	18.70
Moisture	5.36
Ash	10.17
Ether extract	1.88
Proteids	13.43
Soluble in alcohol, sugar, etc., deducted; Soluble in water, dextrin, etc., deducted	29.59
Not determined	4.80
	100.00

The total loss upon successive extraction with 95 per cent. alcohol, cold water, and then hot water, was 37.8 per cent. The amount extracted from alfalfa hay was, in round numbers, 28 per cent. I did not in this case determine the amount of nitrogen removed by the extractions.

The crude fiber in this case contained 77.88 per cent. cellulose, and 22.12 per cent. of lignones; practically identical with the composition of the crude fiber prepared from alfalfa.

The nitrogen-free extract, however, differs both quantitatively and qualitatively from that of the alfalfa. To what extent this difference is due to the difference in the development of the plants at the time the samples were cut, would be interesting to know. The absence of the sugars in the alfalfa sample and their presence in the clover may be wholly attributable to this. Alfalfa is our principal honey plant and yet this sample which was just coming into bloom yields only traces of the sugars. That they are subquently present cannot be doubted; but whether they are ever present in sufficient quantity to constitute more than a fraction of one per cent. of the hay is a question.

PEA-VINE HAY.

As the quantity of pea-vine hay made in this state aggregates a large amount, I shall, at the risk of digressing too much, give a brief presentation of it in comparison with the other hays, particularly in comparison with alfalfa and clover hays. The variety of pease here dealt with, is what is designated the Mexican pea. It is a strong grower and quite prolific. I am indebted to Mr. James A. Kelley, of Monte Vista, Colorado, for one of the samples of hay and to Mr. R. E. Trimble for the other. Both samples are from the San Luis valley, where the pea-vine hay, to a certain extent, takes the place of alfalfa and clover hay of this portion of the state.

I am informed by Mr. Kelley that experiments in feeding pea-vine hay to horses, steers, and sheep have given very satisfactory results, especially so with sheep. Mr. Kelley's statements of its effects upon horses indicate that they are similar to those of alfalfa, but are much milder and he makes no mention of its producing any cough or the heaves. This hay even when cut, after many of the pease have ripened, is an acceptable fodder to cattle and one on which they do well.

The sample furnished by Mr. Kelley was in perfect condition ; the plants were almost at full bloom at the time of cutting, and the pods had merely formed in the older bloom. The leaves were well preserved. The sample obtained for me, by Mr. Trimble, was of hay cut when the plants were quite mature and a goodly number of the pease were ripe. The hay, however, was in good condition. The samples were ground to a coarse powder, from which smaller samples were prepared for analysis.

COMPOSITION OF PEA-VINE HAY.

Condition at time of Cutting.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-Free Extract.	Total Nitrogen.
Cut at time of full bloom	5.871	11.273	3.200	20.200	29.428	30.028	3.232
Water free	....	11.977	3.398	21.460	31.264	31.901	3.434
Cut when in full pod	6.028	7.135	1.839	16.581	30.013	38.404	2.653
Water free	....	7.592	1.957	17.645	31.938	40.888	2.723

We give, in the subjoined table, analyses of pea-vine ensilage, first cutting alfalfa, and clover hay. The analyses of the ensilage and clover hay are reproduced from Bulletin No. 35.

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-Free Extract.	Total Nitrogen.
Pea-vine ensilage	4.710	14.910	3.240	10.950	30.060	36.130	1.752
Water free	....	15.630	3.400	11.300	31.390	38.540	1.839
Alfalfa, average of first cutting	6.210	10.030	1.550	14.850	36.280	31.080	2.376
Water free	....	10.694	1.653	15.833	38.682	33.138	2.533
Clover hay, water free	....	10.630	2.070	14.180	30.520	42.600	....

The analyses show the pea-vine hay to be richer than either clover or alfalfa in proteids, the alfalfa containing 297 pounds, while the pea-vine hay, cut in full bloom, contains 404 pounds per ton ; and it is only a little higher than the clover hay in crude fiber. We also observe a decrease in the ash constituents and the proteids with the ripening of the plant, so that the pea-vine hay forms no exception to this rule

It will be noticed that it removes a large amount of ash. the hay containing an average of 9.204 per cent. of ash or mineral matter.

These ashes were submitted to analysis and the results are given below, together with an analysis of an alfalfa ash, made from plants of first cutting, full bloom.

