IX.—*Notes on the Chemical Alterations in Green Fodder during its Conversion into Ensilage.*

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IN recent numbers of the *Journal of the Chemical Society*, Professor Edward Kinch and Dr. O. Kellner have published some observations on the changes which take place in the nitrogenous constituents of fodders.

Analyses which I have made during the past two years throw additional light on the subject, and are, although somewhat incomplete, presented here.

Professor Kinch found that 55 per cent. of the total nitrogen present in the ensilage of grass was of a non-albuminoid nature, whilst in the original grass only 9 per cent. was of this form. In the case of mangel leaves Kellner found that of the total nitrogen present 27·8 per cent. in the original leaves, 45·5 per cent. in the ensilage, and as much as 59·7 per cent. in the ensilage preserved in stoppered jars was non-albuminoid. In the ensilage of maize I have found :—

	Per cent. of total nitrogen as non-albuminoid.
Original stalks.....	21·2
Ensilage No. 1.....	44·6
Ensilage No. 2.....	49·6
Dried fodder	15·6
Ensilage from young maize	53·3
Ensilage from older maize.....	47·1

These results with grass, mangels, and maize show that in the conditions existing in silos a large portion of the albuminoids are converted into non-albuminoid nitrogenous substances, whilst in the ordinary drying of fodder no such change seems to take place.

Kinch and Kellner both found that a portion of the nitrogen of the original plant was lost or did not appear in the analysis. With grass it was 13 per cent.; with mangels 27·8 per cent. in the unpressed ensilage in the jar, and as much as 59·8 per cent. in that in the open silo. The latter high percentage is doubtless due to the carrying away in the expressed juice of much soluble nitrogenous substance. I am in possession of but few quantitative data in regard to maize, but have found that in the samples of ensilage which I have examined there is a comparatively large amount of ammonia combined with the acids produced by fermentation, acetic and lactic, which of course is lost in drying the specimens for analysis. In the results, this produces an apparent loss of nitrogen in the ensilage itself: it is at any rate a loss of nitrogen of nutritive value. A quantitative determination of the ammonia salts in one specimen of ensilage (Serial No. 1693) gave the following results:—

Weight of ensilage taken	4000·0
Equivalent to dry substance	620·0
Weight of NH_4Cl	8·660
Equivalent to nitrogen.....	2·266
Per cent. of nitrogen from dry substance	0·366
Equivalent to albuminoids	2·287

That the nitrogen was in the form of ammonia and not a more complex amine was proved by the following analysis:—

Weight of ammonia salt taken	0·1000
Weight of platinochloride found	0·4105
Equivalent to NH_4Cl	0·0990

This ammonia salt, probably acetate, would be lost in the process of drying, and produce a corresponding deficit in the relative percentage of nitrogen in the analysis. In fact, a loss of 2·29 per cent. of albuminoids in the dry substance of an average maize stalk, con-

taining 7·50 per cent., amounts to a little more than 30 per cent. of the total nitrogenous substance in the plant, and to about the loss which Kellner found in his experiments with mangel leaves not under pressure. The remaining non-albuminoid nitrogen is probably largely of an amide nature, as, like Kellner, I have found very small amounts of peptones. Attempts, however, to separate any amides in a crystalline condition have resulted in obtaining nothing but a syrupy nitrogenous substance.

The loss of nitrogenous substance from conversion into ammonium salts and decomposition on drying is relatively compensated for by the large loss of carbohydrates, so that in the analytical figures neither loss is prominent, and they are at first glance deceptive. The control of course lies in an absolute knowledge of the weight lost by the fodder in the silo, or in the relative increase in one of the constituents which is less liable to change, as for instance the ash. But as Kellner has shown, pressure is very liable to remove the soluble part of the ash in the juice expressed, and thus entire dependence cannot be placed on this element.

An interesting experiment was carried on at the New Jersey Experiment Station in 1881, in which the ash served as a basis for calculation without apparently vitiating the results.

