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THE AUSTRALIAN SALTBUSH

Its Composition and Digestibility

An Extension of Bulletin 135

By Wm. P. Headden

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THE AUSTRALIAN SALTBUSH

Atriplex semibaccata

By Wm. P. Headden

At one time this plant was thought to hold out considerable promise as a forage which could be produced under very unfavorable soil conditions and also with a very small rainfall. These are desirable properties provided the forage proves agreeable to the animals required to eat it, and it nourishes them well.

Its manner of growth and the difficulties presented in gathering it are minor points easily met, provided the forage is needed and desired. It was not supposed that it would take the place of alfalfa or any other good forage but simply be a substitute under conditions in which better forages could not be produced. Alfalfa needs a good many inches of water to produce even one good crop in a season, but this saltbush is said to do well with very little water; 4.7 inches is the figure given. Our ordinary forage plants will not grow with so little water. The need of forage plants in parts of this state has been attested for years by the makeshifts resorted to, such as the use of Russian thistles, sand-grass and some native saltbushes.

We have given the composition and digestibility of some of these in earlier bulletins, but this seems not to have helped the people whose interests we had in view. We called this plant, the Australian Saltbush, to the notice of dryland farmers 20 years ago in Bulletin 135 of this station.

Analyses Misleading

There is little value in an analysis alone as is abundantly shown in some of these experiments. We used two analyses, one of a hay, clover and mixed grasses, and one of oat-grass to illustrate this. The analysis of oat-grass, *Stipa viridula*, is in every respect apparently better than that of the hay; protein content is 1.8 times as large as in the hay. The amount of ash is not objectionable, the crude fibre is not excessive and the nitrogen-free extract is only about one-sixth less than in the hay. Mixed hay is a good forage. All stock eat it but they will not eat oat-grass, even green, if they can get anything else at all. Perhaps a better illustration of the unreliability of an analysis is a comparison of "native hay" a mixture of native, mostly meadow grasses, and sedges, corn fodders, and hay made of the native saltbush, *Atriplex argentia*. The analysis of these fodders is here produced.

NATIVE AND SALTBUSH (A. argentia) HAY AND CORN FODDER COMPARED

	Native Hay Percent	Corn Fodder Percent	Saltbush Hay Percent
Moisture	5.13	8.21	5.32
Ash	10.64	9.53	19.28
Ether Extract	3.13	1.55	1.46
Proteins (Nx6.25)	6.98	4.62	9.73
Crude Fibre	31.33	29.85	27.33
Nitrogen-free Extract	42.79	46.24	36.88
	100.00	100.00	100.00

The native hay is considered a good fodder. For sheep we found it moderately good, equal to, but not better than corn fodder. I wish to emphasize the fact that the statements made in this connection refer to results obtained with sheep. Other farm animals digest about the same amount as sheep, still the fodder might agree better with other animals. The sheep that we fed on this fodder lost very rapidly. If the rate of loss could have been maintained, the sheep would have lost more than their original weight in 90 days.

Coming back to our analyses, I think that the general judgment based on analytical results would be in favor of the saltbush hay. It is true that the ash is high, nearly twice as high as in the native hay. It is, however, only about two-thirds as high as in dried beet leaves, and the proteins (Nx6.25) are twice as high as in the corn fodder. The crude fibre is lower than in either of the other two and the nitrogen-free extract is only lower by 10 percent than in the corn fodder. These are the usual groups into which we divide fodders. We may add that neither of the plants is known to ever contain anything poisonous to stock as is sometimes the case with green sorghum.

The results of our feeding experiments bear no relation to the compositions set forth in these analyses. The native hay and corn fodder gave equally favorable results, a gain of 3.5 pounds in 5 days. This saltbush hay caused a loss of 9 pounds in 5 days. For our present purpose we consider only the analyses and the results. The native hay and the corn fodder were more than maintaining the animals but they were actually starving on the saltbush in spite of its apparently better analysis.

These are not the only instances that might be given. If Minnesota Early Amber sorghum and corn fodder be compared in the same way, we shall have the following:

	Sorghum Percent	Corn Fodder Percent
Moisture	5.75	8.21
Ash	8.17	9.53
Ether Extract	1.55	1.55
Protein	5.80	4.62
Crude Fibre	23.26	29.85
Nitrogen-free Extract	55.47	46.24
	100.00	100.00

Here we have two quite similar plants and the composition is not so very unlike. The sorghum is the richer in proteins and easily soluble carbohydrates, or nitrogen-free extract, and lower in crude fibre. The feeding results with these samples were: Sheep fed on sorghum lost 7.5 pounds; fed on corn fodder they gained 3.5 pounds, a difference of 11 pounds of flesh in 5 days. The coefficients of digestion are not apparently wide enough apart to account for the results obtained, and by chance, the same sheep were used in the two series of experiments and during the same season, so they were of the same age and the idiosyncrasies of the animals were the same. The only explanation that we have to offer is the evident one, expressed by the loss of 7.5 pounds of flesh, to-wit: The sorghum was lacking something needed by the sheep. We say it did not agree with them, but the corn fodder did. Both of these fodders were in excellent condition when fed and there was no mature corn in the fodder. What principle was lacking in the sorghum we do not know. There were no other signs of any injurious effect upon the sheep.

It is a question whether the ordinary analysis, such as is quoted here, is really sufficient to give more than a general idea of the possible value of a fodder. The coefficients of digestion, at least some of them, perhaps the most of them, may be good, but the testimony of the animals experimented with may be adverse. Our experiments with the hay of a native saltbush illustrates this.

The saltbush was *Atriplex argentia.* The analysis of this hay gave proteins (Nx6.25) 9.73 percent, nitrogen-free extract 36.88 percent, crude fibre 27.33 percent. The average coefficients of digestion found for three sheep were, for protein, 66.35; nitrogen-free extract, 49.16; fibre, 8.29. The same for alfalfa are proteins, 72.54; nitrogen-free extract, 72.89; fibre, 49.93. The consumption of proteins in the two cases, saltbush and alfalfa, was very nearly the same so that the amounts of proteins digested were also nearly the same—1309 grams with alfalfa and 1096 grams with saltbush, but the feeding results were very different. The sheep fed alfalfa gained 9 pounds and those fed saltbush lost 8.5 pounds.

The question arises: Do the differences in the observed coefficients of digestion and the composition of the fodders give us the explanation for the results? Two points are fixed with reasonable certainty—the amounts of the protein, etc., used and the final weights of the animals. The amounts of protein and nitrogen-free extract digested were: Three sheep fed on alfalfa; protein, 1308 grams, nitrogen-free extract, 2544 grams. Three sheep fed on saltbush; protein, 1096 grams, nitrogen-free extract, 3012 grams.

The sheep digested 212 grams less protein and 468 grams more nitrogen-free extract when feeding on saltbush hay than when feeding on alfalfa, but of crude fibre the sheep feeding on saltbush hay digested 1534 grams less than those eating alfalfa hay. If our analytical and experimental results are criteria, then the alfalfa hay is better than saltbush hay because its crude fibre is digestible while that of the saltbush is indigestible. The animals eating alfalfa gained flesh while those eating saltbush lost. The legitimate inference is that the important factor is neither protein nor nitrogen-free extract but the crude fibre. This would be difficult to believe.

