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CARBOHYDRATE METABOLISM IN GREEN SWEET CORN DURING STORAGE AT DIFFERENT TEMPERATURES

By CHARLES O. APPLEMAN, *Plant Physiologist*, and JOHN M. ARTHUR, *Assistant Plant Physiologist, Laboratory of Plant Physiology, Maryland Agricultural Experiment Station* [1]

THE PROBLEM

The present paper deals with the character and kinetics of the processes involved in the rapid depletion of sugar in green sweet corn after it is separated from the stalk and more particularly with the relative rates of these processes at different storage temperatures, accurately controlled.

WORK OF PREVIOUS INVESTIGATORS

In the course of an extensive sweet corn investigation, Straughn[2] clearly shows that the loss of total sugars from green sweet corn is very rapid during the first 24 hours of storage at ordinary summer temperatures. Working with Stowell's Evergreen, he claims that about one-third of the total sugars disappeared during the first 24 hours of storage at a room temperature of about 25° C. A further loss occurred during the next 24 hours, but when the sugars reached 1.80 per cent no further loss was noted. This rate of sugar loss for the first 24 hours of storage at one uncontrolled temperature must be considered as merely an approximation, since analyses of different ears before and after storage were compared. The percentage of sugar in the different ears at the time of picking showed considerable variation. In the same paper it is concluded that there is no material advantage to be gained by storing the corn in a refrigerator. It should be noted, however, that the refrigerator showed a temperature of 23.5° C. during the first 24 hours and thereafter 17° C.

In a later paper by Straughn and Church [3] results are reported showing the change in the sugar content of green corn after a period of 36 hours' storage at room temperature. The data furnish very little additional information on this problem, as the experimental corn was secured upon the open market and the sugar loss in this corn had nearly ceased before

[1] The curves in figures 1 and 2 were drawn by John Paul Jones, of this laboratory.

[2] STRAUGHN, M. N. SWEET CORN INVESTIGATIONS. Md. Agr. Exp. Sta. Bul. 120, p. 37-78. 1907.

[3] STRAUGHN, M. N., and CHURCH, C. G. THE INFLUENCE OF ENVIRONMENT ON THE COMPOSITION OF SWEET CORN, 1905-1908. U. S. Dept. of Agr. Bur. Chem. Bul. 127, 69 p, 11 fig. 1909.

the experiment was begun. However, the data are interesting; they show the usual low sugar content of green corn as it is now purchased on the market. The percentage of sugar in this corn ranged from 1.70 to 1.49.

EXPERIMENTAL METHODS

One of the first problems to solve was a method by which the rate of the carbohydrate changes at different temperatures could be determined without comparing analyses of different ears. The following method was finally adopted: The ears for each experiment were brought to the laboratory within 15 minutes after picking and numbered consecutively. The first set of samples was taken from ears 1 and 2, and all ears were then placed immediately under the experimental conditions. At the end of 24 hours the second set of samples was taken from ears 1 and 2 and the first set from ears 3 and 4. After 48 hours the second set of samples was taken from ears 3 and 4 and the first set from ears 5 and 6. This overlapping method of sampling was continued every 24 hours until the experiment was completed. The change in chemical composition during each consecutive 24-hour period of storage could then be determined by comparing the analytical results of the first and second sets of samples from the same ear.

Stowell's Evergreen corn was stored at seven different temperatures—namely, 0°, 5°, 10°, 15°, 20°, 30°, and 40°C. All the temperatures were controlled within about 1°. The 30° temperature was controlled within 0.1°. The corn was stored with the husks on, and, in the case of the higher temperatures, the ears were placed in large desiccators, with the tubulure on the side left open to allow ventilation. Preliminary experiments showed that, as far as the carbohydrate changes are concerned, active aeration of the small number of ears used in each experiment was not important during the short experimental period of four days.

Under the conditions of the experiments there was very little change in the percentage of water in the corn at any temperature. However, the analytical results from the second set of samples were all calculated to the moisture of the first set in order to avoid false percentages due to loss or gain in water content during storage. In a few cases at the higher temperatures the percentage of water slightly increased on account of the accumulation of respiratory water and possibly water set free by condensation of polysaccharides.

ANALYTICAL METHODS

SAMPLING

Three rows of kernels were removed for each set of samples, care being taken to remove the entire kernel. In order to take the first set of samples, the husks were split lengthwise with a sharp knife and then cut half way around at the base. After the kernels were removed the husks were brought back to place and held by means of rubber bands. For the second set of samples the husks were removed and three rows of kernels taken from the opposite side of the ear.

The corn was thoroughly ground to a mash in a small unglazed mortar and sampled immediately. On account of the short time required to sample the mash it was found unnecessary to surround the mortar with cracked ice. Each set of samples furnished material for the following determinations: Moisture, total sugars as invert sugar, sucrose, free-reducing substances, and starch. The starch was determined as glucose after hydrolysis with dilute acid.

