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COLORADO FODDERS

AN EXAMINATION INTO THEIR COMPOSITION AND COMPARATIVE VALUES

BY

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INTRODUCTORY

In the following pages, I have endeavored to state my results fully enough to enable the reader to clearly understand my interpretation and have, at the same time, given the data so fully that he may draw his own conclusions, and judge whether mine are justified or not.

In this work I have had no predecessor to follow, so far as I know. The study of the chemical composition of timothy hay presented by the Pennsylvania Experiment Station is quite different from the present work, and I have not taken up timothy hay in detail, for reasons given in the proper place. The only attempt to determine the digestibility of the different extracts of any fodder that I remember to have seen mention of, was made in France. I do not recall the fodder or fodders studied or the scope of the investigation.

I do not know that any similar attempt to study the calorific value of the various portions of the fodders and the relative amounts of heat furnished by them, their coefficients of appropriation, has been made.

I have given the analytical data as fully as possible, including the ordinary fodder analyses of both the fodders and the feces, similarly their ultimate analysis, the analysis of their ashes, and what I have, for the purpose of this bulletin, designated as their proximate analysis. By proximate analysis, I mean the division of the fodder into different portions by means of the following solvents: 80 per cent. alcohol, cold water, hot water with subsequent addition of malt extract, 1 per cent. hydric chlorid, 1 per cent. sodic hydrate and chlorin in the presence of water, with subsequent washing with water, boiling sodic hydrate, 1 per cent. solution, and sulfurous acid. The portion which resisted these successive treatments has been designated as residue or cellulose.

The heat or energy, given in small calories, removed by these successive treatments, and the percentage of this heat value appropriated by the animals have been studied in detail for three of the fodders, alfalfa, corn fodder and the saltbush, *Atriplex argentea.*

The distribution of nitrogen and also that of the furfurol, in these various extracts has been determined, but no attempt has been made to distinguish between arabinose and xylose, all being calculated as xylan. Determinations of mucic acid were made on these fodders, and the sugar obtained by treating the alfalfa hay with 1 per cent. hydric chlorid has been considered as being derived from galactan, which is also probably present, according to our results, in some of the other fodders.

The reducing power of the sodic hydrate extract has been indicated as xylan with an interrogation point, because it is very probably not derived from xylan. The quantity of this sugar is altogether insignificant, except in the case of the saltbush, in which it is relatively large.

COLORADO FODDERS

AN EXAMINATION INTO THEIR COMPOSITION AND COMPARATIVE VALUES

By W. P. HEADDEN

SEC. 1. In Bulletin No. 39 of this Station, I endeavored to study alfalfa, clover, pea-vine, and our native hay, but particularly alfalfa hay with special regard to the carbohydrates, including under this term the crude fibre and nitrogen-free extract.

§2. In Bulletin No. 93 I have given the results of experiments on the digestibility of alfalfa, timothy and native hay, also on the saltbush, *Atriplex argentea,* corn fodder and sorghum.

§3. In Bulletin 93, I followed the beaten path and gave the coefficients of digestion as obtained for the usual groups, proteids, crude fibre, nitrogen-free extract, etc. In the present bulletin, I shall take up the same hays and fodders treated of in Bulletin No. 93, but I shall consider them from the standpoint of Bulletin No. 39, following the same general method that I used in that work, but extending it very considerably.

§4. While it might be of scientific interest to study the ether extract, it is not a very important factor in the study of the coarse fodders presented in this bulletin as it, at most, amounts to only a small percentage of these fodders, usually to less than three per cent., and these three per cent. are composed of fats, waxes, coloring and other matters, none of which are involved in the questions which form the object of this study.

§5. I have discovered no good reason for taking up the extract by absolute alcohol, so I began the work by extraction with boiling 80 per cent. alcohol, which removes coloring matter, sugars and extractives. We found that extraction with four portions of alcohol, boiling each portion 20 minutes, was quite sufficient to exhaust the sample. We used 10 grams of hay and 450 c. c. of alcohol. The amount extracted by the fourth portion of alcohol amounted to only 0.30 of one per cent. of the air dried hay.

§6. We attempted to evaporate the extracts to dryness and weigh them, but in checking against the weight of the dried residue we found a difference of about two per cent., *i. e.*, the dried extracts were about this much too low. After considerable work to see if we could not obtain better agreement between the direct weighings of the extracts and the weight of the remaining hay, we decided to take the loss of weight as indicated by the residual hay as the weight of the material extracted. Had we been trying to obtain results to be expressed in terms of the extract, this method would of course, not be admissable, but as we have expressed all results in terms of the air dried hay or fodder, this method has the patent advantage of giving every percentage upon a basis which can be easily duplicated within quite narrow limits which we found would be attended with considerable difficulty if we used the weight of the extracts obtained, as each one showed a deficit for which we could not account. The weight of the residual portion of the hay seemed, furthermore, to be less subject to change, debarring the absorption of moisture which is comparatively easily guarded against, than that of the extract.

§7. As already stated, the boiling, 80 per cent. alcohol extracted the hays readily and even the first portion removed practically all of the coloring matters which, particularly in the case of alfalfa, was large and difficult to remove from the extract.

§8. It was not possible for us to prosecute any examination of these coloring matters, but it was necessary that we should remove them completely from the solution before we could proceed to test for sugars. The matter of decolorizing these solutions proved to be a difficult one. I first tried the effect of adding potassic aluminate and the precipitation of the aluminic hydrate by passing carbon-dioxid through the solution. My idea was that the precipitating aluminic hydrate might carry down all of the coloring matter, this, however, did not prove to be the case and the filtrate from the $Al_2(OH)_6$ had a bright yellow-red color. We pursued this a little further but the results, while interesting in themselves, did not advance the work in hand.

§9. Though I desired to avoid the use of basic acetate of lead, it proved to be the most effective agent in removing the yellow coloring matter, the filtrate however, was green and worked badly with the Fehling's solution, yielding a flocculent precipitate which may have contained cuprous oxid, it probably did, but the precipitate was essentially something else. We found that the addition of cupric sulfate removed the green coloring matter completely, yielding a colorless solution, provided no excess of the cupric sulfate had been added. The use of the basic acetate of lead and cupric sulfate worked well.

In Bulletin 39, I recorded the observation that the reducing power of such extracts are greatly diminished by the addition of basic acetate of lead but that I failed to detect any sugar in the precipitate.

§10. In the present work, it was imperative to establish one fact, *i. e.*, that the combined use of the lead and copper salts did not in any way affect the quantity of sugar, sucrose, present either by removing it with the precipitate or causing its inversion.

§11. In order to establish this point, several portions of the extract which had been made up to a given volume, after the alcohol had been distilled off, were taken and a weighed portion of pure sugar added to some of them. All the portions were then decolorized by the use of lead acetate, sodic sulfate and cupric sulfate, always added in this order, the precipitate filtered off and washed, the excess of copper removed by H_2S and the H_2S expelled by passing $C\ O_2$ through the solution, the two last operations were quite unnecessary, but I thought that it could happen that I might wish to remove the copper and subsequently the $H_2\ S$ in this manner and so I included them in this test. The results showed that the sugar was wholly unchanged both in character and quantity by these operations. This method was therefore adopted, as the substances which exert a reducing action upon the Fehling solution and are removed by these precipitants are neither glucose nor saccharose, the presence and quantity of which I wished to establish. The other substances are of course included in the extract yielded by the hay.

§12. The total reducing power of the cold water extract after inversion by heating with hydric chlorid is attributed to the presence of gums. It is probable that this class of bodies is the source of the reducing sugars produced, but the amount of sugar or gum present in this extract is so small that it is no matter of great moment by what name we designate it.

§13. The reducing power of the hot water extract after the action of malt extract has been expressed as starch. The total amount extracted by the cold and hot water respectively is much less than one would expect, but it must be borne in mind that the hay or fodder had been previously extracted, we may say exhausted, with boiling 80 per cent. alcohol. The amounts extracted by these media are also much more nearly equal than one would expect, the cold water in a few instances actually dissolving more than the hot water and malt extract.

§14. The hydric chlorid used was a one per cent solution. The extraction of the hay or fodder with this reagent gave us more trouble than all other determinations combined. All of the work recorded in this bulletin was done in duplicate and if our results did not agree, the work was repeated until we found how to proceed in order to obtain concordant results.

§15. It is true that agreement of results may not be conclusive proof that the method used is the best one, or even that the work has been correctly done, but their disagreement, when obtained by the same method and under similar conditions, is conclusive of one of two things, either that the operations have been interrupted at different stages or that the method is wholly inadequate and an end point is not attainable. We found that the different hays and fodders resisted the action of this one per cent.

solution of hydric chlorid in very different degrees. In those cases in which the amount of xylan was high, we found that boiling for thirty minutes did not suffice for the accomplishment of our purpose, *i. c.*, to carry the action of the hydric chlorid to an end.

§16. In some fodders and dungs we found it necessary to boil them two, and in a few cases, even three times with separate portions of the acid in order to obtain results which agreed reasonably well. We found, too, that the inversion of this extract was much more difficult than of any of the others,—it being necessary to use ten c. c. conc. hydric chlorid and to digest in the water bath for two hours; this means at our altitude, a temperature of about 85° to possibly 90° C. in the solution, even though the water in the bath is kept boiling briskly. We found that this quantity of acid and time gave us the highest results, measured in terms of the reducing power, and usually a good agreement between the duplicates.

§17. The sodic hydrate used was also a one per cent. solution. The reducing power of this extract, after inversion, was, as a rule, very small. We observed in this connection that the reducing power of this extract was frequently higher in those cases in which we found it difficult to complete the extraction with hydrochloric acid than in others. I interpret this variation as suggesting that the small amount of reducing sugars found in the sodic hydrate extract may belong to the hydric chlorid extract rather than indicate the presence of a hexose sugar.

§18. The residue left after treatment with sodic hydrate was washed free from Na O H, dried, etc. It was next moistened with water and spread out on the inner surface of a small flask which was connected with a chlorin apparatus and allowed to stand for an hour after the flask had become entirely filled with the gas. It was then washed, boiled with dilute Na O H and subsequently with $H_2 S O_4$ and the residue finally dried and weighed as cellulose. The action of chlorin, etc., did not produce any reducing sugars, at least there were none present in the filtrate.

§19. In Bulletin 93, we have recorded our results in determining the coefficients of digestion of the groups, substances usually taken cognizance of in our ordinary fodder analyses, *i. c.*, Dry Matter, Ash, Fat, Protein and Nitrogen-free Extract; in the present bulletin, I intend to present the results of these same experiments using a different series of groups, or to give the coefficients of digestion for the alcoholic extract, cold water extract, hot water extract, one per cent. hydic chlorid extract, one per cent. sodic hydrate extract, chlorin extract, and lastly, of the cellulose or that portion which persistently resists the action of these reagents. In addition to the preceding coefficients, I shall give the coefficients of digestion of those groups which yield the reducing sugars under the conditions already indicated and also of those complexes which yield furfurol on distillation with twelve per cent. hydric chlorid solution, but as I have sought to determine the distribution of these groups and complexes in the different extracts it will be quite impossible to bring the results within the compass of a single table. I will, therefore, be compelled to make two statements of the results which will supplement each other, but which cannot in any sense replace or contradict each other. I will also give the calorific values of the hays, dungs and of the residues yielded by the respective treatments in the case of the alfalfa, corn fodder and saltbush, these being the best for our purposes; timothy hay, sorghum and native hay not suiting so well. Our native hay is a mixture of such character that results obtained with it would be of little value except in a very general sense.

§20. The hays and fodders used in this work are the same as those used in Bulletin 93, in fact, that work was done largely for the purpose of obtaining data according to the conventional methods for the particular samples used n this study. The hays and fodders were intentionally chosen to represent both legumes and grasses grown and preserved under our Colorado conditions.

§21. The distribution of the nitrogen in these extracts appears from the results of the work recorded in Bulletin 39, to present some points of more than usual interest. For instance, we found that 27 per cent. of the total nitrogen in alfalfa hay was removed by extraction with boiling 80 per cent. alcohol and subsequent treatment with cold water. This nitrogen may have been contained in the coloring matters to a greater extent than in some other hays, but it is certainly not all contained in the chlorophyll and it is not probable that it is amid nitrogen for it exceeded the amount that we had previously found in alfalfa hay in this form. The advisability of making these nitrogen determinations is further indicated by the persistence with which some nitrogen remains with the crude fibre after boiling with 1.25 per cent. sodic hydrate solution. In the work referred to we found that 4.51 per cent. of the total nitrogen in alfalfa hay remained in the crude fibre, when it had been prepared in the usual way by boiling for thirty minutes with the 1.25 per cent. sodic hydrate solution. We shall see that this was not a chance result, but indicated a general fact and we shall further see that this statement is correct for the hays and fodders studied in this bulletin.

§22. The distribution of the ash in these various extracts has been wholly disregarded.

§23. The analysis of the dungs present, of course, the same questions that the conventional methods do in regard to the compounds in which the nitrogen is contained, *i. e.*, whether it is contained in undigested portions of fodder or in fecal matter. The results obtained in this work in regard to the nitrogen, are open to the same questions that those of our ordinary analysis and possibly to even more serious ones, for we divide it up into six or seven portions instead of presenting it as the common constituent of a single class without raising any further questions.

§24. The samples of hays fed were of course the same throughout the experiments, so that one analysis represents the whole of any fodder fed and no questions can arise relative to this; concerning the orts and dungs, however, there might be a question. In Bulletin 93, we calculated the coefficient of digestion for each individual animal and took the average of the coefficients so found as the coefficients of digestion of the several hays and fodders. Owing to the tediousness of the work, we followed a different procedure in this case, *i. e.*, we made composite samples of the dungs, by taking the same aliquot part of the dung voided by the different sheep in each 24 hours during the time of the experiment and combining them into a composite sample. The sample of orts was prepared in a similar manner.

ANALYTICAL DATA—ALFALFA HAY.

§25. The following analyses have been brought together in order to present, succinctly as possible, all that our analyses tell us about the fodders and their digestibility.

The average coefficients of digestibility found for this particular alfalfa hay were for the dry matter 62.08, ash 57.67, fat 29.86, protein 72.54, fibre 49.93, and for the nitrogen-free extract 72.89. The general facts presented by the data concerning alfalfa pertain to all of the other fodders.

TABLE I.

ALFALFA HAY.

FODDER ANALYSIS.

ALFALFA HAY		FECES OF SHEEP NO. 6	
Moisture	7.75	Moisture	6.82
Ash	11.77	Ash	12.15
Ether Extract	1.62	Ether extract	3.12
Proteids	15.03	Proteids	10.86
Crude Fibre	30.28	Crude Fibre	40.34
Nitrogen-free extract	33.55	Nitrogen-free extract	26.83
	100.00		100.00

TABLE II.

ASH ANALYSIS.

ALFALFA		CORRESPONDING FECES*	
Percentage of ash in hay..	11.77	Percentage of ash in Feces..	12.15
Sand	8.524	Sand	12.682
Silicic acid	6.844	Silicic acid	8.676
Sulfuric acid	6.269	Sulfuric acid	2.037
Phosphoric acid	3.158	Phosphoric acid	7.629
Carbonic acid	17.399	Carbonic acid	21.081
Chlorin	6.801	Chlorin	0.666
Potassic oxid	27.271	Potassic oxid	3.207
Sodic oxid	4.287	Sodic oxid	1.733
Calcic oxid	14.736	Calcic oxid	29.590
Magnesic oxid	4.006	Magnesic oxid	7.719
Ferric oxid	1.428	Ferric oxid	1.440
Aluminic oxid	0.288	Aluminic oxid	0.879
Manganic oxid (br)	0.180	Manganic oxid (br)	0.330
Ignition	0.341	Ignition	2.481
	101.532		100.150
Oxygen, Equiv. to chlorin..	1.532	Oxygen Equiv. to Chlorin..	.150
	100.000		100.000

TABLE III.

ULTIMATE ANALYSIS.

ALFALFA HAY		CORRESPONDING FECES	
Carbon	43.517	Carbon	45.769
Hydrogen	5.868	Hydrogen	5.494
Nitrogen	2.405	Nitrogen	1.738
Sulfur	0.342	Sulfur	0.189
Chlorin	0.819	Chlorin	0.123
Phosphorus	0.162	Phosphorus	0.405
Potassium	2.665	Potassium	0.323
Sodium	0.374	Sodium	0.156
Calcium	1.239	Calcium	2.569
Magnesium	0.286	Magnesium	0.566
Oxygen plus the remaining ash constituents	42.323	Oxygen plus the remaining ash constituents	42.668
	100.000		100.000

§26. For good, clean, alfalfa hay the ratio of thoroughly air-dried feces to the hay consumed is one to two and seven-tenths or five and one-half pounds of hay eaten will correspond to just a trifle more than two pounds of feces.

§27. The silicic acid has not been taken into account in the preceding analyses because it is very uncertain how much of it is due to fluxing of the minerals constituting the dust and sand found in the ash.

§28. These data show the extent to which the potash is taken up by the animal system, the feces being very poor in this substance

*Sheep No. 6.

while the opposite is the case with the phosphoric acid and lime.

§29. The ultimate composition of the hay and feces does not appear to differ as much as one might expect, so far as the carbon, hydrogen and oxygen are concerned but an ultimate analysis of a mixture of such complex substances as we have to do with in these cases could scarcely be expected to show decided differences, still it shows that 61.6 per cent. of the carbon in the hay consumed, is digested. The feces show a higher percentage of carbon than the hay, which may indicate that the compounds having the higher carbon content are less readily attacked than those with less. These analyses further show that the hydrogen, nitrogen, sulfur, chlorin and the alkalies, particularly potassium, are very largely taken up from the fodder, while the calcium, magnesium and prosphorus are voided with the feces to a very large extent. This is strikingly the case in regard to phosphorus, for according to the ratio given for the hay consumed to the feces voided, 5½ : 2, it results that of 892 parts of phosphorus ingested by sheep, 810 parts are voided with the feces, which indicates a coefficient of digestion of 10.3 per cent. for the phosphorus consumed, which is quite small, averaging 1.31 grams per day, of which only 10.3 per cent. or 0.131 gram was appropriated by the animal. The potassium stands in strong contrast to this with a coefficient of 95.6 per cent. The following pages present some further considerations, based on different data.

§30. The following analyses are of an entirely different character and present a study of the same hay from another standpoint.

§31. The statement of the analyses is given so fully that no further explanation is needed in this place.

TABLE IV.

ANALYSIS OF ALFALFA HAY.

The percentages given in following analyses are computed on air-dried hay.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted...	27.177	27.818	27.50
Cold water, 24 hours digestion, extracted	8.535	8.785	8.66
Hot water and malt extracted... ...	4.790	3.950	4.37
Hydric chlorid, 1 per cent. sol., extracted	12.487	11.968	12.23
Sodic hydrate, 1 per cent. sol., extracted	15.341	17.046	16.19
Chlorin, etc., extracted............	8.372	9.155	8.76
Cellulose, residue	23.298	21.278	22.29
			100.00

SUGARS IN THE EXTRACTS.

Glucose in the alcoholic extract......	1.280	1.280	1.28
Sucrose in the alcoholic extract......	0.942	0.942	0.94
Gums, etc., in cold water extract.....	0.833	0.770	0.80
Starch in hot water and malt extract	1.267	1.260	1.26
Galactan inverted by 1 per cent. HCl	2.960	2.770	2.87
Reducing power of the 1 per cent. Na O H extract	0.320	0.378	0.35

The average of two determinations of galactan made according to the official method was 2.89 per cent. It seems probable that the reducing power of the one per cent. HCl extract of alfalfa hay is wholly due to galactan, but only partly so in corn fodder and in native hay.

TABLE V.

ANALYSIS OF ALFALFA ORTS.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	26.532	26.276	26.40
Cold water, 24 hrs. extracted........	8.580	8.559	8.57
Hot water and malt extracted.......	3.970	4.256	4.11
Hydric chlorid, 1 per cent. sol. extracted	11.687	11.863	11.78
Sodic hydrate, 1 per cent. sol. extracted	16.637	14.885	15.76
Treatment with chlorin, etc., extracted	8.519	9.853	9.19
Cellulose remaining	24.074	24.308	24.19
			100.00

SUGARS IN THE EXTRACTS

Glucose in alcoholic extract.........	1.25	1.25	1.25
Sucrose in alcoholic extract.........	1.67	1.45	1.56
Gums in cold water extract.........	0.47	0.38	0.43
Starch in hot water extract.........	0.94	0.97	0.96
Galactan	3.96	4.45	4.21
Reducing power of sodic hydrate extract	0.70	0.97	0.80

TABLE VI.

ANALYSIS OF DUNG OF SHEEP FED ON ALFALFA HAY.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted...	19.107	19.363	19.24
Cold water, 24 hrs. digestion, extracted	4.912	4.872	4.89
Hot water and malt extracted.......	3.635	3.349	3.49
Hydric chlorid, 1 per cent. sol., extracted	13.580	12.457	13.02
Sodic hydrate, 1 per cent. sol., extracted	12.796	15.166	13.98
Treatment with chlorin, etc., extracted	19.711	15.091	17.40
Cellulose remaining................	26.259	29.702	27.98
			100.00

SUGARS IN THE EXTRACTS

Glucose in alcoholic extract.........	None	None	None
Sucrose in alcoholic extract.........	None	None	None
Gums in cold water extract.........	0.40	0.52	0.46
Starch in hot water and malt extract	0.21	0.21	0.21
Galactan in hydric chlorid extract..	1.37	0.98	1.18
Reducing power of sodic hydrate extract	1.57	1.30	1.44

TABLE VII.

COEFFICIENTS OF DIGESTION FOR THE VARIOUS EXTRACTS OF ALFALFA HAY.

	Fed.	Orts	Consumed.	Voided.	Digested.	Coef.
Total alcoholic extract.....	3671.4	260.5	3410.9	890.9	2520.0	73.88
Total cold water extract....	1157.2	84.6	1072.6	228.4	846.2	78.89
Total hot water malt extract	583.6	40.6	543.0	161.6	381.4	70.24
Total hydochloric acid ext..	1630.9	116.2	1514.7	602.9	911.8	60.20
Total sodic hydrate extract	2161.6	155.5	2006.1	647.3	1358.8	67.72
Total chlorin etc., extract..	1170.6	90.7	1079.9	805.7	274.2	25.39
Total cellulose	2976.1	238.7	2737.4	1295.6	1441.8	52.67
Total dry mater	13351.4	986.8	12364.6	4630.4	7734.2	62.55

§32. The average coefficient of digestion of the dry matter in this hay obtained by the usual method was found to be 62.05. It is given as 63.95 on page 23 of Bulletin 93, but this is a mistake It should be 62.05.

TABLE VIII.

COEFFICIENTS OF DIGESTION OF THE CARBOHYDRATES IN ALFALFA HAY AS INDICATED BY THE SUGARS OBTAINED FROM THE VARIOUS EXTRACTS.

	Fed.	Orts	Consumed.	Voided.	Digested.	Coef.
In alcoholic extract, glucose	170.9	12.3	158.6	00.0	158.6	100.00
In alcoholic extract, sucrose	125.5	15.4	110.1	00.0	110.1	100.00
In cold water ext., gums, etc.	106.8	4.2	102.6	19.4	83.2	81.09
In hot water malt ext. starch	164.2	9.5	154.7	9.7	145.0	93.73
In 1 p. c. hydrochloric acid extract, Galactan	381.9	41.5	340.4	54.6	285.8	83.96
					Excess	
In 1 p. c. sodic hydrate extract, (Hexose?)........	46.7	7.9	38.8	66.7	—27.9	

In chlorin, etc., extract, this extract showed no reducing power.
Cellulose residue after chlorin, etc., treatment 52.67

§33. In the preceding table, it will be noticed that the amount of reducing sugar found in the one per cent. sodic hydrate extract for the dung exceeds the amount found for the extract of the hay by a very considerable amount, 71.91 per cent.

§34. At first, I thought that the small amount of reducing sugar found in the solution obtained by boiling the hays or fodders with the one per cent. solution of sodium hydrate, was due to imperfect extraction by the hydrochloric acid or perhaps owed its origin to complexes which had been attacked by the hydrochloric acid and thereby rendered soluble in the sodic hydrate, but the relatively large amount extracted from the dung by this reagent, for we find the same excessive amount in the dungs corresponding to each of the six fodders suggests that it is not an accident due to the incompleteness of the action of the hydrochloric acid but that it is due rather to the presence of some compound which effectively resists the action of the hydrochloric acid but which is soluble in sodic hydrate and is either hydrolized by this agent or is made susceptible to the action of the hydrochloric acid subsequently used as the hydrolytic agent. If this were the indication of even a duplicate analysis of the dung corresponding to one of the fodders, one would certainly be justified in doubting its sufficiency as the basis of any inference, but it is not simply an accidental agreement of duplicate results, obtained in the analysis of a single sample of dung, but is the result of duplicates made on the dungs corresponding to six fodders which differ materially from one another. This difference between the fodders and the corresponding dungs may be due to changes produced in the fodders during their passage through the alimentary tract or to excrementitious matter proper. It seems probable that it is the latter.

§35. In regard to the reducing sugar produced by the action of the dilute hydric chlorid, I have in the case of the alfalfa attributed it to the presence of galactan because the agreement between the determination of mucic acid and the reducing power of the inverted solution was good; in the other cases I have used the term xylan as a general term for the pentosans hydrolized by the dilute hydic chlorid. Mucic acid determinations made on the samples of corn fodder and native hay indicate the presence of some galactan but its quantity is much less than the total reducing power, so it is probable that both galactan and xylan are present, but I have used the term xylan in all cases except in that of alfalfa.

§36. The total reducing power of the extract yielded to one per cent. sodic hydrate solution by alfalfa hay corresponds to 38.8 grams, whereas the reducing power of the extract yielded by the feces under the same treatment corresponds to 66.7 grams or 1.7 times as much. Whatever the source of this reducing power may be it is evidently much more abundant in the extract of the dung voided than in the hay consumed. It is probable that the excessive reducing power of the sodic hydrate extract of the dung over that of the hay is due to its action on fecal matter and not on the undigested remnants of the hay. This excessive reducng power of the sodic hydrate extract of the dung over that of the hay is not an accident or attributable to inaccurate work, for it is uniformly the case with all of the dungs corresponding to the six fodders used.

§37. This result is similar to that obtained for the coefficient of digestion for the ether extract in the first series of experiments made on the digestion of alfalfa hay in which the amount of ether extract obtained from the feces was more than double the amount consumed. In this case, I attributed this excess to the solubility of fecal matter only after I had canvassed every other apparent explanation, because it was observed in one series of experiments only and was not observed in the case of any other fodder than the alfalfa. If other experimenters have met with such striking results, they have rejected them, as I was tempted to do, for the simple reason that others have done this work in the same way and the recorded results agreed in showing that my results were, to say the least, very exceptional. In this case, however, I have a series of six very different fodders and they agree in showing that, in this respect, there is a marked difference between the fodders and the feces of the animals feeding on them.

