U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF CHEMISTRY.

BULLETIN No. 18.

SUGAR-PRODUCING PLANTS.

RECORD OF ANALYSES

MADE BY AUTHORITY OF

THE COMMISSIONER OF AGRICULTURE,

UNDER DIRECTION OF

THE CHEMIST,

1887-'88.

SORGHUM:

FORT SCOTT, KANSAS; RIO GRANDE, NEW JERSEY.

SUGAR CANE:

LAWRENCE, LOUISIANA.

TOGETHER WITH A STUDY OF THE DATA COLLECTED ON SORGHUM AND SUGAR CANE.

WASHINGTON:
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INTRODUCTORY LETTER.

SIR: I submit herewith, for your inspection and approval, Bulletin No. 18 of the Chemical Division.

In Bulletin No. 17 it is stated that much of the analytical work pertaining to the recent experiments in the manufacture of sugar was not ready for incorporation in that report. This work is now finished and tabulated and will be found in the following pages.

In view of the fact that the experiments which have been conducted for so long a time by the Department in the manufacture of sugar have come to a successful end, I have thought it would be useful here to collect together, in a condensed form, all the important recorded analyses of sorghum which I have been able to find. Where series of such analyses have been made, there are given only the means of the analyses, since to reproduce them singly would extend the size of the bulletin to undue proportions. For those, however, who may desire to study the analyses more minutely, references are given to original publications containing them. I have also added to this part of the work an abstract of recorded tonnage per acre for sorghum, yield of sugar per ton, and other data which may help to assist any one interested in the matter to an intelligent conclusion concerning the merits of sorghum as a sugar-producing plant.

In like manner I have epitomized the results of the analytical investigations which the Department has carried on for several years at Magnolia Plantation, Lawrence, La. Intending investors in establishments for manufacturing sugar should have access to a careful and unbiassed statement of the data on which the industry rests, and in the following pages an effort has been made to furnish this kind of information.

Reports written under the influence of prospective personal profit, or for pushing the claims of a patent, or to gratify personal pique or ambition, are likely to become the argument of the advocate rather than the charge of the non-partisan judge.

The persistent and often malicious misrepresentation of the work which has been done by the Department has not been without its baneful influence, although it has entirely failed of its chief purpose. The large number of persons interested in the culture of sugar beets, sorghum, and sugar cane recognize the value of the work which the

Department has done, a value which misrepresentation can not disparage nor selfish greed pervert.

In the work which has been done under my supervision I am not conscious of having withheld credit from others to whom it was due, nor of having claimed, for the Department, undeserved honor.

Exploring an unknown country, the real path of progress has often been lost to view, and for myself I am content if my labors have pointed out to others the road to success.

The cordial encouragement and support which I have received from you, even in the darkest hour of the work, have been most unqualified, and your faith in the ultimate success of the industry has never faltered.

The process of diffusion, by the efforts of your Department, has been fully established as the best and most economical method of extracting the sugar from the cane, and the way has been opened for private capital to extend and develope the sugar-producing power of our country until it shall be placed on a sure foundation of prosperity.

Respectfully,

H. W. WILEY,
Chemist.

Hon. NORMAN J. COLMAN,
Commissioner of Agriculture.

ANALYTICAL WORK AT FORT SCOTT, SEASON OF 1887.

In the agreement made by the Commissioner of Agriculture with the Parkinson Sugar Company for conducting the experiments in the manufacture of sugar from sorghum during the season of 1887, provision was made for a complete chemical control of the work by the Chemical Division of this Department. Having been directed by the Commissioner of Agriculture to take charge of all the chemical work to be done at the three sugar stations, Dr. C. A. Crampton and Mr. N. J. Fake were directed to perform the analytical work at Fort Scott.

The following general directions were sent for conducting the work:

U. S. DEPARTMENT OF AGRICULTURE, CHEMICAL DIVISION,
Washington, D. C., August 29, 1887.

DEAR SIR: In conducting the analytical work at Fort Scott during the present season, you will be guided by the following general directions:

(1) Samples of cane from the wagon or cane-carrier are to be taken from time to time as last year, representing as nearly as possible the best, poorest, and medium canes which are brought to the factory.

(2) When the diffusion battery is in operation, a given weight of chips is to be taken from each of the cells until one complete round of the battery is represented. These samples are to be preserved in a closed vessel until all are taken and then passed through a small mill and the expressed juice examined in the usual way.

(3) A measured sample of the juice discharged from each cell of the diffusion battery should be taken until one complete round has been made. These mixed samples of juice to be examined in the usual way.

(4) Samples of the juice above examined should be taken after the process of clarification, representing as nearly as possible the same body of juice as above, and examined in the usual way.

(5) After concentration to sirup, a sample should be taken, representing as nearly as possible the juice of the above two numbers and subjected to analysis.

(6) Samples of the *masse cuite*, sugar and molasses are to be taken, carefully labeled, and forwarded to the division here for examination.

(7) When the large mill is running, samples of the mixed juices should be taken as often as convenient and subjected to examination.

(8) The bagasse from the large mill should be examined from time to time, either by exhaustion with successive portions of water in an open vessel, or by exhaustion in a closed flask, a little freshly precipitated carbonate of lime being added to the water of maceration.

(9) Take from each cell of discharged chips a certain quantity representing as nearly as possible the mean character of the chips discharged from that cell after one complete circuit of the battery has been made, pass the samples so obtained through the small mill, and subject the expressed juices to examination.

Concerning the details of the analytical work, little need be said. Double polarization is not necessary except in cases where the canes may be badly injured, and you will use your own discretion in this matter. You will please report by mail to this office at least once a week the general character of the analytical results obtained.

Any special chemical investigations desired by Mr. Parkinson or Mr. Swenson you will make, in so far as these may not interfere with the general work indicated above.

Respectfully,

H. W. Wiley,
Chemist.

Dr. C. A. Crampton,
Fort Scott, Kans.

Later in the season additional instructions were sent to carefully compare the Brix spindles used in determining the total solids in the juice with the direct determination of solids by drying a weighed portion of the juice (2 grammes *circa*) and determining the per cent. water it contained. This was thought necessary because it was found that by determining the water directly in the *masse cuites* they were shown to have a higher co-efficient of purity than the juices from which they were derived.

The large mill which, it was expected, would be in operation, was not erected, and the directions to examine the juices therefrom were therefore superfluous.

The work at Fort Scott was begun on the 2d of September and ended October 19.

The sucrose in the juices was determined by polarization in a Laurent large model instrument, with white light attachment. During the later part of the season a Schmidt and Haensch double-compensating shadow instrument was employed to check the results of the instrument first named.

The glucose was determined by Fehling's (Violette's) solution.

The total solids were determined by Brix spindles and by direct weighing.

Following are the results of the analytical work:

ANALYSES OF JUICES OF SELECTED CANES.

For sampling different lots of cane, comparing saccharine richness, etc., the juice of single canes, or small collections thereof, was examined at different periods. In these cases it would be expected that much greater difference would be found than in the average samples of chips in the second table. The results show how rich single canes of sorghum may be in available sugar, and also how poor.

The maximum content of sugar is found in sample No. 9, viz, 14.20. The minimum is seen in sample No. 8, where the sucrose drops to 2.54 per cent.

DESCRIPTION OF SAMPLES.

No. 1. Orange cane sample from Bullock.
2. Orange cane sample from Bowman.
3. Orange cane sample from Zoak.
4. Late planted early amber from Brown.

No. 8. Honduras cane shipped by freight from Osage, Mich., to Fort Scott.
20. Orange cane from wagons, average sample cut to dry.
21. Amber cane from wagons, average sample cut to dry.
28. Steward's hybrid cane.
29. Honduras cane.
31. Link's hybrid, from land of company west of railroad track.
35. Link's hybrid, same field, east end.
36. Link's hybrid, green from slough.
37. Link's hybrid, brow of hill.
38. Link's hybrid, brow of next hill.
39. Mixture of orange and amber ripe cane.
40. Amber cane from company's land.
41. Link's hybrid, same field, green.
42. Link's hybrid, same field, green.
43. Link's hybrid, same field, green.
148. Sample of cane cut and allowed to lie some time to show effect of inversion.
253. Orange cane badly damaged by chinch bugs.
254. Same, another sample.
256. Orange cane from company's land.
257. Orange cane from company's land.

TABLE NO. 1.—*Various analyses of mill juices from whole canes.*

Date.	No.	Brix (corrected).	Sucrose.	Glucose.
			Per cent	*Per cent.*
Sept. 2	1	16.63	11.30	....
Sept. 2	2	19.13	13.20	....
Sept. 2	3	19.65	13.11	....
Sept. 2	4	19.13	12.17	....
Sept. 5	8	18.43	2.54	....
Sept. 9	20	15.87	7.83	5.43
Sept. 9	21	19.87	14.20	2.50
Sept. 10	28	17.87	11.03	3.43
Sept. 10	29	16.15	9.27	4.23
Sept. 10	31	18.37	12.44	2.23
Sept. 12	35	13.68	8.20	2.81
Sept. 12	36	14.68	9.03	2.46
Sept. 12	37	15.80	9.88	2.82
Sept. 12	38	17.30	12.21	1.75
Sept. 12	41	15.18	10.19	2.19
Sept. 12	42	12.43	5.95	2.78
Sept. 12	43	15.18	10.22	2.71
Sept. 12	39	16.28	10.85	4.91
Sept. 12	40	16.78	11.81	2.19
Sept. 24	148	19.31	3.32	9.36
Oct. 10	253	17.43	12.98	1.78
Oct. 10	254	17.93	13.67	....
Oct. 10	256	12.99	7.75	....
Oct. 10	257	15.31	9.80	....
Means	.....	16.72	10.12	3.35
Maxima	.....	19.65	14.20	9.36
Minima	.....	12.43	2.54	1.75

TABLE NO. 2.—*Mill juices from fresh chips.*

Date.	No.	Brix (corrected).	Sucrose.	Glucose.
			Per cent.	*Per cent.*
Sept. 3	5	15.63	8.06	
Sept. 5	9	17.43	10.78	
Sept. 6	11	16.73	10.45	3.50
Sept. 8	16	16.68	10.34	
Sept. 9	23	15.87	6.20	6.49
Sept. 10	30	16.87	9.48	3.87
Sept. 10	33	16.70	8.56	4.10
Sept. 12	47	17.88	11.39	3.48
Sept. 13	51	17.06	9.56	3.84
Sept. 13	54	16.46	9.21	4.07
Sept. 15	69	17.00	10.08	3.62
Sept. 15	73	16.20	10.21	2.82
Sept. 16	81	15.93	10.15	2.96
Sept. 16	85	14.65	9.36	2.72
Sept. 17	88	17.47	9.99	4.09
Sept. 17	92	16.86	9.99	3.54
Sept. 19	96	16.07	10.40	2.67
Sept. 19	99	16.78	11.19	1.39
Sept. 20	106	16.80	10.21	3.05
Sept. 20	110	15.70	8.91	3.15
Sept. 21	123	17.68	9.48	4.20
Sept. 22	131	17.17	7.70	5.60
Sept. 22	134	17.73	7.07	5.34
Sept. 23	142	17.21	9.84	3.82
Sept. 23	146	16.76	10.24	
Sept. 24	149	19.00	9.86	3.31
Sept. 24	153	17.17	11.28	2.50
Sept. 26	161	16.51	8.89	3.93
Sept. 27	166	14.94	9.04	2.68
Oct. 1	174	16.79	10.39	3.10
Oct. 1	182	16.06	10.30	
Oct. 3	187	15.79	10.38	3.08
Oct. 3	193	15.69	10.38	2.68
Oct. 4	198	16.63	10.18	3.48
Oct. 4	203	15.83	9.88	2.88
Oct. 5	216	16.70	10.00	3.08
Oct. 5	222	16.58	10.26	3.67
Oct. 6	230	18.65	11.51	3.78
Oct. 7	238	16.10	9.60	3.53
Oct. 8	246	15.76	7.46	4.23
Oct. 11	258	15.21	9.59	3.15
Oct. 11	262	14.44	9.18	2.96
Oct. 12	265	14.73	9.13	3.44
Oct. 12	272	15.11	10.45	2.40
Oct. 13	278	14.97	9.22	3.17
Oct. 13	282	15.33	9.62	2.75
Oct. 14	287	15.69	9.54	3.53
Oct. 15	292	13.68	8.30	2.77
Oct. 15	295	14.24	9.02	2.69
Oct. 16	300	15.11	9.13	3.10
Oct. 17	304	15.31	8.85	3.39
Oct. 17	307	13.09	7.99	2.47
Oct. 18	311	15.81	9.47	3.03
Oct. 19	315	14.21	8.18	3.23
Oct. 19	318	14.93	8.46	3.60
Averages.		16.14	9.54	3.40

A study of Table No. 2 reveals the same characteristics of sorghum juices which have been noticed in the work of previous years. The variations of the juice, however, from the mean have not been so pronounced as they were during the season of 1886, owing, doubtless, to the fact that the cane was, after harvesting, more promptly delivered to the factory and worked with less delay than during the previous season.

The maximum per cent. of sucrose was found in the juice obtained on October 6, viz, 11.51. Other notably good juices were secured on September 12, 19, and 21; the sucrose in these cases rising above 11 per cent. The minimum per centage of sucrose was found September 9, viz, 6.20. Other notably poor juices are shown by the analyses of September 22 and October 17.

TABLE NO. 3.—*Diffusion juices.*

Date.	No.	Brix (corrected).	Sucrose.	Glucose.
			Per cent.	*Per cent.*
Sept. 8	17	12.28	7.03	....
Sept. 9	22	12.82	7.00	3.07
Sept. 10	34	12.32	6.51	2.90
Sept. 12	48	12.08	7.23	2.52
Sept. 13	52	12.28	7.19	2.78
Sept. 13	55	12.42	7.47	....
Sept. 15	70	12.08	7.57	2.54
Sept. 15	74	12.62	8.30	2.30
Sept. 16	82	12.38	7.88	2.52
Sept. 16	86	13.10	8.79	2.33
Sept. 17	89	12.28	7.44	2.92
Sept. 17	93	12.28	7.82	2.63
Sept. 19	97	11.32	7.35	2.02
Sept. 19	100	12.28	8.00	1.94
Sept. 20	107	12.32	6.96	2.12
Sept. 20	111	12.32	7.51	2.30
Sept. 21	124	11.61	6.64	2.47
Sept. 22	132	10.85	5.80	2.94
Sept. 22	135	11.61	6.46	2.73
Sept. 23	143	11.47	6.71	2.76
Sept. 23	147	11.57	6.80	....
Sept. 24	150	12.14	6.57	2.28
Sept. 24	154	10.95	6.92	1.93
Sept. 26	162	10.81	6.32	2.40
Sept. 27	167	10.17	6.37	2.02
Oct. 1	175	10.54	6.20	2.20
Oct. 1	183	10.12	6.25	....
Oct. 3	188	10.24	6.15	2.08
Oct. 3	194	10.54	6.64	2.00
Oct. 4	199	10.51	6.27	2.01
Oct. 4	204	10.15	6.44	....
Oct. 5	217	11.05	6.29	2.25
Oct. 5	223	11.68	7.15	2.41
Oct. 6	231	13.10	8.04	2.61
Oct. 7	239	10.98	6.54	2.09
Oct. 8	247	11.51	5.90	3.06
Oct. 11	259	10.39	6.58	2.09
Oct. 11	263	10.49	6.51	1.94
Oct. 12	266	9.97	6.17	2.03
Oct. 12	273	10.82	7.32	1.85
Oct. 13	279	9.71	5.97	1.89
Oct. 13	283	10.27	6.59	1.80
Oct. 14	288	10.17	6.02	1.80
Oct. 15	293	9.34	5.66	1.75
Oct. 15	296	10.24	6.56	1.98
Oct. 16	301	9.45	6.04	1.83
Oct. 17	305	8.74	5.05	2.06
Oct. 17	308	9.51	5.88	1.84
Oct. 18	312	9.67	5.66	2.02
Oct. 19	316	8.64	5.05	1.82
Oct. 19	319	8.77	5.05	2.05
Means	.....	11.08	6.68	2.26
Maxima	.....	13.10	8.79	3.07
Minima	.....	8.74	5.05	1.80

The lowest sucrose in the diffusion juices was found on October 17 and 19, viz, 5.05 per cent., and October 17 and 18, viz, 5.88 and 5.66 per cent. This was at the close of the season. On only four preceding days did the percentage of sucrose fall below 6, viz, September 22, October 8, 13, and 15. The maximum per cent. of sucrose in the diffusion juice was found in sample No. 86, September 16, viz, 8.79.

The sample of mill juice corresponding to this number is found in Table No. 2, sample No. 85. The sucrose in this juice was 9.36 per cent.

Thus, while the content of sucrose in the chip juices for that day was 18 per cent. below the average for the season, the sucrose in the diffusion juice was 2 11 per cent. above it. These numbers show the difficulty of obtaining comparative samples in sorghum examinations. Single analyses are apt to be deceptive, and reliance should be placed rather on the work for the entire season.

TABLE NO. 4.—*Mill juices from exhausted chips.*

Date.	No.	Total sugars.	Date.	No.	Total sugars.
		Per cent.			*Per cent.*
Sept. 9...	24	.99	Oct. 1....	176	.57
Sept. 10...	32	1.19	Oct. 3....	189	.90
Sept 12...	49	.56	Oct. 4....	200	1.01
Sept. 13...	56	.63	Oct. 5....	218	.88
Sept. 15 ..	71	.88	Oct. 6 ...	232	.84
Sept. 16...	84	1.09	Oct. 7....	240	.89
Sept. 17...	90	1.83	Oct. 8 ..	248	1.35
Sept. 19 ..	98*a*	.88	Oct. 11....	260	1.38
Sept. 19...	102	1.19	Oct. 12....	267	.91
Sept. 20...	108	1.14	Oct. 13....	280	1.43
Sept. 20...	112	.84	Oct. 14.....	289	.76
Sept. 21...	125	1.22	Oct. 15....	294	1.02
Sept. 22...	133	1.27	Oct. 18 ...	313	1.42
Sept. 23...	145	.49			
Sept. 24...	151	.77	Average		1.03
Sept. 26...	165	.69			

The sucrose in the juice expressed from exhausted chips was inverted and estimated with the reducing sugar present, and the whole expressed as total sugars.

The ratio of the sucrose in the chips to the reducing sugar shows that the former is more readily diffused than the latter. This ratio was not determined for the whole season. From October 8 to 18, however, seven such analyses were made, with the following results:

TABLE NO. 5.—*Sucrose and glucose in juice from exhausted chips and corresponding diffusion juices.*

Date.	Exhausted chips.			Diffusion juices.		
	No.	Glucose.	Sucrose.	No.	Glucose.	Sucrose.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Oct. 8....	248	.57	.78	247	3.06	5.90
Oct. 11....	260	.51	.87	259	2.09	6.58
Oct. 12....	267	.29	.63	266	2.03	6.17
Oct. 13 ..	280	.48	.95	279	1.89	5.97
Oct. 14....	289	.24	.52	280	1.80	6.02
Oct. 15 ...	294	.27	.75	293	1.75	5.66
Oct. 18 ...	313	.43	.99	312	2.02	5.66
Averages		.40	.78	....	2.09	5.99

Ratio of glucose to sucrose from exhausted chips .... 1 : 1.95
Ratio of glucose to sucrose in diffusion juice .... 1 : 2.86
Ratio of glucose to sucrose corresponding mill juice from fresh chips .... 1 : 2.69

The variations in the quantities of sugar left in the chips were due to differences in the quantity of diffusion juice drawn off at each charge, and to changes in rapidity of working. Rapid working with small quantities of juice drawn off leave more sugar in the chips than slower working and larger charges of diffusion juice.

Up to the 22d of September the quantity of juice drawn at each charge was 2,200 pounds. From this time to October 4, 2,640 pounds were drawn off each time. Thence to the close of the season 2,420 pounds. Assuming that each cell held 2,000 pounds of chips and the cane contained 90 per cent. juice, we have the following data:

Weight of chips in each cell	pounds..	2,000
Normal juice in each cell	do....	1,800
Mean extraction (*circa*)	per cent..	93
Normal juice extracted from each cell	pounds..	1,674
Charge withdrawn up to September 22	do....	2,200
Weight added water	do....	526
Percentage of dilution		32.02
Charge withdrawn September 22 to October 4	pounds..	2,640
Weight added water	do....	966
Percentage of dilution		57.70
Charge withdrawn October 4 to close	pounds..	2,420
Weight added water	do....	746
Percentage of dilution		44.56

With the modern appliances for evaporating sugar juices in multiple effect vacuum pans, the objections which have been urged against diffusion on account of the necessary dilution of the juice are of little force. A dilution of 60 per cent. is not at all incompatible with the complete economic success of the process.