MOISTURE.—Approximately 5 gm. of the mash were placed between tared watch glasses ground tight and held together by means of a clamp. After weighing, the cover glass was removed and the material covered with 1 cc. of alcohol. The samples were then dried to constant weight in a vacuum at 80° C. During the first drying a stream of warm, dry air was passed through the chamber. The watch glasses were clamped together before each weighing.

SUGARS.—When all things are considered, the alcohol method for the extraction of sugars from plant material in general seems preferable to any other yet devised. Since the procedure by different authors varies considerably, a large number of preliminary experiments were performed to determine the best procedure for the alcoholic extraction of sugars from the particular material at hand—namely, green sweet corn at different stages of maturity. The chief problem was to obtain complete extraction of the sugars and at the same time prevent any inversion of cane sugar as well as diastase action.

These experiments show that there is no appreciable hydrolysis of either sucrose or starch during boiling in 40 or 50 per cent neutral alcohol as long as 60 minutes. However, complete extraction was obtained by a much shorter period of boiling, and consequently the loss of alcohol during extraction is very much reduced.

The procedure finally adopted was as follows: Samples of 16 gm. each were weighed out into counterpoised 200 cc. Kohlrausch sugar flasks. A small amount of calcium carbonate was added to neutralize any acids liberated in the mash. It was later found that in the case of sweet corn this is not as important as in the case of many other plant tissues. The samples were covered immediately with 75 cc. of hot 95 per cent alcohol, the alcohol being previously measured into small boiling flasks and brought to boil on an electric hot plate. After the mixture began to boil on the steam bath, 50 cc. of hot water were added. This brought the extraction alcohol down to about 50 per cent. The water in the sample was taken into consideration in making this calculation. The foregoing method precluded any possible enzyme action in the weak alcohol while heating up to the boiling point. Small funnels were placed in the necks of the flasks to condense the alcohol and the mixture was allowed to boil 30 minutes. While still hot, the flasks were made up to the mark with 95 per cent alcohol and allowed to stand over night. They were then shaken, again made up to the mark, tightly stoppered, and stored. The final strength of the alcohol in which the samples were stored was about 64 per cent.

When a large number of samples are taken during a comparatively short time, as was the case in this work, it becomes necessary to store most of the samples for some time. Since the storage problem is an important one, a number of experiments were conducted to determine the best treatment of the samples to prevent any carbohydrate changes during long periods of storage. The final method, previously described, was found to preserve the samples for at least 145 days without any appreciable carbohydrate changes. After boiling, the samples may be safely stored in 50 per cent alcohol. Cold treatment of the samples with 52 per cent alcohol inhibited invertase action, but there was considerable starch hydrolysis after a long period of storage. If the number of volumetric flasks is limited, a measured quantity of the filtered extract can be stored. In this work 150 cc. were frequently stored.

The method employed for the determinations of the sugars in the solutions was essentially the same as the one described by Bryan, Given, and Straughn.[1]

STARCH.—Ten gm. of the mash were weighed into counterpoised 200 cc. Erlenmeyer flasks and immediately covered with 50 cc. of 95 per cent alcohol. About 0.05 gm. of calcium carbonate was added and after thorough shaking the flasks were tightly stoppered and stored. The strength of the cold alcohol in the mixture was approximately 80 per cent. This was found sufficient to preserve the samples for several weeks without any appreciable change in the carbohydrates present. The method of weighing out the samples in small flasks, counterpoised on torsion balances sensitive to one-fifteenth gm. was found to give just as good duplicates as weighing the samples to the third place in weighing bottles. By the former method, the samples could be placed in alcohol in a very much shorter time.

The determinations were made according to the following procedure: Decant the preserving alcohol on to a 9 cm. No. 1 Whatman filter paper; add 75 cc. of 50 per cent alcohol and extract 24 hours at room temperature, shaking noon and evening; decant completely the 50 per cent alcohol; add 50 cc. more of the 50 per cent alcohol and allow to stand two hours, shaking three times; decant the alcohol and when all has run through the filter transfer the mash to the filter; apply suction and drain; add 50 cc. of 50 per cent alcohol to the flask to wash down

[1] BRYAN, A. Hugh, GIVEN, A., and STRAUGHN, M. N. EXTRACTION OF GRAINS AND CATTLE FOODS FOR THE DETERMINATIONS OF SUGARS; A COMPARISON OF THE ALCOHOL AND THE SODIUM CARBONATE DIGESTIONS. U. S. Dept. Agr. Bur. Chem. Circ. 71, 14 p. 1911.

the sides and transfer to the filter. With small portions of 50 per cent alcohol, transfer to the filter any material still remaining in the flask; after the alcohol has drained out of the filter, fill up once more with 50 per cent alcohol and drain. All sugars and any other reducing materials are now removed from the residue on the filter. The filter is filled twice with 95 per cent alcohol and the residue allowed to dry on the filter. The filter paper may be folded over the sample and placed in small stoppered vials for another period of storage if necessary.