PENTOSANS.

§38. There are certain complexes existing in the fodders which when subjected to distillation with hydrochloric acid yield furfurol. In this work, I have considered this furfurol as such and have endeavored to determine its coefficients of digestibility for the various extracts.

§39. In Bulletin 39, we found the total amount of furfurol calculated as xylan yielded by alfalfa, to range for the first cutting from 9.44 to 14.42 per cent.; for the second cutting, hay grown at Rocky Ford, 12.34 per cent. The average found for the cutting of 1894 was 11.44 per cent.; for 1896, 11.48 and the average for all of the determinations made on samples covering the two years was 11.48 per cent.

§40. The furfurol found in the hay used in these experiments, was 8.16 or 13.38 xylan; in the orts 9.95 per cent.; in the feces 12.69 per cent. xylan. There were fed 1786.4 grams of xylan. The orts contained 98.19 grams and the feces 587.6; accordingly 1100.6 grams of xylan had been digested or the coefficient of digestion for the total xylan was 65.12. The corresponding amounts of furfurol are, in the hay fed 1089.5 grams, in the orts 59.9 grams, in the feces 318.9 grams, digestion coefficient 65.18.

§41. We determined the furfurol in the residue after the extraction and not in the evaporated extract for the same reason that we determined the extracts themselves by difference, *i. e.*, because we found a deficiency of about two per cent. on evaporating the extracts to dryness.

TABLE IX.

FURFUROL FOUND IN ALFALFA HAY, ORTS AND THE FECES AND IN THE RESIDUE AFTER TREATMENT WITH THE VARIOUS SOLVENTS.

	Alfalfa hay Per cent.	Alfalfa orts Per cent.	Feces Per cent.
Original Hay	8.160	6.068	7.742
Residue after 80 per cent. alcohol	7.078	5.367	7.638
Residue after cold water	6.494	5.322	Same
Residue after hot water	5.736	5.122	6.940
Residue after 1% hydric chlorid	4.220	3.765	Same
Residue after 1 per cent. sodic hydrate	2.586	2.131	3.778
Residue after chlorin, etc.	1.919	2.080	1.394

TABLE X.

THE COEFFICIENTS OF DIGESTION FOR FURFUROL IN THE VARIOUS EXTRACTS OF ALFALFA HAY.

	Fed.	Orts	Consumed.	Voided.	Digested.	Coef.
Furfurol in alcoholic extract	144.50	6.90	137.60	4.80	132.80	96.51
Furfurol in cold water ext	77.98	0.40	77.58	0.00	77.58	100.00
Furfurol in hot water ext...	101.20	2.00	99.20	32.30	66.90	67.44
Furfurol in hydrochloric acid extract	202.40	13.40	189.00	0.00	189.00	100.00
Furfurol in sodic hydrate ext	218.20	16.10	202.10	146.90	55.20	27 81
Furfurol in chlorin, etc., ext	89.05	10.50	88.55	110.39	—21.84	....
Furfurol in residue, cellulose	256.20	20.50	235.70	64.54	171.16	72.62
	1089.53	59.80	1029.73	358.90	670.83	65.15

§42. The treatment with boiling one per cent. hydric chlorid aims at the removal of easily hydrolized substances which might yield fufurol on distillation with the stronger, 12 per cent., acid. This treatment removes considerable quantities of furfurol yielding substances from the hay which apears to be wholly digestible for we find none in the feces. On the other hand, the hydric chlorid, one per cent. solution, removes hydrolyzable substances from the feces corresponding to 1.03 per cent. of galactan. The one per cent. hydric chlorid solution removes from the hay 1.52 per cent. of furfurol and contains reducing sugars equal to 3.01 per cent. of galactan which is probably the source of the reducing sugar, as the hay yields when treated with hydric nitrate, sp. gr. 1.15, according to the official method, mucic acid corresponding to 2.86 per cent, galactan, so it seems probable that both pentose and hexose sugars are represented in the composition of the hay.

§43. I have elsewhere noted the fact that in making duplicate determinations of this reducing power, it was difficult to obtain agreement in the results and that in some fodders, we had to repeat the treatment as many as three times to get even a fair agreement. I interpret this as indicating a radical difference in the character of the compounds in the different fodders which are attacked by this reagent.

METHOXYL GROUP.

§44. At the time this work was done no tests, so far as I knew, had been made to prove whether this group existed in ordinary plants. Recently, however, it has been shown that certain woods, not known to contain quinine or related alkaloids, yield methyl iodid on distillation with strong hydriodic acid showing the presence of compounds containing the methoxyl group.

§45. The presence of aromatic compounds in the urine of herbivores and the fact of the general prevalence of alkaloidal compounds in plants, some of which contain the methoxyl group, suggested the probability of the presence of this group in the fodders. I accordingly attempted its determination, using the original Zeisel method.

§46. I did not determine this group in the orts, for both the amount of the orts and the percentage of this group present being small, no great error is introduced by the omission, besides my chief object was to establish the presence or absence of the group in the case of each fodder and obtain, if possible, an idea of the amount of these compounds appropriated by the animal, an approximate coefficient of digestion. I did not hope to accomplish more than this.

§47. The duplicate, and in some cases, triplicate determinations, agreed fairly well. The largest difference in twelve sets of duplicates, including also some triplicates, was less than one-half of one per cent. We checked our work using quininc, a commercial article, obtaining a fair agreement in our determination, but the results were a little lower than required by theory, which leads me to infer that my results are too low rather than too high.

METHOXYL GROUP IN ALFALFA HAY FED AND FECES VOIDED.

	I Per cent.	II Per cent.	Av. Per cent.
Alfalfa Hay	1.18	1.23	1.21
Dung, sheep fed alfalfa	2.46	2.31	2.39

§48. The hay consumed was 12,364.8 grams containing 148.38 grams of the methoxyl group; the feces weighed 4,630.5 grams and contained 110.7 grams of methoxyl, giving us a digestion coefficient of 25.42 for this group.

§49. I will anticipate a general result which will be evident when the determinations of this group in all the samples have been given, *i. e.*, that it is present in hays made from grasses and leguminous plants, also in corn fodder, sorghum and the saltbush, *Atriplex argentea*, being most abundant in the last named plant; further that the percentage of this group present in the dung is approximately twice that in the hay or fodder, except in the case of the saltbush in which it is only one and one-half times as much as in the saltbush itself.

AMID NITROGEN IN ALFALFA HAY.

§50. In calculating the proteids we have multiplied the total nitrogen by 6.25 consequently our product is too high, as more or less of the nitrogen is present in the form of amids, compounds containing a higher percentage of nitrogen and, consequently, having a factor less than 6.25, if for example, the nitrogen were present as asparagine, its factor would be 4.7.

§51. In the following statement I have given the proteid equivalent to the amids. I have made no attempt to divide the nitrogen compounds further than into the two groups, proteids and amids.

§52. The amid nitrogen found in samples of alfalfa hay cut at half bloom is as follows, 0.372, 0.350, 0.614; average is 0.444 which is rather far removed from the maximum which is, however, the highest found in eleven samples. The amid nitrogen found in the alfalfa hay used in this series of experiments was 0.446 agreeing very well with the average found for the other samples cut in half bloom.

§53. The proteids in the alfalfa hay fed, corresponding to the amid nitrogen, amounted to 372.11 grams; in the orts 34.66 grams; consumed 337.45 grams; voided 62.23 grams; digested 275.22 grams, from which we obtain 81.55 for the coefficient of digestion for the amid nitrogen.

THE PROTEIDS REMOVED BY THE VARIOUS SOLVENTS AND THEIR COEFFICIENT OF DIGESTION.

§54. As the boiling 80 per cent alcohol removed practically all the coloring matters from the hays, I deemed it advisable to extract them with anhydrous ether and determine the nitrogen removed in this manner. I have assumed that the nitrogen thus removed is principally contained in the coloring matters. For this extraction, I use 30 grams of air-dried hay, macerated it with 150 c. c. of ether for 16 hours, and then subjected it to extraction in a soxhlet extractor for ten hours. Our air-dried hay carries from 5 to 7 per cent. of moisture. I have repeatedly compared the results obtained by extracting air-dried hay with those obtained from the same hay dried in the water oven, also in hydrogen and have seldom found so large a variation that it was of any practical significance. The maximum amount of nitrogen found in the ether extracts of the three hays, alfalfa, timothy and native hay, was contained in the extract from the native hay which contained 0.007 per cent.; that from the timothy contained nitrogen equal to 0.0033 per cent. and that from the alfalfa 0.0032 per cent., calculated on the air-dried hay. The largest one of which corresponds to less than 0.05 per cent. of proteids.

§55. The weight of the dried ether extracts from these three hays varied from 0.5 to 0.75 grams from which it is evident that the coloring matters in these hays must be poor in nitrogen.

§56. If we assume that the nitrogen in these ether extracts is present as proteid nitrogen there would be in that from the native hay approximately 0.05 per cent., a quantity which we can disregard in ordinary work but this is twice as large as the amount found in either of the other two hays.

§57. In regard to the sulfur in alfalfa, the question has frequently suggested itself whether it belonged mostly to the proteids or whether it was present in combination, as sulfuric oxid, probably forming calcic sulfate. Wishing to answer this question in connection with the proteids, we digested a quantity of hay with dilute hydrochloric acid and washed it thoroughly. The sulfuric acid was then precipitated as baric sulfate and weighed after purification. The sulfur present in the hay as sulfuric acid amounted to 0.68 per cent. The total sulfuric acid estimated from that found in the ash, allowing a loss of two per cent. in incineration, was 0.94, leaving sulfur equivalent to 0.26 per cent. of sulfuric acid as proteid sulfur.

§58. Corn fodder treated in the same manner did not show the presence of any sulfuric acid and the sulfur is probably present as proteid sulfur and not in the form of sulfates.

§59. In the following statements, the proteids, respectively the nitrogen calculated as proteids, soluble in 80 per cent. alcohol included the nitrogen soluble in the ether which, as we have just seen, is a very small amount, not more than 0.05 per cent.

§60. The coefficients of digestion for the proteids contained in the various extracts of alfalfa hay:—

TABLE XI.

COEFFICIENTS OF DIGESTION FOR THE PROTEIDS DISSOLVED OUT OF ALFALFA HAY BY THE VARIOUS SOLVENTS.*

	Fed.	Orts	Consumed.	Voided.	Digested.	Coef.
Proteids soluble in boiling 80 per cent. alcohol.......	640.88	46.47	594.41	108.82	485.59	81.69
Proteids soluble in cold water	90.79	26.05	64.74	42.60	22.14	34.20
Proteids soluble in hot water and malt	134.85	9.87	124.98	68.53	56.45	45.17
Proteids soluble in 1 per ct. hydric chlorid	126.84	1.18	125.66	50.47	75.19	59.84
Proteids soluble in 1 per ct. sodic hydrate	937.28	75.58	851.70	154.20	697.50	81.89
Proteids soluble in chlorin, sodic hydrate and sulfurous acid	45.40	5.92	39.48	50.01	(—10.53)	———
Proteids remaining in the cellulose	17.36	1.28	16.08	13.43	2.65	16.48
			1817.05	488.06	1328.99	72.92

§61. The coefficients of digestion found for the proteids by the usual method, and given on page 23, Bulletin 93, are for sheep No. 4, 73.68 per cent.; sheep No. 5, 73.58 per cent.; sheep No. 6, 70.36 per cent.; the average is 72.54 per cent. The coefficient found by calculating it from the sum of the respective extracts of the hay, and dung is 72.92 per cent. actually in better agreement with the two higher coefficients found for sheep No. 4 and 5, than the result obtained for sheep No. 6.

§62. This coefficient, 72.92, would be slightly changed if we made a correction for the amid nitrogen found, but this is nearly correct for the total nitrogen. This statement applies to all the coefficients for the proteids.

THE CALORIFIC VALUE OF ALFALFA HAY.

§63. The calorific value of the hay was determined by means of the bomb calorimeter. By hay, we mean the air-dried hay as fed to the sheep; it contained 7.75 per cent. moisture and 11.77 per cent. ash. Its calorific value was 4,050 calories,† and that of the dung was 4,300 calories. The total hay consumed by the three sheep was 12,364.8 grams. The air-dried feces weighed 4,630.5 grams, which shows that the animals used 62.30 per cent. of the total heat value of the hay. I have assumed that the orts did not

*I have used the term proteids in this place to signify the product of the nitrogen multiplied by 6.25. This remark applies to all of the fodders. Everyone knows that this is conventional and does not mean that there is only one class of nitrogenous compounds present.

†The Calorie used throughout this Bulletin is the small calorie.

differ from the hay because I was compelled to, due to the fact that the orts had all been used for other determinations. The total amount of the orts was small.

§64. The total heat consumed as dry matter by the three sheep was 49,585,495 calories; the total heat value of the dry matter contained in the feces was 18,629,832 calories; there were accordingly 30,955,663 calories appropriated by the sheep, equivalent to 62.43 per cent. of the energy value of the hay. By appropriated I mean that the energy was taken up and either stored in the body or eliminated in some other way than through the alimentary tract as undigested food. The energy escaping in the exhalations, as well as that contained in the urine, is included in the term appropriated.

TABLE XII.

The dry hay gave the following extracts and residue:

	Per cent.
Soluble in boiling 80 per cent. alcohol	21.40
Soluble in cold water	9.38
Soluble in hot water and malt	4.73
Soluble in boiling 1 per cent. hydric chlorid	13.35
Soluble in boiling 1 per cent. sodic hydrate	17.54
Soluble in chlorin, etc.	9.45
Residue—cellulose—	24.15
	100.00

The distribution of the ash in these extracts was not determined.

TABLE XIII.

THE CALORIFIC VALUE OF THE HAY AND OF THE SEVERAL RESIDUES.

The calorific value of the dry hay	4363 calories
The calorific value of residue after extraction with 80 per cent. alcohol	4270 calories
The calorific value of residue after extraction with cold and hot water	4517 calories
The calorific value of residue after extraction with 1 per cent. hydric chlorid	4759 calories
The calorific value of residue after extraction with 1 per cent. sodic hydrate	4603 calories
The calorific value of residue after extraction with chlorin, etc.,	4210 calories

TABLE XIV.

Calories removed from alfalfa hay by the successive treatments.

One gram of hay yields to boiling 80 per cent. alcohol	1007 calories
One gram of hay yields to cold and hot water with malt	443 calories
One gram of hay yields to boiling 1 per cent. hydric chlorid	480 calories
One gram of hay yields to boiling 1 per cent. sodic hydrate	887 calories
One gram of hay yields to treatment with chlorin, etc.	527 calories
One gram of hay yields a residue, cellulose	1017 calories
	4363 calories

TABLE XV.

CALORIFIC VALUE OF THE RESPECTIVE EXTRACTS OF ALFALFA HAY.

One gram of the alcoholic extract gives	4706 calories
One gram of the cold water, hot water and malt extract gives	3140 calories
One gram of the 1 per cent. hydric chlorid extract gives	3596 calories
One gram of the 1 per cent. sodic hydrate extract gives	5063 calories
One gram of the chlorin, etc. extract gives	5598 calories
One gram of the residue, cellulose, gives	4210 calories

TABLE XVI.

THE DRY FECES (ALFALFA HAY) GAVE THE FOLLOWING EXTRACTS AND RESIDUE.

	Per cent.
Soluble in boiling 80 per cent. alcohol	13.405
Soluble in cold water	5.243
Soluble in hot water and malt	3.742
Soluble in boiling 1 per cent. hydric chlorid	13.961
Soluble in boiling 1 per cent. sodic hydrate	14.980
Soluble in chlorin, sodic hydrate and sulfurous acid	18.657
Residue, cellulose	30.012
	100.00

TABLE XVII.

THE CALORIFIC VALUE OF THE FECES (ALFALFA) AND THE VARIOUS RESIDUES.

The calorific value of the dry feces	4525 calories
The calorific value of the residue after extraction with 80 per cent. alcohol	4339 calories
The calorific of the residue after extraction with cold and hot water and malt	4373 calories
The calorific value of the residue after extraction with 1 per cent. hydric chlorid	4441 calories
The calorific value of the residue after extraction with 1 per sodic hydrate	4886 calories
The calorific value of the residue after extraction with chlorin, etc.	4294 calories

TABLE XVIII.

THE CALORIFIC VALUE REMOVED FROM THE FECES (ALFALFA HAY) BY THE SUCCESSIVE TREATMENTS.

One gram of dry feces yields to boiling 80 per cent alcohol	769 calories
One gram of dry feces yields to cold and hot water with aid of malt	362 calories
One gram of dry feces yields to boiling 1 per cent. hydric chlorid	567 calories
One gram of dry feces yields to boiling 1 per cent. sodic hydrate	449 calories
One gram of dry feces yields to chlorin, etc.	1090 calories
One gram of dry feces yields residue, cellulose	1288 calories

TABLE XIX.

THE CALORIFIC VALUE OF THE VARIOUS EXTRACTS OF THE FECES (ALFALFA HAY)

One gram of the alcoholic extract gives	5739 calories
One gram of the cold and hot water, etc., extract gives	4123 calories
One gram of the boiling 1 per cent. hydric chlorid gives	4061 calories
One gram of the boiling 1 per cent. sodic hydrate gives	2997 calories
One gram of the chlorin, etc., extract gives	5842 calories
One gram of the residue, cellulose, gives	4294 calories

TABLE XX.

COEFFICIENTS OF DIGESTION FOR THE HEAT VALUES OF THE VARIOUS EXTRACTS OF ALFALFA HAY.

	Heat Units Consumed	Heat Units Voided	Heat Units Appro.	Coefficient
Alcoholic extract	15,852,166	5,113,449	10,738,717	67.75
Aqueous extract*	5,074,240	1,599,724	3,474,516	68.51
One per cent. hydric chlorid extract	5,447,940	2,448,783	2,999,157	54.75
One per cent. sodic hydrate extract	10,156,378	1,938,059	8,218,319	80.92
Chlorin, etc., extract	6,045,840	4,708,652	1,337,188	24.03
Residue or cellulose	11,522,770	5,570,208	5,952,562	51.66

§65. The coefficients of digestibility of the heat values of the various extracts show the same general features exhibited by the preceding tables, showing , in particular, the high value of the portion soluble in 80 per cent. alcohol which furnishes the largest portion by weight of dry substance digested—over one-third of the total nitrogen digested and one-third of the total heat units appropriated. The sodic hydrate extract furnished, in the case of alfalfa the largest amount of nitrogen, one-half more than the alcoholic extract, less dry matter than either the cellulose or the alcoholic extract and one-fifth less heat than the alcoholic extract.

§66. The values of the extracts, measured by the heat furnished, stand as follows for alfalfa:—Alcoholic extract, 11 millions heat units; sodic hydrate extract, 8 millions; the insoluble portion of the fodder, the cellulose, 6 millions of heat units.

§67. This order does not hold good for the other fodders examined in this manner. The alcoholic extract and the cellulose constitute two of the three most important portions of the fodder, but the hydric chlorid extract stands above the sodic hydrate as a source of heat in the corn fodder.

TIMOTHY HAY.

§68. The timothy hay used was the best that we could obtain in the open market and was grown in the mountains.

§69. Though the hay appeared to be of excellent quality, the sheep did not do well on it, one sheep gained one-half pound in five

*The aqueous extract includes all that was dissolved out by cold water, 24 hours digestion, boiling with water for one hour and subsequently treating with malt extract.

days, the other two together lost one and a half pounds, leaving a net loss of one pound for the three sheep in five days. This is in strong contrast with the results obtained with the alfalfa and corn fodder. The sheep fed alfalfa all gained. The total gain for the three sheep was nine pounds in five days; those fed on corn fodder also all gained, the total gain in five days being three and one-half pounds, so we have 9 and 3 ½ pounds gain respectively for the alfalfa and corn fodder, against a net loss of one pound for the timothy hay. The coefficient of digestion for the dry matter in the alfalfa hay found by the ordinary method of determining it was 62.05, and by considering the extracts individually it was 62.55. In the case of the timothy hay, we obtained in the ordinary manner 51.03, in the manner here pursued 51.10, an excellent agreement in both cases with a difference of 11 per cent.in these coefficients, that of the alfalfa being the higer. The sheep consumed, however, 11,265 grams of dry matter, as alfalfa hay, leaving almost no orts and only 8,223 grams of dry matter as timothy hay, leaving 4,233 grams of orts.

TABLE XXI.

ANALYTICAL DATA. TIMOTHY HAY.

Proximate Analysis.

TIMOTHY HAY		CORRESPONDING FECES Sheep No. 1	
Moisture	6.49	Moisture	6.79
Ash	9.37	Ash	7.84
Ether extract	2.99	Ether extract	2.28
Proteids	5.62	Proteids	5.92
Crude fibre	31.54	Crude fibre	37.26
Nitrogen-free extract	43.99	Nitrogen-free extract	39.91
	100.00		100.00

TABLE XXII.

ANALYSIS OF THE ASH.

TIMOTHY HAY		CORRESPONDING FECES	
Sand	26.249	Sand	43.943
Silicic acid	11.506	Silicic acid	9.126
Sulfuric acid	3.033	Sulfuric acid	1.515
Phosphoric acid	4.239	Phosphoric acid	11.428
Carbonic acid	5.390	Carbonic acid	1.259
Clhorin	7.177	Chlorin	0.798
Potassic oxid	30.118	Potassic oxid	10.721
Sodic oxid	0.146	Sodic oxid	1.122
Calcic oxid	5.586	Calcic oxid	11.981
Magnesic oxid	2.685	Magnesic oxid	3.868
Ferric oxid	0.540	Ferric oxid and Aluminic oxid	1.171
Alumnic oxid	0.176		
Manganic oxid	0.370	Manganic oxid	0.189
Ignition	(4.357)	Ignition	3.000
	101.617		100.121
Oxygen equivalent to Chlorin	1.617	Oxygen equivalent to chlorin	.180
	100.000		99.941

TABLE XXIII.

ULTIMATE ANALYSIS.

TIMOTHY HAY		CORRESPONDING FECES	
Carbon	44.241	Carbon	46.362
Hydrogen	5.832	Hydrogen	6.186
Nitrogen	0.892	Nitrogen	0.954
Sulfur	0.104	Sulfur	0.143
Chlorin	0.506	Chlorin	0.133
Ash	9.370	Ash	7.840
Oxygen (approx.)	39.045	Oxygen (approx.)	38.382
	100.000		100.000

§70. The ash in this analysis, of course, represents the thoroughly oxidized, non-combustible portion of the plant containing a considerable portion of both the chlorin and sulfur. The chlorin and sulfur given above are the quantities contained in the air-dried hay as obtained by direct determination. The percentage of ash as given is too high by the amount of the chlorin and sulfur retained which is from 92 to 98 per cent. of the total sulfur and chlorin respectively, and also by the oxygen which the ash constituents may have taken up. The percentage of oxygen is, for these reasons, retention of chlorin and sulfur and the possible absorption of oxygen by the ash constituents, too low, for which reason, I have designated it as approximate only.

TABLE XXIV.

ANALYSIS OF TIMOTHY HAY.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted..	21.307	20.931	21.12
Cold water in 24 hrs. extracted......	6.858	7.039	6.95
Hot water extracted	3.000	2.968	2.98
Hydric chlorid, 1 per cent. sol. extracted	19.740	20.717	20.23
Sodic hydrate, 1 per cent. sol. extracted	17.108	16.997	17.05
Chlorin, etc., extracted	5.548	5.872	5.71
Cellulose remaining	26.439	25.476	25.96
			100.00

SUGARS IN THE EXTRACTS

	I	II	Av.
Glucose in alcoholic extract.........	1.16	1.44	1.30
Sucrose in alcoholic extract.........	2.83	2.83	2.83
Gum in cold water extract...........	3.12	3.12	3.12
Starch in hot water extract.........	None	None	None
Reducing power calculated as Xylan in hydric chlorid extract	15.77	Lost	15.77
Reducing power calculated as Xylan in sodic hydrate extract..........	0.83		0.83

TABLE XXV.

ANALYSIS OF ORTS OF TIMOTHY HAY.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted..	22.952	23.194	23.07
Cold water in 24 hrs. extracted......	4.034	4.447	4.24
Hot water extracted	2.895	2.461	2.68
Hydric chlorid, 1 per cent. sol. extracted	19.552	19.826	19.68
Sodic hydrate, 1 per cent. sol. extracted	Lost	14.680	14.68
Chlorin, etc., extracted		8.530	8.53
Cellulose remaining		27.120	27.12
			100.000

SUGARS IN THE EXTRACTS

	I	II	Av.
Glucose in alcoholic extract.........	2.48	2.43	2.46
Sucrose in alcoholic extract.........	3.29	3.37	3.33
Gum in cold water extract..........	1.82	2.03	1.93
Starch in hot water extract.........	None	None	None
Xylan in hydric chlorid extract......	14.32	15.39	14.86
Xylan in sodic hydrate extract......	Lost	1.31	1.31

TABLE XXVI.

ANALYSIS OF FECES OF SHEEP FED ON TIMOTHY HAY.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted..	16.592	15.512	16.05
Cold water in 24 hrs. extracted......	2.840	2.818	2.83
Hot water extracted	3.255	3.288	3.27
Hydric chlorid, 1 per cent. sol. extracted	16.230	16.802	16.52
Sodic hydrate, 1 per cent. sol. extracted	16.893	19.226	18.06
Chlorin, etc., extracted	14.272	11.563	12.92
Cellulose remaining	29.918	30.792	30.35
			100.00

SUGARS IN THE EXTRACTS

	I	II	Av.
Glucose in alcoholic extract.........	None	None	None
Sucrose in alcoholic extract.........	None	None	None
Gum in cold water extract..........	0.20	0.0	0.10
Starch in hot water extract.........	None	None	None
Xylan in hydric chlorid extract......	7.91	9.44	8.68
Xylan in sodic hydrate extract......	2.25	2.06	2.15

TABLE XXVII.

COEFFICIENTS OF DIGESTION FOR THE VARIOUS EXTRACTS OF TIMOTHY HAY.