TABLE No. 6.—*Defecated juices.*

Date.	No.	Brix (corrected).	Sucrose.	Glucose.
			Per cent.	*Per cent.*
Sept. 12...	53	13.35	8.25	2.66
Sept. 15...	72	13.02	8.23	2.55
Sept. 16...	87	13.28	8.87	2.23
Sept. 17...	91	12.48	7.90	2.53
Sept. 19...	98	10.90	6.99	1.88
Sept. 19...	101	12.58	8.09	1.97
Sept. 20...	109	12.34	7.93	2.11
Sept. 21...	126	12.05	7.39	....
Sept. 22...	136	11.44	6.32	....
Sept. 23...	144	11.24	6.50	2.35
Sept. 24...	152	10.58	6.43	2.08
Sept. 26...	164	10.81	6.11	2.38
Oct. 1...	184	10.14	6.28	....
Oct. 3...	195	10.58	6.24	2.22
Oct. 4...	201	10.75	6.83	1.75
Oct. 5...	221	10.98	6.74	2.23
Oct. 6...	233	13.20	6.99	2.85
Oct. 7...	241	10.81	6.58	1.80
Oct. 8...	249	11.29	6.00	2.80
Oct. 11...	264	10.01	6.09	2.03
Oct. 12...	274	11.00	7.18	2.02
Oct. 13...	284	10.91	7.10	1.69
Oct. 15...	297	10.51	6.74	2.04
Oct. 17...	309	9.75	5.94	1.87
Oct. 19...	320	8.94	5.11	2.10
Averages	......	11.31	6.91	2.19

Dr. C. A. Crampton has furnished the following additional notes on the foregoing analytical work:

The first analysis of fresh chips was made on September 3, but the chemical control of the factory was not fully instituted until the 8th. This control consisted of daily analyses of the fresh chips as supplied to the battery, of the diffusion juice, the defecated juice, and of the exhausted chips, together with analyses of the semi-sirup *masse cuite* and sugar from nearly every strike that was made. Great care was taken to have the analyses of the different products comparable with each other; the samples were always taken after at least one complete circuit of the battery had been made, as starting up the battery fresh did not allow of a proper extraction of the first cells filled. After the first round had been made a sample of the fresh chips was collected, an equal quantity being taken from each cell filled, the whole properly mixed and run through the small experimental mill, and the juice submitted to analysis. The sample of diffusion juice was taken from the same cells represented by the samples of fresh chips, by collecting and mixing together equal volumes from the drawings from each cell. The sample of exhausted chips was likewise collected from the same cells, and the juice obtained from them by pressure with the small mill. Thus the analyses of these three important products are strictly comparable and represent as truthfully as is possible, so far as the sampling is concerned, the character of the cane entering the battery, of the juice obtained from it, and of the waste matter thrown out. The defecated juices, having been boiled continuously in an open pan, samples could not be obtained which would correspond precisely with the samples of diffusion juice, but they were taken from a large receiving tank, which held the juice from a number of cells, so may be taken as a fair average of the defecated juice as it went to the double effect.

ANALYSIS OF WHOLE CANES, TABLE 1.

These analyses were made for various purposes and are inserted here simply as a matter of reference. They furnish additional proof, if any is needed, of the extreme variability of sorghum cane, and of the fact that analyses of a few selected canes give higher results than the average of a crop, and can not be depended on to show the average composition of a field of cane. Nos. 29-43 were taken from different parts of the same field, and at the same time. They show a content of sucrose all the way from 12.44 to 5.95 per cent. No. 148 shows very well the inversion sorghum undergoes by keeping after it is cut. It was taken from a load brought in by a farmer, and had doubtless lain in the field several days after it was cut. This analysis, which is simply an instance of what has been frequently observed before, shows the necessity for the rapid handling of sorghum after it is cut. It has been proposed to buy sorghum cane by its Brix indication, as is done with beets in some parts of Germany. This analysis, with a Brix indication of 19, and a polarization of 3.32, shows very conclusively that it would not pay very well to buy cane that had stood exposed on the degree Brix given by the juice.

TABLE NO. 7.—*Sirups (thick juices).*

Date.	No.	Brix (corrected).	Sucrose.	Glucose.
			Per cent.	*Per cent.*
Sept. 12	46	37.26	16.10	10.49
Sept. 13	57	41.60	25.75	7.99
Sept. 15	75	54.46	33.00	10.92
Sept. 17	94	41.80	28.70	7.69
Sept. 20	113	59.50	39.10	10.16
Sept. 22	128	....	41.90	14.70
Sept. 23	137	46.80	29.90	9.62
Sept. 24	156	46.60	29.50	....
Oct. 3	196	42.40	28.00	8.69
Oct. 6	234	60.40	35.10	16.26
Oct. 7	243	50.60	33.00	10.36
Oct. 12	268	36.20	24.20	6.42
Oct. 13	275	40.90	27.70	....
Oct. 14	290	39.80	26.70	7.52
Averages	....	46.02	29.90	10.06

The variations in the proportion of sucrose to glucose in the thick juice as shown on Table No. 7 are much greater than would be expected from the analyses recorded in the foregoing tables. The thorough mixing of the products of large numbers of diffusion charges should tend theoretically to equalize the ratios of the two sugars. This remarkable variation is explained partly by the addition of sugar to the clarified juices in order to promote crystallization in the vacuum pan.

TABLE NO. 8.—*Masse cuites.*

No.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Not sugar.	Remarks.
	Per cent.	*Pr. ct.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pr. ct.*	
5309	12.34	4.82	21.69	50.44	53.94	6.81	Not enriched.
5310	11.18	5.28	22.70	52.85	56.73	4.11	Do.
5311	11.47	4.22	15.92	62.40	66.47	1.92	Enriched.
5312	13.86	4.07	16.91	55.93	60.22	4.94	Do.
5313	13.58	4.13	15.62	60.52	65.30	1.37	Do.
5314	12.11	4.58	18.19	50.19	55.32	9.80	Not enriched.
5315	13.83	4.48	19.88	52.18	58.50	3.31	Do.
5316	12.74	4.81	16.82	60.24	64.01	1.62	Do.
5343	13.83	4.02	15.25	60.97	61.25	5.65	Enriched.
5381	16.72	5.09	19.60	57.64	55.83	2.75	Not enriched.
5385	17.80	4.72	21.00	50.28	51.76	4.72	Do.
5386	13.22	4.26	16.55	63.12	62.66	3.31	Enriched.
5387	14.48	4.48	15.83	63.16	62.63	2.58	Not enriched.
5388	13.89	4.83	16.40	57.84	59.64	5.24	Do.
5389	15.19	4.66	19.52	56.70	55.59	5.04	Do.
5344	14.38	4.50	17.36	61.79	61.83	1.93	Do.
5347	11.40	4.49	13.61	65.23	63.38	7.12	Do.
5348	12.96	5.01	15.20	61.79	61.51	5.32	Do.
5349	13.30	4.62	17.30	60.00	60.00	4.78	Do.
5353	12.55	7.14	17.78	59.10	59.62	2.91	Do.
5354	25.61	4.24	15.95	51.90	52.11	2.09	Do.
5355	15.59	4.93	18.18	56.03	58.91	2.39	Do.
5357	13.10	4.92	19.40	55.45	57.37	5.21	Do.
5358	22.01	4.80	16.68	54.86	52.18	4.33	Do.
5383	14.12	4.32	15.70	66.08	59.77	6.07	Do.
Ave ..	14.45	4.70	17.56	51.87	59.06	4.21	

The remarks applied to the analyses of the sirups, Table No. 7, belong equally well to Table No. 8. A distinction is made of the samples fortified by the addition of sugar. The differences between direct and double polarization, which are so plainly shown in the analysis of sirups, *masse cuites*, and molasses, will be discussed in another place. The greater reliance should be placed on the indirect polarization when it is carefully done. Yet the difficulties attending an accurate analysis of these substances are very great, and every precaution known to science will not always lead to perfectly satisfactory results.

The remarkable difference between the direct and indirect polarizations will at once be remarked in the mean results of Table No. 8. In general, as has been already said, the preference should be given to the indirect polarization when carefully done. In the present case, however, the percentage of sucrose by indirect polarization appears to be too high. The mean percentage of organic solids not sugar is only 4.21, a much less proportion than would be expected.

TABLE No. 9.—*Polarization of first sugars.*

No.	Sucrose.	No.	Sucrose.
	Per cent.		*Per cent.*
6	97.90	202	96.60
60	95.00	224	95.20
61	96.70	229	96.40
77	98.10	236	94.80
104	97.80	245	93.80
105	91.20	250	94.90
129	96.50	251	94.20
139	94.20	277	95.30
159	97.30	281	96.10
160	97.60	286	93.70
165	97.20	302	92.40
168	96.30	303	95.60
169	97.10	310	93.60
192	96.70		
		Mean ..	95.64

TABLE No. 10.—*Second sugars.*

No.	Sucrose.
	Per cent.
83	82.30
173	88.70
255	86.40
Mean ..	85.80

The first sugars, as shown by Table No. 9, had a mean content of sucrose equal to 95.64 per cent. The color of these sugars was mostly grayish yellow, and most of the samples could be used for the coarser kinds of table use and for cooking without refining.

Only a small quantity of second sugars was made, it having proved more profitable to sell the molasses than to work it into sugar.

The composition of the second sugars is sufficiently indicated by Table No. 10.

TABLE No. 11.—*Molasses from first sugars.*

Station No.	Serial No.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Not sugar.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent*
261	82	16.43	6.50	28.10	36.67	35.66	13.31
59	5318	25.25	6.18	27.96	37.55	37.60	3.01
79	5320	23.49	5.97	23.76	34.52	35.60	11.18
89	5321	25.56	5.91	23.15	35.16	35.30	10.08
97*a*	5322	28.04	5.22	22.73	38.67	38.90	5.11
103	5323	23.36	6.44	27.47	37.39	37.00	5.73
130	5324	23.01	6.04	24.32	35.16	36.20	10.43
140	5325	22.22	7.12	25.00	31.32	31.70	13.96
Averages		23.42	6.17	25.31	35.81	36.00	9.10

In Table No. 11 is given the composition of the molasses after separating the first sugar. The increase in per cent. sucrose on double polarization is not as great as the results with *masse cuites* would lead us to expect.

The samples taken from the tanks at different times represent fairly well the average composition of the whole for the entire season.

The sucrose remaining after the first crystallization is seen to be nearly 1.5 times the reducing sugar.

The composition of the molasses gives a check on the yield of sugar per ton, which the failure to weigh the cane left to a certain extent undetermined. Supposing that there was no appreciable destruction of reducing sugar during the process of clarification, and no inversion of sucrose during the evaporation, the relative composition of the molasses and diffusion juices will indicate the theoretical yield in sucrose. Since, however, the quantity of diffusion juice drawn off is difficult to determine from the data furnished, the comparison will have to be made on the composition of the normal juice expressed from the samples of fresh chips.

In these juices the mean composition for the season was—

	Per cent.
Sucrose	9.54
Reducing sugars	3.40

In the molasses the proportion of reducing sugars to sucrose is—

$$25.31 : 36.00, \text{ or } 1.42.$$

Now, the product of 3.40 by 1.42 is 4.83; and $9.54 - 4.83 = 4.71$, the percentage of sucrose obtained in first sugars.

In 1 ton of cane chips there are, in round numbers, 1,800 pounds juice. The extraction was 93 per cent., or 1,674 pounds. The theoretical quantity of pure sucrose obtained per ton was, therefore, 78.8 pounds.

The mean polarization of the first sugars was 95.64. Then $78.8 \div 95.64 = 82.38$ = number of pounds actual weight first sugar produced per ton.

The yield per ton is estimated at 100 pounds by Mr. Swenson[1]. By Mr. Cowgill the yield per ton is estimated at 93.8 pounds per ton[2]. A fact worthy of remark will be noticed on comparing this yield with the output at Rio Grande and Magnolia, to be mentioned further on. It is this: That the quantity of sugar obtained at the first crystallization can not be determined by any fixed rule based on the relative proportions of sucrose and glucose in the juice. As the proportion of sucrose diminishes the relative amount obtained rapidly increases. At Rio Grande, for instance, the quantity of sucrose remaining in the molasses after the first crystallization is actually less in some cases than the glucose. In Louisiana, even after a second or third crystallization, more sucrose than glucose will usually—not always—be found in the molasses.

In the working of sorghum of the richness indicated by the foregoing analyses, it is a grave question whether a second crystallization is commercially desirable or even practicable. The difficulty of drying the second *masse cuite* in the centrifugals is often so great as to render it commercially unprofitable. Until the quality of sorghum, therefore, is

[1] Bull. 17, p. 10. [2] Ibid, p. 49.

improved it will be well to base all calculations on the yield of first sugars alone. This yield, with such cane as mentioned, will be 4 to 4.5 per cent. on the weight of clean cane.

TABLE NO. 12.—*Second masse cuite.*

No.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Not sugar (organic).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5345	19.34	7.08	27.30	39.15	38.65	7.63
5384	18.02	6.93	29.70	39.68	44.81	1.04
5356	21.00	7.26	26.45	40.52	41.98	3.31
Means	19.45	7.09	27.82	39.78	41.84	3.99

TABLE NO. 13.—*Molasses from seconds.*

No.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Not sugar (organic).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent*	*Per cent.*	*Per cent.*
5350	25.62	8.06	31.35	32.40	29.08	5.89
5351	24.42	8.00	30.85	35.60	33.58	3.15
5380	26.14	7.53	29.78	31.66	30.68	5.90
Means	25.39	7.86	30.66	33.22	31.11	4.98

In the second *masse cuites* the only marked difference from the first molasses is in the degree of evaporation.

In the second molasses we see the sucrose about in the same proportion as the glucose. It is also less by double polarization—a fact difficult of explanation.

TOTAL SOLIDS IN JUICES.

In Tables Nos. 1, 2, and 3 the total solids represent the readings of the hydrometer graduated to give the quantity of pure sugar in an aqueous solution, and corrected for temperature.

It is evident that in a cane juice containing large quantities of solids other than pure sucrose, these readings can give only approximately the percentage of dry solid matter in solution.

Instructions were therefore sent to Fort Scott to determine dry volatile matter or total solids by evaporating a weighed portion of the juice and noting the weight of the residue dried to practically constant weight at 105° C. This operation was carried on in a flat platinum dish, about 2 grams of the juice being used in each case. The results showed a marked difference in the data furnished by the Brix hydrometer and the direct method, the latter being uniformly lower, thus increasing the apparent purity of the juice. In this operation, however, the difficulty of securing uniform desiccation is great. The greater the quantity of solid matter contained in a given juice the more difficult is it to secure the complete removal of the water. The differences noted, therefore, in the case of the mill juices are greater than in the juices of diffusion. This matter will be referred to again in the Louisiana analyses to follow. In Table No. 14 the differences are given:

TABLE No. 14.—*Comparison of total solids by spindle with results obtained by direct estimation.*

Mill juices.			Diffusion juices.		
No.	Direct.	Indirect.	No.	Direct.	Indirect.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
238	15.67	16.10	239	10.15	10.98
246	14.95	15.76	247	10.54	11.51
258	14.55	15.21	259	9.50	10.39
262	13.85	14.44	263	9.60	10.49
265	14.40	14.73	266	9.00	9.97
272	14.80	15.11	273	10.05	10.82
278	14.40	14.97	279	8.85	9.71
282	14.85	15.33	283	9.40	10.27
292	13.40	13.68	293	8.43	9.34
295	13.60	14.24	296	9.30	10.24
300	14.78	15.11	301	8.58	9.45
304	14.85	15.31	305	8.10	8.74
307	12.50	13.09	308	8.80	9.51
315	13.65	14.21	312	8.75	9.67
318	14.65	14.93	316	7.80	8.64
			319	8.05	8.77
Aver.	14.33	14.81	Aver.	9.06	9.91

Dr. Crampton makes the following observations on this work:

These results are very interesting and important. They show that while the spindles give results but slightly below the actual determination by drying in the case of mill juices, the results with the diffusion juices were, on an average, .85 too high. The spindles used were tested afterwards with a standard solution of pure sugar, and found to give results about .2 too high. They corresponded closely with a delicate saccharimeter tested by Scheibler. The different results given by them in the case of the mill and diffusion juices I am unable to explain, as it would seem more rational that the diffusion juices, being more nearly pure solutions of sugar than the mill, would give results approximating more closely to the standard upon which the spindles were based. It is possible that the large amount of suspended solids in the mill juices may in some way account for the discrepancy. At all events the direct determination doubtless gives more reliable results. Correcting the average results on the basis of the samples in which a direct estimation was made we have:

Total solids in the mill juices for the season	15.66
Co-efficient of purity based on above	60.9
Total solids in diffusion juices for the season	10.23
Co-efficient of purity	65.3

Showing an increase in the purity of the diffusion over the mill juices of 4.4 points. The ratio of glucose to sucrose in the two juices for the season was as follows:

Mill juice	1 : 2.80
Diffusion juice	1 : 2.95

This would seem to show one of two things: Either there was absolutely no inversion in the battery, and the slight difference in favor of the diffusion juice was due to error of analysis, or that the glucose in the cane was not so readily diffusible as the sucrose, and thus a greater proportionate amount of the latter was obtained by diffusion than by milling, sufficient to cover whatever slight inversion there was in the battery, and leave a margin beside. The latter hypothesis seems to be borne out by the analysis of the exhausted chips. Up to October 8 the total sugar remaining in the chips was determined, no separate analyses being made of glucose and sucrose. After that date both sugars were estimated. Table No. 5 gives the results, together with the sucrose and glucose in the corresponding diffusion juices:

TABLE NO. 15.—*Acidity in mill juices and diffusion.*

Mill juice.		Diffusion.	
No.	C.C. $\frac{n}{10}$ alk. for 100.	No.	C.C. $\frac{n}{10}$ alk. for 100.
174	32.0	175	14.4
193	28.8	194	16.8
198	38.0	199	20.0
222	32.0	223	18.4
230	39.0	231	22.8
238	32.4	239	26.0
246	36.0	247	20.0
258	10.0	259	16.0
265	26.0	266	15.2
278	34.0	279	18.0
292	18.0	293	10.0
304	34.0	305	12.0
311	21.0	312	9.0
315	26.0	316	10.0
Mean.	29.1	Mean.	16.3

The work recorded in Table No. 15 was undertaken to show the extent to which the carbonate of lime added to the diffusion cells neutralized the free acids of the juice. The numbers indicate the quantity of tenth normal alkali required to neutralize the acids in 100 cubic centimeters of the juice. Taking as a basis of comparison the total solids in the mill and diffusion juices for the season, as indicated in Tables Nos. 2 and 3, the following data are obtained:

Total solids in mill juices	16.14
Total solids in diffusion juices	11.08
Acidity of mill juice	29.1 cc.

The normal acidity of the diffusion juice, had no carbonate been used, is obtained by the following calculation:

$$16.14 : 11.08 = 29.1 : X; \text{ whence}$$
$$X = 19.98$$

The mean quantity of alkali required for neutralizing the acid in the diffusion juice was 16.3 cubic centimeters. Deduct this number from the calculated normal number and the difference, viz, 3.68 cubic centimeters, represents the amount of acid neutralized.

The percentage of acid neutralized is therefore $3.68 \div 29.1 \times 100 = 12.65$. The action of the carbonate, therefore, in neutralizing the acids is not as far reaching as the experiments made by the Department and recorded in Bulletin 14 would lead us to expect.

Dr. Crampton has made the following report respecting the extraction of sugar:

The mill juice from exhausted chips contained 1.03 per cent. of total sugars. This gives the total sugars as 92.04 per cent. of the amount contained in the cane. Supposing the ratio of glucose to sucrose in the exhausted chips for the whole season to have been the same as that shown during the time that the two sugars were estimated separately, the average sucrose remaining would be .68 per cent. in the juice, or .61 per cent. of the chips themselves. This would give an extraction of 92.87 per cent. of the total sucrose present in the cane.

This is not so good an extraction as has been obtained in previous experiments with diffusion on cane. It is explained by Professor Swenson on the ground that the chips were not made fine enough, gaps in the knives of the small cutters, made by stones, etc., getting into it, allowing of the passage of comparatively large pieces of cane.

WORK AT RIO GRANDE, N. J.

The general instructions sent to the Fort Scott station were given also to the analysts at Rio Grande, with such changes only as the locality required.

Mr. F. V. Broadbent was placed in charge of the analytical work, with Mr. Hubert Edson as assistant. Mr. Broadbent resigned his position early in October. Mr. Edson then took charge of the work and remained until the close of the season. With the assistance of one boy he successfully conducted the chemical control of the factory.