The composition of these ashes is as follows:

	Pea Vines in full bloom.	Pea Vines in full pod.	Alfalfa in full bloom.
Carbon	Trace	Trace	0.112
Sand	5.033	4.524	0.829
Silicic acid	2.620	3.293	0.881
Phosphoric acid	6.726	7.070	5.234
Sulphuric acid	4.767	2.620	5.608
Carbonic acid	18.325	21.455	23.730
Chlorin	6.231	3.765	8.500
Calcic oxid	11.614	16.650	27.620
Magnesic oxid	3.669	4.192	3.798
Ferric oxid	0.659	0.560	0.269
Aluminic oxid	0.366	0.548	0.089
Manganic oxid, brown	0.262	0.560	0.168
Potassic oxid, potash	36.164	30.917	24.240
Sodic oxid, soda	1.366	3.629	0.943
Moisture	Not det'd	0.856	0.000
Sum	100.802	100.939	102.021
Less oxygen, equivalent to chlorin	1.188	0.855	1.920
Total	99.614	100.084	100.101

These results show that the pea is a still heavier feeder, particularly upon phosphoric acid and potash, than the alfalfa plant, which, in the aggregate, removes very large quantities of these substances. The phosphoric acid in the alfalfa ash is quite the maximum found in fifteen samples prepared from alfalfa hay, but is less than that in the ashes of the pea vines. On the other hand, the sum of the lime and magnesia in the ashes of the pea vines is only from one-half to two-thirds of the amount found in the various samples of alfalfa ashes. The ashes of the pea vines compare with those of red clover in the same sense and almost in the same degree as with those of the alfalfa. In regard to the total nitrogen in the plant, it will be observed that the pea vines contain materially more of it than alfalfa does. For the purposes of green manuring, they are easily and quickly enough grown to deserve the attention of our ranchmen. They will serve admirably to add organic matter and nitrogen to the soil and to render other plant food more available.

CRUDE FIBER AND NITROGEN-FREE EXTRACT.

Our subsequent analyses of these samples, of pea-vine hay, with the object of getting more definite information concerning the composition of the crude fiber and the nitrogen-free extract, resulted as follows:

	In full bloom. Per cent.	In full pod. Per cent.
Invert sugar	0.000	0.000
Cane sugar	0.000	3.050*
Dextrin	0.738	0.705
Starch	0.000	2.530
Xylan, inverted by dilute acid.	3.157	7.237
Xylan, soluble in alkali solut'n	0.816	0.659
Lignones, soluble by chlorin..	6.466	10.296
Cellulose	18.646	18.199
Moisture	5.871	6.028
Ash	11.273	7.135
Ether extract	3.200	1.839
Proteids	20.200	16.581
Soluble in alcohol / Soluble in water	28.345	25.841†
Not determined	1.258	.000
	100.000	100.100

I was quite surprised at the absence of starch in the sample in full bloom, but no more so than at the small amount of this substance in the alfalfa and the very small amount in the clover hay. The result for the alfalfa is entirely consonant with the results of the following experiment: A portion of the alfalfa was digested with alcohol and subsequently with cold water, to remove as much of the coloring matter and extractives as possible and then examined under the microscope, at last with the addition of a solution of iodin in potassic iodid, the reaction with the lignocelluloses was very strong, and if there was any reaction for starch it was entirely masked. I at no time succeeding in obtaining a satisfactory test for starch in this manner, though some of the tests might have been interpreted as showing its presence, and I think this interpretation is correct; but it was not clear enough at any time to indicate a large percentage of starch, even after boiling

* A second determination gave 2.94 per cent.   † Sugar, dextrin, etc., deducted.

the sample with water. The extract of this sample of pea vines obtained by first boiling it, after having previously freed it from gums and fats, with fifty times its weight of water for an hour and a half, subsequently digesting with diastase for two hours at 55-60 degrees and inverting with 10 c. c. of concentrated hydric chlorid at a temperature of 90-95 degrees, failed to give any more sugar than was added with the diastase though tested three times.

That starch should be found in the other sample is in accord with the condition of the plant at the time of cutting, i. e., in full pod with many ripe pease. The large percentage of lignones in the crude fiber of the hay made from the maturer vines may be due to the relatively large quantity of pods in the sample and suggests a great difference in the quality of the samples.