	Fed.	Orts	Consumed.	Voided.	Digested.	Coef.
Total alcoholic extract.....	3813.0	1036.5	1776.5	691.4	1085.1	61.08
Total cold water extract....	925.6	196.5	816.1	121.9	694.2	85.06
Total hot water and malt ext.	397.8	120.4	277.4	140.9	136.5	49.21
Total hydrochloric acid 1% extract	2694.4	884.2	1810.2	711.6	1098.6	60.69
Total sodic hydrate (1 per per cent.) extract.......	2270.9	659.8	1511.1	777.9	733.2	48.52
					Excess	
Total chlorin, etc., extract..	760.6	383.0	377.6	551.5	--173.9	——
Total cellulose, residue, ...	3457.7	1218.3	2239.3	1307.4	931.9	41.61
Total	13320.0	4492.7	8808.2	4307.6	4500.6	51.19

Average coefficient of digestion for dry matter given page 29, Bulletin No. 93, 51.03.

TABLE XXVIII.

COEFFICIENTS OF DIGESTION FOR THE CARBOHYDRATES IN TIMOTHY HAY AS INDICATED BY THE SUGARS OBTAINED FROM THE VARIOUS EXTRACTS.

	Fed.	Orts	Consumed.	Voided.	Digested.	Coef.
In the alcoholic extract:						
Glucose	173.2	110.5	62.7	0.0	6.27	100.00
Sucrose	377.0	149.6	227.4	0.0	227.4	100.00
In the cold water extract, Gums, etc.	415.6	86.7	328.9	4.3	324.6	98.69
In the hot water and malt extract, (starch)	0.0	0.0	0.0	0.0	0.0	——
In the 1 per cent. hydrochloric acid (Xylan) extract ...	2100.6	667.6	1433.0	373.9	1059.1	72.23
In the 1 per cent. sodic hydrate (Xylan) extract	110.5	58.9	51.6	92.6	Excess 41.0	——

§71. The furfurol in timothy hay was found to be 12.17 per cent. and there was accordingly 1,621.0 grams fed. The orts contained 11.60 per cent. equal to 521.2 grams and the feces contained 12.73 per cent., equal to 548.4 grams. This gives us 50.12 per cent. for the coefficient of digestion of the furfurol.

§72. I have used the furfurol instead of the complexes yielding it as we know quite certainly that there are probably several compounds present which may yield furfurol. Our coefficient, 50.12, shows no more than that one-half of the furfurol has been digested. If the complexes from which this is derived yield the same amounts of furfurol and are broken down with equal readiness, in the alimentary tract of the animal and by the distillation with the twelve per cent. acid, we would be justified in assuming that one-half of the furfurol yielding substances are available as food for the ruminant. This is probably not far from the facts in the case, but it will be seen from the following table that we have very good reasons for doubting whether the complexes are equally attacked as we assume in making this statement.

TABLE XXIX.

FURFUROL IN THE VARIOUS EXTRACTS OF TIMOTHY HAY AND COEFFICIENTS OF DIGESTION.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Alcohol	86.6	42.7	43.7	13.4	30.5	69.47
Cold water	122.7	17.5	105.2	30.5	74.7	71.07
Hot water	26.6	9.0	17.6	34.5	(—16.9)	——
Hydric Chlorid	542.7	186.9	355.8	263.1	92.7	32.80
Sodic hydrate	456.8	151.0	305.8	270.5	35.3	11.54
Clorin	129.2	39.1	90.1	1.3	88.8	98.54
Cellulose	271.7	74.6	197.1	98.2	98.9	50.12
			1115.5	711.2	404.3	36.24

§73. The results in this table are unsatisfactory, but we repeated a number of the determinations and found no error. The discrepancy between the coefficient found by summing up the amounts in the individual extracts of the hay, orts and dung and that found by determining the furfurol in the hay, orts and dung themselves is altogether too great, but the amount digested in either case is comparatively small and large differences result from comparatively small errors in the work. The general coefficient found was 50.12.

COEFFICIENT OF DIGESTION OF THE METHOXYL GROUP IN TIMOTHY HAY.

§74. The orts, as in the case of the alfalfa, have been considered as containing the same percentage of methoxyl as the hay, which is probably not correct, but this error can be neglected as the difficulties of the determination do not permit of great accuracy at the best. The hay consumed contained 124.20 grams; there was voided 103.70 grams; digested 20.5 grams, or 16.50 per cent.

DIGESTIBILITY OF THE AMIDS IN TIMOTHY HAY.

§75. The amid nitrogen found in the timothy hay used, corresponded to 0.99 per cent. of proteids, or 0.168 per cent. nitrogen and that found for the orts was almost identical, 0.994 per cent.; in the feces we found none. According to this the amid nitrogen is wholly digestible.

§76. This result is aparently not in accord with the results given under the next caption, but we found no amid nitrogen in the feces of sheep fed on timothy hay, native hay, corn fodder or saltbush, that is to say, we found no nitrogen in these samples which was not precipitated by cupric hydrate.

TABLE XXX.

COEFFICIENTS OF DIGESTION OF THE PROTEIDS IN THE VARIOUS EXTRACTS OF TIMOTHY HAY.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Proteids soluble in 80% alcohol	187.81	35.04	152.77	24.12	128.65	82.30
Proteids soluble in cold and hot water	82.58	41.78	40.80	53.41	(—12.61)	....
Proteids soluble in 1% hydric chlorid	98.57	33.25	65.32	42.65	22.67	34.71
Proteids soluble in 1% sodic hydrate	350.31	126.69	223.62	92.61	136.01	58.59
Proteids soluble in chlorin	13.23	10.78	2.45	37.48	(—35.03)	....
Proteids in residue, cellulose	9.32	2.70	6.62	6.89	(—0.27)	....
Total	741.82	250.24	491.58	257.16	234.42	47.69

The general coefficients of digestibility found for the three individual sheep were 47.73, 41.06 and 41.27. Average 43.35.

CALORIES CONSUMED AND VOIDED.

§77. We find the calorific value of dry timothy hay to be 4,414 and 4,417, an average of 4,415 plus; the orts gave 4,392 and the feces 4,709 calories.

§78. The dry matter fed contained 54,979,995 calories; the orts contained 18,586,944 calories and the feces 18,986,688 calories, which indicates the use of 47.83 per cent. of the heat energy of the fodder, or 17,406,363 calories.

§79. This timothy hay proved to be a poor fodder for sheep when fed alone. Two of the sheep lost weight and the third one gained one-half pound between the two weighings.

§80. We did not carry our calorimetric work further with timothy hay for the reason that this hay has been made the subject of study by others. Quite an exhaustive study of it is to be found in the Report of the Pennsylvania State College for the year 1903 and 1904.

NATIVE HAY.

§81. This hay is made up of a mixture of grasses and represents a fodder which is prized by many as an excellent one. The mixture of grasses varies greatly even in hay from the same farm. The results obtained in experiments with this hay are therefore applicable to other samples of it in a general way only, and it is for this reason that we have not determined the heat value of the residues, obtained by extracting the hay with the various solvents adopted in this work.

TABLE XXXI.

ANALYTICAL DATA FOR NATIVE HAY.

NATIVE HAY		CORRESPONDING FECES Sheep No. 6.	
Moisture	5.13	Moisture	5.96
Ash	10.64	Ash	12.41
Ether extract	3.13	Ether extract	5.02
Proteids	6.98	Proteids	5.48
Crude fibre	31.38	Crude fibre	29.29
Nitrogen-free extract	42.74	Nitrogen-free extract	41.84
	100.00		100.00

TABLE XXXII.

ANALYSIS OF ASH IN NATIVE HAY.

ASH OF NATIVE HAY		ASH OF CORRESPONDING FECES	
Carbon	Heavy trace	Carbon	———
Sand	3.375		
Silicic acid	54.736	Sand and Silicic acid	73.913
Sulfuric acid	1.521	Sulfuric acid	0.884
Phosphoric acid	2.133	Phosphoric acid	3.156
Carbonic acid	4.871	Carbonic acid	2.849
Chlorin	4.878	Chlorin	0.347
Potassic oxid	17.786	Potassic oxid	5.373
Sodic oxid	0.640	Sodic oxid	0.845
Calcic oxid	6.180	Calcic oxid	7.587
Magnesic oxid	2.016	Magnesic oxid	1.477
Ferric oxid	0.685	Ferric oxid	0.280
Aluminic oxid	0.273	Aluminic oxid	0.266
Manganic oxid	0.132	Manganic oxid	0.210
Ignition	1.719	Ignition	(2.891)
	100.945		100.078
Oxygen equivalent to chlorin	1.099	Oxygen equivalent to chlorin	0.078
	99.846		100.000

TABLE XXXIII.

ULTIMATE ANALYSIS OF NATIVE HAY.

NATIVE HAY		CORRESPONDING FECES	
Carbon	43.814	Carbon	45.328
Hydrogen	5.792	Hydrogen	5.935
Nitrogen	0.996	Nitrogen	0.919
Sulfur	0.116	Sulfur	0.109
Chlorin	0.673	Chlorin	0.073
Ash	10.640	Ash	12.410
Oxygen, (approx.)	27.969	Oxygen, (approx.)	25.226
	100.000		100.000

§82. The ash analysis of this hay shows a very high percentage of silicic acid. It is a well known fact that the ash of some of the grasses contain a large amount of silica, but this ash is as high or even a little higher than the superior limit usually found. This ash, when evaporated to dryness with hydric chlorid and subsequently treated with water, leaves a felt-like mass of silicic acid which is made up of quadrangular plates with irregular margins. If a stem of this hay be treated with hydric nitrate and potassic chlorate, to destroy the tissues and remove the soluble salts, and then be burned, one can obtain a beautiful skeleton of silica showing the outlines of the epidermal cells and the stomata. The total ash amounts to a little over one-tenth of the weight of the hay, and over one-half of this is silicic acid. The skeleton thus obtained seems to show that the stem is completely sheathed in a siliceous covering. The leaves also furnish skeletons, but these differ considerably in their details from the skeletons of the stems. The silica, however, seems quite abundant in the leaves, almost as much so as in the stems. This blue stem feels harsh to the touch, not so much so, perhaps, as the sedges, but the skeletal silica seems to be even more abundant in the blue stem than in the sedges.

§83. The coefficient of digestion found for this ash, 42.52, seems to be very high, too high in fact, but the separation of the silicic acid and sand in the ash of the feces was particularly difficult.

TABLE XXXIV.

PROXIMATE ANALYSIS OF NATIVE HAY.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	21.469	21.537	21.50
Cold water, in 24 hrs., extracted.....	5.917	5.813	5.87
Hot water extracted	2.975	2.726	2.85
Hydric chlorid, 1 per cent. sol. extracted	20.544	21.049	20.80
Sodic hydrate, 1 per cent. sol., extracted	16.485	16.816	16.64
Chlorin, etc., extracted	5.586	4.868	5.23
Cellulose, residue	27.024	27.191	27.11
			100.00

SUGARS IN THE EXTRACTS

Glucose in alcoholic extract	1.38*	1.38	1.38
Sucrose in alcoholic extract	2.89	2.89	2.89
Gums in cold water extract	2.50	2.50	2.50
Starch in hot water extract	1.10	1.12	1.11
Reducing power expressed as Xylan, hydric chlorid extract............	12.53	12.53	12.53
Reducing power expressed as Xylan, sodic hydrate extract............	Trace	Trace	Trace

*We experienced more trouble than usual with this sample, so I have used averages of several pairs. The results are only approximately correct.

TABLE XXXV.

ANALYSIS OF ORTS OF NATIVE HAY.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	23.377	24.256	23.82
Cold water, in 24 hrs., extracted.....	5.899	5.197	5.55
Hot water extracted	2.999	2.701	2.85
Hydric chlorid, 1 per cent. sol. extracted	20.062	20.066	20.06
Sodic hydrate, 1 per cent. sol., extracted	16.917	16.922	16.92
Chlorin, etc., extracted	7.359	7.772	7.57
Cellulose, residue	23.387	23.086	23.23
			100.00

SUGARS IN THE EXTRACTS

	I	II	Av.
Glucose in alcoholic extract	1.54*		1.54
Sucrose in alcoholic extract	1.72		1.72
Gums in cold water extract	2.83		2.83
Starch in hot water extract	1.12		1.12
Xylan in hydric chlorid extract......	12.53		12.53
Xylan(?) in sodic hydrate extract....	1.28		1.28

TABLE XXXVI.

DUNG OF SHEEP FED ON NATIVE HAY.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	17.430	17.928	17.68
Cold water, in 24 hrs., extracted.....	3.090	3.251	3.17
Hot water extracted	3.351	3.880	3.62
Hydric chlorid, 1 per cent. sol. extracted	15.538	15,230	15.38
Sodic hydrate, 1 per cent. sol., extracted	23.011	22.387	22.70
Chlorin, etc., extracted	9.288	9.078	9.18
Cellulose, residue	28.292	28.246	28.27
			100.00

SUGARS IN THE EXTRACTS

	I	II	Av.
Glucose in alcoholic extract	None	None	None
Sucrose in alcoholic extract	None	None	None
Gums, etc., in cold water extract.....	Trace	Trace	Trace
Starch in hot water extract	None	None	None
Xylan in hydric chlorid extract......	10.13	9.07	9.60
Xylan(?) in sodic hydrate extract...	2.22	2.28	2.25

*This analysis, like that of the hay, was exceedingly unsatisfactory, though done in duplicate and repeated by two different operators.

TABLE XXXVII.

COEFFICIENTS OF DIGESTION FOR THE VARIOUS EXTRACTS OF NATIVE HAY.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Total alcoholic extract.....	2834.1	618.7	2215.4	918.2	1297.2	58.55
Total cold water extract...	773.8	144.2	629.6	164.6	465.0	73.86
Total hot water and malt extract	375.7	74.0	301.7	188.0	113.7	37.69
Total hydric chlorid extract	2741.9	521.0	2220.9	798.7	1422.2	64.04
Total sodic hydrate extract	2193.5	439.5	1754.0	1178.9	575.1	32.79
Total chlorin, etc., extract.	689.4	196.6	492.8	476.7	16.1	3.28
Residue, cellulose	3573.6	603.3	2970.3	1468.1	1502.2	50.57
	13182.0	2597.3	10584.7	5193.2	5391.5	50.94

Average coefficient given for dry matter, Bulletin 93, page 32, 50.53.

TABLE XXXVIII.

COEFFICIENT OF DIGESTION FOR THE CARBOHYDRATES IN NATIVE HAYS, AS INDICATED BY THE SUGARS OBTAINED FROM THE VARIOUS EXTRACTS.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Glucose in alcohol extract.	181.9	40.0	141.9	0.0	141.9	100.00
Sucrose in alcohol extract..	381.0	44.7	336.3	0.0	336.3	100.00
Gums in cold water extract	329.6	73.5	256.1	Trace	256.1	100.00
Starch in hot water and Malt extract	146.3	29.1	117.2	0.0	117.2	100.00
Xylan in hydric chlorid ext.	1651.7	325.4	1326.3	496.3	830.0	62.58
Xylan(?) in sodic hydrate extract	147.6	29.1	118.5	116.8	1.7	1.43
	2838.1	541.8	2296.3	613.1	1683.2	73.30

TABLE XXXIX.

COEFFICIENTS OF DIGESTION OF THE FURFUROL IN THE VARIOUS EXTRACTS OF NATIVE HAY.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Alcohol	107.6	51.3	56.3	21.4	34.9	61.91
Cold water .... } Hot water .... }	87.3	40.2	47.1	43.9	3.2	6.79
Hydric chlorid, 1% Sol.....	711.6	102.7	608.9	240.7	368.2	44.04
Sodic hydrate, 1% Sol......	359.7	51.6	308.1	178.2	129.9	42.16
Chlorin	126.9	17.6	109.3	121.9	-12.6	....
Cellulose	269.0	49.9	219.1	54.9	164.2	74.94
	1662.1	313.3	1348.8	661.0	687.8	50.99

§84. The coefficient of digestion found by calculating the furfurol in the hay fed, subtracting that contained in the orts, etc., is 50.63, which is in good agreement with that obtained by taking the sum of the separate extracts.

TABLE XL.

COEFFICIENTS OF DIGESTION FOR THE PROTEIDS IN THE VARIOUS EXTRACTS OF NATIVE HAY.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Proteids soluble in 80% alcohol	230.69	47.53	183.16	66.47	116.69	63.71
Proteids soluble in cold water and hot water and malt	69.86	18.96	50.90	35.83	15.07	29.61
Proteids soluble in 1% hydric chlorid	97.55	23.12	74.43	27.52	46.91	63.03
Proteids soluble in 1% sodic hydrate	383.60	59.48	324.12	129.82	194.30	58.58
Proteids soluble in chlorin,	29.00	4.93	24.07	27.01	—2.94	——
Proteids remaining in the cellulose	10.55	2.08	8.47	11.95	—3.48	——
	821.25	156.10	665.15	298.60	366.55	55.11

§85. The average coefficients of digestion found for the proteids in native hay, using three sheep, was 62.33, Colorado Experiment Station Bulletin No. 93, page 32.

HEAT VALUE OF NATIVE HAY.

§86. The energy was found to be equal to 4,349 calories for the dry hay and that of the dried feces was found to be 4,579 calories. The calorific value of the fodder consumed was 46,034,165 calories, that of the feces 23,778,747 calories; accordingly the animals appropriated 22,255,418 calories, or 48.34 per cent. of the total energy.

§87. The heat values or energy of the different extracts were not determined because, as stated in the description of this hay, it is made up of a mixture of grasses, sedges, etc., which varies so that this sample cannot be taken as representative except in a general way.

AMID NITROGEN.

§88. The proteids corresponding to the amid nitrogen in native hay amounted to 0.513 per cent., but we were unable to find any in the feces, consequently we infer that they were wholly digestible. The better way to put this is that the quantity of amid nitrogen is so small that, as a fodder constituent, it is wholly negligible.

METHOXYL GROUP IN NATIVE HAY.

§89. This group is present in the hay to the extent of 1.795 per cent., and in the feces to the extent of 2.764 per cent. The hay consumed was 10,585 grams, and the feces voided 5,193 grams, which gives us a coefficient of 23.47 for the digestibility of this group in the hay.

§90. The results obtained in feeding this hay were fairly good, the net result being a gain of three and one-half pounds during the five days between the weighings. The dry matter voided in the feces was almost one-half of that consumed, and the coefficients of digestion were found to be comparatively low. This hay, designated as native hay, commands a high price and is held in high esteem, particularly for horses.

§91. In this experiment no grain or other fodder than the hay was fed. I wished to study the hay and not to determine an advantageous ration, of which it should be a part.

§92. If we compare the data furnished by the results obtained with alfalfa and those obtained in the case of the native hay, we observe very great differences. In the first place, the alfalfa is evidently a more palatable food to sheep than this hay or timothy. There was fed of the native hay, 13,182 grams, the sheep left 2,596 grams; of the alfalfa, 13,350 grams, of which 987 grams were left; of the timothy, 13,320 grams, of which 4,493 grams were left. These hays were all cut in order to induce the sheep to eat it up clean as possible. Sheep prefer, for instance, the leaves of alfalfa to the stems, and I wished to force them to eat the stems as well as the leaves.

TABLE XLI.

THE AMOUNT OF THE RESPECTIVE EXTRACTS DIGESTED AND THEIR COEFFICIENTS OF DIGESTION.

	Native Hay Grams digested	Coefficients	Alfalfa Hay Grams digested	Coefficients
Alcohol, 80%	1297.	58.55	2520.	68.64
Cold water	465.	73.86	846.	78.89
Hot water	114.	37.69	381.	70.24
Hydric chlorid	1422.	64.04	912.	60.20
Sodic hydrate	575.	32.79	1359.	67.72
Chlorin	16.	3.28	274.	25.39
Cellulose	1502.	50.57	1442.	52.67

§93. In regard to the relative amounts of the extracted matter digested and corresponding coefficients, we observe that much larger amounts of those substances dissolved out by the eighty per cent. alcohol, cold and hot water, the latter with addition of malt ex- extract, were digested in the case of the alfalfa than in that of the native hay, and the coefficients of digestion are materially higher. The reverse is the case with those substances dissolved out by the one per cent. hydric chlorid, the quantity digested, as well as the coefficient of digestion, being higher in the case of native hay than in that of the alfalfa. The amount of digestible matter removed from alfalfa by the one per cent. solution of sodic hydrate is greater, about 2⅓ times, than that removed from the native hay. The matter removed by chlorin, etc., is neither considerable in quantity, nor does it appear to be very digestible. The amounts of cellulose digested were approximately the same in the two cases, as are also the coefficients of digestion.

§94. The most important fact to be kept in mind in this comparison is that the same sheep when fed these hays made a uniform gain of three pounds in five days on the alfalfa, or a net gain of nine pounds, whereas two gained one-half pound each and one two and a half pounds in five days, a net gain of three and one-half pounds, when fed the native hay. It may be futile to seek an explanation of these results in the analytical data, but it is the purpose of this bulletin to present the latter as fully as we are at present able to, in order to see whether this may in any way be possible. An examination of the amounts of the various extracts digested and their coefficients of digestion would lead us, possibly justly so, to attach great importance to the alcoholic and sodic hydrate extracts, especially as the latter solvent is supposed to remove the principal portion of the nitrogenous compounds to which we are accustomed to attach great value.

§95. It may be that these two extracts, those obtained by alcohol and sodic hydrate, respectively, do stand in some immediate relation to the respective values of the two hays, but some facts to be presented subsequently in connection with another fodder, while not showing that the above inference is wrong, will lead us to hesitate in drawing conclusions too freely.

§96. The substances removed by chlorination, including subsequent treatment with sodic hydrate and sulfurous acid, was 16 grams in the case of the native hay, 274 grams in that of the alfalfa, the former having a coefficient of 3.28 per cent., and the latter 25.39 per cent., both very low. The residue, which I have designated as cellulose though I know it is not pure, amounts to 1,502 grams in the native hay and 1,442 grams in the alfalfa, much more nearly equal than one would expect. The same, too, being true of the coefficients of digestion, as we find 50.57 for the cellulose from the native hay and 52.67 for that from the alfalfa.

§97. If we study the distribution of the nitrogen in the various extracts and the coefficients of digeston obtained, we find even greater differences, because we deal with smaller numbers and there is, too, a marked difference in the quantity of this element in the two fodders, the alfalfa being much the richer, containing almost 24 times as much nitrogen.

TABLE XLII.

The following figures represent grams of proteids (N. x 6.25).

DIGESTIBILITY OF THE PROTEIDS IN THE RESPECTIVE EXTRACTS.

	Native Hay		Alfalfa Hay	
	Grams	Coefficients	Grams	Coefficients
Alcohol, 80%	115.0	62.98	486.0	81.77
Cold water, hot water and malt..	16.0	32.34	63.0	25.91
Hydric chlorid, 1%	57.0	67.34	132.0	72.38
Sodic hydrate, 1%	184.0	58.63	649.0	80.89
Chlorin, etc.	———	———	12.0	30.19
Cellulose	———	———	3.0	16.48

§98. We have not only a very much larger amount of proteids in the alfalfa, but also very much higher coefficients of digestion. Both hays show that sodic hydrate and alcohol are the two solvents removing the nitrogen. The hydric chlorid standing third in the list, removing one-half as much from the native hay and almost one-third as much from the alfalfa as the alcohol.

§99. In this connection the amid nitrogen should probably be considered; at least, the relative amounts in the hays should be given. The alfalfa consumed contained amid nitrogen corresponding to 337.45 grams proteids, with a coefficient of digestion of 81.55. The native hay contained an amount corresponding to 54.29 grams, the whole of which was digested, as no amid nitrogen was found in the feces.

§100. If we next compare the sugars contained in these two hays, we will find still other differences.

TABLE XLIII.

DIGESTIBILITY OF THE CARBOHYDRATES, MEASURED BY THE REDUCING POWER OF THE INVERTED EXTRACTS.

	Native Hay		Alfalfa Hay	
	Grams	Coefficients	Grams	Coefficients
Alcoholic extract, Sucrose.......	142.0	100.00	159.0	100.00
Alcoholic extract, Glucose.......	336.0	100.00	110.0	100.00
Cold water, gums, etc	256.0	100.00	83.0	81.09
Hot water and malt, starch......	117.0	100.00	145.0	93.73
Hydric chlorid, 1% invert. sugar	830.0	62.58	286.0	83.96

Sodic hydrate, 1% invert. sugar, very minute quantity.

§101. Except in the case of sucrose and starch, we find that the native hay contains more of these substances, or complexes yielding them, than the alfalfa. The most marked instance is the reducing power yielded by the hay on being treated with the one per cent. hydric chlorid, whereby hydrolysis effected the production of sugar equal to 1,326 grams of xylan, of which 830 grams were digested, whereas, in the alfalfa, the same treatment produced 340 grams galactan, of which 286 grams or 83.96 per cent. were digested. The differences here are quite marked and, so far as the quantity digested is concerned, apparently in favor of the native hay.

§102. If we, in like manner, compare the results obtained by determining the furfurol, we will observe that other differences are strongly indicated.

TABLE XLIV.

FURFUROL DIGESTED.

	Native Hay Grams digested	Native Hay Coefficients	Alfalfa Hay Grams digested	Alfalfa Hay Coefficients
Alcoholic extract	35.0	61.99	133.0	96.51
Cold water	3.0	6.79	78.0	100.00
Hot water and malt			67.0	67.44
Hydric chlorid, 1%	268.0	44.04	189.0	100.00
Sodic hydrate, 1%	130.0	42.16	55.0	27.81
Chlorin, sodic hydrate, etc.	....	.....	....	.....
Cellulose	164.0	74.94	171.0	72.62

§103. We observe that the furfurol yielding substances in these two fodders must be very different. Those removed by alcohol, water and hydric chlorid from the alfalfa hay having a much higher coefficient of digestion than those dissolved out of the native hay, while the furfurol yielding bodies removed by the one per cent. sodic hydrate from the alfalfa show a low coefficient of digestion, much lower even than the corresponding substances in the native hay. When we come to the portion that I have designated cellulose, we find the amount of furfurol digested in the two cases and also the coefficients of digestion very close together, so that this factor would apparently fall out of our consideration. The same is indicated by the amount of cellulose digested in these two cases, the three sheep having digested 1,441 grams cellulose fed as alfalfa and 1,502 grams fed as native hay. As pure cellulose yields from 2 to 2.5 per cent. of furfurol, and we obtained for the alfalfa cellulose 1.919 and for that from the native hay, 2.041 per cent. furfurol, the two products are probably almost pure cellulose, and the above results in regard to the cellulose are such as we should expect.