In the following tables are given the results of his work:

TABLE No. 16.—*Juices from diffusion chips.*

Date.	Specific gravity.	Baumé.	Brix (corrected).	Sucrose.	Purity.	Glucose.
				Per cent.		*Per cent.*
Sept. 8	1.057	7.8	14.06	7.94	56.47	....
Sept. 9	1.059	8.1	13.96	8.88	63.61	....
Sept. 10	1.057	7.7	13.53	8.34	61.64	....
Sept. 12	1.052	7.2	12.82	7.95	62.10	....
Sept. 13	1.052	7.2	12.80	8.10	63.28	....
Sept. 15	1.051	7.1	12.96	7.37	56.87	3.46
Sept. 17	1.054	7.5	12.83	8.01	62.43	3.22
Sept. 19	1.050	6.9	12.26	7.29	59.46	3.79
Sept. 19	1.052	7.2	22.92	7.33	56.73	4.07
Sept. 20	1.055	7.6	12.96	7.61	58.72	3.13
Sept. 20	1.057	7.8	13.62	7.52	55.21	3.39
Sept. 21	1.069	9.4	16.47	11.63	70.61	2.52
Sept. 21	1.072	9.8	17.80	12.28	68.99	2.76
Sept. 22	1.063	8.6	15.28	10.88	71.20	2.46
Sept. 23	1.059	8.1	13.90	8.32	59.86	3.04
Sept. 24	1.058	7.8	13.86	8.55	61.69	3.45
Sept. 26	1.061	8.3	14.23	9.09	63.88	2.97
Sept. 27	1.058	7.9	13.71	8.42	61.42	3.63
Sept. 27	1.061	8.3	14.37	8.99	62.56	3.86
Sept. 28	1.060	8.0	14.20	8.80	61.97	3.32
Sept. 29	1.053	7.3	13.02	8.29	63.67	3.30
Oct. 1	1.053	7.3	13.01	7.98	61.34	3.05
Oct. 3	1.055	7.6	14.19	9.25	65.19	3.15
Oct. 3	1.056	7.7	13.74	8.43	61.36	3.99
Oct. 4	1.060	8.2	14.67	8.83	60.19	3.53
Oct. 4	1.058	7.9	14.31	9.34	65.27	3.59
Oct. 5	1.057	7.8	13.80	9.21	66.74	2.70
Oct. 6	1.059	8.1	15.03	9.19	61.14	3.36
Oct. 7	1.057	7.8	13.88	8.94	64.41	3.68
Oct. 8	1.056	7.7	13.66	7.40	61.49	3.71
Oct. 10	1.065	8.9	15.94	10.95	68.70	2.87
Oct. 10	1.065	8.9	16.33	11.64	71.28	3.01
Oct. 11	1.066	9.0	15.61	11.02	70.42	3.05
Oct. 11	1.067	9.1	15.78	10.80	68.44	3.12
Oct. 13	1.056	7.9	13.66	9.08	66.47	2.94
Oct. 13	1.060	8.2	14.58	9.27	63.58	3.29
Oct. 14	1.059	8.1	14.34	9.34	65.13	3.18
Oct. 14	1.057	7.8	13.86	9.61	69.34	....
Oct. 15	1.058	7.9	13.77	8.72	63.33	3.51
Oct. 17	1.070	9.5	16.71	11.40	68.22	3.13
Oct. 17	1.070	9.5	16.86	11.51	68.27	....
Oct. 18	1.069	9.4	16.73	11.47	68.56	3.28
Oct. 19	1.066	8.2	14.30	9.36	65.45	3.06

TABLE No. 16.—*Juices from diffusion chips*—Continued.

Date.	Specific gravity.	Baumé.	Brix (corrected.)	Sucrose.	Purity.	Glucose.
				Per cent.		Per cent.
Oct. 20	1.056	7.7	13.26	8.49	64.02	2.83
Oct. 20	1.056	7.7	13.28	8.52	64.14	2.83
Oct. 21	1.050	6.9	11.90	7.29	61.26	2.56
Oct. 21	1.053	7.3	12.53	7.79	62.17	2.94
Oct. 22	1.048	6.7	11.24	6.81	60.59	2.99
Oct. 24	1.065	8.9	15.21	10.42	68.51	2.07
Oct. 24	1.065	8.9	15.47	10.39	67.16	....
Oct. 25	1.051	7.1	12.26	6.74	54.97	3.74
Oct. 26	1.045	6.1	10.45	4.71	45.07	4.45
Oct. 27	1.056	7.7	13.43	8.85	65.90	3.49
Oct. 27	1.059	8.1	14.10	9.20	65.25	3.73
Oct. 29	1.052	7.2	12.57	8.12	64.60	3.40
Oct. 31	1.053	7.3	12.24	8.16	66.66	3.78
Oct. 31	1.056	7.7	13.05	7.70	59.00	3.55
Nov. 1	1.062	8.5	14.52	9.95	68.52	3.30
Nov. 2	1.062	8.5	14.35	9.96	69.47	3.88
Nov. 3	1.062	8.5	14.74	10.08	68.38	....
Nov. 8	1.061	8.3	14.20	9.48	66.29	3.53
Means ..	1.067	7.8	14.02	8.98	64.05	3.24
Maxima .	1.070	9.5	17.80	12.28	71.28	4.45
Minima..	1.045	6.3	10.45	4.71	45.07	2.07

The analyses of the samples of chips taken from each charge of the battery, often twice daily, show the remarkable fluctuations in sucrose which have always been noticed in sorghum juices.

The mean composition of the normal juice, Table 16, shows a less percentage of sucrose, but a somewhat higher purity than were obtained at Fort Scott.

The maximum percentage of sugar in the juice is not as great as at Fort Scott, and the minimum is not so small. In general it may be said that the canes worked at Rio Grande were slightly inferior for production of sugar to those of Fort Scott.

The theoretical yield per ton, based on the Fort Scott analyses, would have been as follows:

Pounds of juice at 93 per cent. extraction	1,674.
Glucose x 1.42	4.60
Sucrose less glucose x 1.42	4.38
Pure sucrose, first crystallization	73.32
Pure sucrose, etc., at Fort Scott	78.8

The yield obtained, for various reasons, was much less than this.

The tonnage obtained at Rio Grande, however, was fully double that at Fort Scott, and this heavy growth may account for the slightly inferior quality of the cane.

TABLE NO. 17.—*Diffusion juice.*

Date.	Specific gravity.	Baumé.	Brix.	Brix (corrected).	Sucrose.	Purity.	Glucose.
1887.		°	°		*Per cent.*		*Per cent.*
Sept. 8	1.040	5.6	9.0	9.57	5.69	59.46	....
Sept. 9	1.040	5.6	9.1	10.21	6.21	60.82	....
Sept. 10	1.040	5.6	9.1	9.92	5.57	56.15	....
Sept. 12	1.033	4.7	8.1	8.91	5.58	62.62	....
Sept. 13	1.037	5.2	9.0	9.61	6.03	62.75	....
Sept. 15	1.037	5.2	9.2	9.77	5.43	55.58	....
Sept. 17	1.045	6.3	10.4	10.43	6.71	64.33	2.93
Sept. 19	1.040	5.6	9.6	10.16	5.74	56.50	2.85
Sept. 20	1.045	6.3	10.5	10.95	6.18	56.44	3.27
Sept. 20	1.047	6.5	11.1	11.55	6.68	57.84	....
Sept. 21	1.050	6.9	11.8	12.18	8.47	69.54	2.12
Sept. 21	1.050	6.9	12.8	13.22	8.97	67.85	2.17
Sept. 22	1.060	8.2	14.0	14.40	9.90	68.75	2.72
Sept. 23	1.055	7.6	12.8	13.06	7.51	57.50	3.00
Sept. 24	1.051	7.1	12.3	12.30	7.07	57.47	3.24
Sept. 26	1.042	5.9	9.5	9.56	6.18	64.64	2.09
Sept. 27	1.052	7.2	12.4	12.60	7.72	61.27	3.27
Sept. 27	1.055	7.6	12.5	12.80	7.81	61.02	3.51
Sept. 28	1.053	7.3	12.5	12.77	7.47	58.58	3.27
Sept. 29	1.051	7.1	11.6	12.33	7.81	63.34	3.16
Oct. 1	1.046	6.4	10.9	11.58	7.09	61.20	3.09
Oct. 3	1.040	5.6	10.0	11.12	6.86	61.69	2.37
Oct. 3	1.052	7.2	12.1	12.62	7.55	59.83	3.66
Oct. 4	1.044	6.1	10.2	10.90	6.73	61.74	3.19
Oct. 4	1.0'6	7.1	12.8	13.39	8.70	64.97	3.82
Oct. 5	1.043	6.0	10.1	10.35	6.62	63.96	2.50
Oct. 6	1.045	6.3	10.6	11.01	6.98	63.40	2.62
Oct. 7	1.038	5.3	8.9	9.28	5.89	63.43	2.53
Oct. 8	1.035	4.9	7.9	8.44	5.08	60.19	2.03
Oct. 10	1.042	5.9	10.4	10.87	7.42	68.26	2.19
Oct. 10	1.058	7.9	13.6	14.30	10.02	70.07	3.10
Oct. 11	1.057	7.8	13.5	13.73	9.58	69.78	2.94
Oct. 11	1.052	7.2	12.1	12.58	8.49	67.49	2.18
Oct. 13	1.045	6.3	10.5	10.62	6.85	60.47	2.50
Oct. 13	1.052	7.2	12.3	12.66	8.28	65.40	2.94
Oct. 14	1.051	7.1	12.2	12.58	8.11	64.47	2.91
Oct. 14	1.053	7.3	12.3	12.85	8.66	67.39	3.01
Oct. 15	1.047	6.5	10.9	10.98	7.14	65.02	2.81
Oct. 17	1.034	4.8	7.9	8.42	6.19	71.14	1.57
Oct. 17	1.035	4.9	8.2	8.82	6.24	70.75	....
Oct. 18	1.035	4.9	8.2	8.60	6.01	69.77	1.91
Oct. 19	1.036	5.1	8.5	8.82	5.78	65.53	2.13
Oct. 20	1.047	6.5	10.8	11.18	7.09	63.42	2.69
Oct. 20	1.046	6.4	10.8	11.31	6.97	61.64	2.57
Oct. 21	1.039	5.5	9.1	9.51	5.54	54.05	2.46
Oct. 21	1.045	6.3	10.4	10.73	6.52	60.76	2.53
Oct. 22	1.041	5.7	9.5	9.77	5.70	56.19	2.80
Oct. 24	1.035	4.9	8.0	8.40	5.81	69.17	1.32
Oct. 24	1.048	6.7	11.4	11.91	5.77	48.78	....
Oct. 25	1.046	6.4	10.9	11.35	5.92	52.16	3.33
Oct. 26	1.037	5.2	8.5	8.78	3.89	44.31	3.97
Oct. 27	1.050	6.9	11.8	12.08	7.61	63.00	3.54
Oct. 27	1.055	7.6	12.7	13.00	7.97	61.31	3.60
Oct. 29	1.043	6.0	10.0	10.37	6.49	62.58	3.10
Oct. 31	1.036	5.1	8.2	8.38	5.05	60.26	2.75
Oct. 31	1.045	6.3	10.6	11.04	6.23	56.43	3.45
Nov. 1	1.050	6.9	11.7	11.82	6.72	56.93	3.88
Nov. 2	1.059	8.1	13.4	13.40	8.73	65.15	3.68
Nov. 3	1.056	7.7	13.1	13.55	8.63	63.69	....
Nov. 8	1.056	7.7	13.2	13.26	8.41	63.71	3.74
Means	1.046	6.4	10.6	11.18	6.93	61.98	2.86
Maxima	1.060	8.2	14.0	14.40	10.02	71.14	3.97
Minima	1.033	4.7	7.9	8.38	3.89	44.31	1.32

The system of diffusion employed at Rio Grande is fully explained by Fig. 5, Bulletin No. 17. It differs radically from the system of closed diffusion. As operated at Rio Grande last year the extraction was no better than by good milling in Louisiana, while the dilution was fully as great as at Fort Scott and Magnolia.

The defects of the system were both mechanical and chemical, The mechanical difficulty is the same as that which attends all methods of diffusion in which the cane chips are moved instead of the diffusion liquors. From a mechanical point of view, it is far easier and more economical to move a liquid in a series of vessels than a mass of chips. In the Hughes system the whole mass of chips undergoing diffusion, together with adhering liquor, and baskets and suspending apparatus, are lifted vertically a distance of several feet, varying with the depth of the diffusion tanks every few minutes. The mechanical energy required to do this work is enormous, and with large batteries the process would prove almost impossible.

The chemical defects of the system are shown in the exposure of so large a surface to oxidation and the action of invertive ferments. It is not surprising, therefore, to notice a distinct increase in the ratio of glucose to sucrose in the data of Table No. 17. Diffusion in open vessels was tried years ago with the sugar beet, and was abandoned as being both unscientific and expensive. The degree of extraction in open vessels is also less perfect than in closed diffusers where a considerable pressure is exerted on the osmotic liquors. It is but just to say, however, that the poor extraction obtained at Rio Grande is due more to the low temperature at which the diffusion took place than to the open diffusion vessels. I measured the temperature several times at the beginning of the season and found it below 60° C.

By certain modifications made after the close of the season, Mr. Hughes obtained a better extraction. (Bulletin 17, p. 67.)

The composition of the diffusion juices is sufficiently shown in Table No. 17.

TABLE NO. 18.—*Exhausted chip juice.*

Date.	Specific gravity.	Baumé.	Brix.	Brix (corrected.)	Sucrose.	Purity.	Glucose.
		°	°	°	*Per cent.*		*Per cent.*
Sept. 8..	1.019	2.7	4.5	5.05	3.22	63.76	....
Sept. 9..	1.012	1.7	2.2	2.55	1.82	71.37	....
Sept. 10..	1.018	2.6	3.9	4.59	3.07	66.88	....
Sept. 12..	1.017	2.4	3.8	4.42	2.58	62.67	....
Sept. 13..	1.016	2.3	3.7	4.22	2.67	63.27	....
Sept. 15..	1.019	2.7	4.0	4.55	2.62	57.60	....
Sept. 17..	1.016	2.3	3.1	3.12	2.03	65.01	.97
Sept. 19..	1.011	1.6	2.0	2.70	1.73	64.07	.73
Sept. 20..	1.007	1.0	1.2	1.70	.99	58.23	.50
Sept. 20..	1.010	1.4	1.9	2.30	1.16	50.43	.54
Sept. 21..	1.007	1.0	1.3	1.68	.98	58.33	.35
Sept. 21..	1.011	....	....	....	....	....	.39
Sept. 22..	1.018	2.6	4.3	4.96	3.12	62.09	.50
Sept. 23..	1.018	2.6	3.7	4.09	2.31	56.48	1.07
Sept. 24..	1.021	3.0	4.6	4.66	2.67	57.30	1.34
Sept. 26..	1.021	3.0	4.3	4.35	2.83	65.06	1.06
Sept. 27..	1.018	2.6	3.8	4.05	1.78	43.46	1.00
Sept. 27..	1.016	2.3	3.4	3.82	2.22	58.12	.96
Sept. 28..	1.021	3.0	4.3	4.55	2.90	63.74	1.29
Sept. 29..	1.016	2.3	3.5	4.12	2.52	61.16	1.05
Oct. 1..	1.015	2.0	3.3	3.98	2.51	63.07	1.14
Oct. 3..	1.011	1.6	2.4	3.49	2.13	62.03	.82
Oct. 3..	1.021	3.0	4.6	5.04	3.27	64.88	1.42
Oct. 4..	1.016	2.3	3.4	4.23	2.54	60.05	1.15
Oct. 4..	1.022	3.2	4.8	5.55	3.51	63.24	1.42
Oct. 5..	1.007	1.0	1.7	2.00	1.26	63.12	.49
Oct. 6..	1.007	1.0	1.5	2.04	1.02	50.00	.33
Oct. 7..	1.006	.9	1.0	1.33	.81	53.38	.30
Oct. 8..	1.013	1.9	2.8	3.33	1.97	59.16	.91

TABLE No. 18.—*Exhausted chip juice*—Continued.

Date.	Specific gravity.	Baumé.	Brix.	Brix (corrected.)	Sucrose.	Purity.	Glucose.
		°	°	°	*Per cent.*		*Per cent.*
Oct. 10..	1.018	2.6	4.1	4.40	2.81	63.86	.92
Oct. 10..	1.023	3.3	5.6	6.28	3.90	62.10	1.25
Oct. 11..	1.027	3.8	6.4	6.64	4.23	63.70	1.56
Oct. 11..	1.016	2.3	3.3	3.60	2.31	64.17	.75
Oct. 13..	1.021	3.0	4.6	4.77	2.95	61.85	1.40
Oct. 13..	1.022	3.2	4.9	5.34	3.35	62.75	1.37
Oct. 14..	1.023	3.3	5.1	5.42	3.42	63.10	1.41
Oct. 14..	1.019	2.7	4.2	4.82	3.14	65.14	1.02
Oct. 15..	1.018	2.6	4.1	4.35	2.72	62.53	1.04
Oct. 17..	1.009	1.3	1.9	2.23	1.49	66.81	.42
Oct. 17..	1.009	1.3	1.7	2.14	1.29	60.28	....
Oct. 18..	1.006	.9	1.1	1.57	.93	59.23	.29
Oct. 19..	1.016	2.3	4.5	5.03	2.53	50.30	.85
Oct. 20..	1.017	2.4	3.8	4.21	2.89	67.22	.94
Oct. 21..	1.013	1.9	2.9	3.28	2.01	61.28	.79
Oct. 21..	1.021	3.0	4.9	5.25	3.11	59.24	1.29
Oct. 22..	1.013	1.9	2.6	2.87	1.87	65.85	.81
Oct. 24..	1.021	3.0	4.8	5.26	2.76	52.47	.65
Oct. 25..	1.014	2.0	3.2	3.43	1.75	51.01	1.16
Oct. 26..	1.014	2.0	3.4	3.87	1.91	49.35	1.43
Oct. 27..	1.017	2.4	3.9	4.19	2.73	65.18	1.18
Oct. 27..	1.020	2.9	4.5	4.87	3.40	69.82	1.31
Oct. 29..	1.013	1.9	3.1	3.40	2.48	72.94	.84
Oct. 31..	1.015	2.2	3.5	3.67	2.47	64.31	1.08
Oct. 31..	1.023	3.3	5.3	5.53	3.09	54.07	1.62
Nov. 1..	1.023	3.3	5.4	5.45	3.48	62.02	1.41
Nov. 2..	1.024	3.4	5.4	5.43	3.60	66.30	1.43
Nov. 3..	1.019	2.7	4.2	4.48	2.86	63.81	....
Nov. 8..	1.019	2.7	4.4	4.56	2.97	62.94	1.14
Means ..	1.016	2.3	3.61	4.03	2.46	61.04	.98
Maxima.	1.027	3.8	6.4	6.64	4.23	72.94	1.62
Minima .	1.006	.9	1.0	1.33	.81	43.46	.30

In Table No. 18 is shown the composition of the juices expressed from the chips as discharged from the battery. The total sucrose in the fresh-chip juice, as shown in Table No. 16, was 8.98 per cent. There was left in the juice of the discharged chips 2.46 per cent. The juice remaining in the chips suffers a slight dilution during the process of diffusion, but for comparative purposes the quantity of juice in the chips before and after diffusion may be taken as the same.

In this case the percentage of juice extracted is $8.98 - 2.46 = 6.52$ per cent. The percentage of extraction, therefore, based on the percentage of sucrose in juices from fresh and discharged chips, is 72.6. This is about the average extraction of good milling in Louisiana, but is better than the results obtained by milling sorghum. As already stated, the efficiency of the apparatus was greatly increased by some changes made after the season was over.

