

THE COMPOSITION OF GREEN MAIZE AND OF THE SILAGE PRODUCED THEREFROM.

By HAROLD E. ANNETT, B.Sc. (Lond.), S.E.A.C. DIP. *Indian Department of Agriculture* AND EDWARD J. RUSSELL, D.Sc. (Lond.) *Rothamsted Experiment Station, late of the South Eastern Agricultural College, Wye.*

INTRODUCTION.

THE process of making silage is an ancient one¹ and the scientific investigations date back at least to 1873, when Weiske², at the Proskau experiment station, showed that there was a loss of carbohydrate, fibre and protein in making silage from sainfoin and other crops. It was, however, by no means general till after the publication in 1875 of Goffart's remarkable success with maize silage at Burtin, in the barren district of Sologne (Loire-et-Cher)³. Both Grandeau⁴ and Barral⁵ analysed Goffart's silage, the former noted the production of volatile and non-volatile acids and labelled them acetic and lactic acids respectively, in which practice he has been followed by most later analysts. Five years later Kellner⁶ demonstrated by careful quantitative measurements that the decrease in protein was accompanied by an increase in the amount of "amide" nitrogen. In his experiments about 28 per cent. of the nitrogen was lost, but in a subsequent paper⁷ this was traced to volatilisation of ammonia during manipulation of the sample. Kellner considered, and probably correctly, that no nitrogen is lost in the free state from the silo.

Much attention was given to the subject in the wet cycle of years

¹ See e.g. Johnston, *Trans. Highland and Agric. Soc.* 1843, new series, 9, 57. A good historical account is given by Jenkins, *Journ. Roy. Agric. Soc.* 1884, 20, 126.

² Quoted by Voelcker, *Journ. Roy. Agric. Soc.* 1884, 20.

³ *Sur la culture et l'ensilage du Maïs-fourrage* (Memoire présenté à la Société centrale d'Agriculture de France, 1875). On p. 8 he says: "Lorsque j'ai acheté le domaine en 1840...huit malheureuses vaches et cent vingt brébis composaient tout le cheptel d'alors et vivaient misérablement...aujourd'hui le même domaine nourrit abondamment soixante-huit bêtes à cornes, six chevaux, et trois cents moutons." He had about 300 acres.

⁴ *Ibid.* p. 39.

⁵ p. 50 and Part 2, p. 24.

⁶ *Land. Versuchs-Stat.* 1880, 26, 447. Mangold leaves were used.

⁷ Kellner and Sowano, *Land. Versuchs-Stat.* 1889, 37, 16, also Kellner, *Chem. Zeit.* 1890, 14, 905.

ending in 1883: Fry's letters appeared in the *Agricultural Gazette* and *Mark Lane Express* for 1883 and 1884, and were reprinted in book form in 1885¹; numerous papers, scientific and practical, were published in 1884 and 1885, and in the latter year a commission sat under Lord Walsingham to collect evidence and report thereon². Experiments were also made at Rothamsted³. The scientific papers were mainly analytical and did little more than confirm the earlier results. Weiske and Schulze⁴ made maize silage in barrels and observed an increase in the amount of ether extract; they supposed this was due to the conversion of sugar into lactic and butyric acids, both of which are soluble in ether. Analyses were published by Kinch⁵, Lloyd⁶, Richardson⁷, Smetham⁸, Voelcker⁹, and the late Dr A. Voelcker¹⁰, and served to correct a number of misconceptions that had arisen¹¹. As silage never became general in England there have been only few papers published here since 1885.

Meanwhile the subject was being taken up in America. In most parts of the States maize is a far more popular crop than roots, and silage provides the stock with their succulent food in winter. A vast amount of work has been done at the different stations, it is only necessary to mention the investigations of Jordan¹² and Armsby¹³ on the digestibility, which proved conclusively the loss of nutritive value; Woll¹⁴, Hills¹⁵, Collier¹⁶ and King¹⁷ on the loss of dry matter; King¹⁷ on

¹ *Sweet Silage*, 1885, Agric. Press Co. London.

² The Evidence and Report contain interesting accounts of the methods of making silage, its place in the economy of the farm, and its value here and elsewhere.