Our Criteria Unsatisfactory

Assuming that these three parts of the fodders contain all and the only factors that participate in any essential way to the nourishing of the animals, the legitimate inference is, comparing alfalfa and saltbush hay, that the crude fibre must be the important factor in producing the bad results obtained in the case of the saltbush or the good ones in that of the alfalfa hay; but in comparing alfalfa and sorghum, the inference is that the proteins are the important factors. With the digestion of large amounts of proteins we have a good gain; with small amounts, a decided loss, but with corn fodder we have a satisfactory gain, 3.5 pounds, with the digestion of only one-sixth as much protein as they digested when fed saltbush, and one-seventh as much as when fed alfalfa. The nitrogen-free extract digested when corn fodder was fed was considerably less than with either of the other three fodders and the crude fibre was for the three sheep only 130 grams more than was digested when they were fed sorghum. The same three sheep were used in these experiments. The cheapest gain was made with the corn-fodder.

In regard to the water consumed, the saltbush caused the animals to drink about twice as much water as when fed other fodders. How much weight is to be attached to this factor in judging of its value I do not know, but no excess of water was drunk when sorghum was fed, when the loss was likewise 8.5 pounds in 5 days. The proteins digested when sorghum was fed totalled 301 grams by the three sheep. When saltbush was fed, 1098 grams were digested and the loss was nearly equal, 8.5 against 7.5 pounds. The data obtained by analyzing the fodder and determining the coefficients of digestion are not adequate to explain the results obtained. All that we can state is that alfalfa and corn fodder are good fodders for sheep and that sorghum and this saltbush are not good ones for sheep.

So far we have omitted two groups, the mineral constituents or ash, and the ether extract. The ash is highest in the saltbush and next in the alfalfa, and about 9 percent each in corn fodder and sorghum. The ether extract is so nearly the same in each that, so far as the quantity is concerned, we cannot attach any importance to the differences. It does not follow, however, that it is not important.

It seems certain that we have not considered the real causes of the differences in the values of these fodders.

Heat Energy as Criterion

We attempted to find a better explanation in another relation, i. e., in the heat or energy of the fodders. This is no less unsatisfactory. The energy appropriated by the animals was, when fed alfalfa: 30,955,663 small units of heat; corn fodder, 19,424,180; sorghum 25,088,621; and saltbush, 23,149,533. The sheep appropriated more energy from alfalfa and made more gain than when fed corn fodder and the gain is relatively greater with the alfalfa than with the corn fodder, i. e., the energy appropriated from the alfalfa is about 1.6 times that appropriated from the corn fodder while the gain is 2.6 times that made with the corn fodder. This result cannot be wholly due to the energy used for they appropriated more energy with the saltbush and also with the sorghum than with the corn fodder but the animals lost 8.5 pounds in 5 days on these fodders, whereas they gained 3.5 pounds on the corn fodder.

Neither the analyses nor the determinations of the heat or energy values have revealed the actual values of the fodders. The feeding experiments show that alfalfa and corn fodder are good but that sorghum and saltbush are very poor when fed alone.

Sorghum and Saltbush Prepared As Emergency Fodders

The saltbush hay and the sorghum also were gathered as emergency fodders to tide stock over periods of stress. They were fed to animals protected from the weather and made as comfortable as we knew how, but the results show the fodders to be very poorly fitted for the purpose that they were intended to serve. The animals lost flesh rapidly under these favorable conditions. Had they been exposed to cold high winds and snow, it would have been even worse for them.

These are the only fodders prepared with this object in view. Alfalfa, timothy and native hays are out of the question under dryland conditions. Mixed rations are also not to be considered in connection with these emergency fodders. But alone these will not maintain an animal living under the most favorable conditions for even the few days of a digestion experiment,—12 days in all, 7 days preliminary feeding and 5 days actual observation. It was during these last 5 days that the sheep lost 8.5 pounds when fed these fodders. The animals were actually starving tho they were eating plenty.

The question for our dryland farmer was and still is, what emergency ration can be provided which is better than these. For him alfalfa and the ordinary fodders are out of the question. His choice is confined to what he may be able to grow in sufficient volume to supply his requirements. This was the question we had in view in making these experiments and was the reason for our procuring fodders grown under those conditions and prepared for actual use and not for our special purpose. The results, however, have a much wider significance, but this does not alter the practical fact that saltbush hay and sorghum fodder constitute a starvation diet for sheep. How bad this would be if the animals were exposed to cold, or high winds with rain or snow, the writer has no idea.

It seemed unfortunate that these two fodders should be the ones available to the ranchmen of our drylands, a section in which there is sometimes a lack of pasture except in favorable seasons. The native grasses are nourishing but, like other plants, they can make only little growth with the water available. Further, they are slow in reestablishing themselves when broken up or killed out.

It has been stated that the sorghum used was Minnesota Early Amber, a saccharine variety, but I understand the non-saccharine sorghums are more commonly grown.

Australian Saltbush

We studied the Australian Saltbush, *Atriplex semibaccata*. The reasons for this choice were that it was commended as the best of the saltbushes as a fodder and succeeds with a small amount of water.

With us it grew vigorously; of course, it had plenty of water, and the soil was a rich loam. The dryland soil may be good but the water would be much less than it had in our case. The habit of the plant with us was prone but the diameter of single plants was commonly as much as 7 feet. A diameter of 18 feet is recorded for it. We cut it and made it into hay for our digestion experiments. I do not know what kind of a winter pasture it would have made.

The plant with us was an annual but seeded itself abundantly. These cultural features were not the object we had in view but we grew it for eight seasons on two types of soils and it did well in all cases. We fed it green to a horse with good results, at least the animal seemed to do well on it, tho it was not weighed; also to some (3) old sheep for 3 weeks. These animals maintained their aggregate weight. The digestion experiments were made with sheep going on two years old. The results of these experiments are given in Bulletin 135, Colorado Experiment Station, 1908. The coefficients of digestion found were very good indeed. Compared with alfalfa and native hay, they stand as follows:

	Dry Matter	Ash	Fat	Protein	Fibre	Extract
Alfalfa	63.95	57.67	29.86	72.54	49.93	72.89
Australian Saltbush	60.48	59.64	24.46	84.65	27.30	63.83
Native Hay	50.53	42.52	20.55	62.33	55.56	51.30

The alfalfa was of good quality grown at Fort Collins.