TABLE No. 19.—*Sirup (thick juice).*

Date.	Specific gravity.	Baumé.	Brix.	Brix (corrected).	Sucrose.	Purity.	Glucose.
		°	°	°	*Per cent.*		*Per cent.*
Sept. 8...	1.136	17.5	31.4	32.16	18.67	58.05	....
Sept. 9...	1.138	17.7	34.4	31.86	18.47	57.97	....
Sept. 10....	1.181	22.3	40.7	41.12	21.26	51.70	....
Sept. 12....	1.122	15.9	28.8	29.64	16.81	56.71	....
Sept. 13....	1.131	16.9	30.8	31.48	17.45	55.43	....
Sept. 17....	1.124	16.1	28.8	28.83	15.74	54.60	8.01
Sept. 19....	1.128	16.6	29.5	30.08	16.60	55.18	8.49
Sept. 19 ...	1.145	18.5	33.4	33.94	18.22	53.71	10.45
Sept. 20....	1.145	18.5	33.5	34.05	17.38	51.04	10.20
Sept. 20....	1.166	20.8	37.9	38.37	21.00	54.77	....
Sept. 21....	1.154	19.5	36.0	36.69	23.07	62.88	7.44
Sept. 21....	1.149	18.9	34.2	34.74	23.00	66.21	7.26
Sept. 22....	1.164	20.6	37.6	38.26	25.51	66.68	7.64
Sept. 23 ..	1.150	19.1	34.8	35.15	19.25	54.77	8.46
Sept. 24....	1.162	20.4	37.1	37.20	20.56	55.27	9.52
Sept. 26....	1.122	15.9	28.6	28.68	16.90	58.92	5.97
Sept. 27 ..	1.149	19.0	34.6	34.83	20.03	57.56	9.10
Sept. 27....	1.110	14.5	36.2	26.40	15.83	59.96	6.87
Oct. 1....	1.118	15.4	27.5	28.55	17.13	60.00	9.24
Oct. 3....	1.105	13.9	24.5	25.57	15.84	61.95	6.05
Oct. 3....	1 086	11.6	24.0	24.82	12.32	49.64	6.10
Oct. 4....	1.110	14.5	26.0	26.60	15.44	58.05	7.79
Oct. 4....	1.155	19.6	35.4	35.91	21.06	58.64	9.10
Oct. 4....	1.099	13.2	23.2	23.23	12.05	51.87	5.53
Oct. 6....	1.102	13.5	24.4	24.70	16.25	65.79	5.69
Oct. 7....	1.098	13.1	23.1	23.52	13.42	57.10	6.34
Oct. 8 ...	1.087	11 7	20.6	21.28	11.69	54.93	6.59
Oct. 10...	1.154	19.5	35.0	35.74	22.76	63.68	8.38
Oct. 11....	1.115	15.1	26.8	26.98	18.65	69.13	6.32
Oct. 11....	1.140	18.0	32.2	32.52	20.98	64.51	7.46
Oct. 13...	1.172	21.4	39.2	39.30	22.86	58.17	9.70
Oct. 13....	1.138	17.7	32.3	32.55	19.00	58.37	8.32
Oct. 14....	1.149	19.0	34.5	34.89	21.32	61.11	8.70
Oct. 14 ...	1.147	18.8	34.1	34.65	20.89	60.29	8.86
Oct. 15....	1.132	17.0	30.9	31.10	18.78	60.39	7.91
Oct. 17....	1.083	11.2	19.5	19.88	13.73	64.03	3.81
Oct. 17....	1.085	11.5	19.9	20.55	14.04	68.32	....
Oct. 18....	1.134	17.3	31.2	31.84	20.80	65.33	6.38
Oct. 20....	1.171	21.3	39.0	39.59	23.31	58.88	10.12
Oct. 20....	1.144	18.4	33.8	34.15	20.44	59.85	7.95
Oct. 21....	1.121	15.8	28.3	28.62	15.15	52.94	7.59
Oct. 21....	1.154	19.5	35.3	35.60	19.16	53.82	10.82
Oct. 22....	1.163	20.6	37.4	37.54	18.55	49.42	10.70
Oct. 24....	1.183	22.5	41.4	42.02	24.86	59.16	....
Oct. 25....	1.131	16.9	30.6	30.99	15.82	51.05	8.34
Oct. 26....	1.126	16.3	29.5	30.07	10.78	35.84	12.94
Oct. 27....	1.158	19.9	36.3	36.35	21.73	59.78	10.93
Oct. 27....	1.139	17.8	32.2	33.17	19.72	59.45	9.58
Oct. 29....	1.132	17.0	31.7	32.69	17.29	53.88	10.13
Oct. 31....	1.189	23.1	42.0	42.06	21.8	51.83	14.45
Oct. 31....	1.118	15.4	27.7	28.20	15.07	53.44	8.83
Nov. 1....	1.175	21.7	39.6	39.82	20.64	51.83	15.70
Nov. 2....	1.192	23.4	43.1	43.16	25.26	58.50	12.27
Nov. 3....	1.156	19.7	35.8	35.98	21.07	58.28	....
Nov. 8....	1.159	20.0	36.4	36.30	21.26	58.57	10.73
Means..	1.138	17.7	31.99	32.40	18.68	57.65	8.67
Maxima.	1.192	23.4	43.1	43.16	25.26	68.32	15.70
Minima.	1.083	11.2	19.5	19.88	10.78	35.84	3.81

The diffusion juice at Rio Grande, without any treatment whatever, was conducted directly to an open pan and concentrated to a thin sirup.

The disastrous effects of this treatment are shown by the data of Table No. 19. The evaporation of sugar juices in an open pan is to be condemned for lack of economy; but such treatment, before neutralizing the free acids of the juice, must also necessarily invert a large portion of the sucrose.

The glucose per hundred of sucrose in the normal juice at Rio Grande was 36.06; in the sirup it was 46.38.

The pan on which the concentration took place was shallow and furnished with steam-pipes. The liquor ran rapidly through, otherwise the inversion would have been much greater.

TABLE No. 20.—*Masse cuites, Rio Grande, N. J.*

Number.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5336	18.37	5.29	23.33	49.90	52.03
5398	16.13	3.22	20.65	58.97	60.71
5399	17.89	3.32	22.47	51.10	56.42
5400	21.32	5.65	24.55	55.47	54.41
5401	19.90	4.21	26.24	51.30	53.97
5427	17.40	4.92	23.45	55.45	55.11
Averages.	18.50	4.44	23.45	53.70	55.44

Table No. 20 shows that no further inversion has taken place by evaporating the sirup in the vacuum pan. Only a small number of samples of *masse cuite* were obtained, since it required a long working of the battery to furnish enough sirup for a strike. Moreover, no samples of *masse cuite* were taken until Mr. Edson took charge of the analytical work. The data of Table No. 20 are therefore not strictly comparable with those of Table No. 19.

The *masse cuites* at Rio Grande were placed in wagons and kept in the crystallizing room, at the proper temperature, for several days, before being sent to the centrifugal machines. The first and second sugars were thus obtained as one product.

By reason of the omission of clarification the sugar was dried with extreme difficulty. Indeed it was found impossible to dry it so as to make a granular product. The gum, glucose, and other impurities kept it in the form of a waxy mass. A glance at the data of Table No. 21 will show the character of the sugar made. A sugar which still contains 13.08 per cent. of reducing sugar would be regarded with grave suspicion by refiners.

The character of the sugar shows the necessity of careful defecation and clarification. Sorghum juices especially, when worked for sugar, should be as nearly neutral as possible, and great care should be exercised to remove all the scums and to allow suspended matters to settle.

TABLE NO. 21.—*Raw sugars, Rio Grande, N. J.*

Number.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5326	4.61	2.48	12.12	80.3	82.11
5327	6.74	3.75	16.94	67.7	70.65
5328	4.78	2.94	13.02	76.0	77.11
5330	6.67	3.00	14.25	75.0	76.88
5331	3.92	2.71	13.23	69.7	72.79
5332	5.18	2.52	13.13	78.8	77.38
5333	5.11	2.83	13.33	78.4	76.33
5334	5.11	2.69	12.35	73.8	71.95
5359	6.08	3.08	16.78	72.5	72.39
5361	4.41	2.00	13.98	78.2	77.63
5367	5.81	1.54	11.00	81.0	79.77
5368	4.77	1.14	8.20	85.6	84.49
5369	8.40	1.72	12.58	77.2	75.97
5396	5.40	2.01	11.75	80.0	79.61
5397	6.33	2.02	13.15	76.8	77.73
5428	5.30	3.29	13.48	79.2	78.01
Averages..	5.54	2.48	13.08	76.9	76.93

The molasses made at Rio Grande shows the unusual phenomenon of a larger percentage of reducing sugar than of sucrose. This is chiefly due to the fact that it contained so large a quantity of water that it was partly fermented before the analysis was made. The samples stood in the laboratory from October, 1887, to February, 1888; and during this time suffered some inversion.

No. 5342, Table No. 22, is an extreme instance of this inversion. No. 5365 is also an anomalous sample, the data showing some fault of analysis which was not discovered until the tabulation was made. The proportion of sucrose in this sample is entirely too large.

For further data concerning the composition of the molasses consult Table No. 22.

TABLE NO. 22.—*Molasses, Rio Grande, N. J.*

Number.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5335	41.44	6.36	32.35	20.2	23.74
5337	30.14	6.47	33.65	26.6	26.68
5338	29.49	6.12	35.12	26.1	27.92
5340	29.54	6.16	34.68	25.4	27.11
5341	39.17	5.31	32.70	23.0	27.26
5342	40.54	5.49	39.70	11.8	14.44
5360	29.43	6.85	37.05	26.4	27.97
5362	39.12	4.28	35.45	22.5	28.92
5363	36.64	5.32	31.65	38.2	33.91
5364	40.11	5.66	30.21	21.1	23.43
5365	32.32	3.28	28.95	49.5	45.92
5394	30.10	4.81	34.70	26.2	31.53
5395	31.38	3.88	31.05	27.3	30.84
5429	30.98	6.50	35.30	26.6	29.19
Averages	34.31	5.46	33.75	26.5	28.20

RECRYSTALLIZED SUGARS.

In order to fit the raw sugars for market they were melted and reboiled in the vacuum pan.

The composition of these recrystallized sugars is about the same as seconds from sugar cane. The mean percentage of sucrose is 90.7, while the percentage of glucose remains abnormally high.

The analyses of these sugars are found in Table No. 23.

TABLE No. 23.—*Recrystallized sugars, Rio Grande, N. J.*

Number.	Moisture.	Ash.	Glucose.	Sucrose, direct.	Sucrose indirect.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5430	4.12	.64	4.84	92.5	90.76
5431	5.03	.90	8.58	85.1	83.65
5432	4.70	.91	6.54	91.5	89.69
5433	5.84	.32	8.60	92.5	91.37
5434	3.38	.40	2.74	93.5	92.82
5437	3.98	.83	5.93	91.3	89.59
5438	5.37	1.11	6.26	89.0	86.57
5440	3.08	.67	4.13	91.5	90.31
5441	4.20	.67	4.93	91.2	90.08
5442	3.85	.84	5.14	89.0	86.12
Averages..	4.16	.73	5.77	90.7	89.10

TABLE No. 24.—*Nitrogenous bodies in cane juice.*

Number.	Nitrogen.	Albuminoids.	Number.	Nitrogen.	Albuminoids.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
276	.052	.3250	403	.020	.1250
277	.045	.2813	413	.017	.1062
278	.058	.3625	431	.093	.5813
279	.040	.2500	471	.012	.0750
280	.049	.3063	472	.017	.1063
289	.048	.3000	480	.023	.1438
290	.049	.3063	481	.027	.1688
292	.052	.3250	487	.022	.1375
293	.041	.2563	488	.025	.1563

TABLE No. 25—*Nitrogenous bodies in diffusion juice.*

Number.	Nitrogen.	Albuminoids.
	Per cent.	*Per cent.*
282	.023	.1438
405	.014	.0835
415	.013	.0813
433	.054	.3375
483	.016	.1000

TABLE No. 26.—*Nitrogenous matter in diffused chip juice.*

Number.	Nitrogen.	Albuminoids.
	Per cent.	*Per cent.*
281	.008	.0500
473	.009	.0563
482	.012	.0750
489	.014	.0875

The most encouraging feature connected with the Rio Grande experiments is not found in the composition of the cane so much as in the quantity of it which can be grown per acre. The large tonnage obtained enabled Mr. Hughes to get more sugar per acre with 72 per cent. extraction than was made at Fort Scott with 93 per cent. With a good extraction in the battery, the yield at Rio Grande could have been increased fully 20 per cent.

ANALYTICAL WORK AT MAGNOLIA, LA.

The analytical work at Magnolia was divided into three classes, viz:

(1) A study of the composition of the juices from the mill and a partial chemical control of the operation of the factory.

(2) A complete chemical control of the experiments in diffusion.

(3) Miscellaneous work.

The chemical work was done chiefly by Messrs. Crampton and Fake. During the latter part of the season Dr. Crampton was absent, and the control work was done solely by Mr. Fake. The miscellaneous work I did myself, assisted part of the time by Mr. Fake.

The regular chemical work began on the 4th of November, 1887, and ended January 19, 1888.

In sampling mill juices a measured portion was taken from each of six clarifiers, representing the average composition of the juice from 18 tons of cane. In comparative work, the samples were taken as nearly as possible from the same body of juice in different stages of concentration. The samples for the diffusion work were taken as at Fort Scott and Rio Grande.

MILL JUICES.

During the first few days of the season the juices from the mill were run through a sulphur box, where they were saturated with sulphurous dioxide. They then passed through a heater to the clarifiers and thence to the quadruple effect and strike pan without the use of animal char. This method of treatment was abandoned after a short trial, and no further sulphur was used except in one of the diffusion trials.

In Table No. 27 are found the analytical data obtained during this time.

TABLE No. 27.—*Mill juices sulphured.*

Date.	No.	Baumé.	Brix.	Sucrose.	Reducing sugar.	Purity.
		°	°	*Per cent.*	*Per cent.*	
Nov. 2	4	8.8	15.9	12.93	1.11	81.32
Nov. 3	6	9.6	17.4	14.41	1.14	82.81
Nov. 3	8	9.0	16.23	12.87	1.01	78.68
Nov. 4	10	9.0	16.2	13.11	1.11	80.92
Nov. 4	12	8.9	16.03	12.63	1.17	78.79
Maxima ..	.....	9.6	17.4	14.41	1.17	82.81
Minima ...	......	8.8	15.9	12.63	1.01	78.68
Means	.....	9.08	16.35	13.19	1.11	80.50

A comparison of the sulphured and clarified juices was also made; but the duration of the use of sulphur was not long enough to give conclusive data. It would appear from the results of the analyses in Table No. 28 that the process of clarification tended to lower the purity of sulphured juices; an apparent fact which more extended investigation would probably modify.

TABLE No. 28.—*Mill juices.—Comparative samples of sulphured and clarified.*

Date.	Sulphured. Number.	Baumé.	Brix.	Sucrose.	Reducing sugar.	Purity.	Clarified. Number.	Baumé.	Brix.	Sucrose.	Reducing sugar.	Purity.
		°	°	*Pr. ct.*	*Pr. ct.*			°	°	*Pr. ct.*	*Pr. ct.*	
Nov. 2.......	4	8.8	15.90	12.93	1.11	81.32	5	9.1	16.51	13.28	1.28	80.43
Nov. 3.......	6	9.6	17.40	14.41	1.14	82.81	7	9.6	17.31	14.31	1.10	82.66
Nov. 4.......	10	9.0	16.20	13.11	1.11	80.92	11	9.4	16.97	13.56	1.20	77.90
Maxima ..	....	9.6	17.40	14.41	1.14	82.81	....	9.6	17.31	14.31	1.28	82.66
Minima...	....	8.8	15.90	12.93	1.11	80.92	....	9.1	16.51	13.28	1.10	77.90
Means....	....	9.13	16.50	13.48	1.12	81.68	....	9.37	16.93	13.72	1.19	80.33

The daily analyses of the mill juices are recorded in Table No. 29. The variations in the percentage of sucrose were caused by the character of the soil in which the cane was grown. The front lands gave uniformly a cane richer in sucrose than the low lands back from the river. Especially in new back land with a high tonnage was this deficiency noticed.

The mean results show a juice rich in sucrose, poor in reducing sugar, and of satisfactory purity.

TABLE No. 29.—*Mill juices.*

Date.	Number.	Baumé.	Brix.	Sucrose.	Reducing sugar.	Purity.
		°	°	*Per cent.*	*Per cent.*	
Nov. 8....	18	8.9	16.00	12.78	1.23	79.87
Nov. 9....	22	7.9	14.30	10.85	1.11	75.87
Nov. 9....	24	9.1	16.36	13.55	.85	82.76
Nov. 10....	26	8 8	15.90	13.22	.88	83.14
Nov. 11....	31	8.9	16.10	12.27	1.68	79.31
Nov. 12....	35	8 7	15.67	12.35	.94	78.81
Nov. 31....	45	8.9	15.97	12.39	1.55	77.58
Nov. 14....	48	8.9	15.97	12.63	1.42	79.08
Nov. 15...	52	8.5	16.33	13.25	1.15	81.13
Nov. 16....	55	8.6	16.57	13.25	1.68	79.66
Nov. 17...	61	9.3	16.83	13.68	1.18	81.28
Nov. 18...	66	9.25	16.73	13.58	1.05	81.11
Nov. 20...	74	9.4	16.93	13.83	1.04	81.69
Nov. 21...	78	9.5	17.16	14.29	.93	83.27
Nov. 22 ...	83	9.5	17.17	14.94	.65	87.01
Nov. 23 ...	90	9.2	16.63	14.07	.66	84.56
Nov. 24...	94	9.4	16.93	14.00	.76	82.69
Nov. 26....	100	9.1	16.56	13.79	.79	82.66
Nov. 27....	106	9.25	16.70	13.44	.88	80.48
Nov. 28 ..	111	8.3	14.97	12.13	.82	81.03
Nov. 28....	114	9.4	16.91	14.09	.73	83.37
Nov. 29....	116	9.5	17.17	14.46	.78	84.21
Nov. 30 ..	120	8.0	16.41	13.90	.81	84.75
Dec. 1 ...	125	9.7	17.50	14.74	.72	84.22
Dec. 2 ...	133	9.5	17.23	14.85	.68	86.18
Dec. 3....	139	9.25	16.73	12.98	.65	77.04
Dec. 3....	145	8.50	15.28	13.03	....	85.27
Dec. 5 ...	156	9.1	16.44	13.87	.72	84.36

TABLE No. 29.—*Mill juices*—Continued.

Date.	Number.	Baumé.	Brix.	Sucrose.	Reducing sugar.	Purity.
		°	°	*Per cent.*	*Per cent.*	
Dec. 6....	160	9.0	16.21	13.50	.75	83.33
Dec. 6....	162	8.8	15.93	13.37	.70	83.30
Dec. 7....	166	9.1	16.40	14.16	.70	86.34
Dec. 8....	168	8.65	15.60	12.57	.93	80.57
Dec. 8....	172	8.9	16.13	13.55	.72	84.00
Dec. 9....	174	8.5	15.27	12.18	1.00	79.77
Dec. 10....	177	8.4	15.24	12.17	1.14	79.85
Dec. 12....	219	8.3	15.06	12.05	....	80.01
Dec. 13....	226	8.15	14.91	11.94	1.01	80.01
Dec. 13....	227	8.30	14.69	11.72	....	80.00
Dec. 14....	230	8.3	15.04	11.84	.92	78.72
Dec. 14....	231	8.4	15.11	12.13	.87	80.27
Dec. 15....	236	8.15	14.67	11.76	.88	80.16
Dec. 15....	238	8.2	14.83	11.61	.84	78.28
Dec. 16....	239	8.0	14.39	11.33	.94	78.68
Dec. 17...	243	8.0	14.42	11.33	1.02	78.57
Dec. 17....	245	8.15	14.69	11.67	.99	79.45
Dec. 18....	246	8.6	15.51	12.31	1.01	79.37
Dec. 18....	247	8.4	15.24	12.27	.97	80.51
Dec. 19....	248	8.4	15.23	12.08	1.16	79.31
Dec. 20....	252	8.7	15.71	13.04	.86	83.00
Dec. 20....	254	9.2	16.59	13.68	.69	82.45
Dec. 21....	256	9.0	16.23	13.97	.64	86.07
Dec. 21....	259	8.1	14.57	11.66	.78	80.02
Dec. 26....	269	9.3	16.81	14.54	....	86.49
Dec. 26....	270	9.4	17.06	14.78	.45	86.63
Dec. 27....	271	9.4	17.04	14.81	.44	86.91
Dec. 27....	272	9.25	16.73	14.31	.52	85.53
Dec. 28....	275	9.4	17.07	14.92	.44	87.41
Dec. 28....	279	9.6	17.34	15.09	.51	87.02
Dec. 29....	281	9.5	17.23	15.32	.43	88.91
Dec. 29....	285	9.5	17.23	15.18	.40	88.10
Dec. 30....	297	9.75	17.57	15.40	.41	87.65
Dec. 30....	306	9.4	17.07	14.72	.53	86.23
Dec. 31....	310	9.7	17.47	15.33	.47	87.18
Dec. 31....	316	9.4	16.89	14.64	.57	86.67
Dec. 31....	326	9.4	17.08	14.75	.49	86.34
Jan. 1....	331	9.4	17.09	14.61	.68	85.43
Jan. 1....	333	9.25	16.67	14.16	....	85.54
Jan. 2....	334	9.3	16.84	14.87	.55	88.30
Jan. 2....	338	9.2	16.64	14.59	.59	87.68
Jan. 3....	342	9.4	17.01	14.67	.54	86.29
Jan. 3....	344	9.8	17.67	15.55	.28	88.00
Jan. 4....	345	9.6	17.44	15.28	.44	87.04
Jan. 4....	350	9.5	17.19	14.82	.46	86.21
Jan. 5....	351	9.75	17.59	15.33	.43	87.16
Jan. 5....	354	9.5	17.16	14.92	.47	86.94
Jan. 6....	356	9.4	16.93	14.82	.69	87.53
Jan. 6....	361	9.6	17.33	15.26	.55	88.05
Jan. 7....	364	9.4	16.96	14.55	.57	83.79
Jan. 7....	365	9.4	17.00	14.89	.59	87.59
Jan. 8...	367	9.5	17.23	14.76	.60	85.66
Jan. 8....	368	9.1	16.49	13.79	.70	83.57
Jan. 9....	372	9.5	17.17	14.20	.64	85.61
Jan. 9....	373	9.4	16.90	14.41	.65	85.26
Jan. 10....	377	9.25	16.66	13.98	.72	83.31
Jan. 10....	378	9.1	16.51	14.02	.67	84.96
Jan. 11....	382	9.0	16.20	13.87	.82	85.61
Jan. 11....	384	9.3	16.79	14.48	.83	86.19
Jan. 12....	389	9.25	16.69	14.26	.69	85.39
Jan. 12....	390	9.25	16.69	13.73	.96	82.21
Jan. 13....	396	9.1	16.47	13.83	.79	83.97
Means...	....	9.04	16.37	13.69	.77	83.48
Maxima .	....	9.80	17.67	15.55	1.55	88.91
Minima..	....	7.90	14.30	10.85	.40	75.87

The clarification of the mill juices was made in a simple manner. To the juice, as it entered the clarifier from the heater, a quantity of lime was added, nearly sufficient to neutralize the free acid present. The whole was then boiled and swept until no more dirty foam was formed. It was then allowed to subside for half an hour, and the clear juice drawn off.