³ *Agric. Gazette*, 1885, also *Rothamsted Memoirs*, Vol. 4, No. 12.

⁴ *Journ. für Landwirtschaft*, 1883, 32, Heft. 1. Abs. in *Journ. Chem. Soc. Abs.* 1884, p. 1409. Cf. also Palladin, *Ber. der Bot. Gesellschaft*, 1888, 6, 205 and 296.

⁵ *Trans. Chem. Soc.* 1884, 45, 122.

⁶ *Chem. News*, 1884, 49, 210.

⁷ *Trans. Chem. Soc.* 1885, 47, 80.

⁸ *Journ. Roy. Agric. Soc.* 1884, 20, 380.

⁹ See *Report of Commission*.

¹⁰ *Journ. Roy. Agric. Soc.* 1884, 20, 482, other workers quoted in this paper are Moser and Holdefleiss.

¹¹ E.g. it was often supposed that fibre became digestible during the process and some even considered that sugar was produced. Lawes, in his evidence before the commissioners pointed out the fallacy of supposing that poor coarse grass, weeds, etc. would change into useful, nutritious food in the silo.

¹² *Maine Reports*, 1893 and 1894 (*Expt. Station Record*, 1895, 6, 746 and 1896, 7, 884).

¹³ *Pennsylvania Reports*, 1889 (*Expt. Station Record*, 1892, 3, 457).

¹⁴ *Land. Versuchs-Stat.* 1889, 36, 161.

¹⁵ *Vermont Reports*, 1893 (*Expt. Station Record*, 1895, 6, 919).

¹⁶ *New York State Reports*, 1892 (*Expt. Station Record*, 1895, 6, 65).

¹⁷ *Wisconsin Report*, 1894 (*Expt. Station Record*, 1897, 8, 350 and 687: 1898, 9, 393); also *Wisconsin Report*, 1900.

certain physical questions involved; and Babcock and Russell¹ on the bacteriological aspects of the question.

The composition of green maize.

For some years past it has been the practice at the Wye College to grow green maize as a fodder crop and make a certain quantity into silage. The original idea was to see if silage could to any extent take the place of roots, which, on the light chalky soil of the College farm, are often difficult and sometimes expensive to secure. It may at once be stated that green maize was found to be valuable, but silage was only economical in exceptional seasons². The maize was cut during October as opportunity offered, chopped into pieces, and filled into the silo, a cylindrical wooden structure 12 ft. in diameter and 17 ft. high, standing in an extension of the barn. A large sample of the cut pieces (10 or 15 kilos) was drawn, a small subsample taken for analysis, and the bulk weighed into a sack, sewn up and thrown into the silo. This operation was repeated several times during the filling, so that at the end we had several sacks buried at different depths in the silo, each containing weighed quantities of maize of known composition.

The maize is green when cut and far from being ripe. Its composition depends very much on the season; in warm, dry summers there is about 20 per cent. of dry matter, while in cold, wet seasons only about 13 per cent. is found³, the difference falls almost entirely on the nitrogen-free extract, so that if the nitrogen-free extract and water are added together the sum is very fairly constant. The nitrogen, fibre, and ash show only slight differences from year to year. Most of the nitrogen (about 80 per cent.) is present as true protein, not much amino acid or amide being present at the time of cutting. The nitrogen-free extract contains a certain amount of sugar, which appears to be mainly dextrose, but no starch. The juice is slightly acid to litmus paper and contains gallic acid, but we could find neither lactic, malic, succinic, nor volatile fatty acids. Distillation with hydrochloric acid caused furfural to be liberated from the pentosans.

¹ *Wisconsin Report*, 1900.

² E. J. Russell, *Journ. Board of Agric.* April, 1907, p. 14. Reference is also made to the feeding value of silage, which is not dealt with in the present paper.

³ The crop varies in the same way, and is much greater in warm than in cold seasons. The difference in the amount of good stuff per acre is therefore very considerable.

TABLE 1.

Average percentage composition of green maize, end of September and early October¹.