The dry matter of the saltbush is almost as digestible as that of the alfalfa but this tells us only that the animals appropriate almost as much of the one hay as of the other. The ash is both larger in amount in the saltbush and is more freely taken up by the animal. This is not necessarily good, it might be the opposite, but in this case we observed no indication that this was the case. When the plant was fed in the green state, it had a laxative effect at first but this disappeared shortly and the animals did not seem to suffer inconvenience of any sort. The protein is not only very abundant in the hay, 20.6 percent in that used in the digestion experiment, but it has a very high coefficient of digestion, 84.65 against 72.54 for the protein in alfalfa hay, of which it constituted 15.03 percent. The coefficient for the crude fibre is quite low, 27.3, but that for the nitrogen-free extract is fairly high, 63.83. We have put beside these the coefficients of digestion found for a good quality of native hay, which are lower thruout than those for the saltbush. The sheep fed the native hay, whose coefficients are given above, gained 3.5 pounds in 5 days, and on the saltbush 1 pound. The crude fibre is the only group in the native hay having a higher coefficient of digestion than in the saltbush. It should also be noted that, while no sheep in either series lost weight, more than two-thirds of the total gain made when fed native hay was made by a single sheep, the other two making the same gain that two of those fed on saltbush made, while the third animal fed on saltbush neither gained nor lost.

Australian Saltbush Varies Greatly in Composition

The saltbush hay was very good. The plants were cut before many seed were ripe and were cured on canvas in order to save all the leaves. The protein was higher in this sample than any other analyzed. Our samples of this hay made in different seasons varied very greatly in this respect. Some of our samples were the lowest that I found given for the plant and this one was the highest. The plant seems to vary greatly according to the soil in which it is grown but a part of the differences observed may have been due to loss of leaves and other causes. The variation in the composition of the ash points to the soil as having an unusual influence upon this plant. This chlorin, for instance, in the ash of this plant grown on good soil—we can, I think, properly designate it as alkali-free soil—was less than 6 percent, 5.82, whereas in that of plants grown on alkali soils it was 20.8 and

24.33 percent, and the ash in our hay was about 18.0 percent in all of our samples, also in Californian samples, but is given as 13.09 percent in hay grown in South Dakota.*

The hay is not so good as alfalfa hay notwithstanding the high coefficients of digestion for all groups except the crude fibre. On the other hand it is as good as timothy and native hay and decidedly better than the sorghum that we fed.

The details of these data were published in 1908, (Bul. 135, Colo. Exp. Sta.) at which time little or no interest seemed to be taken in the matter and there seemed to be no adequate object for giving the following data, but they present further features of the question which may have value enough to justify their presentation.

DATA ON AUSTRALIAN SALTBUSH. *Atriplex semibaccata.*
Composition of the Hay and Coefficients of Digestion.**

	Moisture	Ash	Fat	Protein	Fibre	N-Free Extract
Hay	3.645	18.635	1.370	20.600	16.382	39.368
Orts—						
Sheep No. 1	3.610	21.668	1.460	20.820	15.233	37.209
Sheep No. 2	3.595	24.251	1.400	20.310	13.287	37.157
Sheep No. 3	3.485	22.156	1.400	20.500	14.502	37.957
Feces—						
Sheep No. 1	4.560	14.974	2.350	7.940	35.417	34.759
Sheep No. 2	4.525	15,894	2.240	8.090	32.142	37.109
Sheep No. 3	4.820	17.848	2.880	7.750	31.205	35.497

Experimental Data—Sheep No. 1 received 6,577 grams of hay.

	Dry Matter	Ash	Fat	Protein	Fibre	N-Free Extract
Hay	6337.27	1225.62	90.11	1354.86	1077.44	2589.24
Orts	4192.00	942.34	63.50	905.46	662.48	1618.22
Consumed	2145.27	283.28	26.61	449.40	414.96	871.02
Voided	1089.93	171.03	26.83	90.67	404.46	396.94
Digested	1055.34	112.25	-0.22	358.73	10.50	574.08
Coefficients of Digestion	49.19	39.57	....	79.74	2.53	58.85

This animal weighed at the beginning of the experiment 78¼ pounds, and at the end 78½ pounds.

Sheep No. 2 received 7,938 grams of hay.

	Dry Matter	Ash	Fat	Protein	Fibre	N-Free Extract
Hay	7648.66	1479.30	108.76	1635.20	1300.40	3125.00
Orts	2056.32	517.28	29.86	433.21	283.41	792.56
Consumed	5592.34	962.02	78.90	1201.99	1016.99	2332.44
Voided	2195.93	365.57	51.52	186.07	739.26	853.51
Digested	3396.41	596.45	27.38	1015.92	277.73	1478.93
Coefficients of Digestion	60.87	62.00	34.70	84.52	27.31	63.41

This sheep weighed at the beginning of the experiment 79¼ pounds, and at the end 80 pounds.

Sheep No. 3 received 7,938 grams of hay.

*Bul. 69, South Dakota Experiment Station.

**Table from Colorado Experiment Station Bulletin 135, p. 10.

	Dry Matter	Ash	Fat	Protein	Fibre	N-Free Extract
Hay	7648.66	1479.30	108.76	1635.20	1300.40	3125.00
Orts	2565.37	588.91	37.21	544.89	385.45	1008.89
Consumed	5083.29	890.39	71.55	1090.31	914.95	2116.11
Voided	2028.29	380.34	61.37	165.94	664.98	755.66
Digested	3055.00	501.05	10.18	924.37	249.97	1360.45
Coefficients of Digestion	60.10	57.28	14.23	84.78	27.29	64.29

This animal weighed at the beginning of the experiment 85.75, at the end 85.5 pounds.

PROXIMATE COMPOSITION OF AUSTRALIAN SALTBUSH HAY

Soluble in	Percent air-dried hay				
Eighty percent alcohol	30.107	Glucose	1.27*	Sucrose	0.45
Cold water	11.695	Gums	0.45		
Hot water and malt	4.452	Starch	0.52		
One percent hydrochloric acid	19.075	Xylan	4.77		
One percent sodic hydrate	15.482	Xylan	0.77		
Chlorin, etc.**	3.897				
Cellulose or residue	14.441				
	99.149				

*The reducing power of this decolorized extract is attributed to glucose and the increase effected by boiling with dilute sulfuric acid to sucrose.

**This consisted of treating the wet residue, after boiling with sodic hydrate, with chlorin for one hour, then boiling with sodic hydrate and finally with sulfurous acid.

EXPERIMENTS WITH SHEEP NO. 1

COEFFICIENTS OF DIGESTION FOR THESE EXTRACTS

	Total fed grams	Orts grams	Consumed grams	Voided grams	Digested grams	Coefficient grams
Eighty percent alcohol	2036.0	1392.7	643.3	172.2	471.1	73.23
Cold water	769.2	556.6	212.6	68.3	144.3	67.88
Hot water	292.8	317.2	-24.4	43.2	-706.	
One percent HCl	1254.6	721.7	532.9	321.7	211.2	39.63
One percent NaOH	1018.2	626.2	392.0	176.7	215.2	54.92
Chlorin	256.3	157.2	99.1	111.1	-12.0	
Cellulose	949.8	567.3	382.5	248.8	132.7	34.95
	6576.9	4338.9	2262.4	1142.0	1126.6	54.12

The orts gave a larger amount of hot water soluble than was contained in the fodder fed. This is the result obtained. We have no facts to give in explanation. The sheep, however, nosed the hay and rejected the leaves and to what extent it moistened these with saliva is unknown and how much difference such a fact might have made is also unknown. Notwithstanding the negative results given in the table, the coefficient of digestion calculated from these experiments for the dry matter of this hay is 49.50 against 49.19 found by using the whole hay and dung voided, so the results seem to be fairly reliable. With feces it has happened to us before that we have obtained negative digestibility due probably to the character of the fecal matter. The preceding table considers the total extracts and does not attempt to divide them into any further components.