Ten tons of green fodder "corn" was divided into two lots on September 1st, one half being stacked in the field, and the other packed in a silo of the capacity of 12 tons, after being cut in short lengths. At the same time, a carefully selected sample of the green fodder was prepared for analysis. In November, 1200 lbs. of the dried fodder was run through a cutter, and an average sample prepared for analysis. On the 23rd of December a specimen of the ensilage was selected. The composition of the three substances was as follows:—

Original substance—	Green stalks.	Dried stalks.	Ensilage.
Water	75·00	39·37	74·50
Ash	1·58	4·63	1·97
Fat.....	0·22	0·66	0·27
N.-free extract....	15·60	32·85	13·58
Crude fibre	6·35	18·65	7·92
Crude albumin....	1·25	3·84	1·76
	100·00	100·00	100·00

Dry substance—

Ash	6.32	7.64	7.71
Fat	0.88	1.09	1.06
N.-free extract....	62.40	54.18	53.24
Crude fibre	25.40	30.76	31.07
Crude albumin....	5.00	6.33	6.92
	100.00	100.00	100.00

As 100 lbs. of the dry matter of the green fodder contained 6.32 lbs. of ash, the amounts of the other constituents corresponding with this weight of ash and therefore with each original 100 lbs. of stalks, were calculated in order to show the absolute loss of each constituent.

	Green stalks.	Dried stalks.	Ensilage.
Ash	6.32	6.32	6.32
Fat	0.88	0.90	0.86
N.-free extract	62.40	44.82	43.64
Crude fibre.....	25.40	25.44	25.49
Crude albumin	5.00	5.24	5.67
Total weight of dry matter to 6.32 lbs. of ash	100.00	82.72	81.98

The loss in this case is seen to fall upon the carbohydrates entirely, and to be as great for the dry fodder as for the ensilage. There is an apparent slight increase in albuminoids, which can be explained by the fact that the calculation is made as if no ash had been lost by being dissolved or expressed in the two preserved samples. This is remarkable as showing that in this case, quite at variance with other instances, the nitrogen suffered little or no loss, and that in fact the whole loss fell upon the carbohydrates. This may be due to the short time during which the maize was in the silo, as all samples which I have examined have not been taken out for several months.

These results at least show how varied the conditions are and how unsafe it is to generalise from any one experiment. This point is made evident in the analyses appended to this paper.

As to the nature of the fermentation and the proximate principles involved, I have made some observations. In but one sample out of many examined has any trace of *Saccharomyces* been found. As a rule the juice expressed from the fresh ensilage is swarming with *Bacillus subtilis*, together with some species of *Bacterium* and *Micrococcus*. No signs of the ordinary lactic or viscous ferment have been observed. The fermentation does not appear therefore to be of an alcoholic nature, or similar to any with which we are well acquainted. Analyses show the presence of an insufficient amount of alcohol, gum,

or free acid for any of the usual forms of fermentation, as can be seen from the following determinations.

Alcohol was never absent in any of the ensilages experimented on, but in all was present in such small quantities as to be distinguished only by the iodoform test.

Lactic acid has always been detected, but never in large quantity. Acetic acid is the chief acid of the ensilage. The relative proportion of the two acids varies largely, the following being a few determinations:—

Serial No.	Per cent. in ensilage of	
	Lactic acid.	Acetic acid.
1003	traces	2·12
1004	0·15	1·59
1500	0·52	0·80
1501	0·24	undet.
1502	0·26	1·02
1677	0·13	undet.
1693	0·11	undet.
		Total as acetic acid.
1840		2·40
1841		1·42

The whole amount of acid present was from 1 to over 2 per cent., the lactic acid not rising above six-tenths of a per cent.

The presence of lactic acid was determined by expressing the juice from a specimen of ensilage, distilling off the volatile acetic acid by repeated distillations, and neutralising the residue with zinc carbonate. The crystals of zinc lactate which were obtained on evaporation were crystallised and analysed. They contained:—

	Analysis.	Theory.
Water	18·46	18·18
ZnO	26·71	27·27

Gum or similar substance is not formed in any large amounts in the silo.