The skimmings and sediments were sent to the filter presses.

The effect of this method of clarification is shown in Table 30.

TABLE NO. 30.—*Comparative samples of raw and clarified juices.*

Date.	Raw.						Clarified.					
	Number.	Baume.	Brix.	Sucrose.	Reducing sugar.	Purity.	Number.	Baume.	Brix.	Sucrose.	Reducing sugar.	Purity.
		°	°	*Pr. ct.*	*Pr. ct.*			°	°	*Pr. ct.*	*Pr. ct.*	
Nov. 8...	18	8.9	16.00	12.78	1.23	79.87	19	9.3	16.79	13.67	1.25	81.41
Nov. 9...	22	7.9	14.30	10.85	1.11	75.87	23	8.7	15.67	12.60	1.12	80.41
Nov. 10...	26	8.8	15.90	13.22	.88	83.14	27	9.25	16.73	14.01	.92	83.74
Nov. 11...	31	8.9	16.10	12.77	1.08	79.31	32	9.0	16.31	13.06	1.12	80.07
Nov. 12...	35	8.7	15.67	12.35	.94	78.81	36	8.9	16.01	13.02	1.20	81.37
Nov. 13...	45	8.9	15.97	12.39	1.55	77.58	46	8.9	15.97	13.19	1.57	82.59
Nov. 14...	48	8.9	15.97	12.63	1.42	79.08	49	9.25	16.68	12.94	1.58	77.58
Nov. 15...	52	8.5	16.33	13.25	1.15	81.13	53	10.0	17.98	14.87	1.21	82.70
Nov. 16...	55	8.6	16.57	13.20	1.08	79.66	56	9.5	17.02	14.21	1.04	83.49
Nov. 17...	61	9.3	16.83	13.68	1.18	81.28	62	10.0	18.10	14.92	1.21	82.43
Nov. 18...	66	9.25	16.73	13.58	1.05	81.11	67	9.55	17.24	14.37	1.08	83.35
Nov. 20...	74	9.4	16.93	13.83	1.04	81.69	75	9.9	17.83	15.13	1.13	84.85
Nov. 21...	78	9.5	17.16	14.29	.93	83.27	79	10.1	18.28	15.64	.95	85.55
Nov. 22...	83	9.5	17.17	14.94	.65	87.01	84	9.8	17.72	15.79	.63	89.11
Nov. 23...	96	9.2	16.63	14.07	.66	84.56	91	9.5	17.17	14.72	.64	85.73
Nov. 24...	91	9.4	16.93	14.00	.76	82.69	95	9.9	17.93	15.25	.72	85.05
Nov. 26...	100	9.1	16.56	13.79	.79	82.66	101	9.75	17.57	14.70	.81	83.66
Nov. 27...	106	9.25	16.70	13.44	.88	80.48	107	9.6	17.38	14.14	.82	81.35
Nov. 28...	114	9.4	16.91	14.09	.73	83.37	115	9.65	17.45	14.83	.70	84.98
Nov. 29...	116	9.5	17.17	14.46	.78	84.21	117	9.8	17.78	15.33	.74	86.22
Nov. 30...	120	8.0	14.41	13.90	.81	84.75	121	9.75	17.63	15.20	.77	86.21
Dec. 1...	125	9.7	17.50	14.74	.72	84.22	126	9.8	17.69	14.72	.75	83.16
Dec. 2...	133	9.5	17.23	14.85	.68	86.18	134	9.9	17.79	15.71	.66	88.26
Dec. 5..	156	9.1	16.44	13.87	.72	84.36	157	9.4	16.94	14.53	.73	85.77
Dec. 6...	160	9.0	16.21	13.58	.75	83.33	161	9.4	17.03	14.48	.70	85.02
Dec. 7...	166	9.1	16.40	14.16	.70	86.34	167	9.1	16.46	14.18	.69	86.14
Dec. 8...	168	8.65	15.60	12.57	.93	80.57	169	8.9	16.07	13.34	.93	83.01
Dec. 9..	174	8.5	15.27	12.18	1.00	79.77	175	8.9	16.03	13.17	1.04	82.16
Maxima	.....	9.70	17.50	14.94	1.55	87.01	.....	10.1	18.28	15.79	1.58	89.11
Minima	.....	7.90	14.50	10.85	.65	75.87	.....	8.7	15.97	12.60	.63	77.58
Means	.....	9.02	16.34	13.48	.94	82.01	.....	9.48	17.12	14.35	.95	83.76

The increased density of the clarified juices, and the consequent higher percentage of sucrose, are due to the evaporation which takes place during clarification. The purity of the juices was raised 1.75 points by the process. A slight destruction of reducing sugars also took place.

After clarification the juices were filtered through bone-black. This char had been so long in use that its decolorizing power was partially destroyed. It served, however, as a most excellent mechanical filter, serving to remove suspended matter which would not subside.

The purity of the juice was raised nearly one point by this filtration. A comparative study of raw, clarified, and filtered juices is given in Table No. 31.

TABLE NO. 31.—*Mill juices.—Comparative samples of raw, clarified, and filtered juices.*

RAW.

Date.	Number.	Baume.	Brix.	Sucrose.	Reducing sugar.	Purity.
		°	°	*Per cent.*	*Per cent.*	
Nov. 8...	18	8.9	16.00	12.78	1.23	79.87
Nov. 9..	22	7.9	14.30	10.85	1.11	75.87
Nov. 10...	26	8.8	15.90	13.22	.88	83.14
Nov. 11...	31	8.9	16.10	12.77	1.08	79.31
Nov. 12...	35	8.7	15.67	12.35	.94	78.81
Nov. 13...	45	8.9	15.97	12.39	1.55	77.58
Nov. 14...	48	8.9	15.97	12.63	1.42	79.08
Nov. 15...	52	8.5	16.33	13.25	1.15	81.13
Nov. 16..	55	8.6	16.57	13.20	1.08	79.66
Nov. 17...	61	9.3	16.83	13.68	1.18	81.28
Nov. 18...	66	9.25	16.73	13.58	1.05	81.11
Nov. 21...	78	9.5	17.16	14.29	.93	83.27
Nov. 22..	83	9.5	17.17	14.94	.65	87.01
Nov. 23...	90	9.2	16.63	14.07	.66	84.56
Nov. 24..	94	9.4	16.93	14.00	.76	82.69
Nov. 26...	100	9.1	16.56	13.79	.79	82.66
Nov. 27...	106	9.25	16.70	13.44	.88	80.48
Nov. 29...	116	9.5	17.17	14.46	.78	84.21
Nov. 30...	120	8.0	16.41	13.90	.81	84.75
Maxima.	....	9.50	17.17	14.94	1.55	87.01
Minima.	....	7.90	14.30	10.85	.65	75.87
Means..	....	8.95	16.37	13.31	1.00	81.39

CLARIFIED.

Date.	Number.	Baume.	Brix.	Sucrose.	Reducing sugar.	Purity.
		°	°	*Per cent.*	*Per cent.*	
Nov. 8...	19	9.3	16.79	13.67	1.25	81.41
Nov. 9...	23	8.7	15.67	12.60	1.12	80.41
Nov. 10..	27	9.25	16.73	14.01	.92	83.74
Nov. 11...	32	9.0	16.31	13.06	1.12	80.07
Nov. 12...	36	8.9	16.01	13.02	1.20	81.37
Nov. 13...	46	8.9	15.97	13.19	1.57	82.59
Nov. 14...	49	9.25	16.68	12.94	1.50	77.58
Nov. 15...	53	10.0	17.98	14.87	1.21	82.70
Nov. 16...	56	9.5	17.02	14.21	1.04	83.49
Nov. 17...	62	10.0	16.10	14.92	1.21	82.43
Nov. 18...	67	9.55	17.24	14.37	1.08	83.35
Nov. 21...	79	10.1	18.28	15.64	.95	85.55
Nov. 22...	84	9.8	17.72	15.79	.63	89.11
Nov. 23...	91	9.5	17.17	14.72	.64	85.73
Nov. 24...	95	9.9	17.93	15.25	.72	85.03
Nov. 26...	101	9.75	17.57	14.70	.81	83.66
Nov. 27...	107	9.6	17.38	14.14	.82	81.35
Nov. 29..	117	9.8	17.78	15.33	.74	86.22
Nov. 30...	121	9.75	17.63	15.20	.77	86.21
Maxima.	....	10.1	18.28	15.79	1.57	89.11
Minima.	....	8.7	15.67	16.20	.63	63.74
Means..	....	9.50	17.16	14.30	1.02	82.21

FILTERED.

Date.	Number.	Baumé.	Brix.	Sucrose.	Reducing sugar.	Purity.
		°	°	*Per cent.*	*Per cent.*	
Nov. 8....	20	9.4	16.96	14.00	1.26	82.54
Nov. 9....	24	9.0	16.23	13.01	1.12	80.16
Nov. 10 ...	28	8.75	15.73	12.40	1.01	78.76
Nov. 11...	33	9.3	16.83	13.62	1.03	80.93
Nov. 12 ...	37	9.1	16.47	13.29	1.16	80.69
Nov. 13....	47	9.2	16.56	13.25	1.39	80.61
Nov. 14....	50	9.55	17.27	13.25	1.60	76.72
Nov. 15 ..	54	9.6	17.38	15.16	1.13	87.22
Nov. 16 ..	57	....	....	....	....	....
Nov. 17 ..	63	9.6	17.30	14.29	1.18	82.60
Nov. 18 ...	68	9.8	17.63	14.27	1.14	80.94
Nov. 21 ...	80	10.0	18.09	15.50	.91	85.63
Nov. 22...	85	10.2	18.39	16.25	.51	88.31
Nov. 23....	92	9.9	17.87	15.64	.54	87.52
Nov. 24 ..	96	....	....	.....	....	....
Nov. 26 ..	102	9.6	17.30	14.63	.77	84.56
Nov. 27....	108	9.9	17.90	14.89	.72	83.13
Nov. 29....	118	9.7	17.47	15.45	.72	88.44
Nov. 30 ..	122	9.75	17.50	15.04	.67	85.77
Maxima .	....	10.2	18.39	16.25	1.60	88.44
Minima..	....	9.0	15.73	12.40	.51	76.72
Means ...	....	9.55	17.23	14.35	.99	83.17

Samples of the sirup issuing from the Yaryan quadruple effect pan were taken from time to time, and the results of the analyses of these sirups are shown in Table No. 32.

TABLE NO. 32.

Date.	Number.	Brix corrected.	Baumé corrected.	Purity.	Sucrose.	Glucose.
					Per cent.	*Per cent.*
Nov. 3..	9	54.37	29.45	81.42	44.27	4.48
Nov. 4..	15	53.34	28.90	80.43	42.9	4.86
Nov. 12..	38	37.45	20.55	80.91	30.3	2.89
Nov. 18..	69	50.90	27.70	82.32	41.9	3.80
Nov. 22..	86	51.56	28.00	87.08	44.9	2.31
Nov. 23..	93	54.18	29.40	85.46	46.3	2.04
Nov. 26..	103	47.60	25.90	76.05	36.2	2.87
Nov. 28..	112	51.53	28.00	85.19	43.9	2.50
Dec. 2..	136	50.19	27.30	89.66	45.0	......
Dec. 4..	151	52.26	28.35	86.68	45.3	2.41
Dec. 6..	163	50.66	27.53	86.46	43.8	2.02
Dec. 8..	170	52.64	28.54	85.49	45.0	2.46
Dec. 15..	237	48.86	26.60	81.87	40.0	3.16
Dec. 20..	253	48.74	26.50	78.17	38.1	3.65
Dec. 22..	260	46.29	25.20	85.98	39.8	....
Dec. 28..	276	48.79	26.60	89.57	43.7	1.36
Jan. 2..	325	50.59	27.50	88.56	44.8	1.64
Jan. 4..	346	50.42	27.40	88.85	44.8	1.60
Means.	....	50.02	27.19	84.45	42.28	2.75

The samples of *masse cuites* were placed in bottles and sent to the laboratory for analysis. In addition to the determinations of the sucrose by direct and double polarization it was also estimated by copper solution.

The mean result of this latter estimation is slightly below the mean of the direct readings. In individual cases a marked variation between the chemical and optical methods is noticed. The percentage of ash, compared with sorghum *masse cuites*, is small.

For details see Table No. 33.

TABLE NO. 33.—*First masse cuites (mill), Lawrence, La.*

Number.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Sucrose by copper.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5715	9.69	2.33	8.06	78.70	78.37	74.94
5717	9.06	2.05	8.75	77.03	76.74	75.62
5719	6.30	2.31	7.03	81.00	80.77	78.58
5720	9.12	2.64	7.31	76.50	76.98	74.80
5721	8.65	2.03	7.06	78.00	77.44	75.04
5727	17.88	4.06	12.36	70.00	71.04	71.48
5729	13.51	2.01	4.56	81.30	80.00	78.17
5730	9.40	....	5.53	75.80	77.71	76.78
5731	8.52	2.41	4.00	80.50	81.06	80.32
5734	10.79	2.79	5.91	74.10	75.58	76.13
5740	7.85	....	6.54	75.90	76.88	76.82
5743	8.47	3.96	6.94	....	....	78.43
5748	8.21	2.58	4.79	79.00	80.23	80.71
5749	9.05	3.10	5.13	76.80	78.45	78.40
5754	10.71	2.17	4.78	77.10	78.08	78.30
5755	10.67	2.63	3.65	80.00	80.92	78.95
5762	10.73	2.66	4.29	77.70	79.31	82.14
5763	9.29	1.94	3.98	79.00	79.39	78.40
5767	8.84	2.14	3.79	83.20	84.31	70.50
5769	....	....	4.26	82.20	83.00	78.99
5770	10.54	2.12	4.46	79.00	80.61	79.38
5773	9.03	2.37	4.75	78.10	79.84	79.10
5776	9.39	2.35	4.83	79.30	80.91	79.53
5780	9.48	2.48	5.26	78.60	80.15	78.28
5783	9.84	2.50	5.21	78.10	79.54	76.75
Averages ...	9.79	2.53	5.73	78.21	79.05	77.46
Mean purity.	....	....	....	....	....	87.63

The high purity of the *masse cuites*, as shown in Table No. 33, as compared with the juices and sirups, may be accounted for as follows:

In the latter the percentage of total solids was calculated from the readings of the saccharometer; in the former by drying and direct weighing. The results of last season's work, both with sugar-cane and sorghum juices, show that by the use of the spindle the percentage of total solids found is always too high. The purity of the juices, therefore, is higher than indicated by the analyses. A note on the subject will be made subsequently.

The direct polarization of the first sugars is given in Table No. 34.

In these sugars there was only a trace of glucose, but no attempt was made to estimate its quantity, not even by Soldaini's reagent (carbonate of copper dissolved in acid carbonate of potassium). For the same reason a double polarization was not necessary.

TABLE NO. 34.—*First sugars, Lawrence, La.*

Date.	No.	Sucrose.	Date.	No.	Sucrose.
		Per cent.			*Per cent.*
Nov. 4	14	96.5	Dec. 16	240	97.0
Nov. 12	34	98.6	Dec. 19	249	97.0
Nov. 16	58	98.2	Dec. 22	262	97.7
Nov. 16	59	*97.3	Dec. 28	280	98.5
Nov. 20	76	98.8	Jan. 2	337	97.6
Nov. 20	77	98.6	Jan. 3	343	*98.0
Nov. 22	89	97.5	Jan. 5	353	96.8
Nov. 26	105	97.0	Jan. 6	362	98.4
Nov. 27	109	97.6			——
Nov. 28	110	98.5	Mean	....	97.8
Dec. 1	130	98.0			

*Cut strike.

FIRST MOLASSES.

Samples of molasses from the first sugars were taken from time to time from the large tank into which the molasses was pumped after issuing from the centrifugals. These samples therefore represent fairly well the composition of the first molasses for the entire season. The same remarks apply to the mean purity as were made in respect of the purity of the *masse cuites*—the water in the molasses having been determined by direct weight.

The mean determinations by the copper method agree well with the results of double polarization, although, as in the case of the *masse cuites*, the individual deviations are large. The presence of invert sugar, optically active, is clearly shown by the differences in single and double polarization.

Analyses follow in Table No. 35.

TABLE NO. 35.—*First molasses, Lawrence, La.*

Number.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Sucrose by Fehling.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5718	31.25	4.32	13.65	47.20	46.97	44.89
5724	28.84	3.92	14.23	45.50	48.21	46.89
5728	39.65	4.48	16.18	33.00	33.33	....
5741	29.39	6.12	....	....	....	....
5744	....	8.43	14.63	32.30	36.70	34.05
5745	30.70	7.48	9.43	46.20	45.34	43.83
5747	29.30	5.64	....	....	....	....
5753	....	4.87	4.25	54.90	52.46	48.09
5760	....	....	10.58	44.10	55.14	56.26
5766	18.82	7.15	13.34	46.20	49.77	50.80
5768	22.95	4.49	8.53	55.50	58.46	59.26
5772	20.94	4.52	8.28	58.50	61.98	....
5775	23.30	5.29	9.80	53.90	57.27	57.72
5778	23.08	4.32	9.52	55.20	59.12	58.44
5781	23.27	4.84	10.05	55.10	58.85	67.70
Averages....	26.79	5.42	10.96	48.28	51.05	51.56
Mean purity.	....	....	....	....	....	69.73

SECOND MASSE CUITE.

The samples of second *masse cuite* analyzed were all, with one exception, taken at the last of the season, when the juice was particularly rich in sucrose. They show therefore a higher purity than the mean of the first molasses. The data in Table No. 36 furnish a further illustration of the fact that the molasses from rich juices have a higher purity than that from the poorer sorghum. These facts are suggestive of the idea that the solids not sucrose in sorghum are less melassigenic than those in sugar-cane.

TABLE No. 36.—*Second masse cuites, Lawrence, La.*

Date.	Number.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Sucrose by Fehling.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Nov. 11	5722	5.49	4.25	13.33	67.10	69.84	68.68
Jan. 2	5761	10.51	4.08	7.31	69.20	72.27	73.20
Jan. 5	5764	....	....	8.30	68.00	70.80	....
Jan. 6	5765	7.15	4.12	5.92	73.00	75.02	75.70
Jan. 12	5784	7.78	4.48	9.69	67.90	69.77	61.81
Averages	....	7.73	4.23	8.91	69.04	71.54	69.85
Mean purity	....	....	....	....	....	....	77.53

SECOND MOLASSES.

The samples of second molasses were taken from large cisterns and represent fairly well the character of this product for the entire season.

The most striking feature of the mean composition of this molasses is the purity co-efficient. After two crystallizations the molasses at Magnolia still had a purity-number only a little below the first *masse cuite* at Fort Scott, and almost identical with that of the first *masse cuite* at Rio Grande.

This number shows the possibility of a large yield of third sugars.

TABLE No. 37.—*Second molasses, Lawrence, La.*

Date.	Number.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Sucrose by Fehling.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Nov. 19	5725	16.33	6.70	21.93	41.70	46.43	44.46
Dec. 24	5751	24.27	7.46	16.60	34.70	38.84	34.84
Jan. 6	5766	18.82	7.15	13.34	46.20	49.77	50.80
Averages	....	19.81	7.10	17.29	40.87	45.01	43.37
Mean purity	....	....	....	....	....	....	56.13

TABLE No. 38.—*Second sugars, Lawrence, La.*

Date.	Number.	Sucrose.
		Per cent.
Nov. 12	44	95.6
Dec. 4	152	90.6
Dec. 8	171	91.8
Dec. 20	255	87.0
Dec. 24	266	85.8
Dec. 25	268	87.3
Jan. 4	349	90.2
Average	....	89.76

CHEMICAL CONTROL OF THE DIFFUSION EXPERIMENTS.

The following data respecting the diffusion experiments are abstracted from Bulletin 17, pp. 83–89:

The first results from the experiments were obtained from the run of December 3, 1887.

The juice was treated with .3 per cent. its weight of lime, and after the precipitation of the lime with carbonic dioxide, an amount of lignite equal to 10 per cent. of the weight of the sugar present was added.

The juice filtered readily through the presses, forming firm, hard cakes. The filtered juice was treated with phosphate of soda, 15 pounds of this salt being added for each 5,000 pounds of juice.

The phosphate produced an abundant flocculent precipitate, which filtered easily through the twin filter presses, giving a juice of remarkable limpidity. The *masse cuite,* however, was dark, and the molasses much inferior in color to that made by the use of bone-black and ordinary clarification.

The phosphate of soda did not produce as favorable results as had been expected, and its further use was discontinued.

Following are the data obtained in the first run:

TABLE NO. 39.—*First diffusion run, December* 3, 1887.