	Good seasons		Bad season	Intermediate seasons		Average of all
	1901 ²	1905 ³	1903 ⁴	1904 ⁵	1906 ⁶	
Dry matter	21.90	18.70	13.35	15.00	15.09	16.81
Ether extract85	.52	.16	.66	.22	.48
Total nitrogen $\times 6.25$	1.90	2.04	1.81	1.59	1.58	1.78
Nitrogen-free extract	13.60	9.88	6.70	8.06	8.39	9.33
Fibre	4.25	5.30	3.83	3.74	3.93	4.21
Ash.....	1.30	.98	.79	.95	.97	1.00
Total nitrogen304	.328	.289	.253	.252	.285
Protein nitrogen267	.210	.212	.166	.214
Non-protein nitrogen } (by difference)061	.079	.041	.086	.071
% of total N. present } as non-protein		18.8	27.3	16.2	34.1	25.0
Sugar98	1.5	.81		1.10
Furfural obtained		2.48	2.01	1.83	1.92	2.06

The crop is never quite even, it is possible on the same day to pick out large, well-advanced plants with hard, woody pith growing alongside of smaller plants, less mature, with soft pith and much more juicy. The difference in composition lies mainly in the water content, the dry matter being much the same in both.

TABLE 2.

Percentage composition of dry matter of (a) large well-advanced and (b) small less mature plants cut the same day.

	Dry matter	Ether extract	Total nitrogen $\times 6.25$	Total nitrogen	Protein nitrogen	Nitrogen free extract	Fibre	Ash	Furfural	Sugar
(a) Mature plants ...	18.95	3.24	10.75	1.72	1.52	55.58	25.01	5.42	11.97	5.74
(b) Immature plants.	12.70	4.76	11.00	1.76	1.67	53.29	25.63	5.32	11.74	4.57

¹ For details of the methods employed see the Experimental Part, pp. 389 et seq.

² 1 sample. ³ 2 samples. ⁴ 2 samples. ⁵ 7 samples. ⁶ 1 sample.

Composition of Silage.

Some months after filling the silo, the sacks were recovered and their contents weighed and examined. The silage had a brownish-green colour, but otherwise the pieces looked unaltered. It had a pungent smell suggesting butyric acid, and was acid to litmus. Numbers of bacteria were present including *Bac. subtilis* and others, but there was no mould of any sort. The composition is curiously constant, showing far less fluctuation from year to year than does the original maize.

TABLE 3.

Average percentage composition of maize silage.

	1901	1903	1904	1905 ¹	1906	Average of all
Dry matter	12·10	12·20	13·79	13·56	13·32	12·99
Ether extract ¹	·16	·10	·83	·56	·29	·39
Total nitrogen ¹ × 6·25	1·33	1·35	1·65	1·69	1·30	1·45
Nitrogen-free extract	5·08	5·67	5·15	5·32	5·61	5·38
Fibre	4·66	4·13	5·06	5·06	5·20	4·82
Ash	·98	·95	1·10	·93	·92	·98
Total nitrogen	·213	·216	·265	·269	·208	·234
Protein nitrogen		·121	·156	·181	·089	·137
Non-protein nitrogen } (by difference)		·095	·109	·088	·119	·103
% of total N. present } as non-protein		43·8	41·1	32·8	57·2	43·72
Nitrogen as NH ₃		·003	·006	·014	·006	·007
Nitrogen as amide			·007	·010	·001	·006
Sugar	nil	nil	nil	nil	nil	nil
Furfural obtained		2·00	1·87	2·26		2·04
Volatile acid (as H ₂ SO ₄)		·17	·07	·08		·09
Non-volatile acid (as H ₂ SO ₄)		·30	·68			·49

When silage is pressed it readily yields quantities of a brownish juice of very complex composition. The amount and nature of the nitrogen compounds in 100 c.c. of a typical sample of this juice were as follows:

Total nitrogen	·161
Nitrogen as NH ₃	·030 = 18·6% of total
Nitrogen as amide	·014 = 8·7% "
Nitrogen as amino acid	·089 = 55·3% "
Nitrogen not accounted for...	·028 = 17·4% "

¹ The figures for total and non-protein nitrogen and ammonia are all somewhat too low because we have not been able to avoid loss of ammonia during sampling. We reduced loss as far as possible by starting the several nitrogen determinations in the wet silage immediately the sample was drawn. The ether extract figures are only approximate. See experimental part for details.