Unchanged sugar has been found in the juice expressed from two ensilages, but as a rule it completely disappears. No. 1003 contained 2·40 per cent., No. 1004 1·07, and No. 1541 0·76 per cent. of reducing sugars.

The fibre is of course increased in relative amount, but absolutely it is probable that it is but slightly altered.

In Table I (pp. 85–86) analyses of a number of ensilages are presented together with those of a dried fodder and several green stalks at

TABLE I.—*Analyses of Maize Silage and of Maize Fodder.*

	Silage. *1003.	Silage. 1004.	Silage. 1500. Frsn.	Silage. 1501. Out 24 hours.	Silage. 1502. (Nesbit.)	Silage. 1540.	Silage. 1541.
Original substance—							
Water.....	77.30	74.10	81.20	81.40	84.00	70.60	84.80
Ash.....	2.01	1.48	1.36	1.44	1.25	2.00	0.91
Oil, &c.....	1.74	1.80	1.71	1.21	1.20	1.80	1.00
Nitrogen-free extract.....	11.24	12.87	9.14	9.47	7.75	15.37	9.40
Crude fibre	5.71	7.04	4.88	4.84	3.88	7.54	2.85
N x 6.25 = "albuminoids"	1.94	2.77	1.71	1.64	1.92	2.69	1.04
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dry substance—							
Ash.....	8.87	5.72	7.21	7.76	7.83	6.81	5.98
Oil, &c.....	7.91	6.73	9.12	6.49	7.53	6.12	6.00
Nitrogen-free extract.....	49.50	49.69	48.59	50.90	48.43	52.25	61.84
Crude fibre	28.15	27.19	25.98	26.05	24.24	25.65	18.76
N x 6.25 = "albuminoids"	8.57	10.67	9.10	8.80	11.97	9.16	6.82
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
In the ether extract—							
Non-volatile free acid	trace	0.56	2.99	1.28	1.65	—	—
In the nitrogen-free extract—							
Sugars, &c., sol. in 80 per cent. alcohol; sol. in water.....	17.76	15.54	—	—	—	—	—
Substances, sol. in 80 per cent. alcohol; insol. in water	3.86	3.14	—	—	—	—	—
Gum, &c.....	2.10	2.89	—	—	—	—	—
In the "albuminoids"—							
Nitrogen	1.37	1.71	1.45	1.40	1.91	1.47	1.09
Non-albuminoid nitrogen.....	—	—	—	—	—	—	—
Per cent. of nitrogen as non-albuminoid	—	—	—	—	—	—	—
In the original substance—							
Acetic acid	2.12	1.59	0.80	—	1.02	2.40	1.22
Lactic acid	trace	0.15	0.52	0.24	0.26	—	—
Juice per cent.....	47.5	40.5	39.5	39.1	49.3	50.8	—
Sp. gr.	1.046	1.0335	1.0197	1.0910	1.017	—	—
Sugars	2.40	1.07	None	None	None	—	0.76
Solids.....	—	8.14	4.67	4.27	4.03	—	—

* 1003, 1542, 1541 from Virginia; 1004, 1652, 1653 from New York State; 1500, 1501, 1502, 1677, 1683 from Indiana.