Sugars in Australian Saltbush Hay

The hay, however, contains some ready-formed sugars, gums, starch, hemicelluloses and cellulose proper. The gum, starch and celluloses can be converted wholly or partly into sugars that will reduce a Fehling's solution, i. e., throw down cuprous oxid. The compounds yielding these reducing sugars are unequally attacked by dilute hydrochloric acid and sodic hydrate. In some cases the hydrochloric acid extract shows a relatively large amount of reducing sugar, in others the sodic hydrate.

In the alcoholic extract after precipitation of coloring and other matters by lead acetate, sodic sulfate and copper sulfate, the solution is colorless unless an excess of copper sulfate has been added. The reducing power of this solution is attributed to the presence of glucose. This reducing power is increased on boiling with addition of sulfuric acid; this increase is attributed to the presence of sucrose because this would be the action of sucrose if it were present. The probability is that these sugars are actually present, but their quantity is small.

The reducing power of the inverted cold water extract is attributed to gums while that of the hot water and malt extract after deduction of the reducing power of the malt extract used is attributed to starch. None of these substances is present in the saltbush hay in any significant quantity.

The hydrochloric acid and sodic hydrate in succession attack the hemicelluloses with the production of reducing sugars. They presumably attack different groups and the sugars produced are proportional to their respective amounts present.

The treatment with chlorin, sodic hydrate, and sulfurous acid in succession had for its object the removal of lignones and the separation of comparatively pure cellulose. This extract showed no reducing action on Fehling's solution.

DIGESTIBILITY OF THE SUGARS IN THE EXTRACTS

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Glucose	83.53	52.95	30.58	none	30.58	100.00
Sucrose	138.18	85.47	52.71	6.51	46.20	87.65
Gums	29.59	25.16	4.43	4.23	0.20	45.14
Starch	34.20	10.44	23.76	none	23.76	100.00
Xylan (HCl)	313.72	195.25	118.47	90.78	27.69	23.37
Xylan (NaOH)	46.03	36.88	9.15	18.49	9.34	
Chlorin	None					
Cellulose	949.81	567.11	382.70	249.42	133.28	34.83

These sugars or carbohydrates, except the xylan, exist ready formed in the hay. Whether the sugar, here called xylan, split out by the sodic hydrate, is derived from the same parent substance in the fodder that yields this sugar on boiling with hydrochloric acid is not established. We have found but one case in the examination of six fodders in which there was any considerable quantity of this sugar, i. e., in corn fodder where the coefficient of digestion was found to be 28.20 percent. This does not mean that the digestion of the sugar proper was low but that the hemicellulose from which it was derived was in this case very resistant. The determination is probably correct and corresponds to an actual difference in the fodder. This is furthermore the only case in which boiling with 1 percent hydrochloric acid failed to remove practically the whole of this sugar or its corresponding hemicellulose.

The presence of fecal matter in the voidings that resists the hydrochloric acid but reacts with the sodic hydrate is indicated in the other cases. In the case of the corn fodder only is the amount of this xylan, formed by boiling the residue from the hydrochloric acid treatment with sodic hydrate, sufficient to show positively that any of it has been digested. Native hay gave a small amount but not large enough to justify considering it a positive result. In all cases except the corn fodder it appears that the whole of this xylan should be obtained in the 1 percent hydrochloric acid extract; in this respect the corn fodder differs from all the others.

Cellulose

The cellulose which in these analyses is comparatively pure, remaining after successive treatments with 1 percent hydrochloric acid, 1 percent sodic hydrate and then with chlorin gas and water with subsequent boiling with sodic hydrate and sulfurous acid shows a big variation in its coefficient of digestibility as is shown by the following arrangement of them.

Corn fodder	54.00 percent
Alfalfa	52.67 percent
Sorghum	47.44 percent
Timothy hay	41.61 percent
Australian Saltbush	34.83 percent
Native Saltbush *A. argentia*	28.97 percent
Native hay	16.47 percent

This cellulose is the crude fibre of our ordinary fodder analysis after it has been treated in the wet condition for one hour with chlorin gas and then boiled successively with sodic hydrate and sulfurous acid and its coefficient of digestion is different from that of the technical crude fibre as ordinarily given. The coefficients for the crude fibre obtained for the samples of fodder just cited were as follows:

Corn fodder	56.71
Native Hay	55.56
Alfalfa	49.95
Sorghum	49.23
Timothy	36.08
Australian Saltbush	27.29
Native Saltbush	8.29

These results show that the cellulose is strongly acted on in the alimentary canal of the sheep but that the chlorin extract is scarcely attacked at all. This may be bad chemistry for the lignones removed by the chlorin treatment are closely related to the resulting woody fibre or cellulose. It would seem, however, that they resist the digestion of the sheep to a greater extent than the fibre or cellulose itself.

Furfural

There are carbohydrates in the fodders which on acid hydrolysis yield reducing sugars and under proper conditions the aldehyde known as furfural which can be made a measure of them. In the following table are the results obtained in trying to find to what extent these are digestible.

COEFFICIENTS OF DIGESTION FOUND FOR FURFURAL IN AUSTRALIAN SALTBUSH HAY AND ITS EXTRACTS.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Hay	602.5	320.3	282.3	122.9	159.3	56.45
Extracts						
Eighty percent alcohol	93.71	0.00	93.71	24.43	69.28	73.93
Cold Water	157.68	97.84	59.84	1.47 (Cold and Hot water)	68.69 (Cold and Hot water)	97.90 (Cold and Hot water)
Hot water	30.32	20.00	10.32			
One percent hydrochloric acid	114.17	108.83	5.34	43.21	-37.87	
One percent sodic hydrate	129.24	51.03	78.21	51.03	27.18	53.26
Chlorin	28.87	19.05	9.82	6.80	3.02	30.57
Cellulose	49.26	26.68	22.58	26.68	-4.10	
			259.82	113.62	146.2	56.27

The coefficients for the furfural found for the different extracts vary and the feces, especially in the case of the hydrochloric acid extract yield more furfural than was contained in the fodder consumed, approximately eight times as much. We offer no explanation. The result for the orts is doubtful. The hydrochloric acid extract has in most cases, five out of seven including the present one, shown a medium coefficient of digestion, that of alfalfa a high one, 100 percent, while our native, the silvery saltbush, like the present one gave a negative result.

The coefficients found for some other fodders are given in the following table:

	Alfalfa Hay	Timothy Hay	Native Hay	Corn Fodder	Sorghum Fodder	Silvery Saltbush
Eighty percent alcohol	99.51	69.47	61.91	94.80	22.91	....
Cold water	100.00	71.07	6.79	100.00		88.99
Hot water and malt	67.44			100.00		
One percent hydrochloric acid	100.00	32.80	44.04	73.17	45.72	
One percent sodic hydrate	27.81	11.54	42.16	31.80	25.47	46.35
Chlorin		98.54		32.57	48.72	26.40
Cellulose	72.62	50.12	74.94			
Coefficients for whole hay	65.15	36.24	50.99	47.07	46.46	37.37

The sheep fed on alfalfa gained 9 pounds, on corn fodder 3.5 pounds, on native hay 3 pounds, on timothy no gain, on sorghum they lost 8.5 pounds and the same when fed the silvery saltbush, *Atriplex argentia*, but when fed Australian saltbush, *Atriplex semibaccata*, they held their own. The total difference found was .75 pound.