§104. In the case of the native hay, we find that the coefficients of digestion for the furfurol are low, except in the case of that yielded by the cellulose. The most marked features are the deportment of those compounds yielding furfurol, but which are soluble in one per cent. solutions of hydric chlorid or sodic hydrate. Such substances removed from alfalfa by one per cent. hydric chlorid seem to be wholly digestible, while those removed by the sodic hydrate are only slightly digestible. The alfalfa consumed contained substances soluble in the one per cent. hydric chlorid, which yielded 189 grams furfurol, while those soluble in one per cent. sodic hydrate yielded 202 grams of furfurol. Those substances present in the native hay soluble in one per cent hydric chlorid yielded a total of 609 grams of furfurol, of which 44.04 per cent. was digestible; those soluble in one per cent. sodic hydrate yielded 308 grams of furfurol, of which 42.16 per cent. was digestible. Another very marked difference between these fodders is the solubility of the substances yielding furfurol in the different media, the furfurol yielded by the cellulose not being considered in the following statements. Hydric chlorid removes from the native hay almost exactly one-half of the furfurol—coefficient 44.04—while it removes about one-quarter of it from the alfalfa, coefficient 100. Sodic hydrate removes from the native hay one-quarter of the furfurol, coefficient 42.16; from the alfalfa one-quarter, with a coefficient of digestibility of 27.81.

§105. The one per cent. sodic hydrate solution seems to remove very considerable amounts of material which is capable of yielding furfurol from both of these fodders, but we were unable to obtain more than minute quantities of reducing sugars in the inverted extracts, which is contrary to what we would expect if this furfurol is derived from pentosans.

§106. The heat values of these two hays, alfalfa and native hay, show more directly, probably, than any other factors their relative values. We find that the animals appropriated 30,519,751 calories when fed on alfalfa, and 22,255,418 calories when fed on the native hay. The same sheep were used in these two experiments, both made under favorable conditions, so that the questions of individualty, etc., are removed as far as far as possible. The net result was a gain of 9 pounds in the one case, alfalfa, and three and one-half pounds in the other, native hay.

§107. Other sheep were used in the experiment with timothy hay, but the conditions were as favorable as we could make them. The energy consumed was 17,406,363 calories, and the result was a net loss of one pound.

CORN FODDER.

§108. The fodder used was in good condition. The stalks were rather heavy for sheep feeding and the amount refused by them was, on this account, rather large. The corn was a variety of dent and had been grown in drills in which the seed had been thinly sown. The fodder was cut in lengths not exceeding one-half inch before feeding. The sheep ate it readily, but refused the heavier stocks, nor could we induce them to eat this portion by grinding it. Each of the three sheep used in this experiment gained weight while being fed on it. No other food was fed in connection with it. The coefficients of digestion for this fodder were found to be quite good, excepting that that for the proteids was much below the average, as we found 36.04 as the coefficient of digestibility for these substances, whereas the average found by other experimentors is 56.1. The total proteids in this fodder is slightly above the average. I know of no reason for the low coefficient, but I have elsewhere observed that the coefficients obtained by us are apt to be below those found by others, due, probably, to the conditions under which our fodders are preserved.

TABLE XLV.

ANALYTICAL DATA FOR CORN FODDER.

FODDER ANALYSIS.

CORN FODDER.		CORRESPONDING FECES. Sheep No. 1.	
Moisture	8.21	Moisture	6.73
Ash	9.53	Ash	12.63
Ether extract	1.55	Ether extract	1.12
Proteids	4.62	Proteids	7.16
Crude fibre	29.85	Crude fibre	30.16
Nitrogen-free extract	46.24	Nitrogen-free extract	42.20
	100.00		100.00

TABLE XLVI.

ANALYSIS OF THE ASH.

CORN FODDER.		CORRESPONDING FECES.	
Sand	13.048	Sand	23.796
Silicic acid	19.812	Silicic acid	38.867
Sulfuric acid	1.313	Sulfuric acid	1.063
Phosphoric acid	5.199	Phosphoric acid	5.158
Carbonic acid	10.319	Carbonic acid	0.060
Chlorin	3.495	Chlorin	0.571
Potassic oxid	28.366	Potassic oxid	3.626
Sodic oxid	2.603	Sodic oxid	0.759
Calcic oxid	6.090	Calcic oxid	10.625
Magnesic oxid	4.501	Magnesic oxid	6.500
Ferric oxid	1.530	Ferric oxid	1.909
Aluminic oxid	0.851	Aluminic oxid	1.343
Manganic oxid	0.260	Manganic oxid	0.170
Ignition	(3.401)	Ignition	5.685
	100.788		100.132
Oxygen equivalent to Cl	0.788	Oxygen equivalent to Cl	0.103
	100.000		100.029

TABLE XLVII.

ULTIMATE ANALYSIS.

CORN FODDER.		CORRESPONDING FECES.	
Carbon	42.661	Carbon	42.754
Hydrogen	5.892	Hydrogen	5.494
Nitrogen	0.739	Nitrogen	1.145
Sulfur	0.099	Sulfur	0.133
Chlorin	0.342	Chlorin	0.152
Ash	9.530	Ash	12.630
Oxygen (approx.)	40.737	Oxygen (approx.)	37.692
	100.000		100.000

§109. The chlorin and sulfur determinations were made on the fodder and not calculated from the ash. The oxygen percentage is only approximate, as the ash contains most of the sulfur and chlorin and probably oxygen taken up during the burning, and these elements enter the analysis in part, at least twice.

§110. The ratio of the air-dried feces to the weight of air-dried fodder consumed is 1:2.33; in the case of alfalfa it is 1:2.7. The portion of the corn fodder left by the sheep amounted to 24 per cent. of the fodder, while the portion of alfalfa left amounted to 7.38 per cent. This difference is considerable when considered in pounds only, but when the character of the two fodders is taken into consideration, the proportion of the corn fodder consumed seems quite favorable. The ratio of the leaves in this fodder to the stems was 2:1, which is not very different from the ratio of leaves to stems in the alfalfa plant, but the corn stalk is very different from the alfalfa stem. Sheep will not eat the alfalfa stems when they are coarse; this is probably due to the hardness of the stems, but, in the case of the corn stalks, they will not eat them even when they have been ground. The results show that only about 10 per cent. or even less of the corn stalks was eaten when cut in lengths of from ¼ to ½ inch. The fodder had been cut close to the ground, so that the whole of the plant was represented in the fodder.

§111. It was hoped that the elementary analyses of the fodders might show some differences suggestive of the wide differences in their actual feeding values, but the range in the ultimate composition of both the fodders and the feces shows that they are of but little value for the purposes of this study, as they show nothing more, that we can interpret, than the fodder analysis.

TABLE XLVIII.

CORN FODDER.

PROXIMATE ANALYSIS.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	29.243	29.985	29.614
Cold water, 24 hours, extracted.....	4.350	4.827	4.589
Hot water and malt extracted......	3.881	2.603	3.241
Hydric chlorid, 1% sol. extracted....	19.550	20.244	19.897
Sodic Hydrate, 1% sol. extracted.....	13.891	13.692	13.792
Chlorin, etc., extracted	3.075	4.020	3.547
Cellulose	26.010	24.630	25.320
			100.00

SUGARS IN THE EXTRACTS.

	I	II	Av.
Glucose in alcoholic extract.........	5.24	5.29	5.26
Sucrose in alcoholic extract.........	4.44	4.09	4.27
Gums in cold water extract.........	0.58	0.45	0.52
Starch in hot water extract.........	None	None	None
Xylan* in hydric chlorid extract.....	12.07	10.88**	12.07
Xylan in sodic hydrate extract......	0.72	0.63	0.63

TABLE XLIX.

CORN FODDER ORTS.

PROXIMATE ANALYSIS.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol............	28.429	27.978	28.20
Cold water, 24 hours...............	2.538	3.379	2.96
Hot water	2.657	1.985	2.32
Hydric chlorid 1% sol.	20.149	20.584	20.37
Sodic hydrate, 1% sol.	14.590	15.443	15.02
Chlorin, etc.	3.626	3.684	3.66
Cellulose	28.011	26.947	27.48
			100.00

SUGARS IN THE EXTRACTS.

	I	II	Av.
Glucose in alcoholic extract.........	8.48	8.79	8.64
Sucrose in alcoholic extract.........	2.35	2.49	2.42
Gums in cold water extract.........	0.47	0.47	0.47
Starch in hot water extract.........	None	None	None
Xylan in hydric chlorid extract†.....	16.32	17.02	16.67
Xylan in sodic hydrate extract......	0.86	0.73	0.80

*There is some galactan present, in two trials we obtained 0.680 and 0.706%. Other trials did not agree in quantity but all showed presence of galactan. Galactan is easily hydrolyzed. This extract is not. The feces also gave a slight precipitate for mucic acid.

**Rejected, inversion incomplete.

†According to the mucic acid determination, there is a small amount of galactan present, but the 16.32% of sugar present is so large that I have calculated it all as Xylan.

TABLE L.

CORN FODDER FECES.

PROXIMATE ANALYSIS.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	16.71	16.27	16.50
Cold water, 24 hours, extracted.....	4.38	4.66	4.53
Hot water and malt extracted......	3.70	3.31	3.51
Hydric chlorid, 1% sol. extracted....	13.49	14.99	14.24
Sodic Hydrate, 1% sol. extracted.....	23.55	Lost	23.55
Chlorin, etc., extracted	11.12		11.12
Cellulose	26.55		26.55
			100.00

SUGARS IN THE EXTRACTS.

	I	II	Av.
Glucose in alcoholic extract.........	None	None	None
Sucrose in alcoholic extract.........	None	None	None
Gums in cold water extract.........	0.36	0.36	0.36
Starch in hot water extract.........	None	None	None
Xylan in hydric chlorid extract......	2.23	3.23	2.73
Xylan in sodic hydrate extract......	2.44	Lost	2.44

TABLE LI.

CORN FODDER—COEFFICIENTS OF DIGESTION OF THE VARIOUS EXTRACTS.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Alcoholic extract	3461.4	737.2	2424.2	635.4	1788.8	73.79
Cold water extract.......	536.4	77.4	459.0	174.4	284.6	54.16
Hot water and malt ext...	378.8	60.6	318.2	135.2	183.0	54.37
Hydric chlorid, 1% extract.	2325.7	532.5	1793.2	548.4	1244.8	69.42
Sodic hydrate, 1% extract.	1612.1	392.7	1219.4	877.1	342.3	36.27
Chlorin, etc.	414.1	95.8	318.3	431.7	(—113.4)	
Cellulose	2959.5	718.4	2241.1	1030.9	1210.2	54.00
			8773.41	3833.1	4940.3	56.31

The general coefficient of digestion for the dry matter in corn fodder was found to be 56.66 per cent.

TABLE LII.

CARBOHYDRATES IN CORN FODDER AND THEIR COEFFICIENTS OF DIGESTIBILITY.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Glucose	656.9	225.9	431.0	0.0	431.0	100.00
Sucrose	499.1	58.6	440.5	0.0	440.5	100.00
Gums, etc.	60.8	12.3	48.5	13.8	34.7	71.56
Starch	0.0	0.0	0.0	0.0	0.0	——
Xylan, 1% hydric chlorid..	1410.8	435.8	975.0	105.1	869.9	89.22
Xylan(?) 1% sodic hydrate	73.6	20.9	52.7	94.0	(-41.3)	——
Cellulose	2959.5	718.4	2241.1	1030.9	1210.9	54.00

TABLE LIII.

FURFUROL FOUND IN CORN FODDER AND IN THE CORRESPONDING ORTS AND FECES.

	Cornfodder Per cent.	Orts Per cent.	Feces Per cent.
Original	11.476	10.625	10.997
Residue after treatment with 80% alcohol	10.792	10.530	10.894
Residue after treatment with cold water	10.768	same	same
Residue after treatment with hot water and malt	10.394	same	same
Residue after treatment with 1% hydric chlorid	5.342	5.841	7.536
Residue after treatment with 1% sodic hydrate	2.636	2.655	3.350
Residue after treatment with chlorin, etc., Cellulose	1.799	1.649	Not det.

TABLE LIV.

COEFFICIENT OF DIGESTION OF FURFUROL IN CORN AND THE PORTION DISSOLVED OUT BY THE VARIOUS SOLVENTS USED.

	Fed.	Orts.*	Consumed.	Voided.	Digested.	Coef.
Corn fodder	1341.4	277.8	1063.6	423.5	640.1	60.20
Soluble in 80% alcohol	80.0	2.5	77.5	4.0	73.5	94.80
Soluble in cold water	2.8**	——	2.8	0.0	2.8	100.00
Soluble in hot water and malt	43.7	——	43.7	0.0	43.7	100.00
Soluble in 1% hydric chlorid	590.3	122.6	467.7	125.5	342.2	73.17
Soluble in 1% sodic hydrate	316.3	80.3	236.0	160.9	75.1	31.82
Soluble in chlorin, etc.	97.8	26.3	71.5	} 129.0	62.3	32.57
Remaining in the cellulose	162.9	43.1	119.8			
			1019.2		479.8	47.07

METHOXYL GROUP IN CORN FODDER.

§112. The average percentage of this group found in the fodder was 1.445, and in the feces 2.033. In discussing this group under the subject of alfalfa, I stated that the results were probably rather low, basing this judgment on the check results obtained on a commercial sample of quinine. This observation applies to all of the samples and particularly, perhaps, to this case, as the amount found in the feces is the lowest in the series.

§113. The assumption that the orts and fodder were so nearly alike that no material error is made by taking them as the same is probably wrong in this case, for the orts were nothing other than corn stalks, which were so hard that the sheep did not eat them. They consisted essentially of the hard parts of the stalk and pith.

*These orts consisted wholly of pieces of stalks too hard for the sheep to eat.

**This figure has, as will readily be understood, no value, but it is the result that we obtained.

§114. The amount of this group, methoxyl, consumed was 129.67 grams, that voided was 78.27 grams, digested 51.40 grams, percentage digested 39.64.

AMID NITROGEN IN CORN FODDER.

§115. The total amid nitrogen found was very small, that found in the fodder was 0.077 per cent., equal to 0.481 per cent. of proteids; that found in the orts was 0.045 per cent., equal to 0.281 per cent. of proteids. We found none in the feces. The total is very small, but it is evident that we have to attribute to it a coefficient of digestion of 100.00.

TABLE LV.

COEFFICIENTS OF DIGESTION FOR THE PROTEIDS IN THE VARIOUS EXTRACTS OF CORN FODDER.

Solvent.	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Boiling 80% alcohol	248.96	33.20	215.76	74.46	141.30	65.49
Cold water	32.73	1.83	30.90	25.85	5.05	16.30
Hot water and malt....	26.89	3.40	23.49	21.22	2.27	9.66
1% hydric chlorid	79.48	9.41	70.07	42.44	27.63	39.43
1% sodic hydrate	115.71	16.73	98.98	110.72	(—11.74)	——
Chlorin, sodic hydrate and sulfurous acid ..	30.39	1.57	28.82	15.43	13.39	46.46
Remaining in cellulose..	5.85	1.05	4.80	4.24	0.56	11.67
	540.01	67.19	472.82	294.36	178.46	37.74

§116. The coefficients found for the three sheep were 37.18, 37.49, 33.45; average 36.04 per cent.

THE CALORIFIC VALUE OF CORN FODDER AND ITS VARIOUS EXTRACTS.

§117 The calorific value of the dry corn fodder was found to be 4,244 calories, and the total heat units fed amounted to 45,-533,876; the total value of the feces was 15,258,816 calories; the total heat value of the orts was 10,850,880 calories; the sheep therefore appropriated 19,424,180 calories, or 56 per cent. of that consumed.

§118. The sheep gained weight, 3½ pounds, during the five days that the test lasted. The gain was for the different sheep 2, 1 and ½ pounds, respectively. The number of heat units appropriated by the sheep is less than in the case of the native hay, 22,255,-418 calories, while the gain in weight is the same; the coefficient of digestion, however, is higher, it being in the case of the native hay 48.34 per cent., and in the corn fodder 56 per cent. In timothy hay it was 47.83 per cent., and the heat units appropriated by the sheep were 17,406,363. One of the sheep gained and two lost, resulting in a net loss of one pound for the three sheep:

Timothy hay, heat units appropriated, 17,406,363, loss 1.0 pounds.
Corn fodder, heat units appropriated, 19,424,180, gain 3½ pounds.
Native hay, heat units appropriated, 22,255,418, gain 3½ pounds.
The percentages of the heat units thus used by the sheep are 47.83, 56.00 and 48.34.

TABLE LVI.

The dry corn fodder gave the following extracts and residue:

	Per cent.
Soluble in 80% alcohol	23.32
Soluble in cold water	5.90
Soluble in hot water and malt	3.54
Soluble in 1% hydric chlorid	21.63
Soluble in 1% sodic hydrate	15.03
Soluble in Chlorin, etc.	3.86
Residue, Cellulose	27.57
	100.00

§119. The distribution of the ash in these extracts was not determined and, consequently, no correction has been made on account of it.

TABLE LVII.

The calorific values of the dry fodder and the respective residues were as follows:

	Calories.
The dry fodder	4244
Residue after extraction with 80% alcohol	4250
Residue after extraction with cold water	4405
Residue after extraction with hot water and malt	
Residue after extraction with 1% hydric chlorid	4459
Residue after extraction with 1% sodic hydrate	4201
Residue after extraction with chlorin, etc.	4134

TABLE LVIII.

CALORIES REMOVED BY THE SUCCESSIVE TREATMENTS.

One gram of corn fodder yields to 80% alcohol	985 calories
One gram of corn fodder yields to cold water	257 calories
One gram of corn fodder yields to hot water and malt	
One gram of corn fodder yields to 1% hydric chlorid	930 calories
One gram of corn fodder yields to 1% sodic hydrate	752 calories
One gram of corn fodder yields to chlorin, etc.	180 calories

TABLE LIX.

CALORIFIC VALUES OF THE EXTRACTS OF CORN FODDER.

One gram of alcoholic extract equals	4224 calories
One gram of cold water extract equals	3009 calories
One gram of hot water and malt extract equals	
One gram of 1% hydric chlorid extract equals	4290 calories
One gram of 1% sodic hydrate extract equals	5003 calories
One gram of chlorin, etc., extract equals	4665 calories
One gram of residue, cellulose, equals	4134 calories

TABLE LX.

The dry feces gave the following extracts and residue:

APPROXIMATE ANALYSIS OF THE DRY FECES.

	Per cent.
Soluble in 80% alcohol	10.48
Soluble in cold water	4.86
Soluble in hot water and malt	3.76
Soluble in 1% hydric chlorid	15.27
Soluble in 1% sodic hydrate	25.25
Soluble in chlorin, etc.	11.92
Residue, cellulose	28.46
	100.00

TABLE LXI.

The distribution of the ash was not determined.

THE CALORIFIC VALUES OF THE DRY FECES AND THE RESPECTIVE RESIDUES.

The calorific value of the dry feces equaled	4248 calories
Residue after extraction with 80% alcohol	4153 calories
Residue after extraction with cold water Residue after extraction with hot water and malt	4252 calories
Residue after extraction with 1% hydric chlorid	4126 calories
Residue after extraction with 1% sodic hydrate	*3889 calories
Residue after extraction with chlorin, etc.	3714 calories

TABLE LXII.

CALORIES REMOVED FROM THE FECES (CORN FODDER) BY THE SUCCESSIVE TREATMENTS.

One gram of feces yields to hot 80% alcohol	530 calories
One gram of feces yields to cold and hot water and malt	236 calories
One gram of feces yields to 1% hydric chlorid	774 calories
One gram of feces yields to 1% sodic hydrate	1138 calories
One gram of feces yields to chlorin, etc.	513 calories
One gram of feces yields a residue, cellulose	1057 calories
	4248 calories

TABLE LXIII.

CALORIFIC VALUES OF THE RESPECTIVE EXTRACTS OF THE FECES (CORN FODDER.)

One gram of the alcoholic extract equals	5057 calories
One gram of cold and hot water with malt equals	2738 calories
One gram of the 1% hydric chlorid extract equals	5069 calories
One gram of the 1% sodic hydrate extract equals	4507 calories
One gram of the chlorin, etc., extract equals	4304 calories
One gram of the residue, cellulose, equals	3714 calories

*We at first doubted this result, so another sample was started de novo and the determination repeated with the result that we obtained 3891 calories as the value of this residue.

TABLE LXIV.

COEFFICIENTS OF DIGESTION FOR THE FUEL VALUES OF THE VARIOUS EXTRACTS OF CORN FODDER.

	Heat units Consumed	Heat units Voided	Heat units Appropriated	Coef.
Alcoholic extract	10,238,976	3,211,195	7,027,781	71.10
Aqueous extracts	2,337,996	848,780	1,489,213	63.69
One per cent. hydric chlorid ext.	7,691,970	2,774,812	4,914,158	63.88
One per cent. sodic hydrate ext.	6,098,657	3,952,639	2,146,018	35.17
Chlorin, etc., extract..........	1,482,734	1,859,328	(-376,594)	....
Residue or cellulose	9,264,294	3,829,138	5,435,160	58.67

ALFALFA AND CORN FODDER COMPARED FROM THE STANDPOINT OF THEIR CALORIMETRIC RELATIONS.

§120. The two fodders first chosen for a complete study were alfalfa and corn fodder. In making this choice, I considered the fact that alfalfa is, beyond all question, our best fodder and, after it, for general all round purposes, corn fodder, probably stands next. Timothy is grown in considerable quantities in some sections of the state, but it is too limited in supply, and too high in price to be thought of as a general fodder, either by itself or for the purpose of balancing an alfalfa ration, unless it be for horses. Timothy has further been studied, and from this standpoint would have been, in part at least, a repetition of other work. Our native hay is a very much better fodder than timothy hay, but the supply of it is limited, the price is high, and its composition is variable, *i. e.*, the grasses, rushes and sedges forming it vary with localities and seasons. I chose corn fodder because it can be produced cheaply in large quantities over a large territory and because the results of feeding indicate that it is as good a fodder as the native hay and a very much better one than timothy hay. I was, in short, guided by the consideration of the utility of the respective fodders. It would have been a mistake to do so to the exclusion of other fodders, as my object has really not been to study good, acceptable fodders, but to discover, if possible, the reasons why one fodder is better than another, why one is good and another poor. While the difference between the values of corn fodder and alfalfa is considerable, it is not wide enough to give the best opportunity for presenting such a study with thoroughly satisfactory results. We will find larger differences when we come to the study of the saltbush, *Atriplex argentea*, which is an exceedingly poor fodder.

§121. There are very salient and interesting contrasts between these two fodders, alfalfa and the saltbush, *Atriplex argentea*, which I may digress to state briefly. The sheep fed on alfalfa gained nine pounds; those fed on saltbush lost eight and one-half pounds in five days. It is true that the sheep to which alfalfa was fed digested a larger amount of dry matter than those receiving saltbush, but not so much more as the difference of 17½ pounds of flesh would apparently indicate. The sheep receiving alfalfa digested 7,246 grams of dry matter, containing 1,315 grams of proteids, 3,274 grams of nitrogen-free extract and 1,875 grams of crude fibre; those receiving saltbush digested 7,051 grams of dry matter, containing 1,116 grams of proteids; 3,011 grams of nitrogen-free extract and 342 grams of crude fibre. The mineral matter contained in the saltbush and digested was very large, 2,315 grams against 779 grams digested with the alfalfa. These are the differences, total dry matter, 195 grams; crude proteids, 199 grams; nitrogen-free extract, 263 grams; crude fibre, 1,533 grams—all the differences so far being in favor of the alfalfa. In the case of the mineral matter, the sheep fed on the saltbush digested 1,536 grams more than those receiving alfalfa. The daily differences in the amounts digested per sheep for the various fodder constituents were as follows: Crude proteids 12.66 grams, nitrogen-free extract 17.5 grams, both in favor of the alfalfa-fed sheep, which were gaining six-tenths of a pound daily, while the saltbush-fed sheep were losing almost exactly the same amount. The only food element digested in considerable excess by the alfalfa-fed sheep, 102 grams daily per sheep, was the crude fibre. This may be the cause of the great difference in the results.

§122. It is not evident what part the mineral matter may have played, though the amount actually absorbed by the sheep was large, 2,315 grams for the three sheep in five days, it produced no looseness of the bowels or other inconveniences that we could observe. This fodder did provoke a marked thirst, but the sheep did not suffer on this account. It does not seem probable that the loss of flesh was due to the mineral constituents contained in the plant. If we may reason from analogy in this case, we would be justified in comparing its results with those produced by sugar beet tops, which contain from 22 to 30 per cent. of ash when dried. The compounds absorbed in the case of the saltbush appear to be the sulfuric acid, chlorin and the alkalies. In eating a like amount of dried sugar beet tops the animals would consume larger amounts of these compounds than in the case of the saltbush, but it is a matter of common experience and knowledge that sheep thrive on the beet tops. If analogy holds in the case, we are justified in adopting the proposition that the loss is probably not due to the inorganic matter digested.

§123. Returning to our comparison of the energy relations of the alfalfa and the corn fodder, it is to be remembered that both fodders proved to be good ones. The alfalfa, however, producing a much greater gain in live weight than the corn fodder did under the conditions of the experiment. The corn fodder, however, considering the coarseness of a large portion of it, one-third of it being stalks which the sheep ate very reluctantly, produced excellent results. I endeavored to induce the sheep to eat as much of the corn fodder as possible, so their ration was not made large enough to encourage them in selecting the most acceptable portions of the fodder. I do not know how much virtue there may be in the corn stalks, but they are certainly in no manner comparable to the stems of alfalfa, whose composition indicates that, without any leaves, they constitute a better fodder than some hays which are held in fair esteem, but sheep will not eat even these when coarse and hard.

§124. The amount of energy appropriated by the animal and the effect produced per unit of heat are the important points, especially from the standpoint of the feeder. Each gram of water free alfalfa is equivalent to 4,363 calories, 62.43 per cent. of which is available, and each gram of corn fodder is equivalent to 4,244 calories, 56 per cent. of which is available, *i. e.*, is taken up by the animal. The sheep receiving alfalfa appropriated 30,955,663 calories and those receiving corn fodder appropriated 19,424,180 calories, a difference of 11,531,483 calories. The former gained nine pounds in weight, the latter three and a half pounds, a difference of five and one-half pounds, which would indicate the consumption of 2,096,634 calories in the form of alfalfa for the production of one pound of gain in the live weight, which corresponds to very nearly two pounds of alfalfa, taking 453 grams as a pound and 62 as the percentage of heat appropriated by the sheep. The energy actually necessary to maintain the animals is considered to be the same in both cases; this is an assumption which is probably not wholly justified, neither is it shown that like amounts of energy in the corn fodder and alfalfa will produce the same results in pounds of mutton as is here tacitly assumed. The calorific value of the urine was not determined in either case, neither was the nitrogen in it determined.

§125. As already stated, the total dry matter consumed by the alfalfa fed sheep was 11,365 grams, while those receiving corn fodder consumed but 8,289. The dry matter digested was 7,046 and 4,642 grams, respectively. The coefficients of digestion found for this dry matter were 62.08 and 56.66, respectively. The percentages of the heat appropriated were very nearly the same as these coefficients, viz: 62.43 and 56.00 per cent. One would scarcely anticipate so close an agreement.