TABLE I continued.—*Analyses of Maize Silage and of Maize Fodder.*

	Silage, 1677. (Blair.)	Silage, 1693. (Blair.)	Silage, 1652. (Young.)	Silage, 1653. (Old.)	Dried fodder, 1654.	(Green fodder, 1628. St. lks. for 1677 and 1693.	Stalks, Egyptian maize, Young authors just out.
Original substance—							
Water.....	81.67	84.50	82.64	78.62	27.25	85.96	84.90
Ash.....	1.04	1.04	1.14	1.21	2.12	1.87	1.11
Oil, &c.	1.09	0.79	1.01	1.46	2.53	0.52	0.44
Nitrogen-free extract.....	10.17	8.47	9.21	11.39	50.02	7.27	9.25
Crude fibre	4.64	3.86	4.96	5.80	12.75	2.48	3.04
N x 6.25 = "albuminoids"	1.39	1.34	1.04	1.52	5.33	1.90	1.26
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dry substance—							
Ash.....	5.08	6.08	6.59	5.68	2.91	13.31	7.39
Oil, &c.	5.96	5.08	5.84	6.82	3.48	3.71	2.89
Nitrogen-free extract.....	55.50	54.64	53.02	53.26	68.76	51.77	61.25
Crude fibre	25.30	24.93	28.98	27.12	17.52	17.67	20.15
N x 6.25 = "albuminoids"	7.56	8.67	5.97	7.12	7.33	13.54	8.32
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
In the ether extract—							
Non-volatile free acid.....	0.72	0.72	—	—	—	—	—
In the nitrogen-free extract—							
Sugars, &c., sol. in 80 per cent. alcohol; sol. in water ..	10.59	8.34	—	—	—	10.02	20.32
Substances, sol. in 80 per cent. alcohol; insol. in water ..	2.00	3.66	—	—	—	2.64	7.17
Gum, &c.	2.91	3.58	—	—	—	2.64	2.29
In the "albuminoids" —							
Nitrogen	1.21	1.39	0.95	1.14	1.18	2.17	1.33
Non-albuminoid nitrogen.....	0.54	0.69	0.51	0.54	0.18	0.46	—
Per cent. of nitrogen as non-albuminoid	44.6	49.6	53.3	57.1	15.6	2.02	—
In the original substance—							
Acetic acid	—	—	—	—	—	—	—
Lactic acid	0.13	0.11	—	—	—	—	—
Juice per cent.....	—	—	—	—	—	—	—
Sugars	—	—	—	—	—	—	—
Solids.....	—	—	—	—	—	—	—

various stages of development. From them, much may be learned as to the variations to be expected.

The composition of the stalks of green maize is subject to very wide variations, as may be seen by the few analyses quoted. This then is a primary cause of differences in the composition of the ensilage, and, although it is due largely to the period of growth at which the stalks are cut, yet there are often marked differences in composition in those of the same stage of development, even in the same field.

In a series of analyses of the stalks of Egyptian sugar corn and Lindsay's horse-tooth corn, completed by me, and published in the Report of the Commissioner of Agriculture for 1881 and 1882, these variations are shown. The specimens, the analysis of which are here given, were all from a small plot of carefully selected stalks only a few rods square, and yet, in many instances, they show the largest variations from a regular series.

The variations which are found in the composition of the stalks while they are in a condition to be packed in a silo, that is to say, from the appearing of the tops until the grain is well formed, are included within the following limits:—

	Highest.	Lowest.
Water in green substance	91·60	79·10
Dry substance.....	20·90	8·40
Ash	9·72	3·54
Oil	3·48	1·68
Carbohydrates.....	69·40	59·60
Crude fibre	31·29	21·56
Albuminoids	11·53	1·67
Percentage of nitrogen as non-albuminoid	70·4	18·0

These limits, together with a study of the individual analyses, serve to show the primary cause of the differences in ensilages.

As to variations produced by other causes, illustrations are found in the samples numbered 1652, 1653, 1677, and 1693.

Numbers 1652 and 1653 are analyses of ensilage from young and old stalks. The younger would naturally contain more ash and albuminoids as it went into the silo, but the nitrogenous substances would be in such a condition, from the greater amount of soluble nitrogen, as to make them more liable to conversion into ammonium salts. This is the case with No. 1652. In it, the ash is higher than in the older specimen, but the nitrogen is lower from a greater loss. The relative amount of non-albuminoid nitrogen is also lower in the younger than in the older sample. In other respects, they do not differ largely, although one was from stalks on which the ears were well formed, and