The Proteins

The coefficient of digestion of the proteins in this Australian saltbush hay, even with sheep No. 1 which did not take kindly to the fodder and made some trouble thru the feeding period, refusing to eat the leaves and behaving itself more or less badly, was high, 79.74 percent, and in the case of the other two sheep, it was 84.52 and 84.78 percent respectively.

COEFFICIENTS OF DIGESTION FOR THE PROTEINS IN THE RESPECTIVE EXTRACTS AS GIVEN BY SHEEP NO. 1

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Eighty percent alcohol	592.25	401.37	190.88	13.50	177.35	92.91
Cold water	49.92	45.09	4.83	18.41	-13.28	2.00
Hot water and malt	39.20	45.65	-5.89	....	2.00	2.00
One percent hydrochloric acid	219.75	116.87	102.88	....	102.80	100.00
One percent sodic hydrate	421.98	277.56	144.42	49.41	95.01	65.77
Residue	26.05	16.96	9.09	9.08	none	
			452.99		375.2	82.82

The nitrogen in the fodder that is soluble in 80 percent alcohol is highly digestible and that soluble in the 1 percent hydrochloric acid is even more so and the quantities extracted by these solvents are large. The quantity soluble in 1 percent sodic hydrate is larger than that soluble in hydrochloric acid and is also quite digestible but less so than the hydrochloric acid soluble.

The Urine

The protein (Nx6.25) found in the feces is assumed to be contained in undigested residues of the fodder and is usually only about 35 percent or less of that eaten. The amount voided in the urine becomes a measure of the use made by the animal of the protein digested, the extent to which it is changed and used up so far as the system is capable of using it. When the nitrogen compounds have reached this stage, they are eliminated. In the case of the native, silvery saltbush hay the animals consumed and digested almost as much protein (Nx6.25) as when they were fed on alfalfa hay; the proteins consumed in the former case were 1651 grams by the 3 sheep in 5 days; in the latter 1813, a difference of 162 grams. It happened that the same sheep were used in the two series of experiments so there was no allowance to be made for the individualities of the sheep. Those fed the saltbush digested 1095 grams of proteins, and those fed alfalfa, 1318 grams, a difference of 223 grams in favor of the alfalfa. While eating the saltbush, they drank a great deal of water and urinated freely. This was not examined nor even measured. The difference between the results of these two experiments was 17.5 pounds of flesh. Those fed on saltbush hay lost 8.5 pounds and those fed alfalfa gained 9 pounds. The sheep feeding on the saltbush hay did not appear to suffer any inconvenience but ate well and were contented. The only unusual features were excessive thirst and free urination. What produced the thirst and urination we do not know. The amount of ash constituents digested was larger in the case of the saltbush by 1524 grams than in the case of the alfalfa. What effect this may have had either in inciting the urination or in provoking thirst, I do not know.

The composition of the two ashes is quite similar. The coefficient of digestion is higher for that in the saltbush, 71.6 against 57.7 percent in the alfalfa. The principal difference in the composition is in the amount of carbonates in the prepared or carbonated ash. Potassium salts are very freshly taken up by the system, more largely so from the saltbush than from the alfalfa. These questions were not entered on beyond the analyses of the ash of the respective hays and dungs.

In the case of the Australian saltbush, we collected the urine and determined the amount of nitrogen eliminated during the period of the experiments. We shall multiply the amount found by 6.25 as tho we were dealing with proteins and this will, I think, serve our purpose. We fed a certain amount of nitrogen which we multiplied by 6.25 and of this a certain amount was taken up by the animal during 5 days. During the same time, it eliminates a given amount which we likewise multiply by 6.25 and the difference gives us the amount changed in the animal's system. The animal itself is either gaining or losing weight and possibly doing neither, when we are just maintaining its condition. In this case the animal is building up out of the fodder eaten just as fast as the life processes are tearing them down. These processes are just in balance and the ration is a maintaining one for the time, at least, over which our observations extend. Our coefficients of digestion are based on such results.

These results are not adequate to answer the further question: Are the fodders sufficient to maintain the animal in normal health over a greater time without the aid of something else? We have called attention to the marked insufficiency of some fodders to maintain the weight of the sheep even for the short period of 5 days, i. e., the native saltbush and the sorghum, while timothy hay scarcely more than maintained the animals, but native hay, corn fodder and especially alfalfa hay enabled the animals to take on weight. The first pair of fodders constituted a veritable starvation diet; the second maintained the animals with a very slightly favorable margin; the third group was increasing the weight of the animals. We have suggested that the composition and coefficients of digestion were not adequate to explain these differences, but we did not examine the urine to see what was becoming of the nitrogen and the heat energy that was digested. We did determine the heat energy ingested and the amount taken up by the animal, i. e., digested, but made no attempt to determine how much was voided in the respiration and urine or otherwise escaped. We could not even attempt to ascertain this fraction but the animals were protected from the weather and wore good fleeces of wool so they were not unduly cooled by unfavorable weather conditions.

The urine voided by sheep No. 1 for which alone we have so far given our data voided during the 5 days the following quantities:

PROTEIN EQUIVALENT TO NITROGEN IN URINE OF SHEEP NO. 1 VOIDED IN 5 DAYS

	Grams Voided	Percent Nitrogen	Grams Protein
First	1023.0	1.335	83.50
Second day	718.5	1.512	67.95
Third day	1150.9	1.287	92.58
Fourth day	1269.3	1.180	94.00
Fifth day	1547.9	1.058	102.36
Total voided			440.29
Total digested			358.76
Excess voided			81.53

According to this there was a loss of proteins greater by about 81.53 grams than the amount taken up from the fodder consumed or 358.76 grams. Our record shows that this sheep gained .25 pound. The total difference is essentially .5 pound. According to our weighings, the animal gained .25 pound but according to our analyses, it should have lost .25 pound. This is on the assumption that the loss and gain depended wholly upon the proteins digested and voided and that the nitrogen voided in the urine is exactly equivalent to the same nitrogen digested by the animal. These quantities, the nitrogen digested by the animal and that in the urine, are so nearly equal and the weight of the animal before and after the experiment is so nearly the same that the conclusion to be drawn is that we were simply maintaining the animal under the conditions of the experiment which were favorable. This was the result obtained in an earlier experiment with old sheep, i. e., they maintained their weight when fed green Australian saltbush for a period of 3 weeks and not for only 5 days as in this experiment.