The filter paper containing the sample was placed in a Kjeldahl flask and covered with 200 cc. of water; sufficient hydrochloric acid was added to give a final strength of acid in the mixture of 2.5 per cent. Hydrolysis was effected by boiling under a reflux condenser for three hours.

A number of the filter papers used for the filtration were hydrolyzed in the same strength of acid and for the same length of time as the samples. Although the papers were claimed by the manufacturers to be starch free, they were found to give a small amount of reducing material after hydrolysis. However, the amount of this material was consistent in all the boxes and in different parts of the box, so it was very easy to make the necessary correction for the filter paper in the final results. The starch was determined as glucose, but of course it includes any other polysaccharides which furnished reducing substances during the acid hydrolysis.

EXPERIMENTAL DATA

The work had not progressed far until it was evident that if the moisture in the corn at the time of picking had fallen below a certain percentage it became a factor in controlling the rate of sugar loss. In order to eliminate this variable factor, so that attention could be focused upon the temperature relation, the experimental ears were carefully selected to represent a fairly definite stage of maturity—namely, the typical milk or best eatable stage. Ears falling below 80 per cent water were excluded from the final calculations.

The work of the first year was repeated on another crop the succeeding year. The results of the two years' work are averaged in Table I. In the experiments of the first year, the carbohydrate changes for each consecutive 24-hour period were not determined in duplicate ears as described for the experiments of the second year. Each percentage in the table, therefore, is the mean of three ears, except in a very few cases where the results of one ear were excluded on account of the moisture content's falling below the arbitrary standard. The results of the experiments at 5° and 15° C. are not given, as they add nothing to the general conclusions. The average percentage of sugars in the corn at the beginning and end of each storage period is indicated by (*a*) and (*b*), respectively.

TABLE I.—*Loss of sugar from green sweet corn during consecutive 24-hour periods of storage at different temperatures*

Number of hours in storage.	Ear lot.	Storage temperatures.									
		0° C.		10° C.		20° C.		30° C.		40° C.	
		Total.[1]	Loss.[1]	Total.[1]	Loss.[1]	Total.[1]	Loss.[1]	Total.[1]	Loss.[1]	Total.[1]	Loss.[1]
ALL SUGARS											
0	1a	5.91		5.83		6.17		5.34		6.72	
24	1b	5.43	0.48	4.83	1.00	4.59	1.58	2.65	2.69	3.64	3.08
24	2a	6.70		3.95		3.68		3.11		2.30	
48	2b	5.96	.74	3.43	.52	2.69	.99	2.68	.43	1.69	.61
48	3a	6.63		4.61		3.07		2.10		2.00	
72	3b	6.36	.27	3.92	.69	2.52	.55	2.03	.07	1.90	.10
72	4a	6.10		3.54		2.24		1.59			
96	4b	5.75	.35	2.93	.61	1.97	.27	1.49	.10		
SUCROSE											
0	1a	3.87		3.77		3.68		3.68		4.50	
24	1b	3.73	0.14	3.00	0.77	2.54	1.14	1.50	2.18	2.18	2.32
24	2a	4.06		2.53		1.84		1.52		1.18	
48	2b	3.77	.29	1.99	.54	1.17	.67	1.24	.28	.76	.32
48	3a	4.49		2.74		1.38		1.02		1.05	
72	3b	4.25	.24	2.30	.44	1.12	.26	.97	.05	.91	.14
72	4a	3.84		1.87		1.11		.71			
96	4b	3.56	.28	1.41	.46	.85	.26	.67	.04		
FREE-REDUCING SUBSTANCES											
0	1a	1.84		1.85		2.07		1.65		1.98	
24	1b	1.70	0.14	1.68	0.17	1.77	0.30	1.16	0.49	1.32	0.66
24	2a	1.66		1.29		1.68		1.56		1.06	
48	2b	1.55	.11	1.28	.01	1.41	.27	1.42	.14	.80	.26
48	3a	1.91		1.73		1.55		1.07		.90	
72	3b	1.89	.02	1.50	.23	1.28	.27	1.04	.03	.93	.00
72	4a	2.05		1.57		1.13		.88			
96	4b	2.00	.05	1.45	.12	1.04	.09	.81	.07		

[1] Total quantities of all sugars before and after storage and losses during storage are expressed in percentages.