A list of the more important compounds present in silage appears in the accompanying paper. It comprises a number of acids containing no nitrogen, which probably have no actual feeding value; among these are formic, acetic, butyric, caproic and hexoic acids, two hydroxyacids, lactic and malic, and also succinic acid. There are also simple nitrogenous compounds, amino acids, basic diamino acids and amides, the feeding value of which is not yet settled, but is certainly less, and probably much less, than that of protein. Finally there are amines which are actually injurious, though whether they normally occur to a sufficient extent to do any harm may be doubted; cases have come to our notice, however, where animals have not thriven on silage and the trouble may very probably be ascribed to these bodies.

It is common to speak of the large amount of "amides" present in silage, but Table 3 shows how very small the quantity really is. Amides occur to a smaller extent than ammonia, and to a still smaller extent than amino-acids. They form only about 5 per cent. of the non-protein nitrogen, and in view of this fact it is highly desirable that the practice of regarding all of the non-protein nitrogen compounds as amides should be discontinued.

The losses going on during ensilage.

On comparing the composition of silage with that of the maize from which it was formed it is possible to discover what has been the loss during the process. An exact quantitative comparison is rendered impossible by the difficulties of sampling and of preventing loss of ammonia, but it is quite clear that a considerable amount of dry matter has disappeared during the process. The loss is not uniform throughout the silo, and no two bags give exactly the same results, but the average of our experiments during 1905 and 1906, set out in Table 4, shows its general distribution.

It will be noticed that the fibre is practically unaltered in amount, and we have confirmed this observation by microscopically examining sections of maize and of the silage afterwards produced. We found that the epidermal cells had undergone no change in the silo beyond a certain amount of shrinkage; even the stomata were unaltered. Similarly the vascular bundles were intact.

The nitrogen-free extract suffers most. Direct tests showed that the sugar disappears almost entirely. The fall in the furfural indicates a decrease in the amount of cellulose, *i.e.* the less resistant cellulose, which alone falls into this group; this was confirmed by microscopic

examination which showed that many of the cells of the mesophyll were completely disintegrated.

The protein suffers considerably, though not in reality as much as the nitrogen-free extract. Hydrolytic decomposition complicated by bacterial action takes place, and although there is not much, if any, loss of free nitrogen the new nitrogenous compounds are less valuable as food than the protein.

TABLE 4.
Mean losses in the silo 1904 and 1905.

	Dry matter	Ether extract	Nitrogen free extract	Fibre	Total nitrogen	Protein nitrogen	Non- protein nitrogen	Ash	Fur- fural
Put in	100	100	100	100	100	100	100	100	100
Brought out..	64	84	45	92	74	45	183	86	68
Loss	36	16	55	8	26	55		14	32
Gain							83		

The figures show an absolute loss of nitrogen, but we are satisfied that a certain amount of ammonia is given off during sampling, and we have no evidence to show how or to what extent losses of nitrogen occur in the silo. In laboratory experiments on silage made in bottles we only observed losses of nitrogen when air was admitted, and this did not happen in the silo.

The figures given for the loss in ether extract are quite accidental, since the value obtained in any particular bag depends on its position in the silo; the bags in the *top* half showed a considerable loss—32 per cent. on the average—those in the *lower* half showed an average gain of 6 per cent. The ether extract of silage contains a number of soluble acids which obviously wash downwards. Further, since these acids are derived from the nitrogen-free extract or protein of the maize it follows that no comparison is in any case possible.

A similar downwash occurs with the soluble ash constituents, the upper bags losing on an average 17 per cent., and the lower bags gaining 2 per cent., hence the average figure given in Table 4 is of no value. The insoluble ash constituents are of course not liable to this movement; but their amount is so small and variable—depending

partly on the presence of stray soil—that the experimental error becomes too large to give the calculations any value.

The general nature of the losses outlined above is probably the same in all silos, though the actual amount varies: our losses are higher than those observed by American investigators, but there is considerable difference between American and English maize at the time of cutting; ours is much less mature, and contains a lower proportion of nitrogen-free extract.