§126. The distribution of the heat values in the different extracts and the coefficients of these extracts, together with their respective amounts, show great differences between the fodders.

TABLE LXV.

	Alfalfa Extract Per cent.	Coefficient	Cornfodder Extract Per cent.	Coefficient
80% alcohol	27.50	73.88	29.61	73.79
Cold water	8.66	78.89	4.59	54.16
Hot water and malt	4.37	70.24	3.24	54.37
1% hydric chlorid	12.23	60.20	19.90	69.42
1% sodic hydrate	16.19	67.72	13.79	36.27
Chlorin	8.76	25.39	3.55	——
Residue	22.29	52.67	25.32	54.00

§127. The most patent difference here is in the case of the sodic hydrate, both in the quantity that is soluble and in the coefficient of digestion. The difference of about 2 per cent. in favor of the portion dissolved out of the alfalfa by the caustic soda is much less than the relative amounts of proteids present in the fodders; while the difference in the amount soluble is only 2 per cent., the coefficient of digestibility is more than double that of the portion dissolved out of the corn fodder.

TABLE LXVI.

THE CALORIFIC VALUE OF THE FODDERS AND THEIR RESPECTIVE EXTRACTS.

	Alfalfa	Corn Fodder
Original fodder	4363	4244
Extracts:		
Alcoholic (hot 80% alcohol)	4706	4224
Cold and hot water	3140	3009
One per cent. hydric chlorid	3596	4290
One per cent. sodic hydrate	5063	5003
Chlorin, etc.	5598	4663
Residue, cellulose	4210	4134

TABLE LXVII.

CALORIFIC VALUES OF THE FECES AND THEIR EXTRACTS.

	Alfalfa	Corn Fodder
Original	4525	4248
Extracts:		
Alcohol (hot 80% alcohol)	5739	5057
Cold and hot water	4123	2738
One per cent. hydric chlorid	4061	5069
One per cent. sodic hydrate	2997	4507
Chlorin	5842	4304
Residue, cellulose	4294	3714

TABLE LXVIII.

THE COEFFICIENTS OF DIGESTION FOR THE HEAT VALUES OF THE VARIOUS EXTRACTS OF ALFALFA AND CORN FODDER.

ALFALFA.

	Heat units Consumed	Heat units Voided	Heat units Appropriated	Coef.
Alcoholic extract	15,852,166	5,113,449	10,738,717	67.75
Aqueous extracts*	5,074,240	1,599,724	3,474,516	68.51
1% hydric chlorid extract	5,447,940	2,448,783	2,999,157	54.75
1% sodic hydrate extract	10,156,378	1,938,059	8,218,319	80.92
Chlorin, etc., extract	6,045,840	4,708,652	1,337,188	24.03
Residue or cellulose	11,522,770	5,570,208	5,952,562	51.66

CORN FODDER

	Heat units Consumed	Heat units Voided	Heat units Appropriated	Coef.
Alcoholic extract	10,238,976	3,211,195	7,027,781	71.10
Aqueous extracts	2,337,996	848,780	1,489,213	63.69
1% hydric chlorid extract	7,691,970	2,774,812	4,914,158	63.88
1% sodic hydrate extract	6,098,657	3,952,639	2,146,018	35.17
Chlorin, etc., extract	1,482,734	1,859,328	(— 376,594)	——
Residue or cellulose	9,264,294	3,829,138	5,435,160	58.67

§128. Though the preceding table is based upon the calorific values of the extracts calculated from the values of the residues, the total differs, in the case of the alfalfa, from that obtained by using the values obtained for the hay and feces by about 5 per cent., which is a closer agreement than I had anticipated. In the case of the corn fodder, the agreement is not so good, but is, even in this case, only 9.3 per cent; the calculated values being the higher in both cases.

§129. These results show that the fodders agree in this, that the alcoholic extract and the cellulose furnish a large percentage of the total heat value appropriated by the sheep, 16,691,297 calories out of a total of 31,720,459 calories, or 51 per cent., approximately. The heat yielded by the cellulose in the two fodders is nearly the same. The hydric chlorid and sodic hydrate extracts are reversed in the two fodders; that is, the sodic hydrate extract shows a very much higher value in the alfalfa and a very much lower one in the corn fodder than the hydric chlorid extract, yielding almost three times as much heat in the case of alfalfa and less than half as much in that of the corn fodder. The high proteid content of the alfalfa may correspond to the higher heat value of the sodic hydrate extract, but the distribution of the nitrogen among the extracts does not lend much probability to this idea, for the sodic hydrate solu-

*Aqueous extract includes all that was dissolved out by successive treatment with cold water, boiling with water for one hour and subsequent digestion with malt extract.

tion dissolves only about one-half of the nitrogen contained in the alfalfa, the other half being contained in the alcoholic extract (7-19) and in the hydric chlorid extract (1-10). The relative amounts of heat appropriated by the animals from these two extracts is remarkably different, 80.9 per cent. of that from the alfalfa being appropriated, while only 35.17 per cent. of that from the corn stalks. In the alfalfa the three portions, *i. e.*, extracts obtained by treatment with alcohol, and sodic hydrate and the residue, or that portion which we have called cellulose, yield five-sixths of the available heat; in the corn fodder it is the extracts removed by alcohol, hydric chlorid and the residue or cellulose that furnish almost six-sevenths of the total heat.

§130. These two fodders agree in showing that the alcoholic extract and the cellulose are two important factors in a fodder; they differ in regard to the third factor, one indicating that the portion soluble in sodic hydrate and the other that that soluble in hydric chlorid, is the third in importance. This is probably the big difference between the two, though both are capable of furnishing more energy than is necessary to simply maintain the animal and contain no constituent whose physiological action is detrimental.

§131. There are many hints that the results are modified to a considerable extent by the fecal matter proper, but it is not separable from the undigested residue of the fodder.

§132. The difference between the sodic hydrate extracts in these two cases is great, not only in the quantity of heat represented, but also in the availability of the heat value of the substances taken into solution. The sheep consumed, in round numbers, ten millions heat units with the alfalfa which had proven insoluble in the alcohol, water and hydric chlorid, of which 80.92 per cent. were available, while the others consumed but six millions from the corn fodder, of which only 35.17 per cent. were available, making an actual difference of over six millions of heat units obtained from this portion of these fodders. These quantities are those actually consumed and appropriated by the sheep and not comparisons based on like weights of the fodders. Such a comparison would result in a more favorable showing for the corn fodder.

§133. The distribution of the nitrogenous substances in the various extracts of alfalfa hay have been given in a previous table and also that for the corn fodder. The big feature in the case of the alfalfa is that nearly 50 per cent. of the total digestible nitrogenous substances is insoluble in alcohol water and hydric chlorid but soluble in sodic hydrate and, further, that 80.89 per cent. of the total, soluble in sodic hydrate, is digestible. This ratio holds, too, for native hay, but the coefficient of digestion for the nitrogenous matters soluble under these conditions is but 58.63 per cent. In the corn fodder we have an entirely different distribution of the proteids among the various extracts, over two thirds of the total digestible nitrogenous substances being soluble in boiling eighty per cent. alcohol and nearly one-half of the nitrogen consumed is soluble in the same menstruum. The large amount of nitrogen, calculated as proteids, in the feces, soluble in sodic hydrate, points clearly, as I interpret it, to the presence of nitrogenous fecal matter, even in excess of the total amount, soluble in this reagent, present in the fodder consumed. This is the most marked instance, so far met with, indicative of the disturbing influence of fecal matter upon the results of our work, but it is not the only one. It seems to be almost a rule that the nitrogen removable by treatment with chlorin, sodic hydrate and sulfurous acid is greater in the feces than in the fodder consumed, though in this particular case it is less. The amount of nitrogen involved in this portion, nitrogen removable by treatment with chlorin, etc., as well as that contained in the final residue, designated cellulose, and also in the portion removed by successive treatment with cold water, hot water and malt, is quite small and, for this reason, of little importance. Their frequent excess in the feces points to the influence of the presence of fecal matter, which differs in the case of different fodders.

§134. The results of the study of the distribution of the nitrogen in the respective extracts, as well as the distribution of the heat values of the extracts, indicate that the greatest differences between these two fodders is in the character of the two extracts obtained by hydric chlorid and sodic hydrate. In studying the results, it is to be borne in mind that there are actually a larger edible ration fed in the case of the alfalfa than in that of the corn fodder, because, as before stated, I tried to induce the sheep to consume the largest possible portion of the corn fodder fed. I am quite convinced that I would have obtained results more favorable to the corn fodder had I fed them from one-third to one-half more of it and thus made it possible for the sheep to select the portions which they liked to a greater extent than they did. There was eaten 11,365 grams of dry matter as alfalfa, and but 8,289 grams as corn fodder. In order to have induced the sheep to eat the same amount of corn fodder as they actually did eat of alfalfa, it would probably have been necessary to increase the ration by one-half. I have so far purposely avoided comparing these fodders weight for weight. It may be well to do so, but very briefly. The three sheep appropriated 19,424,180 calories from the 8,289 grams of corn fodder consumed, or 2,344 calories per gram, while a like number of sheep appropriated 30,955,663 calories from 11,365 grams of alfalfa, or 2,736 calories per gram, which shows a difference in favor of the alfalfa of only 392 calories per gram of fodder eaten.

SORGHUM FODDER.

§135. This fodder was grown in the extreme eastern part of the State without irrigation. It was cut when a few canes were far enough advanced to mature the seed in shock. The fodder stood in shock till the latter part of the winter, but was not fed till the latter part of the spring. The variety was Minnesota Early Amber.

The following is the analytical data:

TABLE LXIX.

FODDER ANALYSIS.

SORGHUM FODDER.		CORRESPONDING FECES. Sheep No. 1.	
Moisture	5.75	Moisture	6.80
Ash	8.17	Ash	11.46
Ether extract	1.55	Ether extract	1.28
Proteids	5.80	Proteids	8.48
Crude fibre	23.26	Crude fibre	28.16
Nitrogen-free extract	55.47	Nitrogen-free extract	43.82
	100.00		100.00

TABLE LXX.

ASH ANALYSIS.

SORGHUM.		CORRESPONDING FECES.	
Percentage of ash in fodder	8.77	Percentage of ash in feces	11.46
Carbon	0.000	Carbon	0.000
Sand	30.097	Sand	43.025
Silicic acid	7.220	Silicic acid	18.718
Sulfuric acid	1.893	Sulfuric acid	0.963
Phosphoric acid	2.838	Phosphoric acid	5.963
Carbonic acid	10.395	Carbonic acid	0.846
Chlorin	6.859	Chlorin	1.576
Potassic oxid	30.980	Potassic oxid	7.944
Sodic oxid	0.073	Sodic oxid	1.316
Calcic oxid	4.730	Calcic oxid	7.548
Magnesic oxid	3.588	Magnesic oxid	6.353
Ferric oxid	0.970	Ferric oxid	1.080
Aluminic oxid	0.443	Aluminic oxid	1.026
Manganic oxid	0.200	Manganic oxid	0.120
Ignition	(1.260)	Ignition	(3.877)
Sum	101.546	Sum	100.355
Oxygen-Chlorin	1.546	Oxygen-Chlorin	0.355
	100.000		100.000

TABLE LXXI.

ULTIMATE ANALYSIS.

SORGHUM.		CORRESPONDING FECES.	
Carbon	42.402	Carbon	43.926
Hydrogen	5.748	Hydrogen	5.826
Nitrogen	0.928	Nitrogen	1.362
Sulfur	0.085	Sulfur	0.115
Chlorin	0.553	Chlorin	0.305
Ash and oxygen	50.284	Ash and oxygen	48.466
	100.000		100.000

§136. The average coefficients of digestion found for this fodder were as follows: Dry matter, 58.46; ash, 44.61; fat, 64.87; proteids, 43.06; crude fibre, 49.23; nitrogen-free extract, 61.06. The three animals to which this fodder was fed lost eight and one-half pounds in five days and consumed 30 to 31 pounds of dry matter per thousand weight of animal. The fodder was evidently acceptable to the animals, but the results were unfavorable.

TABLE LXXII.

PROXIMATE ANALYSIS.

SORGHUM FODDER.	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted	35.492	35.727	35.60
Cold water, 24 hours, extracted	3.966	4.065	4.02
Hot water extracted	7.634	7.468	7.55
Hydric chlorid 1% sol. extracted	18.955	17.480	18.22
Sodic hydrate 1% sol. extracted	11.048	11.982	11.52
Chlorin, etc., extracted	4.327	4.579	4.45
Cellulose	18.578	18.699	18.64

SUGARS IN THE EXTRACTS.

Glucose in alcoholic extract	9.31	9.46	9.39
Sucrose in alcoholic extract	6.80	7.22	7.01
Gums in cold water extract	0.36	0.32	0.34
Starch in hot water extract	2.45	2.52	2.49
Xylan in hydric chlorid extract	13.59	13.78	13.68
Xylan in sodic hydrate extract	0.66	0.68	0.67

TABLE LXXIII.

PROXIMATE ANALYSIS.

SORGHUM ORTS.	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted	41.809	42.624	42.21
Cold water in 24 hrs. extracted	2.960	3.040	3.00
Hot water extracted	2.581	2.400	2.49
Hydric chlorid 1% sol. extracted	17.499	17.412	17.46
Sodic hydrate 1% sol. extracted	12.474	12.727	12.60
Chlorin, etc., extracted	3.066	3.114	3.09
Cellulose	19.611	18.683	19.15

SUGARS IN THE EXTRACTS.

Glucose in alcoholic extract.........	Lost	14.95	14.95
Sucrose in alcoholic extract.........	Lost	10.73	10.73
Gums in cold water extract.........	0.59	0.46	0.53
Starch in hot water extract.........	1.18	1.05	1.12
Xylan in hydric chlorid extract.....	14.94	15.51	15.23
Xylan in sodic hydrate extract......	0.80	0.82	.81

TABLE LXXIV.

FECES OF SHEEP FED ON SORGHUM.

PROXIMATE ANALYSIS.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	15.180	14.986	15.08
Cold water in 24 hrs. extracted......	3.728	3.669	3.70
Hot water extracted	4.190	5.005	4.60
Hydric chlorid 1% sol. extracted.....	22.481	22.205	22.34
Sodic hydrate 1% sol. extracted.....	20.461	20.270	20.37
Chlorin, etc., extracted	11.172	10.039	10.61
Cellulose	22.788	23.826	23.30
			100.00

SUGARS IN THE EXTRACTS.

Glucose in alcoholic extract.........	None	None	None
Sucrose in alcoholic extract.........	None	None	None
Gums in cold water extract.........	0.20	0.20	0.20
Starch in hot water extract.........	0.36	0.39	0.38
Xylan in hydric chlorid extract.....	13.45	13.14	13.30
Xylan in sodic hydrate extract......	1.11	1.11	1.11

TABLE LXXV.

COEFFICIENTS OF DIGESTION FOR THE VARIOUS EXTRACTS OF SORGHUM FODDDER.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Total alcoholic extract..	4742.9	738.1	4004.8	731.3	3273.5	81.74
Total cold water extract.	535.6	52.5	483.1	179.4	303.7	62.86
Total hot water extract.	1005.9	43.6	962.3	223.1	739.2	76.82
Total hydric chlorid ext.	2427.5	305.3	2122.2	1083.3	1038.9	48.95
Total sodic hydrate ext..	1534.8	220.3	1314.5	987.8	326.7	24.85
Total chlorin, etc., ext...	592.9	54.0	538.9	514.5	24.4	4.53
Residue, cellulose	2483.4	334.9	2148.5	1129.9	1018.6	47.41
	13323.0	1748.7	11574.3	4849.3	6725.0	58.10

§137. The coefficients for the dry matter obtained with the three sheep were as follows: 57.53, 58.22 and 59.63; average 58.46 per cent.

TABLE LXXVI.

COEFFICIENTS OF DIGESTION FOR THE CARBOHYDRATES CONTAINED IN SORGHUM FODDDER.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Glucose in alcoholic ext...	1251.0	261.4	989.6	0.0	989.6	100.00
Sucrose in alcohol extract.	934.0	187.6	746.4	0.0	746.4	100.00
Gums in cold water ext...	45.3	9.3	36.0	9.7	26.3	73.06
Starch in hot water ext...	331.7	19.6	312.1	18.4	293.7	94.11
Xylan in hydric chlorid ext	1822.6	266.3	1556.3	645.0	911.3	58.56
Xylan in sodic hydrate ext	89.3	14.2	75.1	53.8	21.3	28.26
	4473.9	758.4	3715.5	726.9	2988.6	80.43

TABLE LXXVII.

FURFUROL FOUND IN SORGHUM FODDER AND IN THE CORRESPONDING ORTS AND FECES.

	Sorghum Per cent.	Orts Per cent.	Feces Per cent.
Original	9.680	10.069	12.530
Residue after treatment with 80% alcohol...	9.410	9.856	12.016
Residue after treatment with cold water....	Same	Same	Same
Residue after treatment with hot water and malt	8.638	Same	11.628
Residue after treatment with hydric chlorid	3.322	4.626	4.662
Residue after treatment with sodic hydrate.	1.957	2.387	2.456
Residue after treatment with chlorin, etc....	1.746	1.641	Not det

TABLE LXXVIII.

COEFFICIENTS OF DIGESTION FOR FURFUROL IN SORGHUM AND IN THE PORTIONS DISSOLVED OUT BY THE VARIOUS SOLVENTS USED.

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Sorghum	1290.5	176.1	1114.4	6076.	506.8	45.48
Soluble in 80% alcohol ...	36.0	3.7	32.3	24.9	7.4	22.91
Soluble in cold and hot water	10.3	5.4	4.9	18.8	(—13.9)	.....
Soluble in 1% hydric chlorid	708.3	86.0	622.3	337.8	284.5	45.72
Sol. in 1% sodic hydrate...	182.7	39.2	143.5	107.0	36.5	25.44
Soluble in chlorin, etc....	27.3	13.0	14.3 }	111.9	106.3	48.72
Remaining in the cellulose	232.6	28.7	203.9 }			
			1120.9	600.4	520.9	46.46

METHOXYL GROUP.

§138. The amount of this group found in the fodder was 1.027 per cent.; in the feces, 3.379 per cent. No determination of this group was made with the orts. The result shows an excess of 45 grams in the feces, which is due either to some mistake in the determination or indicates the probable presence of this group in fecal matter. The results of our determinations, 14 in all, indicate a much higher percentage of this group in the feces than in the fodder consumed. The results in this case are very high for the feces, but it was done in triplicate and the three determinations agree very well.

AMID NITROGEN.

§139. The amount of amid nitrogen found in the sorghum was small, corresponding to only 0.884 per cent. calculated as proteids. We found none or only a trace in the orts and 1.168 per cent. in the feces. The coefficient of digestion found in this case was 51.91 per cent. This is somewhat higher than the coefficient found for the total nitrogen calculated as proteids, 8.95 per cent. higher.

HEAT APPROPRIATED BY THE ANIMALS.

§140. The air-dried fodder possessed a heat value of 3,890 calories per gram; the orts, 1,749 grams in weight, are supposed to have the same value; the feces, which weighed 4,849 grams, had a fuel value of 4,111 calories per gram. The sheep consumed 11,574 grams of air-dried fodder and appropriated 55.72 per cent. of its fuel value.

§141. We did not determine the distribution of the proteids in the various extracts of sorghum and their respective coefficients of digestion, neither did we make a detailed study of the fuel values of the respective extracts, etc.

§142. This fodder had already proved to be a disappointment, but not to as great an extent as the saltbush, so I scarcely hoped to gain anything by extending this work.

§143. The sheep fed on this fodder lost in the five days between the two weighings, 3, 2½ and 3 pounds, respectively, an aggregate loss of 8½ pounds. They appropriated in this period 25,088,621 calories, which was evidently not sufficient to maintain the animals in good condition. The coefficients of digestion for this fodder were quite as promising as those obtained for corn fodder, with the exception of that obtained for the crude fibre; the latter coefficient is nearly 8 per cent lower in the sorghum than in the cornfodder. The dry matter consumed by the sheep when fed corn fodder was 8,289 and 10,934 when fed sorghum; the same sheep were used in these two experiments and the conditions were equally favorable in both series. The sheep all gained on the corn fodder and lost while being fed the sorghum fodder. The sheep appropriated 19,424,180 calories while feeding on corn fodder, as against 25,088,621 while feeding on sorghum. The urine was unfortunately not collected and analyzed. The water drank while feeding on corn fodder weighed 27½ pounds, and as the weather was cold, the water was warmed to about 22° C. before it was offered to the sheep. The weight of water consumed while feeding on sorghum was 60½ pounds and was not warmed, as the temperature of the water was at this time about 15° C. The daily consumption of water was a trifle over twice as much per sheep while feeding or sorghum as while feeding on corn fodder. In the former case, it was four pounds, and in the latter nearly two pounds per sheep. This amount of water, 4 pounds, is probably not excessive, as the sheep fed on alfalfa drank almost 4¾ pounds daily and made a gain of about three pounds each in the five days, but they did appropriate nearly 6,000,000 more calories than the sheep feeding on sorghum. The three sheep used in the experiment with the alfalfa were not the same three used in the sorghum experiment, but each of the sheep used in the alfalfa experiment gained about three pounds in five days, and each of those used in the sorghum lost about three pounds in five days.

§144. It is evident from the context that the gain and loss is in terms of live weight, this being the only kind of gain or loss considered in this bulletin.

SALTBUSH, *Atriplex argentea.*

§145. This plant is used to some extent in the eastern part of this state in making a hay to feed during heavy storms when the stock cannot otherwise obtain forage enough to sustain themselves. I undertook the study of this plant in the hope that it might prove worthy of commendation as a fodder, as some of the Australian saltbushes have proved to be. The uncertainty of raising crops in the eastern portions of the state make it desirable to find some plant which will serve the purpose of a good forage and which will grow sufficiently well under the prevailing conditions to produce a fair crop. The people most directly concerned in this have used this native plant; therefore, I undertook its examination.

§146. Its effects upon the sheep, three in number, were not injurious. They seemed to suffer no inconvenience except that they drank a large quantity of water and voided an excessive amount of urine, which had an offensive odor. They otherwise appeared healthy. They ate freely of this hay and chewed their cuds contentedly. If I had made a second experiment and not allowed them to drink so much water, more favorable results might have been obtained.

TABLE LXXIX.

ANALYTICAL DATA FOR THE SALTBUSH, *Atriplex argentea.*
FODDER ANALYSIS.

SALTBUSH.		CORRESPONDING FECES. Sheep No. 4.	
Moisture	5.32	Moisture	6.53
Ash	19.28	Ash	10.53
Ether extract	1.46	Ether extract	1.32
Proteids	9.73	Proteids	6.27
Crude fibre	27.33	Crude fibre	40.44
Nitrogen-free extract	36.88	Nitrogen-free extract	34.91
	100.00		100.00

TABLE LXXX.

ANALYSIS OF THE ASHES.

SALTBUSH.		CORRESPONDING FECES.	
Carbon		Carbon	
Sand	30.097	Sand	43.025
Silicic acid	7.220	Silicic acid	18.718
Sulfuric acid	1.893	Sulfuric acid	0.963
Phosphoric acid	2.838	Phosphoric acid	5.963
Carbonic acid	10.395	Carbonic acid	0.846
Chlorin	6.859	Chlorin	1.576
Potassic oxid	30.980	Potassic oxid	7.944
Sodic oxid	0.073	Sodic oxid	1.316
Calcic oxid	4.730	Calcic oxid	7.548
Magnesic oxid	3.588	Magnesic oxid	6.353
Ferric oxid	0.970	Ferric oxid	1.080
Aluminic oxid	0.443	Aluminic oxid	1.026
Manganic oxid	0.200	Manganic oxid	0.140
Ignition	(1.26)	Ignition	(3.877)
Sum	101.546	Sum	100.355
Oxygen equivalent to chlorin	1.546	Oxygen equivalent to chlorin	.355
	100.000		100.000

ANALYSIS OF THE ASH.

TABLE LXXXI.

ULTIMATE ANALYSIS.

SALTBUSH. Atriplex argentea.		CORRESPONDING FECES.	
Carbon	41.370	Carbon	44.700
Hydrogen	5.581	Hydrogen	5.961
Nitrogen	1.557	Nitrogen	1.003
Sulfur	0.320	Sulfur	0.205
Chlorin	3.965	Chlorin	0.234
Ash	19.280	Ash	10.530
Oxygen (approx.)	27.927	Oxygen (approx.)	37.367
	100.000		100.000

§147. The sulfur and chlorin determinations were made on samples of the fodder, as in previous instances, and not calculated from the ash.

TABLE LXXXII.

SALTBUSH, *Atriplex argentea.*

PROXIMATE ANALYSIS.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	22.243	21.877	22.06
Cold water in 24 hrs. extracted......	6.777	7.101	6.94
Hot water extracted	5.762	5.852	5.81
Hydric chlorid 1% sol. extracted.....	19.214	19.719	19.46
Sodic hydrate 1% sol. extracted.....	15.734	17.686	16.71
Chlorin, etc., extracted	10.803	9.762	10.28
Cellulose	19.467	18.003	18.74
			100.00

SUGARS IN THE EXTRACTS.

	I	II	Av.
Glucose in alcoholic extract.........	0.88	0.63	0.76
Sucrose in alcoholic extract.........	1.28	1.23	1.25
Gums in cold water extract.........	0.57	0.57	0.57
Starch in hot water extract.........	1.45	1.45	1.45
Xylan in hydric chlorid extract.....	7.48	7.62	7.55
Xylan in sodic hydrate extract......	2.11	1.67	1.89

TABLE LXXXIII.

SALTBUSH ORTS.

PROXIMATE ANALYSIS.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	21.537	21.391	21.47
Cold water in 24 hrs. extracted......	6.548	6.317	6.43
Hot water extracted	3.239	3.685	3.46
Hydric chlorid 1% sol. extracted.....	17.301	17.450	17.38
Sodic hydrate 1% sol. extracted.....	17.152	17.289	17.22
Chlorin, etc., extracted	11.856	11.857	11.86
Cellulose	22.367	22.011	22.18
			100.00

SUGARS IN THE EXTRACTS.

	I	II	Av.
Glucose in alcoholic extract.........	0.61	0.50	0.56
Sucrose in alcoholic extract.........	1.10	1.13	1.12
Gums in cold water extract.........	0.92	0.70	0.81
Starch in hot water extract.........	1.25	1.18	1.22
Xylan in hydric chlorid extract.....	7.29	7.40	7.35
Xylan in sodic hydrate extract......	2.37	2.46	2.42

TABLE LXXXIV.