The data in Table I show that the loss of sugar from corn during storage is not uniform, but becomes slower and slower as a final equilibrium is approached. The relative rates of processes of this kind at different temperatures can be determined accurately only by comparing the times required to perform equal amounts of work at all temperatures, and not by comparing the amounts of work performed in equal times. In other words, we must compare the times required at the different temperatures to bring the process to the same stage. We are thus comparing stages where the ratio between the reacting material and the products is the same. Osterhout [1] has recently emphasized this point in a "Note on measuring the relative rates of life processes."

In order to make it possible to determine, on this basis, the relative rates of sugar loss at the different temperatures, the experimental results in Table I can be easily interpolated by a simple graphic method, to be described later, if they can be expressed in curves all starting from the same point.

This could be decided only after a careful consideration of all the factors involved. If mass action alone were responsible for the gradual decline in the rate of sugar loss, then, at a given temperature, the average rate of change in any unit of time would be proportional to the sugar concentration. For a range of original sugar from about 4.5 to 7 per cent and of water from 78 to 80 per cent this was found to be the case for the first 48 hours of storage even at 30° C. (Table II).

TABLE II.—*Proportion of sugar lost during first 48 hours of storage at 30° C.*

Ear No.	Reducing sugar before storage.	Loss during storage.		Total sugar before storage.	Loss during storage.		Sucrose before storage.	Loss during storage.	
		Actual.	Proportional.		Actual.	Proportional.		Actual.	Proportional.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	1.70	0.68	37	6.16	3.59	58	4.24	2.77	65
2	2.40	1.02	42	7.20	3.87	54	4.80	2.95	61
3	2.60	1.05	40	6.74	3.88	58	4.14	2.89	69
4	.96	.22	43	4.47	2.59	58	3.33	2.33	69
5	1.66	.82	49	5.91	3.41	58	4.25	2.68	63
6	3.00	1.31	44	6.55	3.69	57	3.55	2.43	68

The sugar loss ceases when an appreciable amount of sugar is still present. Therefore, the speed of the counter process, that is, the formation of sugar, becomes a factor to be reckoned with when the processes have nearly reached an equilibrium. If at the beginning of storage the percentage of sugar in ear 1 is considerably greater than in ear 2, the latter would reach the equilibrium position sooner than ear 1. At the end of 72 hours of storage at 30° C. ear 1 might still have 2 per cent sugar while in ear 2 the sugar content might be only 1 per cent. The sugar loss in ear 2 being nearer the equilibrium point, the speed of the counter process would be greater in this ear than in ear 1. Therefore, during the next 24 hours the proportionality between the sugar lost and the sugar

[1] OSTERHOUT, W. J. V. NOTE ON MEASURING THE RELATIVE RATES OF LIFE PROCESSES. *In* Science, n. s., v. 48, no. 1233, p. 172–174, 3 fig. 1918.

present would not be the same in the two ears. This was proved experimentally.

In considering the rate of the counter reaction in connection with the problem at hand—namely, the possibility of expressing the experimental results in curves all starting from the same point—it must be borne in mind that it becomes appreciable only near the point of equilibrium, and even then it would affect the proportionality between the sugar present and the sugar lost in different ears at the same temperature only when the percentage of sugar in the ears at the beginning of storage varied considerably.

A decrease in the quantity of active enzymes present would produce a steady fall in the values of the velocity constants; this would cause a decreasing rate of actual sugar loss. There is no evidence that this occurs up to 30° C.

In view of the foregoing facts, together with the fact that the ears selected for the final calculations were all in practically the same stage of maturity and therefore contained nearly the same percentage of original sugar, the following procedure in preparing the data for construction of curves all starting from the same point seemed justified. The sugar lost during each 24-hour period of storage was calculated as proportions of the sugar present in the ears at the beginning of each period. The percentages of sugar found in the ears analyzed at the beginning of each experiment were then averaged. Ten ears with not less than 80 per cent water were included in the final average.

Taking this mean as the starting point for all temperatures and applying the proportions of sugar lost during each succeeding 24-hour period, calculated from the experimental data, a new set of proportions was obtained, based upon the same original sugar content in all cases. A single concrete case may serve to clarify the foregoing procedure. The total sugar in all the ears analyzed at the beginning of each experiment averaged 5.766 per cent. During the first 24 hours of storage at 30° C. the average loss of total sugar in three ears was 50.28 per cent of the initial sugar present; that is, the total sugar in the corn was 50.28 per cent less than at the beginning of storage. Applying this proportion to an initial sugar content of 5.766 per cent, we obtain, after the first 24-hour period of storage at 30°, a total sugar content of 2.867 per cent. Making use of all the experimental proportions in the same manner, the percentage of total sugar present at the end of each 24-hour period of storage was calculated, assuming that the sugar content at the beginning of storage was 5.766 per cent. Each calculated percentage was then substracted from 5.766, the initial sugar present. The sugar loss, expressed as percentages of the initial sugar, could then be calculated for the following storage periods: 24, 48, 72, and 96 hours. The same procedure was followed for all the sugars at all the temperatures, with the results shown in Table III.