When a farmer makes silage on a large scale he often wants to know what loss takes place in his silo. The most convincing way of demonstrating this is, of course, to bury weighed bags of material as we have done, but a sufficiently accurate result can be obtained by assuming that the fibre undergoes no change, or only a 5 per cent. loss, and calculating on this basis the amount of each constituent that should be present. This method is much better than another which is sometimes used—viz. to assume that the ash is unchanged in amount and to use it as the basis of calculation; in the first instance, as we have just seen, the soluble ash is liable to wash downwards, and in the second place the percentage of ash is so small that a trifling error in sampling or determination very considerably affects the result. Of course there is in any case the difficulty of getting the average composition of the green material and the silage, which is only got over by taking a number of samples. In our experiments more than one-third of the total dry matter was lost, including more than half the nitrogen-free extract and the protein; in the latter case some of the decomposition products, the amino-acids etc. remained in the silo, so that the actual loss of nitrogen was only 26 per cent. The fibre appeared to undergo no change.

Experimental details.

Analytical methods. The determinations of fat, total nitrogen, fibre, etc., were all made in the ordinary manner. Non-protein nitrogen was estimated by Stutzer's method, the substance is boiled with a mixture of copper hydrate and glycerine which dissolves the non-protein but leaves the protein in the insoluble residue. The method is no doubt open to objection because some proteins may dissolve and some insoluble non-protein bodies, *e.g.* the purin bases, may remain insoluble. But when used for purposes of comparison and not with an idea of getting absolute results we consider that it gives quite valuable information.

To determine the quantities of nitrogen present as ammonia, amide, and amino-acid respectively we adopted the very elegant methods used by Drs Horace Brown and Millar, described in the *Transactions of the Guinness Research Laboratory*, Vol. I. Part 1, 1903. We have found them work very satisfactorily with our substances.

The furfural obtained on distillation with hydrochloric acid was converted into its hydrazone and weighed. Krug's method of working was adopted, but we prefer not to attempt expressing our results in terms of any particular pentosan. It is well known that several groups of bodies give furfural on distillation, including pentosans, celluloses (the so-called "oxy-celluloses"), glycuronic acid, etc., but that certain members of the groups yield instead non-volatile hydroxy-furfurals, and hence cannot be estimated in this way. In view of the fact that the furfural yielding bodies of green maize have not been carefully examined we prefer to give the experimental figure only, and in the Tables have given the actual weight of furfural obtained from 100 parts of substance. No doubt the less resistant or "oxy-celluloses" are responsible for much of the furfural.

Method of procedure. The maize was cut up, roughly dried at about 80° C, ground in a coffee mill and reduced to a fine powder in the Maercker mill. Drying could now be completed, and samples taken for analysis.

A different scheme had to be adopted for silage. As the bags were recovered from the silo they were weighed, brought to the laboratory, and samples taken as speedily as possible for the various nitrogen determinations. But no matter how quickly we worked we could not altogether avoid loss; our figures for total nitrogen and free ammonia are therefore low. Still, the loss is much less than if the samples had been dried before the nitrogen was determined, for the nitrogen found in the dried material is always less than one expects by calculating from the amount in the original wet silage. It will be observed that in three cases the difference is approximately equal to the amount of ammonia present in wet silage, but in the other cases it is much greater.

Samples 1 to 4 were drawn from the 1905 silage, sample 5 was taken in 1906, and sample 6 comes from a silo on another farm.

Another sample of silage was quickly drawn for the determination of the volatile acid. It was distilled in steam, and the distillate titrated with standard alkali. The results are only approximate, the higher acids come over so slowly that the distillate never really becomes

neutral. The non-volatile acid was estimated by titrating the residue in the flask, but we soon gave up this determination because of the difficulty of getting a sharp end reaction.

TABLE 5.

Percentage of nitrogen in the dry matter of silage.

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Calculated	1·90	2·10	2·41	2·15	1·58	2·31
Found	1·42	1·61	1·19	1·24	1·45	1·70
Loss during drying	·48	·49	1·22	·91	·13	·61
Ammonia found in wet silage...	·41	·36	·33	·94	·01	·07

A third sample was dried, ground, and used for the estimation of ether extract, fibre, ash, and nitrogen-free extract. The ether extract results are only approximate, samples continue losing weight for days in the extraction apparatus. Some of the acids are only slightly soluble in ether, the colouring matter also dissolves with difficulty.

The bulk of the sample was then used for qualitative examination.