TABLE II.—*Egyptian Sugar Corn (Maize), planted April 30th, 1881.*

	Stalks.						
	526. July 5th, top just out.	540. July 11th, anthers not out.	547. July 11th, anthers out, filling.	562. July 18th.	576. July 25th, silk out.	580. August 1st, ear formed.	694. August 8th.
Development—							
Height, in feet	7·0	7·2	8·5	9·0	9·2	10·2	10·0
Diameter, in inches	1·2	1·2	1·1	1·2	1·2	1·6	1·2
Total weight, in grams	1242·0	1097·0	1037·0	1378·0	1642·0	1722·0	1068·0
Weight of stalk	960·0	585·0	5·42	618·0	575·0	636·0	593·0
" leaves	216·0	468·0	430·0	651·0	737·0	864·0	300·0
" top	66·0	44·0	35·0	26·0	78·0	32·0	9·0
" ear	—	—	—	83·0	252·0	190·0	166·0
Per cent. of stalk in whole plant	77·3	53·3	52·1	44·9	35·0	37·0	55·5
Dry substance—							
Ash	9·72	9·09	6·53	5·60	4·81	5·87	4·97
Crude fat	2·58	1·80	1·68	3·48	2·75	2·35	2·10
Nitrogen-free extract	50·60	51·20	52·41	60·45	61·53	66·72	67·37
Crude fibre	27·01	26·38	31·29	26·04	26·09	22·07	21·82
Crude albumin	10·09	11·53	8·09	4·43	4·85	2·99	3·74
Total nitrogen	1·61	1·85	1·29	0·71	0·78	0·48	0·60
Non-albuminoid nitrogen	0·99	1·27	0·85	0·31	0·39	0·29	0·33
Per cent. of nitrogen as non-albuminoid	61·4	68·6	65·9	43·7	50·0	60·5	55·0
Original substance—							
Water	91·60	91·30	88·30	85·90	83·20	80·20	80·60
Ash	0·82	0·79	0·76	0·79	0·81	1·16	0·96
Crude fat	0·21	0·16	0·19	0·49	0·46	0·47	0·41
Nitrogen-free extract	4·25	4·45	6·14	8·53	10·34	13·21	13·07
Crude fibre	2·27	2·30	3·66	3·67	4·38	4·37	4·23
Crude albumin	0·85	1·01	0·95	0·62	0·81	0·59	0·73

the other from stalks on which the ears had made no appearance. In comparison with the ensilages, the dried fodder, No. 1654, from stalks of the same field as the old ensilage, No. 1652, shows several advantages. As has been already remarked, its nitrogenous constituents have not suffered so much change, only 15·6 per cent. being in a non-albuminoid form as compared with 53·3 and 47·1 per cent. in the ensilages. A smaller loss of carbohydrates has left the relative percentages of fibre, fat, and ash, low; and the evidence points to the fact that the stalks must have dried rapidly and with few changes, furnishing a fodder of much better composition than that analysed in New Jersey.

In Nos. 1677 and 1693, we have analyses of two specimens of ensilage taken from the same silo within a few days of each other. One has lost more ash and nitrogen than the other, and this is due probably to greater pressure on the first sample, which had lost expressed juice carrying with it nitrogenous matter and ash. In other respects they are much alike. The variations in composition, which are found among the analyses of ensilage, lie within the following limits:—

	Highest.	Lowest.
Water	84·80	70·60
Ash	2·01	0·91
Oil	1·80	0·79
Carbohydrates	15·37	7·75
Fibre	7·54	2·85
Albuminoids ($N \times 6\cdot25$)..	2·77	1·04
Per cent. of nitrogen as non-albuminoid	53·3	47·1
Or for dry substance—		
Dry substance.....	15·20	29·40
Ash	8·87	5·68
Oil.....	9·12	5·08
Carbohydrates	61·84	48·43
Fibre	28·58	18·76
Albuminoids	11·97	5·97

By comparison with the extremes for green stalks, it is seen that the albuminoids are higher in the dry substance of one of the ensilages, No. 1502, than in the dry substance of any of the stalks. The high figures in the ensilage are probably only relative, due to a great loss of carbohydrates and little change of albuminoids.

Exact quantitative experiments are greatly to be desired, in order that we may have some explanation of the interesting changes which undoubtedly occur.

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