TABLE III.—*Sugar loss from green sweet corn during different periods of storage at different temperatures, expressed as percentages of the same initial sugar at all temperatures*

TOTAL SUGARS

Number of hours in storage.	Storage temperature.				
	0° C.	10° C.	20° C.	30° C.	40° C.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
24	8. 12	16. 98	25. 61	50. 28	45. 79
48	14. 51	27. 95	45. 73	57. 09	60. 15
72	18. 03	38. 71	55. 50	59. 00	62. 16
96	22. 00	49. 22	62. 10	61. 84	....
SUCROSE					
24	3. 51	20. 78	31. 05	59. 42	51. 03
48	10. 39	37. 49	56. 12	66. 76	64. 68
72	15. 08	47. 46	64. 22	68. 55	69. 24
96	21. 25	60. 54	70. 16	70. 19	....
FREE-REDUCING SUBSTANCES AS INVERT SUGAR					
24	7. 58	9. 26	14. 72	29. 96	33. 48
48	13. 61	10. 52	28. 84	36. 19	49. 76
72	14. 62	16. 71	40. 79	39. 74	49. 76
96	16. 97	23. 33	45. 65	43. 19	....

The data in Table III, showing the rate of actual loss for total sugars and sucrose, were plotted as curves (fig. 1 and 2).

The curve for 0° C. shows a more rapid sugar loss than is typical for this temperature. In the first place, it required some time for the corn to cool down to this temperature. At the end of each 24-hour period a pair of ears were removed from the cold chamber in order to take the first set of samples. Although the sampling period was short, the temperature of the corn would soon rise a few degrees above 0°. The loss of sugar at the sampling temperature is accumulative in the curve.

The inversion of sucrose appears to be the controlling process in the sugar loss, as the curves for the decrease of sucrose are very similar to those for the loss of total sugar.

TEMPERATURE COEFFICIENT.—Since the curves in figures 1 and 2 all start from the same point, by means of a simple graphic method the relative rates of sugar loss at the different temperatures can now be determined by comparing the times at different temperatures required to do the same amount of work. As an illustration we will choose a stage in the depletion of sugar when 40 per cent of the total sugar is lost; in other words, at this point the sugar in the corn is 40 per cent less than at the beginning of storage. A horizontal line is drawn from this point through all of the curves. Vertical lines are now dropped from the points of intersection to the base line. The times in hours required at the different temperatures to bring the sugar loss to this point are read off on the base line (see fig. 1). The procedure was repeated for all the percentages given on the ordinate.

The relative rates of sugar loss at the different temperatures are expressed in Table IV as the reciprocals of the times in hours required to bring the process to five different stages. The temperature coefficients were obtained from these reciprocals. The results at 40° C. were not

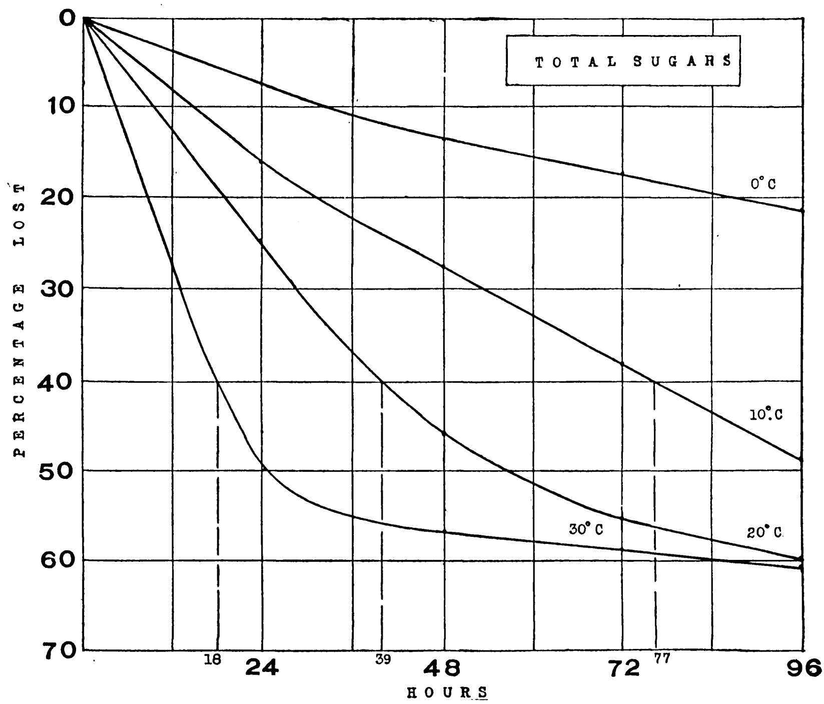

FIG. 1.—Depletion of total sugars in green sweet corn during consecutive 24-hour periods of storage at different temperatures. The ordinates are given by the numbers on the left of the figure and represent the loss of sugar expressed as percentages of the initial sugar, which was 5.91 per cent, wet weight.

included in the foregoing calculation as there was evidently destruction of the enzymes or other alteration in the system by the high temperature.