	Total solids.	Sucrose.	Glucose.
Juice from chips:	*Per ct.*	*Per cent.*	*Per cent.*
First	15.20	12.01	.96
Second	14.45	11.92	1.00
Third	15.45	12.84	1.02
Average	15.03	12.26	.99
Diffusion juice:			
First	10.88	8.88	.83
Second	10.40	8.65	.74
Average	10.64	8.76	.78
Exhausted chips:			
First sample	....	.51	....
Second sample	....	.76	....
Third sample	....	.91	....
Average	....	.73	....
Carbonatated juice	11.09	9.20	.70
Waste water	....	....	.12
Semi-sirup	51.80	42.20	3.39
First sugar	....	97.50	....
Molasses from first sugar	76.30	45.00	11.11
Second sugar	....	91.60	....

Cane used	tons	80.3
First sugar per ton	pounds	146.1
Second sugar per ton	do	40.1
Total first and second sugars	do	186.2
Third sugar	do	15.0

	Pounds.
The total sugar in the cane at 90 per cent. juice was	220.6
Of this there was obtained 146.1 pounds at 97.50	144.4
And 40.1 pounds at 91.6	36.7
Total pure sucrose obtained	181.1
Left in chips	14.6
Total left in molasses and lost in manufacturing	24.9

NOTE.—The third sugar will not be dried until in May or June, 1888. The estimates of third sugar have been made by Mr. E. C. Barthelemy.

EXTRACTION.

The percentage of sucrose left in the spent chips was .73. Sucrose in cane was 11.03 per cent. The per cent. of extraction is therefore $11.03 - .73 = 10.30 \div 11.03 \times 100 = 93.4$.

SECOND TRIAL.

Another trial was made of the diffusion machinery, beginning December 9. Carbonatation was again used, but without lignite or any further treatment. The juice passed directly from the filter presses to the double-effect pan.

The quantity of lime employed was .6 per cent. the weight of the juice. The filtration was perfect. The experiment was remarkable in showing that a perfect defecation can be made with carbonatation with a much smaller percentage of lime than had been supposed necessary.

The *masse cuite* was dark, but the sugar a fair yellow.

Following are the data of the run:

TABLE No. 40.—*Second diffusion run, December* 9, 1887.

	Total solids.	Sucrose.	Glucose.
Fresh chips:	*Per ct.*	*Per cent.*	*Per cent.*
First sample	14.06	11.70	1.04
Second sample	15.65	13.64	.76
Third sample	15.70	13.52	.75
Fourth sample	15.59	13.02	.81
Fifth sample	14.00	11.18	1.02
Average	14.98	12.61	.88
Diffusion juice:			
First sample	9.36	7.83	.67
Second sample	8.67	7.25	.58
Third sample	9.68	7.61	.55
Fourth sample	10.40	8.69	.91
Fifth sample	10.20	8.45	.78
Average	9.66	7.96	.69
Carbonatated juice:			
First sample	9.12	7.73	.65
Second sample	8.74	7.35	.57
Third sample	10.20	8.55	.50
Fourth sample	11.40	9.00	.73
Average	9.86	8.16	.61
Exhausted chips:			
First sample	....	1.58	....
Second sample	....	1.69	....
Third sample	....	.48	....
Fourth sample	....	.32	....
Fifth sample	....	.40	....
Average	....	.89	....
Semi-sirup	47.70	38.90	2.96
First sugar	....	96.60	....
Molasses from firsts	72.20	42.40	10.50
Second sugar	....	87.30	....

Yield of first sugar per ton	pounds	182
Yield of second sugar per ton	do	43
Cane used	tons	90
The total sugar in the cane at 90 per cent. juice was	per ton	226.98
Of these there were obtained 128 pounds at 96.6		123.6
And 43 pounds at 87.3		37.5
Total pure sucrose obtained	per ton	161.1
Pure sucrose left in chips	do	17.8
Pure sucrose left in molasses and lost in manufacture	do	41.1
Third sugar estimated	do	17.0
Percentage sugar in cane extracted		92.16

The poor yield was due to use of thick chips during the first part of the run, causing a loss of 1.6 per cent. sucrose in the chips.

THIRD TRIAL.

In this run the use of carbonatation and lignite was discontinued. The diffusion juices were treated with sulphur fumes until well saturated. They were then treated with lime and clarified in the usual way.

The clarification took place readily. The quantity of scums was very small, and the sediment subsided rapidly, forming a thin layer on the bottom of the tank, permitting the clear liquor to be easily and completely drawn off. The juice passed at once from the clarifiers to the double effect pan and subsequently received no further purification.

Following are the analytical data obtained:

TABLE No. 41.—*Third diffusion run December 10 and 11, 1888.*

	Total solids.	Sucrose.	Glucose.
Fresh chips:	*Per ct.*	*Per cent.*	*Per cent.*
First sample	14.39	11.89	.79
Second sample	12.77	10.63	.77
Third sample	14.49	12.06	.80
Average	13.88	11.53	.78
Diffusion juice:			
First sample	9.42	7.82	.62
Second sample	9.41	7.87	.59
Third sample	9.55	7.86	.67
Average	9.46	7.85	.63
Sulphured juice:			
First sample	9.69	8.17	.66
Second sample	9.12	7.53	.58
Average	9.40	7.85	.62
Clarified juice:			
First sample	9.95	8.21	.67
Second sample	9.89	8.06	.63
Third sample	10.32	8.39	.71
Average	10.05	8.22	.67
Exhausted chips:			
First sample	....	.80	....
Second sample	....	.50	....
Third sample	....	.77	....
Fourth sample	....	.93	....
Average	....	.75	....
Semi-sirup	44.70	34.60	2.87
First sugar	....	96.30	....
Molasses from first sugar	72.90	36.70	12.07

First sugar per ton .... pounds..	143
Number tons cane used	110

The molasses from the first sugar was boiled to string proof, and put in wagons. A good crystallization of second sugar was secured but, the molasses having been left too acid, a good separation was not secured. Mr. Barthelemy therefore decided to reboil the molasses with some of the product of the mill process, and therefore no statement of the quantity of second sugar can be given. It was estimated at 30 pounds per ton.

The cane from which this run was made was grown on new back land and was the poorest of the whole season.

The percentage of sugar extracted of total sugar in cane was 92.80.

FOURTH TRIAL.

In this run the diffusion juice was treated with lime until almost neutral. It was then boiled, skimmed, and allowed to settle. The scums and sediments were of small volume and were all returned to the battery.

The juice received no other treatment whatever for clarification. It was converted to sirup in a double effect vacuum pan. The capacity of this pan was not quite great enough to evaporate the juice as fast as furnished by the battery. For this reason the run which might have been finished in two days occupied a part of a third day. The quantity of cane worked was 200 tons.

The following is a record of the analytical data obtained:

TABLE NO. 42.—*Fourth diffusion run, December* 29, 30, *and* 31, 1887.

	Total solids.	Sucrose.	Glucose.
Juices from fresh chips:	*Per ct.*	*Per cent.*	*Per cent.*
A. M., first day	16.46	14.23	.49
P. M., first day	17.27	15.33	.43
Midnight, first day	17.26	15.12	.43
A. M., second day	17.13	14.84	.45
Midnight, second day	16.97	14.93	.54
A. M., third day	16.19	13.90	.61
P. M., third day	16.26	14.05	.50
Average fresh chip juice for run	16.79	14.60	.49
Diffusion juices:			
First sample, first day	9.72	8.71	.32
Second sample, first day	10.09	9.01	.29
Third sample, first day	11.38	10.16	.30
Fourth sample, first day	11.60	9.31	.53
First sample, second day	11.10	9.87	.32
Second sample, second day	10.92	9.69	.33
Third sample, second day	10.94	9.77	.44
First sample, third day	10.45	9.31	.35
Second sample, third day	10.87	9.69	.38
Average diffusion juice for run	10.78	9.50	.36
Clarified juices:			
Average for first day	10.75	9.34	.32
Average for second day	11.77	10.36	.32
First sample, third day	12.01	10.36	.41
Second sample, third day	11.61	9.78	.38
Third sample, third day	11.25	9.51	.36
Average clarified juice for run	11.48	9.87	.36
Juices from exhausted chips:			
First sample, first day	....	.52	....
Second sample, first day	....	.61	....
Third sample, first day	....	.83	....
First sample, second day	....	1.12	....
Second sample, second day	....	.72	....
Third sample, second day	....	.95	....
First sample, third day	....	1.09	....
Second sample, third day	....	1.30	....
Third sample, third day	....	1.10	....
Average exhausted chip juice for run	....	.91	....
Semi-sirup for first strike	37.37	33.10	.99
Masse cuite, first strike	....	81.20	....
First sugar from first strike	....	98.40	....
First molasses from first strike	76.22	51.80	7.76
Semi-sirup for second strike	40.00	35.10	1.19
Masse cuite	....	80.60	....
First sugar	....	98.90	....
Molasses from second strike	79.00	55.60	....
Average extraction	....	93.8	....
Pounds first sugar per ton	....	165.5	....
Per cent. sugar extracted obtained in firsts	....	66.2	....

Second sugar per ton	pounds..	45.9
Third sugar per ton (estimated)	do....	*18.0
Cane used	tons..	200

* On February 29 I was informed by letter from Governor Warmoth that the third sugars from the fourth run had been dried and weighed, yielding 3,723 pounds, or 18.6 pounds per ton.

FIFTH TRIAL.

The fifth and last run of the diffusion battery was begun on January 14 and finished on the 18th. This trial was made after the milling work had been completed. The diffusion juices were treated precisely the same way as the mill juices had been, and after passing over bone-black were concentrated to sirup in a Yaryan quadruple effect, which has been in use with the mill juices during the manufacturing season.

The working of all the machinery during this final trial was satisfactory, and the even march of the whole work promoted the efficiency of the machinery and the successful manipulation of the juice.

TABLE No. 43.—*Analytical data of fifth run.*

No.	Brix.	Sucrose.	Glucose.
Fresh chips:	°	*Per cent.*	*Per cent.*
397	16.87	14.23	74
400	16.39	13.45	.87
403	16.39	13.79	.89
405	17.09	14.73	.68
408	16.86	12.11	.75
411	17.16	14.73	.64
414	16.93	14.06	.70
417	17.00	14.50	.61
420	16.70	13.93	.73
423	16.79	14.11	.74
426	17.19	14.17	.61
429	16.73	14.19	.59
437	17.11	14.55	.61
440	16.17	13.48	.75
443	16.17	13.43	.76
446	16.60	13.99	.63
449	16.63	14.39	.65
452	16.77	14.28	.63
459	16.23	13.29	.77
465	16.03	13.79	.76
468	16.07	13.35	.85
472	16.84	14.34	.64
475	16.37	13.54	.82
478	16.51	14.17	.70
484	16.94	14.38	.65
490	16.57	14.52	.63
Maximum	....	14.73	.89
Minimum	....	12.11	.59
Mean	....	13.98	.70
Diffusion juices:			
398	11.37	9.28	.60
401	10.67	8.66	.64
404	10.61	8.92	.49
409	10.38	8.53	.41
412	11.01	9.10	.45
415	10.91	8.60	.48
418	10.71	8.76	.40
421	10.65	8.77	.40
424	10.57	8.51	.44
427	10.52	8.90	.46
430	10.65	9.05	.32
438	10.27	8.46	.35
441	10.73	8.94	.45
444	10.88	8.99	.42
447	9.5	7.68	.34
Diffusion juices—continued.	°	*Per cent.*	*Per cent.*
450	9.88	8.12	.42
453	10.87	9.00	.38
460	9.89	....	.45
466	10.67	8.41	.61
469	10.47	8.01	.72
473	10.17	8.02	.48
476	10.15	7.86	.48
479	10.31	7.92	.47
485	10.59	8.26	.52
491	9.69	7.53	.61
Maximum	....	9.28	.72
Minimum	....	7.53	.34
Mean	....	8.41	.47
Exhausted chips:			
399	....	.52	....
402	....	.21	....
407	....	.52	....
410	....	.32	....
413	....	.52	....
416	....	.41	....
419	....	.33	....
422	....	.42	....
425	....	.42	....
428	....	.55	....
431	....	.42	....
439	....	.50	....
442	....	.50	....
445	....	.42	....
448	....	.46	....
451	....	.69	....
454	....	.55	....
461	....	.51	....
467	....	.42	....
470	....	.39	....
474	....	.43	....
477	....	.54	....
480	....	.34	....
486	....	.22	....
492	....	.48	....
Maximum	....	.69	....
Minimum	....	.21	....
Mean	....	.44	....

The molasses from the first sugars being very rich, the method of reboiling to grain was employed. To this end the molasses of the first strike, having been reduced to 55 to 60 per cent. of total solids, was boiled on a nucleus of first sugar left in the pan from the second strike. In this way all the molasses was boiled to grain with most gratifying results except that from the last strike of the first sugars.

The attempt to boil this to grain did not succeed in giving a *masse cuite* which could be dried with ease. The molasses running from the machines was so thick that it clogged them up. Seven large sugar wagons were filled with this material and set in the hot room.

The sugars made were equal in every respect to those obtained by milling in similar instances. Without counting the second sugar above named, the grained sugar per ton amounted 181.5 pounds. The grained sugars in wagons will yield not less than 7,500 pounds, or 18 pounds per ton.

The third sugars are estimated by Mr. Barthelemy at not less than 16 pounds per ton.

The total yield per ton of the fifth run will reach therefore 215.5 pounds per ton. The number of tons of cane used was 417.

TABLE NO. 44.—*Summary of results.*

Number of run.	Cane.	Mean sucrose in juice.	Mean glucose in juice.	Sugar grained in pan per ton. First sugar.	Wagon sugar per ton. Second sugar.	Wagon sugar per ton. Third sugar (estimated).	Total sugars per ton.
	Tons.	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	80.3	12.26	.99	146.1	40.1	15	201.2
2	99.0	12.61	.88	128.0	43.0	18	189.0
3	110.0	11.53	.78	143.0	30.0	12	185.0
4	200.0	14.60	.49	165.5	45.9	18	229.4
5	417.0	13.98	.70	181.5	18.0	16	215.5

MASSE CUITES, SUGARS, AND MOLASSES FROM THE DIFFUSION RUNS.

Following are the data of the analyses of the *masse cuites*, sugars, and molasses from the diffusion runs.

In Table No. 45 are the results of examination of samples afforded by the first diffusion run.

TABLE NO. 45.—*First run, juices after carbonatation clarified with sodium phosphate.*

	No.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Sucrose by Fehling.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Masse cuite	5732	9.20	....	5.91	75.40	76.96	78.94
	5734	10.79	2.79	5.91	74.10	75.58	76.13
Averages	.....	10.00	2.79	5.91	74.75	76.27	77.54
First sugar	5733	0.51	0.48	....	97.59	....	....

TABLE NO. 46.—*Carbonatation, second run, diffusion, Lawrence, La.*

	No.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Sucrose by Fehling.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
First masse cuite...	5735	9.53	3.90	6.21	75.7	76.22	76.94
First molasses	......	....	....	10.50	42.4	....	....
First sugar..........	5737	.58	.48	....	96.6	....	....
Second sugar........	5752	3.23	2.83	1.36	87.3	86.49	84.20

TABLE NO. 47.—*Juice sulphured, third run, diffusion, Lawrence, La.*

	No.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Sucrose by Fehling.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Masse cuite	5736	8.42	3.79	6.79	73.9	76.19	76.58
Molasses	5739	34.04	7.53	12.07	36.7	....	....
Sugar	5738	.46	.82	....	96.3	....	....

TABLE NO. 48.—*Fourth run, clarification by lime, diffusion, Lawrence, La.*

	Number.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Masse cuites...............	5756	9.42	2.63	....	77.40	78.48
	5759	9.27	2.57	....	....	....
Averages............	....	9.35	2.60	....	77.40	78.48
Molasses..................	5758	24.01	5.28	7.77	51.80	....
Sugar......................	6757	.27	.32	....	98.4	....

TABLE NO. 49.—*Fifth run, juices bone-blacked, diffusion, Lawrence, La.*

	No.	Moisture.	Ash.	Glucose.	Sucrose direct.	Sucrose indirect.	Sucrose by Fehling.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
First masse cuite..	5785	8.83	2.47	5.25	79.3	80.53	80.75
	5787	10.68	2.47	4.36	76.5	78.77	78.80
	5790	12.04	3.49	4.24	73.7	75.33	75.41
Averages.....	......	10.52	2.81	4.62	76.5	78.21	78.33
First molasses.....	5786	39.59	3.94	9.93	39.0	41.98	43.82
	5788	42.86	3.98	7.78	38.2	41.14	42.79
	5791	31.57	6.71	13.82	48.4	49.79	43.92
Average......	......	38.01	4.88	10.51	41.9	44.30	43.51
Second masse cuite	5792	10.21	4.52	7.06	70.9	73.36	77.23
	5789	24.33	7.44	15.30	38.4	43.81	45.82
Second molasses...	5793	....	7.80	14.50	45.3	51.22	53.14
Averages	......	24.33	7.62	14.90	41.9	47.52	49.48

The second molasses from the fifth run of diffusion, on account of the crowded condition of the sugar-house, could not be kept separate from the mill products. It will be noticed that this molasses was still exceedingly rich in sucrose.

The apparent percentage of sucrose is as high as in the first molasses, but this is due to the much higher content of water in the latter product.

Nevertheless the sugar yield would still be very large to reduce the third molasses to the relative proportions of sucrose and glucose contained in the sample from the Calumet plantation, sent by W. J. Thompson, the analysis of which will follow.

In view of this exceeding richness it would seem that the estimated yield of third sugars from the run given in Bulletin 17, viz, 15 pounds per ton, is entirely too low. This yield would doubtless have been fully 30 pounds per ton.

While the chemical control of the diffusion experiments has proved reasonably satisfactory, yet there remain many points of interest which can only be determined by more extended investigations.

Among these may be mentioned the marked oxidizing power of the bone-black on diffusion juices. These juices on reaching the bone-char-filters were as nearly neutral as possible. On issuing from the filters they were intensely acid, and were again treated with lime before a second filtration. Diffusion juices have proved to be much more amenable to treatment for clarification than our first experiments with diffusion applied to sorghum indicated. A simple treatment of the juice with lime, careful skimming and subsequent precipitation of the sediment in settling tanks, appears to be all that is necessary to make a fine article of raw sugar, either with sorghum or sugar canes.

SUMMARY OF DATA FOR FOUR YEARS AT MAGNOLIA.

BY G. L. SPENCER.

The crop of 1887 was in many respects a remarkable one. In the early spring the cane was considerably larger than in average seasons. The stand was unusually good. Favorable rains and exceptionally good weather permitted a very thorough cultivation. The rows were well shaded before the 1st of July. All these favorable conditions united to make this crop the best in the history of the plantation. Magnolia seemed to be especially favored. When the fields above and on the opposite side of the river were too wet for cultivation those of Magnolia were in the best possible condition.

The following is a brief résumé of the growing seasons of the four years since the establishment of the Magnolia station:

Season of 1884.—The spring weather was favorable and continued so until the 1st of June, then followed a period of wet weather lasting until August, which was a very dry month. September and October were favorable to the ripening of the cane. During the rolling season there were frequent and heavy rains. The tonnage was good, and the quality of the cane excellent.

Season of 1885.—Exceptionally wet weather continued through the early part of this season. The rainfall from April to July was limited to two or three showers. There were frequent rains in August and September. The rest of the season was exceptionally cool and dry. A severe wind storm in September completely prostrated the cane. The wet weather in September and the wind storm damaged the cane very materially. The tonnage was large.

Season of 1886.—In January a freeze of remarkable severity threatened damage to the stubble. Small crops were predicted for the next season. The crop was small, but the shortage was not attributable to the results of the freeze.

February, March, and April were cold and wet; consequently the cane obtained a late start. May was dry and cool; June and July were too wet to permit of proper cultivation; August was dry and exceedingly hot. These adverse conditions all tended to stunt the cane. Although the start was good the tonnage was small. The juice was exceptionally rich and pure.

Season of 1887.—The cane obtained an early start. The weather was favorable throughout the season. The crop was but little damaged by the heavy wind storms in August and October. The tonnage was exceptionally large and the juice excelled in richness and purity.

It may be seen from the above résumé that two of the seasons were very favorable, one of these exceptionally so.

The following table of averages shows the quality of the juices for the four seasons:

Season.	1884.	1885.	1886.	1887.
Degree Brix	16.54	15.80	16.20	16.37
Per cent. sucrose	13.05	12.11	13.50	13.69
Per cent. glucose	.67	1.02	.61	.77
Co-efficient of purity	78.69	76.64	83.33	83.48

The quality of the cane in 1885 was exceptional. The proportion of glucose is considerably above the average for the four seasons. The percentage of sucrose is low. The analyses for this season show fully thirty pounds less available sugar present than those for 1887.

A comparison of the analyses of juices for the seasons of 1886 and 1887 shows that they were of almost exactly the same average quality, although in the latter season the tonnage was about twice that of 1886. Many planters considered it impossible to obtain a very large tonnage and at the same time a rich cane.