The pea-vine hay made from the less mature vines resembles the alfalfa samples not only in the amount of lignones present in the crude fiber, but also in the amount of xylan yielded upon distillation, 11.17 per cent. The amount of the lignocelluloses present varies with the maturity of the plant, especially those which are not susceptible to hydrolysis by dilute acids and alkalies increasing with maturity, while the cellulose remains nearly constant.

The furfurol yielding complexes, expressed as xylan, are less abundant in the mature plants than in the younger, but the difference is probably within the limits of error due to the method, and not conclusive as regards their variation in the plant. The sample made from plants in full bloom yielded 11.17 per cent. xylan, and the one cut, when the plants were in full pod, gave 10.23 per cent. The range in the percentage of xylan found in our alfalfa samples is from 8.9 to 14.50 per cent., but fluctuates so irregularly that no evident relation can be discovered between the development of the plant and the amount of xylan found and the same would probably be the case with the pea-vine hay if our series of samples were only slightly extended. It is true, too, that our method is not very sharp and small differences in percentages have so slight a significance that the range of only about six per cent. may be taken as establishing the xylan content of alfalfa and pea-vine hays at about ten or twelve per cent. The relation of the lignones to the xylan found is not made apparent by our results, if any exists at all; the ratios obtained are approximately as follows: for clover, 0.30:1; for alfalfa, 0.47:1; for pea-vine hay, cut when the plants were in full bloom, 0.42:1; but for pea-vine hay cut when the plants were in seed, the ratio found is 1:1. There is evidently no approximation to a uniform ratio shown by these figures.

The residue obtained from the mature sample by successive extractions with alcohol and cold water yielded, upon distillation with hydric chlorid, xylan equivalent to 8.01 per cent. of the air dried hay, or 78.2 per cent. of the total xylan. This seems to indicate a greater difference between the pea-vine hays, in regard to the character of the lignocelluloses present, than in regard to the other constituents. The deportment of the hay from the vines in pod toward heat, i. e., the readiness with which it browns, is probably due to the large amount of these lignocelluloses present. I have not observed so great a sensitivness in any sample of fodder which I have analyzed. The roots of alfalfa alone have exceded it in this respect.

Accepting the phloroglucin reaction as indicative of the amount of these lignocelluloses, I began a series of observations on samples of alfalfa taken from the same root, at intervals of seven days, the first sample being taken when the stems were only four or five inches high. The intention was to continue the taking of samples from this plant at the stated intervals until the plant was fully ripe, and to study the development of the lignocelluloses in thin sections under the microscope for each internode of stems throughout the whole period of growth. An accident to my chosen plant, it having been cut up, brought this experiment to a sudden end. My observations indicated the absence of these in the very young joints, and their subsequent development in two rings, the first continuous with the fibrovascular ring whose outer margin was fluted, while the second one lay outside of this and was composed of individual bundles, sometimes, but not always, coalescing so that the ring was broken.

The co-efficient of digestion of the proteids in these pea-vine hays, as determined by artificial digestion, are rather higher than, but not very different from, those found for the proteids in alfalfa hay. They are, for the pea-vine hay, cut when the plants were in full bloom, 84.71; and, cut when the plants were in full pod, 81.61.

I can not find that the co-efficient of digestion of such hay has been determined by experiments with animals, though such experiments have been made with pea straw, the proteids of which have a digestion co-efficient of 61; also with pease in which the co-efficient is, for ruminants, 89; for horses, 86; and for swine, 88, from which it would appear that the proteids in such pea-vine hays are of nearly as much value as the proteids in the pease themselves. In this statement, the amount of amids which may be present in the pea vine is not considered.

The crude fiber of the pea-vine hay, sample in full bloom, was composed of 74.25 per cent. of cellulose, and 25.75 per cent. of lignones. This is quite close to the composition of the crude fiber from the alfalfa and clover hays in which the cellulose was 79.96 and 77.88 respectively.

Whatever the value of the lignones may be, this seems to be true of these three leguminous hays, cut when the plants are in full bloom or earlier, i. e., that there is about six or seven per cent. of them present which resist the action of dilute acids and alkalies, even when the soluble portions of the hay have been removed by previous extractions with alcohol and water. In the sample of pea-vine hay in pod these lignones increased and the cellulose in the crude fiber amounted to 63.82 per cent. I have already suggested the presence of a large percentage of pods as a possible explanation. This, however, only means a particular stage in the development of the plant.

UPLAND AND MEADOW HAY.