Some of the curves for the sugar loss, expecially those for sucrose, approach true logarithmic curves; and satisfactory constants were obtained for most of the storage period by applying the simple unimolecular equation. During the latter part of the period there was a falling off in the velocity constants, due no doubt to the counter reaction. The simple uni-molecular equation assumes that the reaction proceeds to completion or so near completion that the speed of the counter may be ignored. However, as Osterhout has shown in the paper previously cited, it is not necessary to determine the true velocity constants of a process under different conditions if only the relative rates are desired. This may be accomplished in the manner indicated in Table IV by comparing the reciprocals of the times required to do the same amount of work.

In general, it may be stated that up to 30° C. the rate of sugar loss in green corn is doubled for every increase of 10°. This applies to both total sugars and sucrose. It should be noted, however, that between 0° and 10° the temperature coefficient for sucrose is considerably greater than 2.

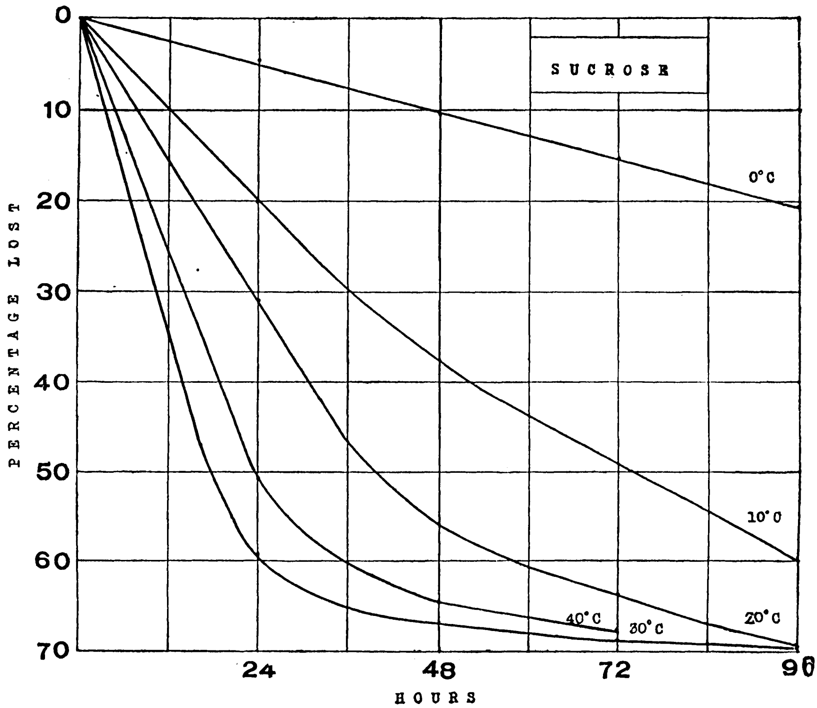

FIG. 2.—Depletion of sucrose in green sweet corn during consecutive 24-hour periods of storage, expressed as percentages of the initial sucrose in the corn, which was 3.87 per cent, wet weight.

RESPIRATION.—In a former paper the writer[1] has shown that respiration in green sweet corn after it is first pulled from the stalk is comparatively high. During the first 24 hours of storage at 30° C. the corn with the husks removed respired at an average rate of 50 mgm. of carbon dioxid per kgm. per hour. This rate became slower and slower until it reached, in eight days, a constant rate of about 18 mgm. of carbon dioxid per kgm. per hour. Respiration of course consumes sugar and therefore accounts for some of the depletion of sugar in sweet corn

[1] APPLEMAN, Charles O. RESPIRATION AND CATALASE ACTIVITY IN SWEET CORN. *In* Amer. Jour. Bot., v. 5, p. 207–209, 1918.

during storage. During each consecutive 24-hour period of storage the percentage of sugar in the corn, however, is only slightly altered by respiration, as shown by the following illustration. Straughn, in the paper previously cited, averaged the weight of kernels and cobs from 18 ears and found that the kernels averaged approximately 50 per cent of the total weight. If we assume that all of the carbon dioxid came from the kernels, then 500 gm. of kernels would produce 1,200 mgm. of carbon dioxid during the first 24 hours' storage at 30°. From the formula

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$$

1,200 mgm. of carbon dioxid would correspond to the consumption of 818.61 mgm. of sugar. The consumption of this amount of sugar by respiration would free in the system 491.343 mgm. of water.