The yield and quality of the cane in 1887 indicate that a large cane does not necessarily carry a weak juice. On the contrary, some of the heaviest cane on Magnolia was the richest, containing about 15.5 per cent. sucrose in the juice. All this cane, including the heaviest, was quite ripe.

WORK AT MAGNOLIA PLANTATION.

Crop of 1887–'88.*

Tons of cane		13,344
Acres plant-cane		275
Acres first year's stubble		242
Acres second year's stubble		87
Total		604
Average tonnage per acre		22.09
Total weight, first sugar	pounds	1,659,120
Total weight, grained seconds	do	220,484
Total weight, wagon seconds	do	327,269
Total weight, third sugars	do	214,178
Total weight, all sugars	do	2,421,051

*Averages for entire crop, including diffusion work.

Average yield of sugar per ton of cane	pounds..	181.43
Per cent. of yield, sugars		9.072
Total gallons of molasses		58,350
Total pounds of molasses, at 11½ pounds per gallon		671,025
Per cent. of yield of molasses		2.514
Per cent. of yield of masse cuite (*i. e.*, sugar and molasses)		11.586
Pounds sugar per acre		4,008.3
Pounds molasses per acre		1,110

Magnolia Plantation.

Crop of 1887–'88.*—*Diffusion work.*

Tons of cane worked		913
First sugar	pounds..	121,964
Second sugar, grained	do....	31,764
Second sugar wagons	do....	15,935
Third sugar wagons		14,653
Total sugar		184,316
Average yield, first sugar, per ton	pounds..	133.58
Average yield, second sugar grained, per ton	do....	34.17
Average yield, second sugar wagons, per ton	do....	17.46
Average yield, third sugar wagons, per ton	do....	16.05
Total sugar per ton of cane		201.26
Per cent. of yield		10.063

Magnolia Plantation.

Crop 1887–'88.

	First period.	Second period.	Third period.	Fourth period.	Fifth period.	Sixth period.	Total.
Tons of cane rolled	494	2,261	2,244	2,260	806	3,966	12,431
Extraction, per cent.	78.60	79.02	79.01	78.46	79	79.30	78.94
Pounds 1st sugar per ton cane	101	*132.80	*139.94	*123.50	*122.70	*144.50	*138.83
Pounds 2d sugar per ton cane	34	8	36.36	29.60	40.50	41.60	25.05
Pounds 3d sugar per ton cane	16.05	16.05	16.05	16.05	16.05	16.05	16.05
Total sugar per ton cane, lbs.	151.05	156.85	192.35	169.15	179.25	202.15	179.93

* Includes grained seconds.

Magnolia Plantation.

Crop of 1887–'88.—*Mill work.*

Total tons of cane rolled		12,431
Pounds of juice		19,626,062
Extraction per cent cane		78.94
First sugar	Pounds..	1,537,156
Second sugar grained	do....	188,720
Second sugar wagon	do....	311,334
Third sugar wagon	do....	199,525
Total sugars	do....	2,236,735
Average first sugar per ton cane	do....	123.65
average second sugar grained per ton cane	do....	15.18
Average second sugar wagon per ton cane	do....	25.05

* Average of all the cane worked by diffusion.

Average third sugar wagon per ton cane	pounds..	16.05
Average total sugar per ton cane	do....	179.93
Per cent. of yield, sugars		8.996

SPECIAL ANALYTICAL WORK.

Several problems were presented during the progress of the work at Magnolia for solution. It is difficult to get time during the progress of manufacture to study such special problems; as much time, however, as I could take from the general supervision of the work was given to this special analysis.

COMPARISONS OF DIRECT AND INDIRECT POLARIZATION.

If sorghum and cane juices were composed alone of a solution of sucrose, the quantity of this substance could be determined at once by a direct polarization; unfortunately for the simplicity of chemical manipulation, such is not the case. These juices contain other substances which are optically active. In sorghum juices especially we find large quantities of substances present other than sucrose, which have the power to affect the polarized ray.

In cane juices the substances which tend to produce right-handed rotation are soluble starch, so-called, and its derivatives, dextrine and dextrose.

Of the substances tending to produce left-handed rotation at ordinary temperatures may be mentioned invert sugar and certain nitrogenous bodies.

Were these left-handed and right-handed bodies present in neutralizing proportions they would have no effect upon the polariscopic determinations of the sucrose, but such is not always the case; hence, a direct reading on the polariscope of sugar juices can not always be relied upon to give exact data concerning the proportion of sucrose present.

In the case of juices the variation may not be marked, but after concentration a direct polariscopic reading of the *masse cuite*, or molasses, may prove very erroneous.

To determine the magnitude of this variation in the juices of sirups and molasses from sugar cane, the following analyses were made.

In Table No. 50 are found data relating to clarified juices.

These samples were taken with the greatest care. The measurements were made in tared flasks, with a weighed quantity of the juice, and all of the analytical operations conducted with the greatest precautions. It will be seen by consulting the mean data of the table that the percentage of sucrose was increased from 14.49, the direct reading, to 14.67, the percentage given by the polariscope after inversion. The mean quantity of sucrose is increased by about one-third of the percentage of the reducing sugar present.

TABLE No. 50.—*Single and double polarization of mill juices, Magnolia.*

Number.	Single polarization sucrose.	Invert polarization.	Temperature.	Sucrose by double polarization.	Increase.	Glucose.
	Per cent.		° C.	*Per cent.*		*Per cent.*
1	14.7	— 4.84	24.0	14.90	0.20	....
2	12.75	— 4.39	23.0	12.92	0.17	....
3	15.53	— 4.75	25.5	15.46	— 0.07	.53
4	13.75	— 4.90	23.0	14.07	0.32	.40
5	13.02	— 4.43	21.5	13.09	0.07	.36
6	13.95	— 4.35	27.0	14.02	0.07	.47
7	16.45	— 5.23	29.0	16.74	0.29	.42
8	15.58	— 4.57	31.0	15.84	0.26	.53
9	16.23	— 4.98	31.25	16.52	0.29	.56
10	16.18	— 4.90	27.0	15.40	0.22	.57
11	14.80	— 4.68	28.0	14.99	0.19	.64
12	12.73	— 4.18	....	12.84	0.11	.56
13	13.65	— 4.95	....	13.93	....	....
Averages	14.49	....	....	14.67	.19	.50

In Table No. 51 is given the single and double polarization of sirups derived from the juices in Table No. 50.

The same precautions were taken in the selection of samples and in the analytical manipulation as in the preceding table.

The increase in the percentage of sugar on double polarization in the case of the sirups is equivalent to about one-half of the percentage of glucose present. It will be noticed in Table No. 50 that there are numerous examples of a like proportionate increase. In sample No. 3, in Table No. 50, there is an actual loss of sucrose, the second reading being .07 less than the first. This result was doubtless due to some error which all the precautions taken could not avoid.

TABLE No. 51.—*Single and double polarization of sirups from mill juices.*

Number.	Single polarization.	Double polarization.	Temperature.	Sucrose.	Increase.	Glucose.
2	*Per cent.*	°	° C.	*Per cent.*		*Per cent.*
4	44.04	— 17.49	26.0	45.07	1.03	....
5	45.25	— 16.23	23.0	46.40	1.15	1.39
6	41.50	— 15.43	19.0	42.27	0.77	1.19
7	43.00	— 14.28	26.5	43.81	0.81	1.44
8	46.88	— 14.58	28.5	47.37	0.49	1.28
9	45.53	— 14.74	29.5	46.63	1.10	1.63
10	42.15	— 13.28	31.25	43.19	1.04	1.51
11	44.85	— 14.80	26.5	45.62	0.77	1.76
12	42.85	— 13.31	27.0	43.04	0.19	1.92
	39.98	— 13.26	25.25	40.53	0.55	1.81
Averages	43.60	....	....	44.39	.79	1.55

In Table No. 52 are found the data of polarizations of various samples of molasses taken at different times during the season. Unfortunately, in only three cases was the percentage of glucose determined. In these cases the increase on double polarization is equal to almost half the percentage of glucose present. The mean increase, however, viz, 8.30 per cent., would probably not have been much greater than one-third of the mean percentage of glucose present in the molasses.

TABLE No. 52.—*Differences between single and double polarizations of molasses.*

Number.	Single polarization.	Polarization after inversion.	Temperature.	Sucrose.	Increase.	Glucose.
	Per cent. sucrose.		° C.	*Per cent.*		*Per cent.*
1	46.0	— 24.2	20.	52.4	6.4	....
2	45.5	— 23.1	20.	51.2	5.7	....
3	25.1	— 24.1	20.	36.7	11.6	25.25
4	45.8	— 20.4	23.5	51.6	5.8	....
5	28.2	— 23.7	22.5	39.04	10.84	....
6	27.1	— 23.54	21.0	37.9	10.8	23.90
7	36.9	— 23.32	22.0	45.3	8.4	16.60
8	38.0	— 22.33	24.0	45.7	7.7	....
9	35.7	— 21.78	21.0	43.1	7.5	....
Averages	36.48	....	....	44.77	8.30	....

Description of samples.—No. 1, sample of first molasses; No. 2, sample of first molasses; No. 3, sample of third molasses; No. 4, sample of first molasses; No. 5, sample of third molasses; No. 6, sample of third molasses; No. 7, sample of second molasses; No. 8, sample of second molasses; No. 9, sample of second molasses.

In Table No. 53 are found the analyses of some samples of molasses sent by Mr. W. J. Thompson, of Calumet plantation. In these samples we have again the remarkable illustration of the error into which the analyst would fall who would rely upon a single polarization alone. As a check upon the results the sucrose was determined also with an alkaline copper solution. The percentage obtained in this way agrees remarkably well with that got by double polarization.

In these cases the total increase is a little less than one-third of the amount of glucose present.

TABLE No. 53.—*Composition of third molasses.*

[Furnished by W. J. Thompson, Calumet plantation, Patterson, La.]

No.	Serial number.	Moisture.	Ash.	Sucrose direct.	Sucrose indirect.	Sucrose by copper.	Albuminoids.	Glucose.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	5918	25.09	7.55	15.85	25.34	26.00	1.97	29.20
2	5919	26.15	9.35	17.45	26.02	26.14	2.40	28.98
3	5920	25.30	7.84	17.15	25.92	26.19	2.49	30.07
4	5921	26.09	7.01	17.05	25.46	25.59	2.30	31.31

TABLE No. 53 (*bis*).—*Composition of third molasses, average sample from Magnolia plantation.*

No.	Moisture.	Ash.	Sucrose direct.	Sucrose indirect.	Sucrose by copper.	Albuminoids.	Glucose.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5958	30.37	9.54	20.73	27.65	27.78	1.92	21.12

Aside from the larger quantity of water in the third molasses from Magnolia, the chief difference between the Calumet and Magnolia samples is found in the smaller percentage of reducing sugar in the latter.

These results with the sugar-cane juices show that when single polarization alone is practiced the real percentage of sucrose can be approximately obtained by adding to the direct reading one-third of the percentage of glucose present.

The results also show the preponderance of lævo-gyratory impurities in cane juices.

The left-handed disturbance, however, is greater than would be expected from the amount of invert sugar present.

We would, therefore, conclude that the albuminous matters present are also active, or that in the reducing sugar naturally contained in the juice there is a preponderance of lævulose.

In sorghum juices I have shown in a previous publication that the differences between direct and double polarization are not so great. This is due to the fact that in sorghum there is a large portion of so-called soluble starch and dextro-gyratory bodies.

STUDY OF INVERSION IN THE YARYAN QUADRUPLE EFFECT.

To determine the invertive effect of concentrating the juices in the Yaryan quadruple effect pan, a series of careful analyses of entering juices and issuing sirups was made. The samples were taken in the following way, viz: From the feed-box of the Yaryan apparatus a measured sample of the juices was taken every two minutes for thirty minutes; four minutes after taking the first sample of juice and every two minutes thereafter for thirty minutes a measured sample of the issuing sirup was taken. After mixing the samples of juice and sirup were subjected to analysis. It will be seen that by the above method the samples of juice and of sirup were strictly comparable. In each case the sample for analysis was weighed out and made up to a standard volume in a tared flask. The analytical manipulations were conducted with every possible precaution.

The results of the work are given in Tables Nos. 54 and 55.

TABLE NO. 54.—*Test for inversion in Yaryan pan.—Clarified juice.*

No.	Date.	Total solids.	Purity on direct polarization.	Purity on indirect polarization.	Sucrose direct polarization.	Sucrose indirect polarization.	Reducing sugars.	Reducing sugars to 100 of sucrose direct polarization.	Reducing sugars to 100 sucrose indirect polarization
	1887-'88	*Per cent.*			*Per cent.*	*Per cent.*	*Per cent.*		
1	Dec. 28	15.93	86.32	88.32	13.75	14.07	.40	2.91	2.84
2	Dec. 28	14.53	89.61	90.09	13.02	13.09	.36	2.75	2.75
3	Jan. 4	15.88	87.85	88.29	13.95	14.02	.47	3.47	3.35
4	Jan. 5	17.88	92.00	93.62	16.45	16.74	.42	2.55	2.51
5	Jan. 6	17.17	90.73	92.26	15.58	15.84	.53	3.40	3.36
6	Jan. 7	17.93	90.52	92.14	16.23	16.52	.56	3.46	3.39
7	Jan. 8	16.71	90.85	91.56	15.18	15.40	.57	3.75	3.70
8	Jan. 9	16.78	88.20	89.33	14.80	14.09	.64	4.33	4.27
9	Jan. 10	14.18	89.77	90.55	12.73	12.84	.56	4.41	4.37
Averages.		16.33	89.54	90.68	14.63	14.83	.50	3.45	3.39

TABLE No. 55.—*Sirups.*

[Dates and numbers correspond to comparative samples in above table.]

1	Dec. 28	51.23	88.33	90.60	45.25	46.40	1.39	3.07	3.00
2	Dec. 28	46.70	88.87	90.51	41.50	42.27	1.19	2.87	2.82
3	Jan. 4	49.02	87.72	89.35	43.00	43.81	1.44	3.35	3.28
4	Jan. 5	50.54	92.76	93.73	46.88	47.37	1.28	2.73	2.70
5	Jan. 6	51.16	88.99	91.14	45.53	46.63	1.63	3.59	3.50
6	Jan. 7	47.60	88.55	90.74	42.15	43.19	1.51	3.57	3.50
7	Jan. 8	....	....	....	44.85	45.62	1.76	3.92	3.86
8	Jan. 9	48.83	87.76	88.15	42.85	43.04	1.92	4.48	4.46
9	Jan. 10	45.22	88.41	89.63	39.98	40.53	1.81	4.53	4.47
Averages.		48.79	88.92	90.48	43.55	44.32	1.55	3.57	3.51

Any inversion which would take place in the process of concentration would be indicated by an increase in the ratio of reducing sugar and sucrose.

In the entering juices the mean ratios are as follows, viz:

By direct polarization, 3.45 parts reducing sugar to 100 of sucrose.

By double polarization, 3.39 parts reducing sugar to 100 of sucrose.

For the issuing sirups the ratios are as follows:

By direct polarization, 3.57 parts reducing sugar to 100 of sucrose.

By double polarization, 3.51 parts reducing sugar to 100 of sucrose.

It will be seen by the above numbers that the inverting effect of the Yaryan pan is practically nothing. It amounts to only one-tenth of a pound to 100 pounds of sugar made or 2 pounds to the ton of sugar.

ANALYSES OF BAGASSE.

Sixteen determinations were made at various times during the season of the quantity of water and sugar in the bagasse. The samples were taken as follows: From time to time during fifteen to twenty minutes a handful of the bagasse issuing from the mill was taken and placed in a covered vessel. These samples were then thoroughly mixed together and a portion taken for analysis. Small quantities of bagasse were taken from the selected portion and cut into very fine chips. Weighed portions of these chips were then dried at 105° C., and weighed for the determination of moisture.

For the determination of sucrose, weighed portions of the bagasse were extracted in a marked stoppered bottle for two hours at the temperature of boiling water. After cooling, the contents of the bottle were poured in a mortar and thoroughly rubbed up with a pestle. The sucrose was determined in a filtered portion of the liquid, due allowance being made for the volume occupied by the fiber of the cane. The results of the analyses are given in Table No. 56.

TABLE No. 56.—*Composition of bagasse.*

No.	Date.	Water.	Sucrose.	No.	Date.	Water.	Sucrose.
	1888.	*Per cent.*	*Per cent.*		1888.	*Per cent.*	*Per cent.*
1	Jan. 4	52.60	8.58	10	Jan. 8	54.99	7.50
2	Jan. 4	52.87	7.59	11	Jan. 9	55.08	7.95
3	Jan. 5	52.99	8.10	12	Jan. 9	54.69	7.65
4	Jan. 5	53.89	8.19	13	Jan. 10	53.59	7.44
5	Jan. 6	52.51	7.73	14	Jan. 10	55.88	6.88
6	Jan. 6	51.69	8.00	15	Jan. 11	56.71	7.74
7	Jan. 7	53.12	8.07	16	Jan. 11	56.78	7.95
8	Jan. 7	52.68	7.95				
9	Jan. 8	53.97	7.35	Averages......		54.00	7.79

It will be seen that the mean percentage of the water in the bagasse was 54 and the sucrose 7.79. It appears from the above analyses that the bagasse contains water other than that in the sugar juice of the cane. This fact is also shown by the following phenomenon.

If a sugar-cane be passed through a small mill, the top entering the mill first, drops of water will be seen to issue from the butt of the cane as it approaches the rolls; if this water be tasted it will be found to be free from sugar. It appears, then, from the analyses of the bagasse and the phenomenon just related that the sap in the circulatory organs of the cane is entirely different from the sugar juices stored in its cells.

ESTIMATION OF TOTAL SOLIDS BY HYDROMETERS AND BY ACTUAL WEIGHT.

Attention has already been called in this bulletin to the error which may arise from estimating the total solids in sugar juices and sirups from the specific gravity as determined by a hydrometer.

In Table No. 57 is given a comparison of the results obtained in estimating the total solids in cane juices by careful drying in a flat dish partly filled with sand. The method of procedure was as follows:

A flat platinum dish was filled about two-thirds full of pure dry sand and weighed; from a weighing bottle about 2 grams of the cane juice was placed on the sand, and the exact amount taken obtained by reweighing the weighing bottle.

The dish was now dried at 100° until the moisture was nearly all driven off, and then for a half an hour at 105°. In each case the amount of total solids as given by the Brix saccharometer was greater than that obtained by actual drying. The mean increase was .56 per cent.

TABLE 57.—*Comparison of total solids by spindle and drying on sand.*

JUICES.

No.	Date.	By drying.	By spindle.	Increase.	No.	Date.	By drying.	By spindle.	Increase.
	1888.	*Per ct.*	*Per cent.*			1888.	*Per ct.*	*Per cent.*	
1	Jan. 4	15.68	16.07	.39	8	Jan. 8	16.76	17.23	.47
2	Jan. 5	17.87	18.64	.77	9	Jan. 9	16.53	17.17	.64
3	Jan. 6	16.81	16.93	.12	10	Jan. 9	16.75	17.30	.53
4	Jan. 6	17.17	17.80	.63	11	Jan. 10	15.87	16.66	.79
5	Jan. 7	16.57	16.96	.39	12	Jan. 10	14.18	14.85	.67
6	Jan. 7	17.93	18.54	.61					
7	Jan. 8	16.71	17.46	.75		Av'ges	16.57	17.13	.56

TABLE 58.—*Sirups.*

1	Jan. 4	48.54	49.02	.48
2	Jan. 5	50.54	52.72	2.18
3	Jan. 6	50.85	51.82	.97
4	Jan. 7	47.60	48.64	1.04
5	Jan. 9	48.83	50.22	1.39
6	Jan.10	45.22	46.76	1.54
	Av'age.	48.60	49.86	1.27

In Table 58 the same comparison is made with sirups. In order that the sirups might not occlude moisture a less quantity was taken than of the juices, so that the total solid residue might be the same. The mean increase in the case of sirups as determined by the Brix spindle was 1.27 per cent. With sugars and molasses enough alcohol must be added to the dish containing the sand and samples to dissolve the latter thoroughly and distribute them evenly through all parts of the sand. Not being quite satisfied with the result obtained by the method given above, I tried the device of using paper coils for the absorption of the juices whose total solids were to be determined.

The manipulation was as follows: A piece of thick filtering paper 40 centimeters in length and 5 to 8 centimeters wide was rolled into a coil and tried at 105°. While still hot it was placed in a dried weighing tube and carfully stoppered. When cold it was weighed together with the tube.

About 2.5 grams of the juice is now placed in a small beaker covered with a watch glass and weighed. One end of the coil is dipped into the beaker and held there until the juice is absorbed. By means of the dry end, the coil is transferred to the air bath, placed in an upright position with the wet end up and dried for two hours at 100°. While still hot it is again placed in the weighing tube, and, when cold, weighed.

By reweighing the beaker and the cover the weight of juice taken is accurately determined. The increase of weight of the coil gives the total quantity of solid matter present in the weight of juice taken. This method was introduced so late in the season that only a few trials of it were made, but they were eminently satisfactory. The results are given in Table No. 59:

TABLE NO. 59—*Total solids by drying on paper coils.*

MILL JUICES.