FECES OF SHEEP FED ON SALTBUSH.

PROXIMATE ANALYSIS.

	I Per cent.	II Per cent.	Av. Per cent.
Eighty per cent. alcohol extracted....	12.802	11.295	12.05
Cold water in 24 hrs. extracted......	3.248	3.719	3.48
Hot water extracted	3.050	3.023	3.04
Hydric chlorid 1% sol. extracted.....	21.700	22.315	22.00
Sodic hydrate 1% sol. extracted.....	16.902	20.464	18.68
Chlorin, etc., extracted	18.932	15.319	17.13
Cellulose	23.366	23.865	23.62
			100.00

SUGARS IN THE EXTRACTS.

	I	II	Av.
Glucose in alcoholic extract.........	None	None	None
Sucrose in alcoholic extract.........	0.21	0.21	0.21
Gums in cold water extract.........	0.38	0.38	0.38
Starch in hot water extract.........	None	None	None
Xylan in hydric chlorid extract.....	5.03	6.55	5.79
Xylan in sodic hydrate extract......	4.15	3.47	3.81

TABLE LXXXV.

COEFFICIENTS OF DIGESTION FOR THE VARIOUS EXTRACTS OF SALTBUSH, *Atriplex Argentea.*

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Total alcoholic extract...	4250.1	682.6	3567.5	1052.8	2514.7	70.49
Total cold water extract..	1337.1	204.4	1132.7	304.1	828.6	73.15
Total hot water and malt extract	1119.4	109.0	1010.4	265.6	744.8	73.54
Total hydric chlorid ext..	3749.2	552.7	3196.5	1922.1	1274.4	39.87
Total sodic hydrate extract	3219.3	547.3	2672.0	1632.0	1040.0	49.00
Total chlorin, etc., extract	1980.6	376.9	1603.7	1496.6	107.1	6.28
Total residue, cellulose ...	3610.5	705.2	2905.3	2063.6	841.7	28.97
	19266.2	3178.1	16088.1	8736.8	7351.3	45.70

The general coefficients obtained for the digestibility of the dry matter were 46.40, 45.84 and 46.50, with the individual sheep; average, 46.25 per cent.

TABLE LXXXVI.

COEFFICIENTS OF DIGESTION FOR THE CARBOHYDRATES IN THE SALTBUSH, *Atriplex Argentea.*

(As indicated by the sugars obtained from the various extracts.)

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Glucose in alcohol extract	146.4	17.8	128.6	0.0	128.6	100.00
Sucrose in alcohol extract	240.3	35.6	204.7	14.6	190.1	92.87
Gums in cold water ext...	109.8	25.7	84.1	32.2	51.9	61.71
Starch in hot water and malt extract	279.4	38.8	240.6	0.0	240.6	100.00
Xylan in hydric chlorid ext	1454.6	233.6	1221.0	505.9	715.1	58.57
Xylan(?) in sodic hydrate extract	364.1	76.9	287.2	332.9	(—45.7)	——

TABLE LXXXVII.

FURFUROL FOUND IN SALTBUSH, *Atriplex argentea,* AND IN THE CORRESPONDING ORTS AND FECES.

	Saltbush Per cent.	Orts Per cent.	Feces Per cent.
Original	9.642	10.488	10.926
Residue after treatment with 80% alcohol...	9.642	10.363	10.926
Residue after treatment with cold water....	9.058	Same	Same
Residue after treatment with hot water and malt	7.608	10.140	10.440
Residue after treatment with hydric chlorid.	4.708	6.036	5.298
Residue after treatment with sodic hydrate..	2.570	2.985	3.364
Residue after treatment with chlorin, etc....	2.042	1.216	Not det

TABLE LXXXVIII.

COEFFICIENTS OF DIGESTION FOUND FOR FURFUROL IN THE SALTBUSH, *Atriplex argentea.*

	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Furfurol in Saltbush.....	1857.6	333.2	1524.4	954.6	569.8	37.38
Furfurol soluble in 80% alcohol	0.0	0.0	0.0	0.0	0.0	——
Furfurol soluble in water and malt	391.9	9.6	382.3	42.1	340.2	88.99
Furfurol soluble in 1% hydric chlorid	558.7	130.4	428.3	449.6	(—21.3)	——
Furfurol soluble in 1% sodic hydrate ...	412.0	97.0	315.0	169.0	146.0	46.35
Furfurol soluble in chlorin, etc.	101.7	56.2	45.5 }	293.9	106.4	26.49
Furfurol remaining in the residue	393.4	38.6	354.8 }			
			1525.9	954.6	571.3	37.37

TABLE LXXXIX.

COEFFICIENTS OF DIGESTION FOR THE PROTEIDS IN THE VARIOUS EXTRACTS OF THE SALTBUSH, *Atriplex argentea.*

Solvent.	Fed.	Orts.	Consumed.	Voided.	Digested.	Coef.
Boiling 80% alcohol	691.7	62.3	629.4	76.1	553.3	87.91
Cold water	57.0	26.7	30.3	45.4	(—15.1)	——
Hot water and malt	108.4	6.7	101.7	37.1	64.6	63.52
1% hydric chlorid	133.1	27.8	105.3	59.4	45.8	43.50
1% sodic hydrate, ...	618.4	79.5	538.9	161.3	377.6	70.10
Chlorin, sodic hydrate and sulfurous acid	236.4	18.4	218.0	154.5	63.5	29.13
Remaining in cellulose...	—29.3	6.8	22.5	22.4	00.1	0.00
	1874.3	228.2	1646.1	556.3	1098.8	66.21

§148. The coefficients of digestion found for the proteids with the three sheep were 67.56, 64.69 and 66.83. The average is 66.36. Bulletin 93, page 38.

METHOXYL GROUP IN THE SALTBUSH, *Atriplex argentea.*

§149. The saltbush hay was examined for the presence of this substance in the same manner that the other fodders were examined. The amount found was 2.104 per cent. I assume that the difference in the amount of this group present in the orts and in the hay is so small that no serious error is made in considering them the same, and I, therefore, made no attempt to determine this group in the orts. The amount in the feces is 2.929 per cent. The total weight of this group consumed was 338.49 grams; the amount voided was 255.90 grams; the amount digested was 82.6 grams, or 24.40 per cent.

§150. Alfalfa, timothy, native hay, corn fodder and the saltbush agree in showing that the substances containing this group are broken down to the extent of about 25 per cent. of the amount present. The result obtained with sorghum was wholly unsatisfactory; though the determination of this group in the feces, corresponding to the sorghum, was made three times and in the sorghum itself twice, with satisfactory agreement in every case. The result, however, indicates that fecal matter may yield this group or, perhaps, it is safer to interpret it that the substances containing this group in the case of sorghum are not digested at all, and that the excess of methoxyl in the feces is due to some error in our determination which we failed to detect, even though we repeated it.

AMID NITROGEN.

§151. The amid nitrogen found in the saltbush hay corresponded to 4.180 per cent of proteids, while that in the orts represented only 1.556 per cent. of proteids. We failed to find any in the feces. As we usually interpret these results, the amid nitrogen was wholly digestible, or has a coefficient of 100.00 per cent.

THE FUEL VALUE OF SALTBUSH, *Atriplex argentea.*

§152. The total dry matter consumed by the sheep in five days was 15,253 grams. We found the calorific value of this dry matter to be 3,886 calories per gram, or a total of 59,273,158 calories. The dry matter in the feces was 8,200 grams, with a heat value of 4,398 calories per gram, or a total of 36,063,600 calories. The sheep, accordingly, appropriated 23,224,811 calories, or 39.16 per cent. of the fuel value—the lowest coefficient of all the fodders used.

§153. The amount of urine voided in this instance was so exceptionally large that it certainly ought to have been collected, weighed and examined, at least the nitrogen determined. The animals' systems were certainly flooded by the large amount of water drank, 196 pounds in five days, which is a little more than three times as much as the same sheep drank when fed on alfalfa hay and over four times as much as when fed on timothy hay. The heat required to raise this quantity of water from the temperature at which it was drank, 14.5° C., to the the body temperature, taken as 101° F., would be 2,014,387 calories. So large a factor as this must have considerable influence upon the effects produced by the fodder, aside from the lively diffusion induced by the presence of an unusual quantity of water in the system.

TABLE XC.

The dry saltbush hay had the following approximate composition:

Solvent.	Per cent.
Boiling 80% alcohol	17.681
Cold water, 24 hours digestion	7.329
Hot water and malt extract	6.133
One per cent. hydric chlorid	20.560
One per cent. sodic hydrate	17.649
Chlorin, sodic hydrate and sulfurous acid	10.860
Residue, cellulose	19.788
	100.000

TABLE XCI.

THE FUEL VALUES OF THE SALTBUSH HAY AND THE RESPECTIVE RESIDUES.

Dry Saltbush, Atriplex argentea hay	3886 calories
The residue after extraction with 80% alcohol	3986 calories
The residue after extraction with cold water	4284 calories
The residue after extraction with hot water and malt	4346 calories
The residue after extraction with 1% hydric chlorid	4854 calories
The residue after extraction with 1% sodic hydrate	4712 calories
The residue after extraction with chlorin, etc.	4458 calories

TABLE XCII.

THE HEAT UNITS REMOVED FROM ONE GRAM OF SALTBUSH HAY BY THE VARIOUS SOLVENTS.

Boiling 80% alcohol	565 calories
Cold water, 24 hours digestion	108 calories
Hot water and malt extract	220 calories
One per cent. hydric chlorid	649 calories
One per cent. sodic hydrate	900 calories
Chlorin, sodic hydrate and sulfurous acid	558 calories
The residue, or cellulose	886 calories
	3886 calories

TABLE XCIII.

THE FUEL VALUES OF THE RESPECTIVE EXTRACTS OF THE SALT-BUSH, *Atriplex argentea.*

One gram of the alcoholic extract	3196 calories
One gram of the cold water extract	1474 calories
One gram of the hot water and malt extract	3587 calories
One gram of the hydric chlorid extract	3157 calories
One gram of the sodic hydrate extract	5099 calories
One gram of the chlorin, etc., extract	5138 calories
One gram of the residue, cellulose	4458 calories

TABLE XCIV.

THE DRY FECES GAVE THE FOLLOWING EXTRACTS AND RESIDUE.

Solvent.	Per cent. Dissolved.
Boiling 80% alcohol	6.278
Cold water, 24 hours digestion	3.711
Hot water and malt extract	3.235
One per cent. hydric chlorid	23.452
One per cent. sodic hydrate	19.909
Chlorin, sodic hydrate and sulfurous acid	18.249
Residue, cellulose	25.166
	100.000

TABLE XCV.

THE FUEL VALUES OF THE DRY FECES (*Atriplex argentea*) AND THE RESPECTIVE RESIDUES PER GRAM.

The dry feces	4398 calories
The residue after extraction with 80% alcohol	4323 calories
The residue after extraction with cold water	4334 calories
The residue after extraction with hot water and malt	4379 calories
The residue after extraction with 1% hydric chlorid	4871 calories
The residue after extraction with 1% sodic hydrate	4801 calories
The residue after extraction with chlorin, etc., cellulose	4398 calories

TABLE XCVI.

THE HEAT UNITS REMOVED FROM ONE GRAM OF FECES BY SUCCESSIVE TREATMENT WITH THE RESPECTIVE SOLVENTS.

Boiling 80% alcohol	346 calories
Cold water, 24 hours digestion	151 calories
Hot water and malt extract	101 calories
One per cent. hydric chlorid	715 calories
One per cent. sodic hydrate	1002 calories
Chlorin, sodic hydrate and sulfurous acid	976 calories
Remaining in the residue or cellulose	1107 calories

TABLE XCVII.

THE FUEL VALUE OF THE RESPECTIVE EXTRACTS OF THE FECES PER GRAM.

Alcoholic extract	5510 calories
Cold water extract	4069 calories
Hot water extract	3122 calories
One per cent. hydric chlorid extract	3049 calories
One per cent. sodic hydrate extract	5033 calories
Chlorin, sodic hydrate and sulfurous acid extract	5347 calories
The residue or cellulose	4398 calories

TABLE XCVIII.

COEFFICIENTS OF DIGESTION FOR THE HEAT VALUES OF THE VARIOUS EXTRACTS OF THE SALTBUSH (*Atriplex argentea*) HAY.

	Heat units Consumed	Heat units Voided	Heat units Appropriated	Coef.
Eighty per cent. alcohol extract	8,619,612	2,837,650	5,781,962	67.07
Cold water extract	1,647,934	1,236,976	410,956	24.94
Hot water and malt extract	3,357,432	827,330	2,530,102	75.37
1% hydric chlorid extract	9,900,352	5,863,227	4,037,125	40.78
1% sodic hydrate extract	13,721,409	8,218,889	5,502,520	40.09
Chlorin, sodic hydrate and sulfurous acid extract	8,508,528	7,999,112	509,416	5.99
The residue or cellulose	13,449,786	9,077,472	4,372,314	32.51
	59,205,051	36,060,656	23,149,533	39.12

§154. The coefficient obtained by using the composite samples of the hay and feces was 39.16 per cent., the same as we here obtain by calculation from the values obtained for the various extracts and the analysis of the fodder.

§155. The ordinary fodder analysis indicates no reason why this saltbush hay should not be, at least, a fairly good fodder. There is present more crude proteids than in the average hay, as much nitrogen-free extract as in alfalfa hay and less crude fibre than in alfalfa hay, timothy hay, native hay or corn fodder. The only abnormally abundant constituent is the ash, which amounts to nearly one-fifth of the weight of the dry hay, but three-tenths of this is sand. This amount though large is less than is found in the dried leaves of the sugar beet which are fed with excellent results, to both cattle and sheep. The percentage of ash in the dried beet leaves, not including the crown, ranges from 23 to 27 and to even more than 30 per cent. in the leaves of fodder beets. In this saltbush the ash was found to be 19.28 per cent., somewhat less than the amount found in our sugar beet leaves. The analysis of this ash shows less chlorin, sulfuric acid and soda than the ash of the beet leaves and no more soda than the alfalfa ash. The results of the feeding experiment were, however, not favorable, as each of the three sheep lost weight, one sheep lost one-half pound, one two pounds, and the third six pounds. This loss of six pounds may have been due to the individuality of the sheep more than to the fodder, but aside from this the results in the other two cases show that the fodder is a very poor one. The coefficients of digestion obtained for these groups of food elements, *i. e.*, the ash, proteids, crude fibre and nitrogen-free extract, show some extreme differences, *i. e.*, the coefficient of digestion for the crude fibre as shown by the three sheep was 6.02, 15.35 and 3.49 respectively, and the sheep with which we obtained a coefficient of 15.35 per cent. was the one that lost the most, six pounds in five days. The crude proteids, on the other hand, show the highest coefficients of digestion obtained except for the proteids contained in the alfalfa. The total proteids digested by the three sheep fed on alfalfa hay with a gain of nine pounds was 1325 grams, the proteids digested by the sheep fed on the saltbush hay with a total loss of eight and one-half pounds, was 1090 grams, a difference of 235 grams in the weight of the proteids digested. The coefficient obtained for the nitrogen-free extract was very low, 49.16, whereas it was practically 73 in the case of the alfalfa whose nitrogen-free extract has a very high coefficient of digestion. The percentage of the nitrogen-free extract present in the hay is about the same as in alfalfa hay; that for the crude fibre is somewhat lower than in the other fodders forming the subjects of this study, but the percentage of ash is decidedly higher than even the alfalfa and has a very high coefficient of digestion, 71.55, against 57.67 for the alfalfa ash. The high percentage of ash found for the saltbush hay is partly due to the presence of a great deal of sand amounting to 30 per cent. of the ash. The high coefficient of digestion for the ash is fully accounted for by the fact that the base occurring in the largest quantity is potash, making over 75 per cent. of the bases present. The potash is very largely absorbed by the system while lime and magnesia are absorbed by the system in small quantities and these make up the rest of the bases. It is to be noted that in this saltbush so good as no soda salts are present in its ash, only 0.073 per cent. sodic oxid. I have already made mention of the fact that this fodder caused the animals to drink very freely, as much as 15 pounds of water a day, which is very much more than they drank when fed on other fodders, ten times as much as the minimum that the same sheep drank when fed on timothy hay and twice as much as the maximum when fed on alfalfa hay.

§156. If we take up what I have designated as the proximate analysis of this saltbush, *i. e.*, the relative amounts dissolved out of the fodder by treating it successively with 80 per cent. alcohol, etc., we find that it is quite unlike the other fodders, but approaches most nearly to timothy hay, from which it differs in two respects, *i. e.*, in having somewhat less cellulose and in the amount of material removed by chlorin which is much larger than in the case of timothy or any of the other fodders.

§157. This timothy hay proved to be a poor fodder, each of the sheep losing flesh while receiving it as an exclusive ration. The results with the saltbush were very uneven, one sheep lost but one-half pound in the five days, another lost six pounds. I take it that the saltbush was really bad for the latter sheep, though it ate the hay freely and digested a little more dry matter than the sheep that lost only one-half pound. The difference in the loss cannot be attributed to this sheep's having drunk more water than the other, for it drank less by a few pounds, so that the disturbing influence of an excessive amount of water would probably not be greater in the one case than in the other.

§158. The portion removed from the fodders by treatment with chlorin and subsequent washing with sodic hydrate and sulfurous acid, is usually small, but amounts to 10.28 per cent. in the saltbush. The coefficient of digestion found for this portion is always low. In this case it was found to be only 6.28 per cent. The low coefficient for this portion may be more apparent than real. The percentage of it present in the feces is always comparatively high, in some cases exceeding the amount consumed. This may be, and probably is due to fecal matter, a large percentage of which is removable by this chlorin treatment, which of course would lower the coefficient found, even to the extent of reducing it to zero or showing, as is the case of some extracts, that there was more voided than was ingested.

§159. The sucrose determination in several of the fodders is rendered very doubtful, almost certainly erroneous, by the fact, as the investigation shows conclusively, that some of the substances which yield furfurol are taken into solution by alcohol and presumably yield a reducing sugar when the extract is inverted by heating with dilute acid. This doubt does not attach to the glucose, as this determination does not involve the inversion of the solution, unless such may have taken place during the repeated boilings with alcohol or during its evaporation, which was done on the water bath to avoid either local or general overheating.

§160. The fact that the alcoholic extract of the feces, corresponding to the saltbush, shows the presence of some substance equivalent to 0.21 per cent. of sucrose cannot be taken as conclusively showing the presence of sucrose, but merely that the extract contains some material susceptible of yielding a reducing power equal to this. In the case of corn fodder and sorghum, especially as a saccharine variety was used, the presence of some sucrose in the alcoholic extract of the fodder was to be expected, but the feces corresponding to these fodders yield no sucrose to the boiling 80 per cent. alcohol. The same doubt attaches itself to the starch determination that has been mentioned in connection with the sucrose, *i. e.*, we have depended upon boiling the fodder with water for one hour, cooling it and adding malt extract to bring the starch into solution, but we observe that this process removes enough furfurol in every case in which any starch was found to raise a question as to whether the reducing power was due to inverted starch or to a pentosan.

§161. The sugar found in the hydric chlorid extract of the saltbush and in the other fodders is probably xylose, except in alfalfa in which case the mucic acid found is very nearly equal to the sugar obtained by the Fehling solution and only a small portion can be attributed to xylose. My results with corn fodder are not satisfactory, but the four tests made agree in showing the presence of some mucic acid. In this case we know that both glucose and sucrose were present and whether their presence may have given rise to a mistake or not may be a question. Assuming that they did not, it would appear that other hexoses as well as pentoses are present in this fodder. In this event, the three fodders, alfalfa hay, corn fodder, and saltbush hay, are quite unlike and we find the coefficients of digestion for the sugars formed by the thorough inversion of the hydric chlorid extract to be 83.96, 89.22 and 58.57 respectively, which would indicate that the source of this sugar is different in the saltbush form than in the other two fodders. As already stated it is probably due to galactan in the alfalfa and possibly to both hexose and pentose groups in the corn fodder. The digestibilty of the hydric chlorid extract, that is all that this reagent dissolves out of these fodders, is nearly the same in the alfalfa and corn fodder, 60 per cent. in the former, and 63.88 per cent. in the latter, but it is only 39.88 per cent. for that of the saltbush.

§162. The furfurol has been considered as such and no attempt has been made to specify the particular source from which it was derived. The amount consumed in the different fodders varied from 1030 to 1526 grams and the coefficients of digestion found varied from 37.37 in the saltbush to 65.15 in the alfalfa. If there is any relation between the digestibilty of the furfurol and the value of the hay it is a very general one. The merits of the six fodders used in this study were as follows: Alfalfa, very decidedly the best, corn fodder and native hay standing next, timothy hay next, with the sorghum and saltbush standing far behind the others. The coefficient of digestionof the furfurol in these fodders was found to be as follows: Alfalfa, 65.15, native hay 50.97, corn fodder 47.07, timothy hay 50.13, sorghum 46.46 and saltbush 37.37 per cent. A study of the amount of furfurol removed by the successive treatments to which the hays and fodders were subjected establishes the fact that they deport themselves somewhat differently, the saltbush showing the same amount, relatively, after as before extraction with alcohol, while the other samples showed a decided loss. That extraction with cold water should remove a little furfurol would be expected, provided the material removed and susceptible of inversion is really due to gums. We, however, find that it is uniformly small, as is also the case with the hot water and malt extract. The two reagents that remove the greater portions of the furfurol are the hydric chlorid and sodic hydrate, but the cellulose often contains as much as either of these. The distribution of the furfurol in the various extracts of alfalfa, the saltbush and corn fodder, may be restated to make clear these differences.

TABLE XCIX.

	Alfalfa Grams	Corn Fodder Grams	Saltbush Grams
Furfurol soluble in 80% alcohol	144.5	1341.4	0.0
Furfurol soluble in 1% hydric chlorid	202.4	590.3	428.0
Furfurol soluble in 1% sodic hydrate	218.2	316.3	315.0
Furfurol remaining in the cellulose	256.2	162.9	400.0*

§163. These results point to very great differences in the properties of the compounds yielding the furfurol. A further study of the different tables will be seen to indicate that the leaves and stems are very different in this respect.

§164. The coefficients of digestibility as indicated by the results obtained point to further differences. We have for the coefficients for the furfurol in the above extracts the following:

TABLE C.

	Alfalfa	Corn Fodder	Saltbush
Soluble in alcohol	96.50	94.80	0.0
			Apparently
Soluble in hydric chlorid	100.00	73.17	None
Soluble in sodic hydrate	27.18	31.82	46.35
Retained in the cellulose	72.62	32.57	26.49

§165. The coefficient given for the digestibility of the furfurol in the cellulose of the saltbush includes the portion removable by treatment with chlorin, etc. It will be recalled that, in the case of the saltbush, the group which we designate crude fibre has an exceedingly low coefficient of digestion, 15.35 being the highest obtained with either of the sheep.

§166. We will see later that the significance of these differences are quite important. The testimony of the scales in regard to the live weight of these animals is that the alfalfa is an excellent fodder, that the corn fodder is good and that the saltbush is a very poor one. I am fully aware of the importance attached to the nitrogenous substances present in a fodder in the theories of animal nutrition, but the results so far obtained in this experiment, as I interpret them, point clearly to the equal importance of the character of the carbohydrates in the fodder.

§167. The amount and distribution of the proteids in the fodders and their respective extracts have already been given, but we

*This includes the portion removable by chlorin in the above extracts.

bring them together for the three fodders that we have tried to study a little more fully than the others, *i. e.*, alfalfa, corn fodder and the saltbush, *Atriplex argentea*.

TABLE CI.

	Alfalfa	Coefficent of Digestion	Corn Fodder	Coefficent of Digestion	Saltbush	Coefficent of Digestion
The crude proteids consumed.	1817.15	72.92	472.82	37.74	1646.10	66.21
Soluble in 80% alcohol, consumed	594.41	81.69	215.76	65.49	629.40	87.91
Soluble in hydric chlorid, consumed	125.66	59.84	70.07	39.43	105.30	43.50
Soluble in sodic hydrate, consumed	851.70	81.89	98.98	0.00	538.90	70.10
Soluble in chlorin, etc., consumed	39.58	0.00	28.82	46.46	218.00	29.13

§168. We have here very great differences and, if we were to draw conclusions and base them upon the analytical results in regard to the quantity and digestibilty of the proteids present, we would certainly place the saltbush quite close to the alfalfa, but the results of the feeding, expressed in gain or loss of live weight, places the corn fodder far above the saltbush with a gain of 3½ pounds of flesh as against a loss of 8½ pounds or a total difference of 12 pounds live weight. It is only just to add that 6 pounds of the loss chargeable to the saltbush was made by one of the three animals, but even if this be due to the individuality, idiosyncrasy perhaps, of the animal, it suggests that the saltbush may be a bad fodder for many sheep, unless we were unfortunate in getting the one out of many among the three chosen with which it would give particularly unfavorable results. I have elsewhere referred to this possibility and have pointed out that the aggregate loss of the two that did not lose such an exceptional weight, was 2½ pounds, while those fed on corn fodder gained 3½ pounds, so that after assuming that the third sheep receiving the saltbush was so sensitive to its action as to render this sheep wholly unfitted for use in the experiment, the results obtained with the remaining two indicate that this plant is not fitted for a forage plant. The corn fodder, so far as the proteids are concerned, is not so good as the saltbush, but if we consider the carbohydrates as indicated by the sugars obtained in the inverted solutions, or by the furfurol obtained, and their coefficients of digestion, the corn fodder would appear to be much the better of the two, and this is the fact. This view of the importance of the carbohydrates will receive some confirmation when we briefly review the energy supplied by these three fodders and their extracts.

§169. The methoxyl group occurs in all of the fodders, but it is not very abundant, and its coefficient of digestion is low.

§170. The amid nitrogen is not abundant in these hays but its coefficient of digestion is high. How much energy it may yield in its changes either absolutely or in comparison with the albumenoids, I do not know.

§171. Perhaps the most suggestive results are those obtained with the bomb calorimeter. The percentage of heat which disappears from the fodder in its passage through the animal, varies with the different fodders; for the saltbush we found that 39.16 per cent. of the energy had disappeared; for the corn fodder 56.00 per cent., and for the alfalfa 62.43 per cent. In studying the respective extracts, the results agree in showing that the alcoholic extract furnished the largest amount of heat. Next to this in the case of the alfalfa and the saltbush comes the sodic hydrate extract, but in the corn fodder, the residue or cellulose furnishes the second largest quantity. The third largest quantity is furnished in the case of the alfalfa and saltbush by the cellulose and in the corn fodder by the hydric chlorid extract, as shown by the following statement of the heat units appropriated by the sheep from the respective portions:

TABLE CII.