TABLE IV.—*Reciprocals of the times, in hours, required at different temperatures to bring the sugar depletion in sweet corn to five different stages. Also the temperature coefficients obtained from these reciprocals*

Percentage of initial sugar lost.	Storage temperature.	Reciprocals of time periods.		Temperature coefficients.	
		Total sugars.	Sucrose.	Total sugars.	Sucrose.
	°C.				
10	0	0.0303	0.0213	......	......
	10	.0666	.0833	2.2	3.91
	20	.1041	.1282	1.56	1.53
	30	.2083	.2777	2.00	2.16
20	0	.0122	.0108	......	......
	10	.0320	.0416	2.62	3.85
	20	.0520	.0666	1.62	1.60
	30	.1111	.1388	2.13	2.08
30	10	.0184	.0268	......	......
	20	.0354	.0427	1.92	1.59
	30	.0724	.0925	2.04	2.16
40	10	.0131	.0191	......	......
	20	.0252	.0326	1.92	1.71
	30	.0555	.0694	2.30	2.12
50	10	.0101	.0136	......	......
	20	.0173	.0256	1.71	1.88
	30	.0406	.0555	2.34	2.17
60	10	......	.0104	......	......
	20	......	.0171	......	1.64
	30	......	.0416	......	2.43
Average temperature coefficient			......	2.04	2.14

For the sake of simplicity, we will confine the system to 100 gm. of corn and suppose that at the beginning of storage it contained 5 gm. or 5 per cent sugar and 80 gm. or 80 per cent water, a fair average for the corn used in this work. According to the foregoing rate of respiration this system would lose 163.72 mgm. of sugar during the first period of storage of 24 hours. At the same time 98.269 mgm. of water would be freed in the system. Our system would now contain 80.0983 gm. of water and 4.8363 gm. of sugar. By correcting for the slight loss of dry matter, the system would contain 80.1507 per cent water and 4.8395 per cent sugar. These percentages would be those found by actual analysis of the 100 gm. of corn after 24 hours' storage, assuming that no other changes occurred besides respiration.

If we now calculate the percentage of sugar on the basis of the original water in the system, as was done in all cases in this work, the percentage of sugar would be 4.8726, showing a loss by respiration of 0.1274 per cent.

It should be noted that the rate of respiration chosen for this illustration was the rate for the highest period at 30° C. It was also assumed that all of the carbon dioxid came from the kernels. During the immature stages of the corn it is very probable that some of the sugar in the cob is consumed by respiration.

During the later periods at the high temperatures and for all periods at the low temperatures, the change in the percentage of sugar by respiration during the short periods of 24 hours would be practically within the experimental error for the sugar and moisture determinations.

One ton of husked green sweet corn, during the first 24 hours of storage at 30° C. would lose approximately 3.2 pounds of sugar on account of respiration.

Under certain conditions, however, respiration may become an important factor in accelerating the depletion of sugar from green sweet corn. One of the products of respiration is heat. This heat of respiration will raise the temperature on the inside of large piles of green corn to a very marked degree. The increased temperature accelerates not only the respiratory process itself but also the other processes responsible for most of the sugar loss. Aeration of green corn is therefore important in order to dissipate the heat of respiration. In other words, green corn should not be allowed to remain in large piles for even a short time, especially during midsummer temperature.

STARCH FORMATION.—If the sugar is all converted into starch or other polysaccharides, hydrolyzed by dilute acids, then the sum of the total sugars and the polysaccharides as glucose should be the same before and after storage. During the first period there is a slight deficit after storage, especially in the more immature ears. A part of this deficit is due to the high respiration of this period; but some of it is probably accounted for, in the immature ears when the sugar is high, by the formation of cellulose. During the later periods of storage many of the ears, depending largely upon the stage of maturity, show a slight increase in the sum of the total sugars and polysaccharides. This is true especially at the higher temperatures and is probably accounted for by the sugar of the cob being drawn into the grain for starch formation as the sugar in the grain is depleted. Analyses of cobs from immature ears gave a total sugar content of about 7 per cent. The sugar in the cob decreased slightly during storage, but there was no starch formation in the cob.

After noting these exceptions, which alter the balance only slightly, it may be stated in general that most of the sugar loss in green sweet corn is balanced by the gain in polysaccharides, chiefly starch (Table V).