The preceding statements are based upon the coefficients of digestion obtained experimentally and on the assumption that the proteins are important compounds in the fodder, which may not be correct. There are, however, other relations which we may adopt and which give us another measure, i. e., the heat produced when the fodder is completely burned, compared with that of the feces. We may even go farther and ascertain the value of the respective extracts of the hay and the feces and in this way ascertain how much energy the fodder yields to the animal's system. We can also ascertain the amount of heat or energy that escapes from the animal as urine. The amount lost from the body to the air and as water vapor we could not determine. Other experimenters have determined this not for our fodder, however, but for other fodders.

We have tried to work out our problem in this regard as far as we could and present the results.

We designated the ascertainment of the amount of soluble matter yielded to various solvents by the hay, orts and dung as a proximate analysis in Bulletin 124 and shall use the same designation here.

PROXIMATE ANALYSIS OF AUSTRALIAN SALTBUSH HAY, ORTS AND DUNG OF SHEEP NO. 1 FED ON IT.

	Hay	Orts	Dung
Soluble in 80% alcohol	30.958	32.098	15.081
Soluble in cold water	11.695	12.830	5.980
Soluble in hot water	4.452	7.310	3.780
Soluble in 1% hydrochloric acid	19.075	16.633	28.167
Soluble in 1% sodic hydrate	15.482	14.432	15.475
Soluble in chlorin, etc.	3.897	3.622	9.728
Cellulose	14.441	13.075	21.789
	100.000	100.000	100.000

HEAT VALUES OF ONE GRAM OF EXTRACT OF SALTBUSH, A. semibaccata, HAY, ORTS AND DUNG GIVEN IN SMALL CALORIES.

	Hay	Orts	Dung
Alcoholic extract	3404	3793	4753
Cold water extract	3839	2773	3193
Hot water, etc., extract		1846	3106
One percent hydrochloric acid	2809	2834	2914
One percent sodic hydrate	5079	4281	5039
Chlorin, etc., extract	5167	5083	6014
Cellulose	3876	3892	3986

Coefficients of digestion for the Heat Values

	Heat Units consumed	Heat Units voided	Heat Units appropriated	Coefficients
Whole Hay	10,082,149	4,621,674	5,460,470	54.15
Eighty percent alcohol	1,646,895	817,516	829,379	50.36
Cold water	1,352,170	217,124	1,135,046	83.97
Hot water	Negative*			
One percent hydrochloric acid	1,479,147	935,394	543,753	36.71
One percent sodic hydrate	4,053,809	891,933	3,161,906	78.00
Chlorin, etc.	526,277	667,544	-141,283	....
Cellulose	1,475,436	992,214	482,923	32.74

*This means that the orts contained more than the fodder fed.

The total urine voided by this animal in the 5 days of the experiment weighed 5706.9 grams. The heat value of this urine varied a little with the volume so we give the sum of the heat values found for the daily voidings which was 764,958 calories.

The heat appropriated by the animal from the whole hay was 5,460,470 calories. The urine voided was 764,958. This leaves 4,695,512 calories to be accounted for by the respiration and body losses of the animal, because there was no material gain in weight.

Heat Appropriated

The percentage of the total heat value appropriated by the animal, the coefficient of digestion, was, according to the results obtained by calculating this on the whole hay used, 54.15 percent. The amount indicated by the average of the positive results obtained with the different extracts of the fodder is 56.33 percent, as close an agreement as the method justifies us in expecting.

The results so far given were obtained with sheep No. 1, to which the fodder was not very acceptable, especially the leaves. Further, the animal showed signs of restlessness by butting the water container and otherwise. However seriously these facts may have modified our results, they are not bad; the animal actually gained a little flesh, not much, it is true, but enough to show positively that it did not lose in this time.

It should be kept in mind that our object is simply to ascertain whether this fodder is of sufficiently high quality to support animals for a reasonable period and not to ascertain its effect upon the growth and health of the animal if fed exclusively for a long period, when it might prove unable to maintain the normal health and functions of the animal. This is a question beyond our purpose and is a test in which many fodders considered good would fail to give favorable results. Only a few if any fodders when fed exclusively constitute a perfect ration.

In this connection, we recall the fact that the exigencies of the dry farmer are so pressing that sand grass and Russian Thistle are sometimes made into hay and the sorghum referred to in this and in Bulletin 135 was grown for this purpose.

RESULTS OBTAINED WITH SHEEP NO. 2

Reference to page 10 will show that the coefficients of digestion of the whole fodder obtained in the case of sheep No. 2 and No. 3 are somewhat different from those obtained with sheep No. 1 and are higher thruout. That for the dry matter of the hay is 60.87, ash 62.00, fat 34.70, protein 84.52, crude 27.31, and nitrogen-free extract 63.41. The coefficients for fat and crude fibre are low tho they are higher than those obtained in the case of sheep No. 1. The portion designated crude fibre from different plants shows different coefficients of digestion and apparently is far more important than is usually indicated in the literature of feeding. The coefficient for the proteins is high in each of the three cases.

COEFFICIENTS OF DIGESTION FOUND FOR THE EXTRACTS.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Eighty percent alcohol	2457.5	660.8	1796.7	361.4	1435.3	79.8
Cold water	928.3	226.6	701.7	136.3	565.1	80.5
Hot water and malt	383.9	128.7	255.2	90.8	164.4	64.4
One percent hydrochloric acid	1514.2	429.0	1085.2	643.6	441.6	40.7
One percent sodic hydrate	1228.9	301.4	927.5	312.7	614.8	62.3
Chlorin	309.3	78.7	230.6	216.3	14.3	6.2
Cellulose	1146.4	298.3	848.1	517.5	330.6	37.8

The crude fibre usually given in a fodder analysis corresponds to the last two portions in this table. The results agree with the preceding one for this portion in showing that its digestibility is low and that the portion digested belongs to the cellulose proper and not to the lignones which we aimed to remove by treatment with chlorin and subsequently with sodic hydrate and sulfurous acid.

We have already explained the significance of sugars in these analyses; that they correspond to certain carbohydrates from which they are derived. The only ready-formed sugars are the glucose and sucrose. The gums and starch exist in the fodder as such and are readily available carbohydrates. The portion designated as xylan means a form of sugar derived from the hemicelluloses by the action of hydrochloric acid and sodic hydrate used in succession. These results are probably not derived from the identical carbohydrates in different fodders. Most fodders, on being boiled with hydrochloric acid, yield the whole of this sugar that it is capable of yielding but not with equal readiness. A portion of the fodders resists the action of our solvents, even the most active ones, in the form of cellulose, a carbohydrate as well as the compounds from which the sugars given are derived, but this is not wholly indigestible tho' it has resisted all solvents. It is the last residue.