	Alfalfa	Corn Fodder	Saltbush
Alcoholic extract yielded	10,737,717	7,027,781	5,781,962
Sodic hydrate extract yielded	8,218,319	2,146,018	5,502,520
Hydric chlorid extract yielded	2,999,157	4,914,158	4,037,125
Residue or cellulose	5,952,562	5,435,160	4,372,314

§172. These results are quite consonant with those obtained from the study of the extracts which show that the respective fodders yielded the following quantities of digestible material in grams:

TABLE CIII.

	Alfalfa	Corn Fodder	Saltbush
Alcohol extract	2520	1789	2515
Hydric chlorid extract	912	1245	1274
Sodic hydrate extract	1359	342	1040
Residue	1442	1210	841

§173. The fuel value of these different portions are not equal and the coefficients of digestion are also unequal, so that a close agreement could not be expected. The general deportment of the timothy and native hay would seem to place them close to corn fodder. The sorghum shows a large amount of digestible alcoholic extract, hydric chlorid extract and cellulose, but less of the latter two than the corn fodder and though they seem to be large enough in quantity and fairly proportioned, the sheep lost weight amounting to almost three pounds each while being fed on this sorghum fodder.

§174. The amount of residue or cellulose digested in the various trials, the comparative uniformity of the coefficient of digestion and fuel value, indicate a very considerable food value for this portion of the fodder. It is the only portion of the saltbush that was not digested in the usual quantity. The general coefficient obtained for the crude fibre was only 8.29 in which is included the portion soluble in chlorin. When we consider the fuel value of this cellulose, it is higher, by a little, than that prepared from the other fodders, but the coefficient of digestion is very low, only 32.51 per cent. But it is higher than the coefficient found for the crude fibre of this hay, in fact it does not agree at all, except in that it is much lower than the coefficients which we found for this portion of the other fodders. The energy of the saltbush is, in general, low. The amount of water drunk was large and the animals were permitted to drink whenever they wished to. These two things may have interfered with the digestion of the cellulose, *i. e.*, there may not have been enough energy available to effect its breaking up and to carry on the other bodily functions.

DISCUSSION OF RESULTS AND RECAPITULATION

§175. In Bulletin No. 39 of this Station, I attempted to find some way to examine a fodder which would give us more satisfactory information regarding the value of the fodder than the old method furnished. I designated it as "A Study of Alfalfa and Some Other Hays". It is now ten years since that bulletin was published and I here present a brief review of the further work done in this line, extending it very materially to include the distribution of the nitrogen in the different extracts and also that of the pentosans. Further the determinations of the fuel value of the fodders and residues obtained by exhausting the fodders with different menstrua and therewith the energy value of the extracts themselves have been added.

§176. The analytical work has been supplemented by digestion experiments made with sheep, using three individuals in each experiment. When I commenced this portion of my study, I scarcely hoped to be able to carry it to the extent that it has been carried; had I foreseen the end, I would certainly have collected the urine and included this factor in the work, but even then the work would have been incomplete, though it would have been a little more satisfactory than it is at present.

§177. It is not expected that everybody will find interest enough in this subject to lead them to read all of the analytical results to see what errors have been made, and to weigh the force of each individual result obtained, so I may be pardoned for giving, in the form of a recapitulation, a general statement of the work.

§178. The fodders studied are alfalfa hay, timothy hay, native hay, saltbush hay, *Atriplex argentea,* corn fodder and sorghum fodder.

§179. It seems superfluous to state that we used the best quality of these different fodders that we could obtain. The alfalfa was probably rather old when cut and the hay had been preserved in a stack, so that some of it was not in prime condition, but, with these two reservations, it would be classed as very good hay.

§180. The timothy hay was grown in the mountains and was as good a quality as we could obtain. The native hay was, as is all the hay to which this name is applied, a mixture of grasses and sedges, and the results obtained with one sample of it will apply only in a general way to any other sample.

§181. The saltbush, *A. argentea*, was included in this study mainly because we need a plant to use in the eastern portion of the State as a forage plant. Irrigation is out of the question in this section of the State, and the rainfall is so light that ordinary forage plants do not furnish much forage, if they succeed in living. This saltbush grows abundantly some seasons and in some places, and the ranchmen have cut it, made it into hay and used it to feed their stock during severe storms when the cattle were unable to graze on the plains, and needed something to enable them to endure the storms which, I understand, are often severe, being accompanied by low temperatures and high winds.

§182. I do not know that anyone has observed the effects of this fodder under any conditions, favorable or otherwise, so that our observations and results will be of commercial interest to this section of the State whether they are favorable or not. Further, the saltbushes have not been studied, not even the Australian saltbush, *Atriplex semibaccata,* which is a very different and, as a fodder, I hope, a much more valuable plant than this. It has, at least, been recommended by the California Experiment Station and in a preliminary feeding experiment made by myself it promised to be a fair fodder even when fed alone.

§183. I desired to study the composition, digestibility and feeding value of this class of plants, so this native saltbush which had already been used as a substitute for our better known forage plants, seemed to me to be a subject which would answer my purpose very well indeed, and might possibly be of considerable benefit to the State. I regret that my results do not justify any hope of adding a good forage plant in this indigenous saltbush. As a subject for the study of the questions discussed in this bulletin, however, it serves my purpose very well, for it proves to be a very poor fodder, one scarcely fit to be used under any circumstances and certainly not fit for use under conditions of stress and with cattle already reduced in vitality by continued exposure and lack of a generous supply of food.

§184. This fodder probably contains nothing positively poisonous or injurious, it is simply deficient as a fodder. One of the three sheep experimented with lost only one-half pound but another lost six pounds. We will later try to point out wherein it is deficient. None of the fodders studied serve better than this saltbush to make clear our principal object in this work, *i. e.,* to discover, if possible, what causes the difference between fodders—why one is a good fodder and another a poor one—to discover some way of judging correctly whether a fodder is good or poor without having to feed it, but this is after all, a comparatively convenient, rational and conclusive method and the results obtained by it need no summing up except as to cost.

§185. The other fodders studied were corn fodder and sorghum fodder. The results obtained with these fodders, particularly in feeding them, were wholly unexpected,in that the former gave better results than was anticipated and the latter very unfavorable ones, which was contrary to what I had expected. Even now, I am scarcely content to accept the results of our feeding experiment. As will be seen subsequently, there is nothing in the composition, judged either by the regulation fodder analysis, or by what I have called the proximate analysis, or in its fuel values to suggest an inferior value for this sorghum fodder, but each of the three sheep fed on this fodder lost very nearly three pounds in five days during which time they not only consumed but digested a very fair amount of food, three pounds per hundred weight of animal daily.

§186. Our object was primarily to study the fodders to find out how we might learn more about the reasons why fodders are so different in value. The groups into which we have been accustomed to divide fodders are not definite groups, but are the best that we have had and they have not yet been displaced. Students have long felt that the results left much to be desired and have adopted other methods of investigation, in order to find out the value of the fodders, their composition, the heat values of the components, and the energy actually furnished to the animal.

§187. It occurred to me that an endeavor to study the carbohydrates might add something to our present knowledge and I chose the line of work presented in Bulletin No. 39, but I realized that it was only an attempt and left much that was unsatisfactory. Some of the results were not concordant and the work was not carried far enough and was not accompanied by any results obtained by these lines of examination in combination with feeding tests, the results of which should serve as facts on which to base our interpretations. I have tried to obviate these faults in the investigation now presented.

§188. I have adhered to the general line of experimentation outlined in Bulletin No. 39, so that the present work may properly be considered a continuation and extension of that. The general method of examination was to exhaust the fodders with boiling 80 per cent. alcohol, cold water, boiling water and after cooling with malt extract, boiling 1 per cent. hydric chlorid, boiling 1 per cent. sodic hydrate, and lastly, with chlorin, subsequently washing with 1 per cent. sodic hydrate and hydric sulfite. I have not yet seen any good reason for changing this order of procedure. The results show, however, that it does not effect a division of the fodder into any definite groups. By this I mean that the extracts consist of mixtures of substance whose composition cannot be established in this way. I hoped, for instance, to be able to determine the sucrose in the alcoholic extract, but I find from the determinations of the furfurol removed from the fodder, that it is quite probable that the alcoholic extract contains pentosans which may yield reducing sugars on heating with dilute acids, or inversion, so there is doubt whether sucrose, ordinary cane sugar, in a fodder can be determined in this way, especially when present in small quantities. The same is true of the starch determinations, because we found that boiling for one hour and treating with malt extract removed furfurol as in the preceding instance. This shows that the pentosans are dissolved by a considerable range of solvents. Further, we find them present in all of the extracts except possibly that obtained by the treatment with chlorin and subsequent washing with sodic hydrate and sulfurous acid to remove the products of chloridization. Some furfurol is removed from the crude fibre by this treatment but we did not find any reducing sugar in the extract obtained; it is, of course, possible that the action of the chlorin was so drastic that it oxidized and radically changed the furfurol yielding substances so that there remained no hydrolizable carbohydrates of this type in the extract. The residue left, after all these treatments, the cellulose yields from 1.6 to 2.1 per cent. furfurol, showing that substances yielding from one-sixth to one-third of the total furfurol yielded by the fodder, resist all of these treatments and constitute a portion of the cellulose thus obtained. This is probably oxycellulose which may be the source of the furfurol removed by the treatment with chlorin and the subsequent washings.

§189. Again, we find that the nitrogen content of the fodder is distributed unevenly throughout the extracts, some of it, a very little, escaping all of the solvents and remaining in the cellulose. The compounds corresponding to the amid-nitrogen are quite easily soluble and might readily pass into the 80 per cent. alcohol solution, but we find in the case of the alfalfa, for instance, that one-third of the nitrogen, calculated as proteids, is soluble in this menstruum, whereas, the amid-nitrogen, provided it were wholly soluble in 80 per cent. alcohol, could not constitute more than one-fifth of the total, showing that large amounts of nitrogenous substances other than amids went into solution. These statements will suffice to make clear the meaning of the assertion that this procedure does not effect the division of the fodder into well defined groups, and it was not expected that it would, but rather that it might enable us to find differences between the fodders which would at least help to explain the differences observed in their feeding values.

§190. It is and has been known, for the past twenty-four hundred years, that alfalfa hay is a good fodder, so there is nothing new in such a statement. The new thing is the general recognition of the fact and the interest taken in it. I have acknowledged this very generally accepted estimate of the value of this fodder in choosing it as the standard of comparison in this work. It may not be a good standard for the comparison of all hays, as only a few of our hays are made from this class of plants, *i. e.,* the pea vine, the clovers, etc., even in my work it stands alone, a leguminous hay, though pea vine and red clover hay were included in the work presented in Bulletin No. 39. As a standard of value for different hays made from grasses it may not be a good one, but as a standard of value in this study no better one could, in my opinion, be adopted. It is a favorably known fodder, yielding good results wherever used and its use is rapidly becoming more extensive than heretofore. The results of our investigation of this hay show the following points of interest: But little danger in its use, the green plant may produce bloating in cattle and the feeding of musty and dusty alfalfa hay is charged with producing the heaves in horses, further when fed alone it produces looseness of the bowels and increased urination. These are the evils chargeable to this plant; the rest to be said is favorable, it being an excellent fodder, even for horses when fed with proper precautions, while for fattening cattle and sheep it is unexcelled. For these good reasons, I have chosen it as the first subject for study.

§191. The average composition of this hay is now very generally known; it is characterized by the presence of a high percentage of nitrogen, commonly expressed in terms of crude proteids which usually range from 12 to 15 per cent. of the hay. The group indicated by the term crude fibre is rather abundant, being from 30 to 35 per cent. in good hays, and that understood by the term nitrogen-free extract, is about the same, 30 to 35 per cent. In a general way, then, we may represent alfalfa hay as being composed of one-third crude fibre, one-third nitrogen-free extract, one-sixth proteids while the other sixth is represented by ash and ether extract. The other leguminous hay, common in some parts of Colorado, is pea vine hay. This is, when cut in full bloom, somewhat richer in proteids, with about the same, perhaps a little smaller, percentage of crude fibre and nitrogen-free extract. Red clover hay is occasionally met with and is, so far as the observations of this department go, something richer in nitrogen-free extract, but otherwise about the same as alfalfa. The leguminous hays differ from those made from grasses in that they contain less nitrogen-free extract, 30 to 36 per cent., in samples of alfalfa, third cutting, occasionally as much as 41 per cent., against 42 to 50 per cent. in the hays made from grasses. They are richer in crude fibre, ranging from 32 or 33 to occasionally 40 per cent. for alfalfa against 20 to 30 and sometimes more in the hays of the grasses. They further contain from two to three times as much crude proteid—from 11 to 17 or 18 per cent. against 5 to 9 per cent., rarely more, in that made from the grasses. Such are the differences between the two classes of hays as shown by the ordinary fodder analyses.

§192. The differences between the hay of leguminous plants and that of grasses is further shown by the large portion removed by simple solvents such as water and alcohol. The total amount dissolved out of the air-dried hays by 80 per cent. alcohol and water in the order followed in this work is for alfalfa, 40 per cent.; red clover hay, 35 per cent.; pea vine hay, 34 per cent.; timothy hay, 31 per cent.; native hay, 30 per cent.; corn fodder, 37 per cent.; sorghum, 47 per cent., and the saltbush experimented with, 28 per cent. The 80 per cent. alcohol extracts from these air-dried fodders and hays, the following amounts: From alfalfa, 27 per cent.; corn fodder, 29 per cent.; timothy hay, 21 per cent.; native hay, 21 per cent.; sorghum, 36 per cent., and from the saltbush hay, 22 per cent. A quantity of alfalfa was digested with cold water for 24 hours and the loss then determined, when it was found to be 40 per cent. Apparently then, water alone will remove from alfalfa as large an amount of extractives as alcohol and water when used successively; this was not established by repetitions of this experiment. No precaution was taken against fermentative changes. This result is consonant with the well known susceptibility of alfalfa to injury by moisture, even a heavy dew sufficing to discolor it. I did not submit the hay to the ordinary fodder analysis after treating it in this manner. The results would doubtlessly have been interesting if I had done so, but I have an old analysis of a hay damaged by a succession of showers necessitating the exposure of the hay to both extraction and fermentation. Making no allowance for the large loss of weight, which must have been suffered in this case, we have the following difference in the hay as cut and gathered: Crude fibre as cut 26.46 per cent., as gathered 38.83 per cent.; crude proteid as cut 18.71 per cent.; as gathered 11.01 per cent.; and the nitrogen-free extract 38.91 per cent. as cut, and 33.64 per cent. as gathered. These results are affected by the mechanical losses as well as chemical, but they serve to suggest that it is not only an important consideration for the farmer but a good point of attack for the student of such subjects. The hays made from the grasses, and the native hay, being a mixture of grasses and sedges, may in this respect be fairly representative of such as are usually used in hay making, yield just about one-half as much to alcohol and water as the leguminous hays.

§193. The other well known class of fodders represented in our study is corn fodder. The dry matter of this fodder differs according to the ordinary fodder analyses from that of the leguminous hay in containing nearly one-half more nitrogen-free extract, and from one-third to one-half as much crude proteid, while the crude fibre is not far from the same, though not nearly so constant, being sometimes more and sometimes less.

§194. The solubility of the nitrogenous substances of these different fodders in 80 per cent. alcohol may further exhibit their differences, as well as the extent to which these substances are soluble in this medium. The nitrogen has, of course, been calculated as proteids by multiplying by 6.25, the usual factor. The following table gives the weight in grams of the proteids in the fodders fed, and the amount which was soluble in the respective solvents.

TABLE CIV.

	Alfalfa	Corn fodder	Timothy	Native hay	Saltbush
80% alcohol	640.0	249.0	189.0	231.0	692.0
Cold water	91.0	33.0			57.0
			83.0	70.0	
Hot water and malt	135.0	27.0			108.0
1% hydric chlorid...	127.0	79.0	99.0	98.0	133.0
1% sodic hydrate ...	937.0	116.0	350.0	384.0	618.0
Chlorin	45.0	30.0	13.0	29.0	236.0
Residue or cellulose.	17.0	6.0	9.0	11.0	29.0
Total proteids fed ..	1992.0	540.0	743.0	823.0	1873.0

§195. We see that the two hays, timothy and native hay, yield between one-quarter and one-third of their nitrogen to the alcohol, which is nearly as high a ratio as in the case of alfalfa and the saltbush. The maximum relative portion is observed in the case of the corn fodder in which the amount dissolved amounts to nearly one-half. There is either no relation between the soluble nitrogen and the value of the fodder, or it is so greatly modified by other factors that it is entirely concealed. Of these fodders, alfalfa produced the largest results, *i. e.*, 9 pounds of flesh in five days; the corn fodder and native hay next with 3½ pounds each; the saltbush and sorghum last with a loss of 8½ pounds each.

§196. The amount of nitrogenous matter dissolved out of the hays by water, after previous treatment with the 80 per cent. alcohol is very small, but the loss of the alfalfa hay which has been exposed to the rains suggests, at least, that the nitrogenous matter soluble in the alcohol may also be soluble in water. Be this as it may, neither cold or boiling water removed any very considerable portion after the previous treatment with alcohol. The two exceptions to this are the saltbush and the alfalfa. We also notice that it is these two, saltbush and alfalfa, from which the 1 per cent. hydric chlorid removes the largest quantities of the proteids, that is, absolutely but not relatively, for in the alfalfa, for instance, about one-sixteenth of the nitrogen is dissolved out by the 1 per cent. hydric chlorid, while in the corn fodder and timothy hay it is about one-seventh.

§197. The similarity between the alfalfa and the saltbush in regard to the amount of proteids present and their solubility in these solvents is striking and two things regarding them is very evident, *i. e.*, while one-half of the proteids were removed from the alfalfa by the 1 per cent. sodic hydrate, only one-third of them was removed from the saltbush, but the amount removed by chlorin and subsequent washing with 1 per cent. sodic hydrate and hydric sulfite is five times as great. The relative quantities, owing to the fact that the quantities fed were so nearly alike, are the same, *i. e.*, one-fortieth and one-eighth respectively. The nitrogenous substances removed by the chlorin and the subsequent washings usually amount to but a few grams and are apparently often more abundant in the feces than in the hay or fodder, but in the saltbush hay such proteids(?) are unusually abundant and they have a coefficient of digestion, according to our experiments, of about 29 per cent., which is, of course, very low. We evidently have to do with nitrogenous substances quite different in character and while our division of them into groups is not satisfactory, we still have three big groups, those removed by 80 per cent alcohol, always with a good or even high coefficient of digestion; those soluble in hydric chlorid differing very much in their digestibility, from 39 to 63 per cent. in the different fodders, and those soluble in sodic hydrate which have high coefficients of digestion, except in the case of the corn fodder in which this group of nitrogenous substances is not nearly so large as in the other fodders and is, apparently, so good as indigestible. The proteids soluble in cold and hot water are not considerable in quantity, except in the alfalfa and saltbush, and are not very digestible, while those removed by chlorin, etc., are small in quantity, except in the case of the saltbush, in which they constitute an eighth of the total, and either show a low coefficient of digestion, 29 per cent. in the case of the saltbush, or are more abundant in the feces than in the fodder fed.

§198. What the bearing of these facts may be on the feeding values or properties of the fodders is not clear.

§199. It may be well to consider some facts, as well as we may, but without assuming that we know anything about them. The alfalfa and saltbush, for instance, constitute the extremes in our series of fodders, perhaps I should, to be logical in interpreting our results, class sorghum and saltbush together. As already stated, I cannot but entertain a strong opinion that the sorghum should be studied further, because of the very unfavorable results obtained. It must, however, be acknowledged that the results in the case of the three sheep were uniform and unfavorable, though the fodder was apparently of excellent quality and in very good condition. The results showed a loss of almost three pounds in each of the three sheep, which certainly ought to have more weight than my opinion that the sorghum is a better fodder than these results indicate. We did not make as full a study of the sorghum as of the other fodders and for these two reasons I have less to say about the sorghum than about the others.

§200. With this explanation regarding the sorghum, I will consider the saltbush as constituting the most inferior fodder of the series, and yet, as stated before, this fodder is richer in proteids than either of the remaining five, alfalfa alone excepted. With the alfalfa, we fed, in round numbers, 2,000 grams of proteids, coefficient of digestion 72.5, with the saltbush practically 1,900 grams, coefficient of digestion 66.4. The three sheep fed on alfalfa gained 9 pounds, those fed on saltbush lost 8½ pounds. It is, of course, wholly improbable that other constituents had no disturbing effects on the results, but it is also very probable that the nitrogenous substances soluble in the different reagents are of very different value and it is not the amount of the proteids (N x 6.25) present, but their character which determines their value. It may be that the large amount of chlorin-soluble nitrogen present in the saltbush, constitutes not only an analytical difference, but a nutritive one also. It is evident that the sheep digested rather more proteids when fed on alfalfa but the difference is not very big, 239 grams. The amounts of proteids digested where corn fodder was fed were quite small, less than one-fifth of that digested in the case of the saltbush and one-sixth of that in the case of the alfalfa. The amount digested when native hay was fed was less than one-half of that digested in the case of the saltbush. Both the native hay and corn fodder proved to be good fodders, all of the sheep gaining while receiving them; the aggregate gain in the two lots of three sheep each, was three and one-half pounds for each lot.

§201. The animals were not fattened on these fodders and killed to see the relation of muscle to fat, so I do not know anything about this feature of their effects. The amount of the alcohol-soluble proteids in the corn fodder is larger than that in any of the other solvents, being 217 grams out of a total of 473 grams. In the case of the native hay the two solvents removing the largest quantities of proteids are the sodic hydrate and alcohol. The contrast in the results produced in these experiments is that the sheep receiving saltbush digested 1,091 grams of proteids and were losing flesh, some of them rapidly; those receiving the other fodders were gaining, though they received much smaller amounts of proteids with either the corn fodder or native hay and only 239 grams more when fed alfalfa, but in this case the lot made a gain of nine pounds against a loss of 8½ pounds in the lot receiving saltbush.

§202. The question which I have tried to present is, do the facts exhibited by the results of this proximate analysis offer any suggestions regarding the reasons for so great a difference in the feeding values of these fodders.

§203. We will later give a reason for the assertion that the alcoholic extract is the most important portion of the fodder and we observe that the proteids of the saltbush, soluble in alcohol and digestible, is greater even than in alfalfa, so that it would seem probable that this portion of the saltbush, unless it should contain some therapeutically active and deleterious substance, is probably the most valuable portion of this fodder, but if the fuel values are safe criteria, it is of comparatively small value compared with that of the corresponding alfalfa extract, giving a little over one-half the energy. This, of course, applies to the whole extract from which we cannot single out the effect of the nitrogenous matter.

§204. The carbohydrates in the alfalfa and the saltbush are evidently quite different; if we take the total sugars as the measure, they stand as 9 to 26, there having been fed with the alfalfa, carbohydrates capable of giving 900 grams of sugars, while the saltbush gave 2,600 grams. The furfurol also indicates a great difference. There was consumed with the alfalfa 1,030 grams of furfurol and 1,524 grams with the saltbush. The coefficient of digestion for the furfurol in the alfalfa was 65.2, and for that in the saltbush 37.4. The weight of alfalfa fed was 13,351 grams, and of saltbush 16,088 grams. The difference in the coefficients of digestion is also very marked, 37.4 in the case of the saltbush and 65.2 in that of the alfalfa. The difference in the character of the carbohydrates is still further indicated by the low degree of digestibility shown by the residue, which I have for convenience sake called cellulose, which is 29 for that from the saltbush and 53 for that from the alfalfa. The action of chlorin, together with the subsequent washing with sodic hydrate and sulfurous acid does not show as great a difference in these cases as in that of some other fodders, though the amount removed from the saltbush is the greater by about 1.6 pounds per hundred. This portion of the fodder seems to be uniformly very difficult of digestion, the coefficient in the case of the saltbush being but 6.3. I have elsewhere suggested that the low coefficient uniformly obtained for this portion of the fodder may be apparent only, due possibly to a close resemblance between it and fecal matter, as we have found this portion in the feces larger than the total fed in several instances. The hydric chlorid with which the fodders were boiled till no more sugars were produced, also shows a decided difference. The alfalfa consumed, 12,364 grams, yielded but 340 grams of sugar, calculated as galactan, whereas the 16,088 grams of saltbush yielded 1,455 grams of sugar calculated as xylan; here again the coefficients of digestion indicate wide difference of properties. The alfalfa sugar, galactose, shows a coefficient of 84, and the saltbush sugar, xylose, a coefficient of 58.6.

§205. The nitrogenous substances may contribute a small proportion of these sugars, but they undoubtedly are, for the most part, derived from other compounds.

§206. The difference in the coefficients of digestion for the respective residues becomes still more significant when it is called to mind that this residue is one of the three important portions of the fodder, as will be more fully shown under the discussion of their relative heat values. We will find that the coefficients of digestion, 53 for the residue from the alfalfa and 29 for that from the saltbush, are not consonant with the heat values obtained, but still we will see that they are nearly so and that the saltbush residue yielded less than three-fifths as much energy per unit of weight as that from the alfalfa.

§207. The corn fodder was found to be a good fodder, producing a gain of 3½ pounds in the three sheep. There was digested by the sheep in this instance 4,940 grams of dry matter, equal to 56.3 per cent. of that consumed, 1,789 grams of which was soluble in alcohol, 1,245 grams soluble in hydric chlorid, and 1,210 insoluble.

§208. In this case the sugars indicate the presence of a large portion of alcohol-soluble carbohydrates, glucose and cane sugar, together amounting to 872 grams, which is wholly digestible, and 975 grams in the form of galactan and xylan, sugars inverted by the action of the dilute hydric chlorid; these practically constitute the whole of this class of substances in the corn fodder, as cold water, hot water and sodic hydrate together remove but 100 grams of sugars from the whole amount of corn fodder consumed; the cellulose is, of course, to be added to these to obtain the total carbohydrates. The furfurol removed by alcohol is very small in amount, so that while some pentosans are present the amount is at most, insignificant; 77.5 grams were consumed and the coefficient of digestion was found to be 94.8 per cent., so, aside from our knowledge of the fact that sucrose and reducing sugars occur in the juices of the corn stalk, there is no question but that the sugar found did not come from the inversion of other carbohydrates. The total amount of furfurol found to have been removed by hot water and malt seems to be open to question, as our duplicate determinations did not agree very well. The hydric chlorid extract furnished very nearly one-half of the sugars found and a little more than one-half of the furfurol found in the extracts of the fodder; this, of course, does not include the residue or cellulose.