TABLE V.—*Depletion of sugar in green sweet corn balanced chiefly by formation of polysaccharides hydrolyzed by dilute acid*

Ear No.	Total sugars plus polysaccharides as glucose.							
	First period.		Second period.		Third period.		Fourth period.	
	0 hours.	24 hours.	24 hours.	48 hours.	48 hours.	72 hours.	72 hours.	96 hours.
0° C.								
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	11.01	11.04	12.40	12.39	11.07	11.29	13.57	13.56
2	10.72	10.67	14.84	15.35	....	....	13.41	12.68
Average.	10.86	10.86	13.62	13.87	11.07	11.29	13.49	13.12
10° C.								
1	14.56	14.53	15.26	15.89	15.86	15.35	14.29	15.05
2	11.79	11.37	14.01	13.50	11.93	11.58	10.81	10.49
Average.	13.18	12.95	14.64	14.70	13.89	13.47	12.55	12.77
20° C.								
1	11.50	11.09	15.19	15.13	11.28	10.56	10.93	10.46
2	10.82	9.97	13.64	13.58	10.21	10.24	13.34	13.76
3	....	....	12.13	11.20	12.67	12.20	....	....
Average.	11.16	10.53	13.65	13.30	11.35	11.00	12.14	12.11
30° C.								
1	14.75	14.10	13.39	13.55	13.30	13.32	12.48	12.66
2	12.20	10.53	16.77	17.24	12.16	12.66	12.17	12.61
3	....	....	13.13	12.01	10.80	12.36	11.43	12.17
Average.	13.48	12.31	14.43	14.26	12.08	12.78	12.02	12.48

SUMMARY

The data recorded in this paper apply to Stowell's Evergreen corn, picked in the typical milk or best eatable stage and having a water content of approximately 80 per cent.

A method was devised by which the rate of sugar loss from green sweet corn could be determined for consecutive 24-hour periods of storage by comparing analyses of corn from the same ear.

The depletion of sugar in green sweet corn after it is separated from the stalk does not proceed at a uniform rate but becomes slower and slower until finally the loss of sugar ceases when the initial total sugar has decreased about 62 per cent and the sucrose about 70 per cent. Calculated on the basis of original moisture, the corn contained, when the depletion of sugar ceased, approximately 1.5 per cent total sugar as invert sugar, 0.7 per cent sucrose, and 0.8 per cent free-reducing substances. The actual percentage of sugars would depend upon the amount of water in the corn after storage. Under the experimental conditions there was very little change in the percentage of water in the corn employed in this work.

Reversibility of the chief processes involved in the sugar depletion, resulting in an equilibrium between the rate of sugar loss and the rate of sugar formation, would account for the cessation of actual sugar loss.

During the early periods of storage, the falling off in the rate of actual sugar loss is due to mass action. When the equilibrium is nearly reached the counter reaction, that is the formation of sugar, also tends to slow up the rate of sugar loss. Any destruction or decrease in the quantity of enzymes present would produce a falling off in the value of the velocity constant, with a consequent decrease in the rate of actual sugar loss. There is no evidence that this occurs up to 30° C. At 40° there is actual destruction of the enzymes or other alteration on the system. The rate of actual sugar loss must not be confused with the velocity constant.

Raising the temperature simply hastens the attainment of the equilibrium positions, which seem to be about the same for all temperatures. At 30° C., 50 per cent or most of the total sugar loss occurs during the first 24 hours of storage. At 20°, 25 per cent, and at 10°, or good refrigerator temperature, only about 15 per cent is depleted during the same period.

Relative rates at different temperatures, of processes that become slower and slower until an equilibrium is reached, can be accurately determined throughout this entire course only by comparing the times required to bring the process to the same stage at all temperatures. In order to make this comparison possible the experimental results were interpolated by a simple graphic method. The temperature coefficient was then obtained by comparing the reciprocals of the times

required to do the same amount of work at the different temperatures. In this manner the temperature coefficients were determined for six different stages. Up to 30° C. an average coefficient of 2.03 was obtained for the loss of total sugars and 2.14 for sucrose. From 0° to 10° it was greater than 2 in the case of sucrose.

In general, it may be stated that the rate of sugar loss, until it reaches 50 per cent of the initial total sugar and 60 per cent of the sucrose, is doubled for every increase of 10° up to 30° C.

Respiration in green corn is comparatively high when the corn is first picked but falls off rapidly with storage. This process, however, accounts for only a small part of the actual decrease in the percentage of sugar in the corn during the consecutive 24-hour periods of storage even at 30° C. One ton of husked green sweet corn during the first 24 hours of storage at 30° would lose approximately 3.2 pounds of sugar on account of respiration.

Respiration may become indirectly a more important factor in accelerating the depletion of sugar by raising the temperature on the inside of large piles of green corn.

Most of the decrease in the percentage of sugar in green sweet corn during storage is due to condensation of polysaccharides, chiefly starch.