Sugars Digested by Sheep No. 2.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Glucose	100.8	26.2	74.6	None	74.6	100.0
Sucrose	170.6	36.7	133.9	7.8	126.1	94.2
Gums	35.7	10.2	25.5	5.1	20.4	80.0
Starch	41.3	12.2	29.1	None	29.1	100.0
Xylan, hydrochloric acid	378.6	92.8	285.8	176.5	109.3	38.2
Xylan, sodic hydrate	55.6	16.1	39.5	32.0	7.5	19.0
Chlorin						
Cellulose	1146.3	299.0	847.3	538.7	308.6	36.4

Furfural Digested by Sheep No. 2.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Whole fodder	113.1	18.6	94.5	52.8	41.7	44.1
Soluble in:						
Alcohol	189.9	49.6	140.3	16.7	123.6	87.9
Cold water	36.6	Little	36.6	Little	36.6	100.0
Hot water	137.8	56.4	81.4	62.7	18.7	23.0
Hydrochloric acid	155.9	25.6	130.3	65.3	65.0	49.8
Sodic hydrate	34.8	6.6	28.2	18.8	9.4	33.3
Chlorin	59.5	19.9	39.6	30.1	9.5	24.0
Cellulose	727.6	176.7	550.9	246.4	304.5	55.3

Proteins in Extracts Digested by Sheep No. 2.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Whole fodder	1628.3	434.0	1194.3	186.2	1008.1	84.6
Soluble in:						
Alcohol	714.6	156.8	557.8	30.7	527.1	94.4
Cold water	60.3	24.1	36.2	18.2	18.0	49.7
Hot water	47.3	27.8	19.5	12.4	7.1	36.6
Hydrochloric acid	265.2	64.0	201.2	40.2	161.0	80.0
Sodic hydrate	509.3	147.9	361.1	62.3	298.8	82.7
Chlorin						
Cellulose	31.4	9.5	21.9	18.4	3.5	16.2
			1202.7		1020.5	84.9

The amount of proteins digested by the sheep in 5 days was 1020.5 grams. The sheep gained 340.2 grams during this time. The ration was doing a little better than maintaining the animal. Supposing the gain of 340.2 grams to have been good edible mutton with 50 percent water and 15.5 percent protein in the dry matter, there would have been 26.4 grams of protein in it. The sheep digested 1020.5 grams of proteins and we here account for 26.4 grams, leaving 994.4 grams not accounted for. The urine contained nitrogen equivalent to 886.0 grams of proteins leaving a difference of 108.1 grams.

The statement is given in the following table.

Urine voided by Sheep No. 2 in 5 days.

	Volume in cc.	Sp. Gr.	Grams	Percent Protein	Protein
First day	2940	1,0359	3045.5	5.731	174.5
Second day	2930	1.0370	3038.5	4.688	142.7
Third day	3219	1.0340	3327.7	5.062	168.4
Fourth day	3730	1.0340	3856.8	5.790	223.3
Fifth day	3740	1.0340	3867.2	4.581	177.1
Total nitrogen voided calculated as protein					866.0

If our determinations are correct there was a small daily loss of nitrogen which was more than offset by gains of some sort, about four times more gain than nitrogen lost, but the loss was small and the final result was a slight gain in the weight of the animal.

Using the total hay fed, orts left and dung voided and determining the heat values, we find that the sheep actually appropriated 56.65 percent of it.

In the following table we have subtracted the value of the orts from that of the hay fed and given the difference under the caption of "consumed."

Heat units, small calories, taken up by Sheep No. 2 from the various extracts.

	Consumed	Voided	Digested	Coefficient
Whole Hay	21,095,910	9,144,800	11,951,110	56.6
Soluble in:				
Eighty percent alcohol	6,201,871	1,824,709	4,377,162	70.57
Cold water	2,774,043	337,479	2,436,564	87.81
Hot water and malt	439,310	191,043	248,267	56.51
One percent hydrochloric acid	3,135,414	1,720,986	1,414,428	45.11
One percent sodic hydrate	4,604,981	1,629,480	2,975,501	64.76
Chlorin, etc.	1,234,244	1,207,603	26,641	2.16
Cellulose	3,535,720	2,201,963	1,333,757	37.72

The coefficients are carried out to the second decimal place; this may seem a useless refinement but even so if the amount consumed be multiplied by the coefficient the product will not be exactly equal to the amount digested for every .001 percent added or rejected is equivalent to 10 units per million.

This table of heat units appropriated gives us a pretty clear idea of the relative values of the different extracts. The alcoholic extract of the Australian saltbush furnishes by far more heat than any other extract. The sodic hydrate, cold water and hydrochloric acid follow in order. The residual cellulose is only a little behind the hydrochloric acid extract in value but its coefficient of digestion is lower.

This animal voided a total of 17,135.7 grams of urine which had an average value or 88.9 calories per gram or a total of 1,523,364 calories. If we add to this the calories necessary to heat this urine to body temperature, we will account for 370,131 more calories. The further unaccounted-for losses are the heat of all other discharges and the cooling of the body.

The heat values of these extracts are very different and those of the dungs are different from the corresponding ones of the hay, but the preceding table gives the values as used by the animal, the result that we wish to present.

RESULTS OBTAINED WITH SHEEP NO. 3

Coefficients of Digestion found for the Extracts.
Extracts soluble in:

	Consumed	Voided	Digested	Coefficient
Eighty percent alcohol	1633.7	347.3	1286.4	78.7
Cold water	637.9	141.6	496.5	78.8
Hot water and malt	234.0	59.5	174.5	74.6
One percent hydrochloric acid	954.3	664.5	289.8	30.4
One percent sodic hydrate	840.0	280.0	560.0	66.7
Chlorin, etc.	218.8	190.8	28.0	12.8
Cellulose	791.3	446.9	344.4	43.5

Coefficients of Digestion found for the Sugars.

	Consumed	Voided	Digested	Coefficient
Glucose	71.9	0.0	71.9	100.0
Sucrose	119.6	8.5	111.1	92.8
Gums	21.9	9.0	12.9	58.9
Starch	37.3	0.0	37.3	100.0
Xylan, hydrochloric acid	206.6	163.8	96.8	37.1
Xylan, sodic hydrate	37.5	22.4	15.1	40.2
Chlorin, etc.				
Cellulose	792.1	447.1	345.0	43.6

Coefficients of Digestion found for Furfural.

	Consumed	Voided	Digested	Coefficient
Whole Hay	520.4	200.6	319.8	61.5
Extracts soluble in:				
Eighty percent alcohol	84.3	14.4	69.9	82.9
Cold water				
Hot water and malt	173.3	6.7	166.5	96.0
One percent hydrochloric acid	87.8	77.7	10.1	11.5
One percent sodic hydrate	109.1	58.5	50.1	46.4
Chlorin, etc.	25.0	18.8	6.2	24.8
Cellulose or residue	40.6	23.9	16.7	41.1
	520.0		320.0	61.5

Coefficients of Digestion for Proteins, found for Sheep No. 3.

	Consumed	Voided	Digested	Coefficient
Whole Hay	1082.6	168.4	914.2	84.4
Soluble in:				
Eighty percent Alcohol	486.8	36.3	450.5	92.7
Cold water	40.1	19.6	20.5	51.1
Hot water and malt	18.2	6.2	12.1	66.2
One percent hydrochloric acid	191.8	29.1	162.7	84.8
One percent sodic hydrate	327.3	60.8	266.5	81.4
Chlorin, etc.				
Cellulose	19.4	16.1	3.3	17.0
	1083.6		915.6	84.5

Proteins equivalent to Nitrogen Eliminated in Urine.

	cc voided	Sp. Gr.	Grams	Percent Proteins	Amount
First day	2055	1.044	2140.5	5.856	125.6
Second day	2310	1.047	2418.5	6.281	151.9
Third day	2360	1.046	2368.5	5.968	147.3
Fourth day	2740	1.042	2855.0	6.788	193.8
Fifth day	2620	1.043	2732.6	5.956	162.7
Proteins equivalent to nitrogen voided					781.3

The amount digested was 915.6 grams. We have a difference of 134.3 grams which in this statement would appear as gain, essentially .3 pound. The animal lost .25 pound. The temperature of the animal and the processes of life were maintained with this slight difference in the proteins concerned.