§209. The amount of proteids consumed with the corn fodder was much less than in the other two instances, alfalfa and saltbush. With the alfalfa 1,817 grams were consumed and 1,325 digested;

with the saltbush 1,646 grams were consumed and 1,090 grams digested; but with the corn fodder there was only 473 grams of proteids consumed and 179 grams digested. This fodder seems to give favorable results, though the composition of the fodder is very different from the others in respect to the amount and character of the carbohydrates and also in regard to the proteids, the latter, in particular, being largely soluble in the 80 per cent. alcohol. This is especially noticeable with the portion digested, as 141 grams out of the 178 digested were soluble in the alcohol. Another point of difference between the proteids of these three fodders is the low degree of digestibility of the proteids contained in the corn fodder. This is true with both the general coefficient and the coefficients obtained for the proteids in the extracts. The general coefficients of digestibility for the proteids are 73 for those of the alfalfa, 66.4 for those of the saltbush, and 36 for those in the corn fodder. Alcohol dissolves approximately one-third of the total proteids out of alfalfa, and these have a coefficient of digestion of 81.7; from the saltbush a trifle more than one-third, and the coefficient of digestion was found to be 88; from the corn fodder, it dissolves a little less than one-half of the nitrogen, calculated as proteids, of which 65.5 per cent. was found to be digestible.

§210. The other solvents removed quite small amounts of proteids from the corn fodder and these have quite low coefficients of digestion. The sodic hydrate dissolves the second largest portion of the proteids out of the fodder, but it is so good as indigestible. This is in marked contrast with the other fodders, in which cases the amounts of proteids dissolved out by the sodic hydrate are both absolutely and relatively much greater, and the coefficient of digestion is high in each case, 82 for that of alfalfa and 70 for that of the saltbush, against zero for that of the corn fodder. It is possible that the coefficient obtained for this portion of the proteids is erroneous, but it is not probable, and it is safe to assume that the coefficient of digestion of this portion of the proteids in corn fodder is very low, indeed, probably zero, as above stated.

§211. The most notable features so far developed are that the soluble carbohydrates, *i. e.*, all that portion of the fodders not included under the proteids, and the residue or cellulose vary within narrow limits, except for those soluble in hydric chlorid. The most important extract is that obtained by alcohol, in which, it is true, that large quantities of proteids occur, but their coefficient of digestion is, in the cases of the saltbush and corn fodder, less than the general coefficient for the extract, so that the coefficient for the carbohydrates must be higher than that found for the extract. This does not hold for the alfalfa. The coefficients of digestion found for the alcoholic extracts of these three fodders are as follows—alfalfa, 68.6; saltbush, 70.5; corn fodder, 73.8. We see that they are quite close together, and as the percentage of the respective fodders soluble in alcohol are not very unlike, it seems just to assume that in the absence of any injurious constituent they have approximately the same value, but such is not the case, as is indicated by the heat values appropriated by the animals, according to which the relative values of the three alcoholic extracts stand as 1 to 1.5 to 1.9 nearly. The alfalfa extract having a value of 1.9 and that of the corn fodder 1.5, if the saltbush extract be taken as 1. The second important division of the carbohydrates is represented by the hydric chlorid extract and here we find very great differences indicated by the coefficients of digestion. This portion of the alfalfa has a coefficient of 60.2; that of the corn fodder 69.4, while that of the saltbush has a coefficient of only 39.9. The percentage of this portion present in these fodders was found to be as follows: Alfalfa, 12.2; corn fodder, 18.9, and saltbush, 17.0. We observe that the coefficient of digestion for this group of substances in the saltbush is low and the percentage of it present in the hay is high, from which standpoint it would be an important factor in judging of the value of the fodder. The coefficients of digestion found for the corresponding heat values were, for the alfalfa, 54.75; for the corn fodder, 63.88, and for the saltbush, 40.7. The indication of these coefficients, too, is that this portion of the saltbush extract is inferior to that of the other two. The heat appropriated by the sheep per gram of this extract consumed, stood in the ratio of 1.3 to 1.8 to 2, the saltbush again being the lowest and the alfalfa the highest. The deportment of the proteids present in these different fodders has been referred to in a previous paragraph, where it is shown, though not explicitly stated, that the proteids in the saltbush resemble those of the alfalfa in their quantity and deportment toward the different solvents, so here we find the proteids in the alcoholic extract of the corn fodders relatively high and those of the alfalfa and saltbush relatively low, but the absolute amount of proteids in the hydric chlorid extract of the corn fodder is small and of no significance, while the actual weight of the proteids dissolved out of the alfalfa and saltbush, respectively, is much greater than in the case of the corn fodder, but it is not sufficiently large to materially modify the statements made relative to the value of the carbohydates represented by this portion of the fodder.

§212. The sodic hydrate extracts of the three fodders differ greatly; that from the alfalfa shows a coefficient of digestion of 67.7, but about 43 per cent of the total extract is proteids (N. x 6.25); that of the corn fodder is poor in proteids and has a coefficient of only 36.3, while that from the saltbush is richer in proteids, about 20 per cent. of the extract consumed being proteids, and has a coefficient of digestion of 49, but that of the proteids contained in this extract is 70, so that the substances, other than proteids in this extract must have a low coefficient, which is consonant with the result obtained in the case of the corn fodder. The portion of this extract, sodic hydrate, having the greater value is probably the nitrogenous substance, while the carbohydrates possess the lesser value.

§213. None of our results are more instructive probably than those shown by the portion which resists the action of our solvents, even the chlorin followed by the caustic soda and sulfurous acid. We find that this residue from the alfalfa hay has a coefficient of digestion of 52.8, and that from the corn fodder a coefficient of 54.0 per cent. The boiling one per cent. solutions of hydric chlorid and sodic hydrate are pretty active agents, but moist chlorin is much more active, still the animal digestive processes effect the solution of upwards of 50 per cent. of the material in the good fodders, alfalfa and corn fodder, which has resisted these agents, while in the poor fodder, saltbush, these processes are capable of bringing only 29 per cent. of this residue into solution. It will be shown a little later that the heat values show a similar result.

§214. There is no evidence, that I have discovered, that the saltbush had any deleterious effect on the sheep, though I have been told that it acts as a laxative on cattle, and it did induce excessive thirst and urination in the sheep experimented with. There were no indications that the sheep were in the least uncomfortable. While the nitrogenous substances in this forage may be inferior in value to those in the alfalfa, there is no proof that they are. Two things are, however, clear—that they are much more abundant and have a much higher coefficient of digestion than those of the corn fodder; in fact, this fodder approaches the alfalfa in this respect more closely than either of the other fodders used in the experiment, and while I know nothing relative to the fuel value of the nitrogenous compounds, it may be assumed that the differences are not sufficient to completely reverse the indications given by the coefficients of digestion obtained for the proteids, according to which the saltbush should have a very much higher feeding value than the corn fodder, and nearly equal to that of the alfalfa. On the other hand, all of the data obtained indicate that the carbohydrates, whether soluble in the various menstrua or not, are difficultly digestible and, taken all together, are of low fuel value. This is particularly the case with the two important portions, the portion removed by hydric chlorid, 1 per cent. solution, and the cellulose or residue, the former having a coefficient of digestion of 39.9 and the latter of 29.0 per cent., as against 69.4 and 54.0 per cent., respectively, in the corn fodder. The factor in this fodder which seems to determine its feeding value is the character of the carbohydrates that it contains. The nitrogenous matters contained in the saltbush are abundant and are highly digestible. The carbohydrates are resistant to the processes of digestion. The sheep digested large amounts of protein, 1,090 grams, but relatively small amounts of carbohydrates, and the lot lost 8½ pounds in five days. The results obtained with this fodder are in strong contrast with the other two; with the alfalfa the sheep ate and digested large quantities of both nitrogenous compounds and carbohydrates, both those soluble in hydric chlorid, 1 per cent. solution, and those which resisted the action of all of our solvents; with the corn fodder, they consumed a relatively small amount of nitrogenous compounds, having a low coefficient of digestion, 37.7 per cent., and a relatively large amount of carbohydrates with a high coefficient of digestion. The total amount of dry matter consumed as corn fodder was smaller than with any other fodder used, still each of the animals gained flesh, the lot gaining 3½ pounds in five days.

§215. The urine was not collected in any instance, an omission which is especially regretable in the case of the saltbush, because a large amount of nitrogenous matter was digested and there was a pronounced loss, especially with one of the sheep, 6 pounds. This is the only case in which we found marked differences in the individuals, but we did observe that one of the animals evidently did not like portions of the timothy, and while two of them lost a little, one gained a little, while on an exclusively timothy ration. With the other fodders, they either all lost or all gained. With the alfalfa they each gained three pounds, with the sorghum they each lost about three pounds, with the corn fodder and native hay they each gained, the total gain for each lot being three and one-half pounds.

§216. The other fodders, timothy hay, native hay and sorghum, were not studied to the same extent as those already given. Of these three, the native hay is the only one on which the lot made a gain; one sheep made a gain of one-half a pound on the timothy, but each of the others showed a loss, so that the lot showed a slight loss.

§217. As the same general result, *i. e.*, a gain of three and a half pounds in each case, was obtained with the corn fodder and native hay, we will present the salient points in the character of these fodders so far as we can; the alcoholic extract of the corn fodder furnished 1,789 grams of digestible matter, 73.79 per cent. of the total extract; that of the native hay furnished 1,297 grams, 58.55 per cent of the total; the hydric chlorid extract of the corn fodder yielded 1,245 grams digestible matter, equal to 69.42 per cent. of the extract; that of the native hay 1,422 grams, equal to 64.04 per cent. of the extract; the sodic hydrate extract of the corn fodder yielded

342 grams of digestible matter, equal to 36.27 per cent. of the extract; that of the native hay yielded 575 grams, equal to 32.79 per cent. of the extract; the residue or cellulose from the corn fodder yielded 1,210 grams of digestible matter, equal to 54 per cent. of the residue and that of the native hay yielded 1,502 grams, equal to 50.57 per cent. of the residue.

§218. In the case of the timothy hay, the values of the respective extracts stand in the same order, but the digestible matter furnished in each case, the sodic hydrate extract excepted, is less than in the two preceding cases; the alcoholic extract furnished 1,085 grams of digestible matter; the hydric chlorid extract 1,099 grams; the sodic hydrate extract 733, and the residue of cellulose 932 grams. The digestible proteids (N. x 6.25) in these extracts were determined; in the alcoholic extract there were 129 grams; in the hydric chlorid extract 23 grams, and in that obtained by means of sodic hydrate 136 grams. The digestible proteids in the corresponding extracts of the corn fodder were found to be 141 grams in the alcoholic, 28 grams in the hydric chlorid, and none in the sodic hydrate extract. We see again, in the timothy hay, as in the saltbush, that a larger amount of proteids were digested and a decidedly smaller amount of carbohydrates, the most marked deficiency being in the portion designated as residue or cellulose. The feeding results were a loss in both cases, though with the timothy hay, it was only slight, and one sheep showed a slight gain, but this sheep digested two-thirds more crude fibre than either of the other two. This may, however, be an accident only. The proteids in the various extracts of the native hay were not determined.

§219. The extracts of the sorghum stand in the same order as those of the corn fodder, and the amount of digestible matter contained in the alcoholic extract is much larger, nearly twice as large, but that furnished by the hydric chlorid extract and by the residue or cellulose, furnishes one-sixth less than in the case of the corn fodder.

§220. So far as our analytical results and also the energy values obtained are reliable criteria, sorghum fodder would appear to be a good one, but the results as indicated by the weights of the sheep at the beginning and end of this experiment indicate that it is a poor fodder. The results were uniform, *i. e.*, each of the sheep lost three pounds and the conditions of the experiment were as favorable as we could make them; everything, in fact, was in favor of obtaining good results with this fodder. The weather was fair and moderately cool. The sheep were used to being handled. They fed freely and were allowed a liberal ration, still they lost weight, and the same sheep gained when fed on corn fodder, so that the individuality of the sheep is eliminated so far as this comparison of the corn fodder and sorghum is concerned. As I have elsewhere stated, any inferences from the analytical results or determinations of the fuel values and all personal opinion regarding the value of such sorghum fodder must be held in abeyance when the feeding results are so strongly against them.

§221. I do not know what the general judgment relative to the value of this fodder is, but Mr. Payne, who grew this sorghum, tells me that he and the party who joined him in his work with this sorghum, came to the conclusion that when fed alone it was of no value, which agrees with the results of my feeding experiments.

§222. The pentosans as represented by the furfurol show very marked differences. The four portions of the fodders which are of the most importance cannot be designated as in the case of the extracts, because they vary with each fodder. The alfalfa was beyond all question the best fodder experimented with, and we find considerable quantities of furfurol in each of the extracts made, but the three most important portions of the hay in furnishing digestible furfurol were the alcoholic and hydric chlorid extracts and the residue or cellulose. The sodic hydrate removed more furfurol from the fodder than any other solvent, but its coefficient of digestion is very low, 27.80 per cent., while the coefficient of digestion for the whole extract was high, 67.7 per cent. Cold water, hot water and malt extract and chlorin, with the subsequent washing with sodic hydrate and hydric sulfite, each remove some furfurol, but the quantities are relatively small and the coefficients of digestion vary greatly, which, owing to the relatively small quantities involved, is probably a matter of small importance. This class of substances, the pentosans, constitute about one-eleventh of the total dry matter digested by the sheep fed on alfalfa, about one-tenth of that digested as corn fodder and about one-thirteenth of that digested as saltbush, which is the smallest amount found in any of the six fodders.

§223. The fodders which stood nearest in value to the alfalfa were the native hay and corn fodder. This does not mean that they were nearly equal to it by any means, but the two fodders giving the next best results measured by the increase in the live weight. The lot receiving alfalfa gained nine pounds, while the lots receiving native hay and corn fodder, respectively, gained three and one-half pounds each. The lot receiving timothy hay lost one pound. The timothy and native hays are representative of the small grasses, as distinguished from the corn fodder, and are more nearly alike so far as the distribution of the pentosans is concerned than the native hay and corn fodder. From the smaller grasses, timothy and the native grasses, the largest quantities of furfurol are removed by the hydric chlorid and sodic hydrate. The next largest portion remains in the residue or cellulose. The coefficients of digestion of the furfurol contained in the respective portions of these hays are very different. The furfurol removed by the hydric chlorid has a coefficient of 32.8 in the case of timothy hay, and 44.04 in the native hay; that removed by the sodic hydrate has a coefficient of 11.54 in the timothy and 42.16 in the native hay, and that remaining in the cellulose has a coefficient of 50.12 per cent. in the timothy and 74.94 in the native hay. The furfurol in some of the other extracts shows higher coefficients of digestion, but owing to the smaller quantities concerned are of less importance.

§224. The amount of furfurol in the cellulose is usually large. In the cellulose from the alfalfa, 235.7 grams; from the timothy, 197.1 grams, and from the native hay, 219.1 grams. The alfalfa and native hays proved to be good fodders, the timothy hay a poor one.

§225. The distribution of the furfurol in the different portions of the corn fodder agrees with that of the hays already mentioned, in regard to the hydric chlorid and the sodic hydrate extracts, but the cellulose shows less furfurol and it has a very much lower coefficient of digestion. In the case of the corn fodder, the hydric chlorid extract shows the largest amount of furfurol, 371.8 grams, with a high coefficient of digestion, 66.25. The sodic hydrate extract consumed contained 236 grams of furfurol, coefficient of digestion 31.82. The next extract in importance, as indicated by the furfurol, was the hot water extract, in which the furfurol was wholly digestible. I have very strong misgivings as to the correctness of this determination and, for this reason, have attached but little importance to it; if, as I surmise, there is an error in this determination, it will increase the relative importance of the hydric chlorid extract. This corn fodder proved as efficient as the native hay in results obtained, *i. e.*, a gain of 3½ pounds live weight in the lot fed, but this lot did not consume as much dry matter by 1,811 grams as the one receiving native hay. The general coefficient of digestion obtained for the furfurol in corn fodder was found to be 60.19 per cent., which does not agree with that obtained by taking the sum of the furfurol found in the different extracts, being about 12 per cent. higher.

§226. It will be observed that on three of these fodders, the respective lots of sheep gained, and on the other three the lots lost. I have already mentioned timothy hay as one in which the lot receiving it lost in weight. The other two were sorghum and the saltbush, *Atriplex argentea*. Regarding the distribution and digestibility of the furfurol, representative of the pentosans, we find that in the sorghum, the three portions, the hydric chlorid extract, the sodic hydrate extract and the cellulose, contain practically the whole of it, and that the furfurol shows the following coefficients of digestion, 45.72, 25.44 and 48.72, respectively. In the saltbush we have to add the aqueous extract to the above. The alcoholic extract removed no furfurol or equivalent pentosan, but both glucose and sucrose were present and the extract was abundant, 3,197 grams of it having been consumed. The next salient feature in this connection is the low coefficient of digestion found for the furfurol, *i. e.*, 37.37; the pentosans extracted by the 1 per cent. solution of hydric chlorid are indigestible in this case, whereas it is highly digestible in the alfalfa and corn fodder and has a coefficient of 44.04 in the native hay. The coefficient of digestion for the furfurol in the cellulose of the alfalfa and native hay is 72.6 and 74.9, respectively, and is very low in that of the corn fodder, 32.57. There is no means of judging how much pith cellulose is represented in this corn fodder, and I know nothing about the deportment of this variety of cellulose. It is quite possible that this may have a noitceable influence on this result. In the three fodders which we find to be inferior or poor, timothy, sorghum and saltbush, we have low coefficients for the furfurol, the general coefficients being 36.24, 46.46 and 37.37, respectively, and for the furfurol in the cellulose 50.12, 48.72 and 26.49, respectively.

§227. I will again call attention to the fact that the cellulose obtained as the result of these treatments has, as a rule, a fairly high coefficient of digestion in those fodders which proved to be the best ones, in alfalfa 52.8, in corn fodder 54.0, in native hay 50.6, but lower in the other three, timothy, sorghum and saltbush, 41.6, 47.4 and 29, respectively. The digestible proteids in these fodders were in the alfalfa 1,325.09 grams, in the native hay 366.55 grams, and in the corn fodder 178.46 grams; these are the three fodders which caused the sheep to gain, the other three, timothy, sorghum and saltbush, caused them to lose. The following amounts of proteids were digested while the sheep were on these fodders, with the timothy 234.42 grams, with the sorghum 300.91 grams, and with the saltbush 1,089.80 grams, so that the loss is scarcely to be attributed to a lack of digestible proteids. The sheep digested almost as many grams of proteids with the sorghum as with the native hay and almost 1½ times as much as they digested in the form of corn fodder. They digested six times as much in the form of saltbush as in that of corn fodder, and while the one lot gained 3½ pounds on the corn fodder, the other lot lost 8½ pounds on the saltbush. My interpretation is that the differences in the results point to the absence of a sufficient amount of easily digestible carbohydrates in the timothy hay, sorghum and saltbush.

§228. I have in mind a little more definite idea when I use the term easily digestible than we sometimes have when we use this term. I do not simply mean that large quantities of the carbohydrates are taken up and a condition of comfort and general well being produced in the animal, but that the amount of energy necessarily used up in carrying on the animal functions while on the fodder and that used up in transforming the fodder constituents into forms which are assimilable by the animal are relatively small. In the case of the corn fodder, we observe better results with lower consumption of dry matter and energy than in the native hay—the two fodders producing the same results—while still larger quantities of both dry matter and energy were appropriated with the sorghum and saltbush, resulting in a loss instead of a gain. There was evidently more energy available for the production of flesh in the case of the corn fodder than in the two latter cases, though the total energy used up was less.

§229. We cannot present so full an account of the heat or energy relations of these fodders. We have determined the general values for all of the fodders, but have studied only three of them in detail. The amount of heat appropriated by the sheep from the respective fodders was as follows, given in small calories: Alfalfa, 30,955,663; sorghum, 25,088,621; saltbush, 23,149,533; native hay, 22,255,418; corn fodder, 19,424,180; timothy hay, 17,406,363 calories. We see that the energy appropriated by the animals does not stand in the order of the gain or loss. Alfalfa produced the greatest gain, and sorghum the greatest loss, with the saltbush very close to it. The native hay and corn fodder each produced a moderate gain, while the timothy produced a slight loss. As the urine was not collected, it could not be examined, and we do not know how much of the energy appropriated was voided in this form.

§230. The amounts of dry matter digested in the experiments with these several fodders were as follows: Alfalfa, 7,734 grams; saltbush, 7,351 grams; sorghum, 6,725 grams; native hay, 5,392 grams; corn fodder, 4,940 grams; timothy hay, 4,501 grams. We see that the order is the same as in the case of the heat or energy appropriated. The greatest gain, that made on alfalfa, agrees with the greatest amount of heat appropriated and the largest amount of dry matter digested, but the next two fodders on which gains were shown are not the next in the order of the energy appropriated or the dry matter digested, but form the fourth and fifth in this order, the timothy standing only about 2,000,000 calories below the corn fodder. The lot receiving the sorghum and appropriating 25,088,621 calories, showed a loss of 8½ pounds, and the one receiving the saltbush and appropriating 23,149,533 calories showed a loss of 8½ pounds, while that receiving timothy and appropriating 17,406,363 calories lost but one pound, and that receiving corn fodder and appropriating 19,424,180 calories gained 3½ pounds.

§231. It would seem then that it is not merely a question of the amount of energy that disappears or is appropriated, that produces the beneficial effects of a fodder, but that these may depend upon other factors, for instance, the amount of energy used up in the process of digestion. We have in the case of the corn fodder favorable results with smaller quantities of material than with any other fodder. We have 4,940 grams of dry matter digested which contained 178.46 grams of proteids, 1,734 grams of carbohydrates as sugars and pentosans, 1,211 grams as cellulose, and 1,817 of extractive matter, not more specifically classified, and from this the animal appropriated 19,424,180 heat units and showed a gain of three and one-half pounds of flesh. On the other hand, we find that the lot fed on the saltbush digested 7,351 grams of dry matter containing 1,090 grams of proteids, 1,280 grams of carbohydrates as sugars and pentosans, 2,064 grams of cellulose, and 2,917 grams of extractives which we have not endeavored to more nearly classify, and from this the animals appropriated 23,149,533 calories, losing at the same time eight and one-half pounds. It is just that I should repeat that, while each of the three sheep lost, one of them lost but one-half pound, but the aggregate for the lot was 8½ pounds.

§232. The heat values of the various extracts of the alfalfa, corn fodder and saltbush were determined, and we found that, as a source of energy, the portion that I have designated cellulose is one of the most important.

§233. I have designated it cellulose to distinguish it from crude fibre, because the portion usually designated as crude fibre was treated in a moist condition with chlorin and then washed and boiled with one per cent. sodic hydrate and subsequently with sulfurous acid. This treatment with chlorin, etc., removed a considerable portion of the energy, but this energy is of little value in any of the fodders, the greatest value being observed in the case of the alfalfa, in which 24.0 per cent. of this energy was appropriated, but in the saltbush and corn fodder it was of no value. The total amount of energy removed from the crude fibre of the saltbush by this treatment was 8,508,528 calories out of a total of 59,205,051 for the hay, and from that of the alfalfa 6,045,840 calories out of a total of 49,585,495 calories fed. The relative quantity of heat removed from the crude fibre of the corn fodder by the chlorin is much less, *i. e.*, 1,482,734 calories out of a total of a little over 25 millions consumed and was wholly non-available. The alcoholic extract is again shown to be the most important portion of the fodder. The heat appropriated from this portion of the alfalfa was 10.7 millions calories out of a total of 30.9 millions; from that of the corn fodder, 7 millions out of a total of 19.4 millions, and from that of the saltbush, 5.8 millions out of a total of 23.2 millions.

§234. The second portion in importance was not the same in the three fodders, it being the sodic hydrate extract in the alfalfa and saltbush and the cellulose in the corn fodder. In the alfalfa 8.2 millions calories and in the saltbush 5.5 millions calories were appropriated from the sodic hydrate extracts, but this extract of the corn fodder furnished only 2.1 millions calories. The third protein in importance in the alfalfa and saltbush was the cellulose, which furnished 5.95 millions and 4.4 millions calories, respectively, in these cases. The fourth one in order of value is, in the alfalfa and saltbush, the hydric chlorid extract, from which the sheep appropriated 3 millions and 4 millions calories, respectively. The extracts of the alfalfa have, in the order given, furnished the larger amounts of heat, both absolutely and relatively, but this is reversed in the hydric chlorid extract, that of the saltbush furnishing the larger quantity. The order of extracts of the corn fodder in regard to their heat value is a different one, the alcoholic extract standing first, the residue or cellulose standing second, the hydric chlorid extract standing third, and the sodic hydrate extract falling to the fourth place. In the alfalfa and saltbush, we have a large amount of proteids, but we have seen that these are very freely dissolved by the alcohol and are represented almost as largley by the alcoholic extract as by that of the sodic hydrate, as the following amounts digested in the two extracts will show:

Alfalfa	Alcoholic extract, 486 grams;	sodic hydrate, 698 grams
Saltbush	Alcoholic extract, 553 grams;	sodic hydrate, 378 grams
Corn Fodder	Alcoholic extract, 141 grams;	sodic hydrate, 000 grams
Timothy Hay	Alcoholic extract, 129 grams;	sodic hydrate, 131 grams
Native Hay	Alcoholic extract, 117 grams;	sodic hydrate, 194 grams

from which I infer that it is not probable that the value of the sodic hydrate extract in the alfalfa and saltbush is dependent upon the proteid content of the hays, but due to other compounds. In passing this subject, it may be noted that the proteids soluble in alcohol have as high or higher coefficients of digestion than those soluble in the sodic hydrate. The proteids soluble in hydric chlorid are less in amount and have lower coefficients of digestion than those soluble in alcohol or sodic hydrate.

§235. There appear now good reasons why the native and timothy hays might have repaid us for making a comparative study of them, even though the timothy has already been studied in this sense, at least to some extent, and the native hay could give results of a general value only.

§236. The native hay and corn fodder are apparently much more similar than any other two of the six; they gave the same feeding results and both effected it at a comparatively small cost of energy. This is particularly the case with the corn fodder, which produced a gain of 3½ pounds in the weight of the sheep receiving it on the minimum weight of dry matter digested and a minimum of energy, 4,940 grams of dry matter, 19.4 millions of calories, and a gain of 3½ pounds. Alfalfa produced a greater gain, but the sheep digested 7,734 grams of dry matter, appropriated 30.9 millions of calories and gained 9 pounds. The effect of poor fodders are best shown by comparison with these, as sorghum, for instance, the sheep digested 6,725 grams of dry matter, 25 millions calories, and lost 8½ pounds; as saltbush, they digested 7,351 grams of dry matter, 23.1 millions calories and lost 8½ pounds.

§237. The methoxyl group is present in all of these fodders, but it is not abundant and is digested to only a small extent, as indicated by our results, and whether it plays any part in determining the value of the fodder or not, is not apparent.

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