These names are applied to hay made from grasses growing for the most part on level grounds along streams or where water courses have been.

The grasses making up this class of hay are numerous. Prof. C. S. Crandall, of the Department of Botany, kindly determined those present in the sample analyzed. The first two in the list made up the major portion of the sample. They were as follows: *Andropogon scoparius, Mich.; Carex marcida, Booth.; Elymus canadensis, L.; Panicum virgatum, L.; Sporobolus asperifolius, Thurb.; Sporobolus cryptandrus, Gray; Poa tenuifolia, var. rigida, Vasey; Andropogon furcatus, Muhl.; Chrysopogon avenaceus, Benth.; Calamovilfa longifolia, Hack.; Agropyrum tenerum, Vasey; Bouteloua oligostachya, Torr.*

This hay was made in the latter part of August, 1896; it was cut from land belonging to Mr. J. J. Ryan, and lying close to the Big Thompson river, near the town of Loveland, this county.

This hay was considered to be a good quality of this class which is in large demand, at all seasons. The market value of such hay is always greatly in excess of that of alfalfa, usually a little less than twice that of alfalfa hay, and often fully twice. I am, myself, not in position to express an opinion as to what extent this difference in price is due to the difference in the supply of the respective hays, but persons who keep horses for road purposes, liverymen and others, will not use alfalfa hay. On the other hand, feeders of cattle and sheep use alfalfa principally, if not exclusively, in this section. I do not know how this matter stands relative to pea-vine hay, but the pea-vine silage has been fed with very satisfactory results.

It would seem that the low esteem in which alfalfa is held as feed for horses, is mostly due to its action upon the kidneys and bowels of the animal and also to the fact that the loss in feeding horses alfalfa hay is very large, due to their not eating the leaves readily, and lastly, because the alfalfa is sometimes dusty. It may be that this is in part a practical recognition of the fact that the nutritive ratio of the whole hay is rather a narrower one than is desirable. Be this as it may, an average alfalfa hay has a much larger percentage of proteids than the upland hay, also less crude fiber, and the proteids in the alfalfa have a higher co-efficient of digestion. The same is in a measure true of clover hay, but the upland hay is preferred for feeding animals at work.

The composition of the upland hay was as follows:

	Per cent.
Moisture	3.047
Ash	7.886
Ether extract	2.219
Proteids	6.131
Crude fiber	40.372
Nitrogen-free extract	40.351
Total	100.000

The co-efficient of digestion for the proteids found by artificial digestion was 45.77, about equal to that given for the proteids in late cut timothy. I gave on a preceding page an analysis of hay made from Stipa viridula, in comparison with an analysis of a mixed hay. In that analysis the proteids are given as 8.91 per cent. We see that it is richer also in this constituent than our native hays, which are in great demand at all times. Not only is the amount of the proteids larger in the Stipa, but their co-efficient of digestibility is also higher, being 64.71. It would have been interesting to have studied the Stipa hay still further to see if we could solve the question why this grass is not eaten, but we were compelled to drop the comparative study at this point, and all that we are justified in stating is that, in spite of the fact that cattle do not eat it, it has, according to analysis, the composition of a good fodder, better in some respects than mixed hay, and that the co-efficient of digestion for its proteids is higher than that of our native hay, which is considered a very desirable one.

The native hay yields, when analyzed according to our method, exceedingly different results from the leguminous hays.

While the following analysis may not be so exact as one might wish, it is not far from the truth, and shows that there is a very great difference between the two classes of hay—hay made from leguminous plants and hay made from the grasses. Subsequent investigation may, it is true, modify these results somewhat, but we think that this difference exists and that it is fully as great as appears from the results of our analysis. I know of no analysis of hay made in a similar manner; a single determination of sugar—sucrose—in a sample of timothy hay, by Professor Stone, is all that I can find. He gives the sugar in his sample of timothy hay as 2.53 per cent.

ANALYSIS OF UPLAND HAY.