Heat units, small calories, taken up from the various extracts by Sheep No. 3.

	Consumed	Voided	Digested	Coefficient
Extracts soluble in:				
Whole Hay	19,199,736	8,376,961	10,822,775	56.4
Eighty percent alcohol	5,541,344	1,739,626	3,801,718	68.6
Cold water	2,699,223	474,502	2,224,721	82.4
Hot water and malt	301,700	97,432	204,268	85.2
One percent hydrochloric acid	2,834,601	1,821,394	1,013,207	35.7
One percent sodic hydrate	5,170,814	1,441,720	3,729,094	72.1
Chlorin, etc.	1,041,668	1,070,709	None	
Cellulose	3,154,425	1,856,997	1,297,428	41.1

The sheep voided a total of 12,615 grams of urine which had an average calorific value of 92.9 calories giving a total or 1,171,933 calories to which is to be added enough calories to heat 12,615 grams of urine from 15°C. which we may assume as the temperature of the water drunk, to the temperature at which it was voided, approximately 272,484 calories, the loss with other discharges and the cooling of the body.

Importance of Proteins

While it is evident that too much stress should not be placed on the so-called proteins (Nx6.25), it is customary to give these the first place in importance. It is convenient, at least, to exhibit the relations of these in our fodders, and we will choose that one which is accepted as our very best for comparisons. Of course all of our other fodders must fall below it in its general value but not necessarily in all of their constituents.

In Colorado Experiment Station Bulletin 128, 1907, we present alfalfa and one of our native saltbushes, *Atriplex argentia.* The alfalfa hay used in the experiments given carried 15 percent proteins and the saltbush 9.7 percent. Three sheep fed on alfalfa hay consumed 1817 grams of proteins and digested 1328 grams. The same sheep fed on native saltbush hay consumed 1646 grams and digested 1099. Of the 1328 grams proteins digested when fed alfalfa, 508 grams were soluble in 80 percent alcohol and cold water. Of 1099 grams digested when fed native saltbush hay, 553 grams were soluble in alcohol and cold water.

It may be stated in this connection that, owing to the small amount of extract obtained on treating a hay, alfalfa for instance, with cold water after previous extraction with 80 percent alcohol, a portion of alfalfa hay was extracted with cold water for 24 hours. In this time the water dissolved out, or better, the hay lost 40 percent of its weight. The inference was that cold water alone would remove practically as much from the hay as 80 percent alcohol and water used in succession. The hay treated in the course of our analysis, yielded in round figures 37 against 40 percent dissolved by the cold water in 24 hours.

In making alfalfa hay, it is a common practice to rake it into windrows as soon as it has wilted a little. This is done primarily to avoid loss of leaves and prevent breaking off more stems than can be avoided. Sometimes, however, changes in the weather bring about the wetting of the hay while it is in the swath, when a comparatively light rain will wash the hay badly and it does not require a heavy rain to wet it and injure it, even when it is bunched. The figure just given, 40 percent washed out of air-dried hay in 24 hours, suggests the possible extent of the damage.

The Hydrochloric Acid and Sodic Hydrate Extracts Persistent

The presentation of the relative value of these extracts shows that there is still a good deal of value left corresponding to the hydrochloric acid and sodic hydrate extracts which are less readily attacked, but what the effects of fermentative action may be we do not know. It probably increases the action of moisture greatly. These are the three important portions of the hay.

The total amount of hay eaten was 12365 grams; of these 4482 were soluble in water or alcohol and water and 3611 grams were insoluble in alcohol and water, but soluble by successive treatments with 1 percent hydrochloric acid and 1 percent sodic hydrate. The portion soluble in alcohol and water (we actually used these two solvents but it seems from the result of our experiment that water alone would have dissolved as much) is roughly one-quarter more than that dissolved by the hydrochloric acid and sodic hydrate used in succession after the water extraction. This portion soluble in water is not only greater in quantity but has a higher coefficient of digestion. The proteins (Nx6.25) carried by the alcohol and water were 662 against 976 grams in the hydrochloric acid and sodic hydrate together. Their coefficient of digestion was about the same, not far from 80 percent.

Heat Units Removed by Successive Treatments

If we take the heat units removed from the hay, we have for alcohol and water 1550 calories per gram of hay and 1367 for the hydrochloric acid and sodic hydrate. Whichever way we choose to consider it, the alcoholic and aqueous extracts taken together constitute the most valuable portion of the hay and are equal to about 40 percent of its total value.

We have not studied the effects of rain on hays to any greater extent than herein indicated, except that we have analyzed alfalfa hay that had been damaged by rain. We have, however, studied the effects of rain upon the composition of the wheat plant quite extensively and found that the effects were very great.

The general impression of the damage done to alfalfa hay due to its getting wet, either in swath, windrow or cock is fully justified. The fact that the composition of the wheat plant, and with it the wheat or grain, is greatly affected by wet weather, justifies us in inferring that the alfalfa and other forage plants are susceptible to the same action.

This is an interesting subject and very important for our farmers. Wetting the ground in irrigating the crops produces an entirely different effect from drenching rains upon the plants even when standing and in a growing condition. When the plant is cut and lying in swath, it simply loses a big portion of its value. Alfalfa hay has approximately one-half of its value washed out. Even wheat straw and also the grain give up a good deal to water.

The relation between the original value and these losses is given approximately by the extracts and their composition and thermal values.

I shall forego further suggestions that present themselves as of possible interest and state succinctly a few important facts in the way of a review.

BRIEF SUMMARY

We grew the Australian saltbush for eight successive seasons. It was planted on undesirable land for two seasons and grew satisfactorily. On better land, it produced plants 7 feet in diameter but much larger plants are mentioned in the California publications.

Its composition apparently varies with character of soil, both in its nitrogen content and in the amount and composition of its ash. The chlorin may be quite high or moderately low.

With us it had a good supply of water but it is asserted that it does well with only a small amount of water, 4.7 inches.

With us it is an annual but seeds itself freely. Its growth is prone but good yields of hay can be gathered. The plants were cut and cured with more care than could be given the hay on a large scale.

The plants were fed green to a horse and to three sheep. The animals all did well, apparently suffered no inconveniences or at most of a very temporary nature. The sheep maintained their weight for 3 weeks.

Digestion experiments were made also with three sheep, younger animals than the preceding ones. These also maintained their weight for the period of observation. The coefficients of digestion found are given in the preceding pages. There has been developed no objectionable features in it as a fodder; the one most seriously so is that none of the animals that we weighed made more than slight gains. All experiments were made under favorable conditions.