	Per cent.
Invert sugar	0.00
Cane sugar	0.98
Dextrin	0.00
Starch	0.40
Xylan, inverted by dilute acid	1.77
Xylan, soluble in dilute alkali	0.79
Lignones, dissolved by chlorin	3.12
Cellulose	27.93
Moisture	3.05
Ash	7.89
Ether extract	2.22
Proteids	6.13
Soluble in alcohol, sugar, etc., deducted / Soluble in water, dextrine, etc., deducted	19.75
Not determined	35.97
	100.00

The reaction of the original sample and also the crude fiber prepared from it with phloroglucin is very much fainter than that given by the leguminous hays. I regret that we did not determine the total xylan by distillation, as that might have added something to our knowledge of the thirty-six per cent. which is missing. But the comparative faintness of the phloroglucin reaction indicates that the pentaglucoses are not present to the same extent as in the alfalfa and other leguminous hays.

In the usual fodder analysis the two most striking points are the high percentages of crude fiber and nitrogen-free extract. In the second analysis the most remarkable percentages given are for the cellulose and those things embraced under the term "not determined," which includes substances soluble in dilute acid and dilute alkali, but insoluble in alcohol and water. The portion soluble in alcohol and water is low and a large portion of the 40.3 per cent. nitrogen-free extract is included in the 36 per cent. "not determined."

In order that the comparison of these analyses may be facilitated, we bring them together in the following table:

	Alfalfa Hay, coming in bloom.	Clover Hay Heads, half turned.	Pea-vine Hay in full bloom.	Pea-vine Hay in full pod.	Upland Hay.
Invert sugar	0.00	1.33	0.00	0.00	0.00
Cane sugar	Trace	0.21	0.00	3.05	0.98
Dextrin	Trace	4.03	0.74	0.71	0.00
Starch	1.11	0.76	0.00	2.53	0.40
Xylan, by acid	3.76	4.03	3.16	7.24	1.77
Xylan, by alkali	0.15	0.72	0.82	0.66	0.79
Lignones	6.66	4.99	6.47	10 30	3.12
Cellulose	25.59	18.70	18.65	18.20	27.93
Soluble in alcohol, sugar, etc., deduted	13.87	29.59	28.35	25.84	19.75
Soluble in water, dextrin, etc., deducted	11.88				
Moisture	7.21	5.36	5.87	6.03	3.05
Ash	9.81	10.17	11.27	7.14	7.89
Ether extract	1.15	1.88	3.20	1.84	2.22
Proteids	15.16	13.48	20.20	16.58	6.13
Not determined	3.65	4.80	1.25	0.00	35.97
	100.00	100.00	100.00	100.10	100.00
Co-efficient of digestion for the proteids	79.15	76.43	84.71	81.61	45.77

This shows the pea-vine hay to contain the largest percentage of proteids, with the highest co-efficient of digestion, with the alfalfa next in both respects. The pea-vine hay has the lowest percentage of cellulose and the upland hay the highest; in this respect the pea-vine and clover hays stand quite apart from both the alfalfa and upland hays. The sugars and starch, which we have for the most part understood by carbohydrates, are present in small quantities. The sample showing starch to be present in the largest quantity contained some mature seeds, which contain from 48 to 50 per cent. of starch. The sugar found in the same sample may be correct, but I think it admits of a doubt.

CONCLUSIONS.

First.—That the composition of alfalfa hay grown under the same climatic conditions does not vary from year to year, more than samples of the same year, which is within fairly narrow limits.

Second.—That climatic or seasonal differences do affect the composition of the hay. This, however, affects the different cuttings of the same year, rather than the crops for a whole year, but this effect is comparatively small and expresses itself most pronouncedly in the percentage of crude fiber.

Third.—That the amount of the proteids in alfalfa hay does not decrease with, but rather increases, with age, if the hay is kept in a close mow.

Fourth.—That the changes in the hay probably affect the amount and character of the nitrogen-free extract.

Fifth.—That the proteids of the different cuttings are about equally digestible, as determined by means of pepsin-hydrochloric acid. There is, however, a slight difference in favor of the hay cut when the plants were in full bloom.

Sixth.—The digestibility of the proteids does not vary materially from year to year, nor is it affected by the age of the hay, if well kept.

Seventh.—That the lignocelluloses in alfalfa increase with the age of the plant, but there are exceptions which can not be justly attributed to methods of determination.

Eighth.—That the presence and amount of sugar, starch, etc. depend upon the development of the plant at the time of cutting, and is at all times comparatively small.

Ninth.—That the lignocelluloses are more abundant in the leguminous hays than in those made from our native grasses, but that the cellulose is much more abundant in the latter.

Tenth.—That the soluble portion of leguminous hays is greater than that of the little hay made from the grasses which accounts for their susceptibility to weathering