No.	Date.	Total solids.	Total solids by spindle.	Total solids by sand.
	1883.	*Per cent.*	*Per cent.*	*Per cent.*
1	Jan. 11	16.22	16.53	16.05
2	Jan. 12	15.80	16.70	16.16
3	Jan. 13	15.94	16.87	....
4	Jan. 17	15.42	16.07	....
Averages	....	15.85	16.54	....

TABLE NO. 59—*Total solids by drying on paper coils*—Continued.

DIFFUSION JUICES.

1	Jan. 16	10.10	11.37	....
2	Jan. 17	9.80	10.67	....
3	Jan. 17	9.57	10.47	....
Averages	....	9.82	10.84	....

As in the case of drying in sand, the amount of solid matter found in juice is uniformly less than was indicated from the reading of the spindle.

EFFECT OF TREATMENT OF MOLASSES WITH SUPERPHOSPHATE OF LIME AND ALUMINA.

It is the custom in the sugar-houses of Louisiana to dilute the molasses and treat it with superphosph ate of lime and alumina, or other chemicals, before reboiling it for sugar. To determine the effect which this treatment had upon the molasses, the analyses which are recorded in Table No. 60 were made.

TABLE NO. 60.—*Treatment of molasses with superphospnate of lime and alumina.*

MOLASSES BEFORE TREATMENT.

No.	Total solids.	Purity, direct polarization.	Purity, indirect polarization.	Sucrose, direct polarization.	Sucrose, indirect polarization.	Glucose.	Glucose per 100 sucrose.	Glucose per 100 sucrose, indirect.
	Pr. ct.			*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	65.59	71.30	77.50	46.75	50.80	6.33	13.55	12.47
2	61.72	71.29	76.17	44.00	47.01	5.71	12.96	12.16

MOLASSES AFTER TREATMENT.

1	63.86	72.70	76.80	46.30	48.91	6.17	13.33	12.64
2	60.45	72.01	75.89	43.53	45.88	5.43	12.43	11.84

REMOVED SKIMMINGS.

1	67.03	77.20	78.90	51.70	52.90	6.71	12.97	12.68
2	64.69	75.36	79.15	48.75	51.20	6.17	12.65	12.03

The table is divided into three parts, the first being the analysis of the molasses before treatment; second, analysis after treatment; and third, the analysis of the removed skimmings.

In the three cases the numbers refer to the same sample. It is quite difficult to secure the same density in each case, and comparison should be made with the ratio of the reducing sugar to the sucrose. From this it is seen that the skimmings, which were removed and which were supposed to be gum, were nothing but air-bubbles, surrounded with a film of molasses. It is difficult to see any beneficial result attending the treatment in question.

EFFECT OF DIFFERENT METHODS OF CLARIFICATION.

In order to determine the amount of organic matter removed by different methods of clarification the following experiments were made: Weighed samples of mill juice were treated with subacetate of lead until no further precipitation took place. The precipitate was then thoroughly washed with hot water until all excess of lead was removed and then dried.

Similar treatment was given to the same juice after clarification by lime in the usual way, after filtration through lignite, and after single carbonatation. The results are recorded in Table No. 61.

TABLE No. 61.—*Effects of different methods of clarification.*

	Raw.	Clarified.	Lignite.	Carbonated.
Weight of lead precipitate:				
December 20, 1887, grammes	2.1919	1.9452	1.7685	1.2725
December 21, 1887	2.2964	2.1515	2.1930	1.7058
Per cent of lead:				
December 20, 1887	62.08	52.43	69.53	71.68
December 21, 1887	66.01	69.31	71.68	71.52
Sucrose, per cent:				
December 20, 1887	13.08	13.45	15.12	13.99
December 21, 1887	13.78	14.01	15.02	14.74
Albuminoids, per cent:				
December 20, 1887	.07	.07	.03	.06
December 21, 1887	.11	.07	.03	.05
Purity:				
December 20, 1887	81.75	82.50	84.38	85.67
December 21, 1887	85.34	86.32	84.71	88.58

It is seen that the weight of the dried precipitate is in every case greatest in the raw juice and least in that which had been subjected to single carbonatation. The purity of the juice was increased least by ordinary clarification, next by filtration through lignite, and most of all by carbonatation.

In regard to the removal of albumen, filtration through lignite appears to be the most efficacious method.

Carbonic dioxide gas in gases from lime-kiln and bagasse chimney.

The quantity of carbonic acid in the gases from the lime-kiln and bagasse chimney is given in Table No. 60.

The object of determining the percentage of CO_2 in the bagasse smoke was to see if it could be used in the process of carbonitation. Since, with cane juices, this process requires so little lime it seems probable that the gases from the Bagasse chimney can be used for this purpose.

TABLE No. 60.—*Carbonic acid gas from furnace.*

Date.	Hour.	Number.	CO_2.
			Per cent.
November 27	11 a. m.	1	12.5
Do	12 m.	2	13.88
Do	1 p. m.	3	15.89
Do	3 p. m.	4	18.54
Do	5 p. m.	5	21.47
Do	8 p. m.	6	23.93
November 28	9 a. m.	7	21.60
Do	4 p. m.	8	20.80
Do	9 p. m.	9	20.54
November 29	6 a. m.	10	12.33
Do	3 p. m.	11	12.39
Do	9 p. m.	12	10.02
November 30	7 a. m.	13	15.61
December 1	10 a. m.	14	22.04
Do	5 p. m.	15	28.60
December 3	9 a. m.	19	11.25
December 9	4 p. m.	20	25.92
December 10	5 a. m.	21	33.50
Do	10 a. m.	22	25.42
December 11	2 a. m.	23	29.89
Do	11 a. m.	24	17.88

Carbonic acid gas from Bagasse chimney.

December 2	9 a. m.	16	11.44
Do	11 a. m.	17	11.15
Do	3 p. m.	18	8.8

DATA RELATING TO SORGHUM AS A SUGAR-PRODUCING PLANT.

The problem of the possible profitable production of sugar from sorghum has occupied the attention of chemists, agronomists, and manufacturers for many years.

I will not insist here on the immense advantages which would accrue to American agriculture by the development of an indigenous sugar industry. There is no true friend of our farming interests who does not wish our sugar to be produced at home, and if sorghum can help to the consummation of such a wish we ought to know it.

A full discussion of these aspects of the subject can be found in my presidential address before the Washington Chemical Society, delivered on the 9th of December, 1886.[1]

It seems to me that we have now reached a point in the study of the problem of the production of sugar from sorghum where it is possible, by a careful review of the ground already passed over, to secure an accurate notion of the progress which has been made.

It is to this task that I have devoted the present study. For convenience the study of the problems may be divided into three parts, viz: (1) Chemical, (2) experimental, (3) practical.

CHEMICAL.

The amount of analytical work which has been done on sorghum in this country is enormous. At most I can give only a summary of the recorded results.

This analytical work may be best studied by dividing it into two groups, namely: (*a*) Work done by the Department of Agriculture and (*b*) other work.

(*a*) WORK DONE BY THE DEPARTMENT OF AGRICULTURE.

The first analyses of sorghum canes by the Department of Agriculture were made by Dr. C. M. Wetherill in 1862.

[1] Second Ann. Bulletin Washington Chemical Society, pp. 11 *et seq.*

A mean of seventeen analyses of imphee and sorghum showed the following results:[1]

	Sorghum.	Imphee.	
		First mean.	Second mean.
	Per cent.	*Per ct.*	*Per ct.*
Sucrose	4.29	4.13	6.19
Glucose	6.08	7.00	3.65
Total sugars	10.37	11.13	9.84

Dr. Wetherill also gives a table of mean results obtained by others (p. 533), and adds the following observations:

It follows, from the experiments thus quoted and reported, that the largest proportion of cane sugar to uncrystallizable sugar is afforded by the juice analyzed by Lawrence Smith, to wit, as 10 to 2. My average results fall far below this; yet if the analyses of my best canes are taken, their juice will compare favorably with that of the analysis of Smith. For example, by the analyses numbered 8, 10, 11, for every 10 parts of cane sugar found we have, respectively, 2.1, 1.8, and 1.8 per cent. of uncrystallizable sugar. It is remarkable that in analyses 10 and 11 the juices differing so much in actual saccharine richness should contain the same relative proportion of cane sugar to uncrystallizable sugar. When my mean results are compared with the results afforded by the practical experiment of Mr. Lovering, who grew the sorghum, analyzed its juice, and converted the same into cane sugar and molasses, it appears that my mean of sorghum analyses gives very nearly the same proportion of cane sugar to uncrystallizable sugar, and that my imphee mean gives a larger proportion of cane sugar. I think that my analyses and their means will give a moderately accurate reflection of the present state of the sorghum and imphee culture in our country.

There are, doubtless, finer canes grown than I have examined, and richer both in sirup-making quality and in the proportion of cane sugar present; but the analyses probably represent the present condition of the cane as planted.

Henri Erni[2] reports one analysis of sorghum. It gave:

	Per cent.
Sucrose	10.31
Glucose	2.07

He adds:

Contrary to my expectations, I found that the expressed sorgho juice of ripe cane whether neutralized by lime or not, refused to crystallize, for what solidified or granulated after long standing of the sirup was grape-sugar. This fact has been established by the largest and most skillful farmers and experimenters, and admitted at the western sorghum conventions. The result might be ascribed to the total inversion previously of the cane-sugar by the influence of acid, or of a ferment, but this is not the case, as I have repeatedly been able to prove. The following extreme case may suffice for illustration of this fact: In the sugar determination which is here given, cane-sugar was found, and yet the most persistent efforts failed to produce a single crystal in the concentrated liquid.

[1] Department of Agriculture, report 1862, pp. 514 *et seq.*
[2] Agricultural Report 1865, p. 48.

Dr. Thomas Antisell[1] reports analyses of frozen and fresh canes. The juice from frozen canes had the following composition:

	Per cent.
Sucrose	11.10
Glucose	8.90

The juice of the fresh canes had the following composition:

		Per cent.
No. 1.	Sucrose	7.86
	Glucose	4.38
No. 2.	Sucrose	5.94
	Glucose	3.60

Dr. Antisell adds the following observations:

Contrasting the amount of sugar in the fresh and dry cane, the latter greatly preponderates; and were the question only on the amount of sugar to be obtained, the decision would be in favor of working on the partially dried canes; but on observing the ratio of glucose and cane sugar in the fresh juice and that expressed later, it will be remarked that the relative amount of glucose is much higher, so that the sugar appears to be gradually passing into glucose the longer it remains in the cane, showing that the fermenting causes are as active within the stem of the drying cane as after the juice has been expressed and exposed to the air. Several attempts were made in the laboratory to granulate the sugar of this juice; but whether neutralized and defecated or not, the invariable result was the disappearance of cane sugar, and a uniform sirup of uncrystallizable sugar. Thus far, then, laboratory examinations indicate the necessity of evaporating the juice of the recently cut canes, if it is desired to obtain any crystallizable sugar.

In 1878 Dr. Collier began his extensive studies of sorghum. Dr. Collier gave the following result of the analyses made by the Department of Agriculture in 1879[2]:

Early amber, from August 13 to October 29, inclusive, fifteen analyses, extending over seventy-eight days, 14.6 per cent. sucrose.

White Liberian, from August 13 to October 29, inclusive, thirteen analyses, extending over seventy-eight days, 13.8 per cent. sucrose.

Liberian, from September 13 to October 29, inclusive, seven analyses, extending over forty-six days, 13.8 per cent. sucrose.

Honduras, from October 14 to October 29, inclusive, three analyses, extending over sixteen days, 14.6 per cent. sucrose.

In 1880 these analyses were continued in large numbers on samples of cane grown in the Department grounds and on others sent in from various localities. The details of these analyses are to be found in the Annual Report of the Department of Agriculture for 1880, pp. 37 *et seq.*

The canes, according to development, were divided into nineteen classes. With the seventh stage, the seed is just entering the milky state. Since a large part of the seed will still be in this state, when the

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[1] Department of Agriculture, report, 1866, p. 48.

[2] Sorghum., p. 186.

manufacture is to be carried on on a large scale, I give the means of the analyses of the different varieties from that stage on[1]:

Stages.	Glucose.	Sucrose.	Available sucrose.	Number juices analyzed.
	Per cent.	*Per cent.*	*Per cent.*	
7	3.86	7.38	4.06*	70
8	3.83	7.69	4.26	111
9	3.19	8.95	5.50	266
10	2.60	9.98	6.60	217
11	2.35	10.66	7.22	166
12	2.07	11.18	7 77	170
13	2.03	11.40	8.00	183
14	1.88	11.76	8.33	191
15	1.81	11.69	8.21	217
16	1.64	12.40	8.86	359
17	1.56	12.72	9.73	197
18	1.85	11.92	8.27	191
19	3.09	12.08	7.82	30
Mean	2.44	10.83	7.28	181

* The method of determining available sugar does not clearly appear.

These analyses were continued in great detail during the following years, 1881 and 1882, and the results are found in the reports of the Department.[2]

The averages for the whole number of samples for each stage after the sixth is given below.[3]

Stages.	Glucose.	Sucrose.	Available sucrose.
	Per cent.	*Per cent.*	*Per cent.*
7	3.69	6.08	0.00
8	3.70	7.47	1.14
9	3.30	8.76	2.86
10	2.96	10.00	4.14
11	2.74	12.01	6.34
12	2.47	13.06	7.61
13	2.21	13.98	8.87
14	2.22	14.34	9.24
15	1.84	15.99	11.14
16	1.72	15.94	11.02
17	1.83	16.61	11.77
18	1.75	15.23	9.83
After 18th	1.73	11.89	6.33
Mean	2.47	12.41	6.95

The effect of frost on the character of the juice was also investigated.[4] The frost produced a loss of sucrose amounting to 15.5 per cent., and a gain of glucose, 29.1 per cent.

Dr. Collier makes the following observations on the results of the analyses:[5]

GENERAL RESULTS OF ANALYSES BEARING UPON THE QUESTION OF AVAILABLE SUGAR.

By reference to the table giving the general results of all the analyses of the several varieties of sorghum in 1879, 1880, and 1881, the aggregate number of analyses being

[1] Department of Agriculture, Report 1880, pp. 110, 111.

[2] Department of Agriculture, Report 1881–1882, p. 370 *et seq.*, and Investigations of Sorghum as a Sugar-Producing Plant, special report, 1883.

[3] Department of Agriculture, Report 1881 and 1882, pp. 438 *et seq.*

[4] Department of Agriculture, Report 1881 and 1882, p. 460.

[5] *Op. cit.*, p. 462.

4,042, and the varieties analyzed being about forty, these results having been obtained from as many distinct varieties by so large a number of separate analyses made in successive years, the general conclusion reached appears established beyond question.

It will be seen that during the early stages of development of these plants, up to and including the sixth stage, the available sugar is given as a minus quantity, *i. e.*, the amount of sucrose in the juice is less than the sum of the glucose and other solids. It will also be seen that in the seventh stage the available sugar is practically none, being only .13 per cent., and this stage represents the period when the seed is in the milky stage. It is then obviously absurd to expect to obtain any sugar by working up the crop until it has advanced beyond this condition toward maturity.

It will also be observed in the table that during these early stages the amount of this minus available sugar remains nearly the same, the average for the first five stages being 3.22 per cent., and also that the available sugar after it first appears rapidly increases in quantity, and remains practically constant through the several subsequent stages; and in this it agrees, as will be seen, with the development of the sucrose, which at a certain period is very rapid, and afterward nearly constant through the season, while, as has been remarked, the sum of the glucose and solids is nearly the same throughout.

EFFECT OF SUCKERS ON COMPOSITION OF JUICE.

The injurious effect of suckers on the juice is shown by the following average analyses of thirty-four varieties.[1]

	Suckered.	Unsuckered.	Ratio.
	Pr. ct.	*Per cent.*	*Per cent.*
Sucrose	13.17	10.55	100: 80.1
Glucose	2.14	2.95	100:137.9
Solids	3.10	3.58	100:115.5
Available sugar	8.08	4.49	100: 55.6

ANALYSES OF JUICES FROM SMALL MILLS.[3]

These analyses were made from September 12 to October 22, 1881. The canes were taken from the experimental plots in the Department grounds and from some other localities in the vicinity of Washington.

The mean results are as follows:

	Per cent.
Sucrose	9.89
Glucose	3.85
Available sugar	3.09

ANALYSES OF JUICES FROM LARGE MILL.[3]

The analyses were made from September 27 to October 27, 1881. The total quantity of cane ground was 229 tons 444 pounds.

The mean composition of the juice for this entire season was as follows:

	Per cent.
Sucrose	6.94
Glucose	6.38
Not sugars	1.90

[1] *Op. cit.*, p. 465.

[2] Department of Agriculture, Report 1881 and 1882, pp. 178 *et seq.*

[3] Department of Agriculture Report, 1881 and 1882, pp. 506, 507.

In respect of the character of the cane, Dr. Collier makes the following reports:[1]

THE WORK OF THE LARGE SUGAR MILL.

Mention has already been made of the several plots of sorghum of different varieties upon the lands of Mr. Patterson, Mr. Golden, and Dr. Dean, which were intended for working upon a scale of sufficient magnitude to afford a practical demonstration of the economical production of sugar upon a commercial scale.

Owing to the backward spring and the ravages of wire and cut worms, two successive plantings of seed almost entirely failed, and it was only after thoroughly coating the seed with coal-tar that a final stand of cane was secured. This third planting was concluded June 18, fully seven weeks after the planting of the plot upon the Department grounds, the examination and working of which has already been discussed in the preceding pages. To any one who has carefully perused this report thus far, or either of the reports of the preceding years, giving the results of our examination of sorghum, it is entirely useless to say that this delay was fatal to success in the production of sugar, and that failure was inevitable unless all our previous experience was to be falsified.

The failure of the crop to mature, as had been confidently predicted during the summer, was fully realized, and at last, with the assurance that the frosts would soon render the crop unfit even for sirup, owing to its immature state, it was resolved to begin work, since, with the limited capacity of the mill, it would require at least two months to work up the entire crop of 135 acres. Accordingly the work of cutting the cane began September 19, and grinding began September 26, and was continued without any serious interruption until October 28. At this time the cane still remaining upon the field, through the effect of frosts and succeeding warm weather, had become worthless, and the cane from only 93½ acres in all was brought to the mill, the last portions of which had already become sour and offensive.

ANALYSES IN 1882.[2]

Beginning with the stage when the seed was in the milk, I give below the mean results of Dr. Collier's analyses of many different varieties of sorghum in 1882:

	Glucose.	Sucrose.	Available sugar.
	Per cent.	*Per cent.*	*Per cent.*
Seed in milk..........	2.90	8.45	3.20
Seed in dough	2.171	9.88	5.054
Seed hard..............	1.33	10.48	6.233
Sucker seed in milk ...	1.203	11.448	7.426
Sucker seed in dough..	1.12	12.25	8.19
Sucker seed hard......	1.45	12.63	8.56

[1] *Op. cit.*, p. 504.

[2] Sorghum as a Sugar-producing Plant, by Peter Collier, Special Report, 1883, p. 17.

COMPOSITION OF JUICE IN BLADES AND STALKS.

Numerous analyses were made[1] to determine the relative composition of stalk and leaf juice. This comparison will be sufficiently indicated by some of the analyses quoted below:

	Stalks.			Leaves.		
No.	Sucrose.	Glucose.	Not sugar.	Sucrose.	Glucose.	Not sugar.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	10.29	3.21	1.84	2.84	1.66	7.82
2	14.64	1.87	1.54	2.15	1.52	9.21
3	11.79	1.15	3.03	4.23	2.25	6.76
4	13.31	.93	3.28	2.23	2.50	7.71

Dr. Collier adds the following observation:[2]

It is to be observed that in no case was there any available sugar in the juice from the leaves, owing not to the excess of glucose, but to the much larger percentage of solids not sugars in the leaf juice.

FURTHER ANALYSES OF FROSTED CANES.[3]

	Per cent.
Analyses before frost, November 3, 1882.—Means:	
Sucrose	12.44
Glucose	1.23
Not sugar	2.68
Available sugar	8.62
Juice extracted	58.19
Analyses after thirteen frosts, December 8.—Means:	
Sucrose	14.35
Glucose	2.85
Not sugar	2.98
Juice extracted	39.17
Loss of juice	32.69
Gain in sucrose	15.35
Gain in glucose	131.71
Loss in available sugar	1.16

ANALYSES DURING THE YEAR 1883.

Numerous analyses were made by the Division of Chemistry of the Department of Agriculture during the season of 1883, under my super vision.

Considering that it had been sufficiently well established by the researches of Dr. Collier, that small plats of cane under careful culture and proper fertilization afforded an extremely rich saccharine plant, I directed attention chiefly to the character of the juice as a whole. The analyses represent the average composition of the juice from 746,350 pounds of cane.[1]

[1] *Op. cit.*, pp. 29-30.
[2] *Op. cit.*, p. 30.
[3] *Op. cit.*, p. 34.
[4] Bull. No. 3, pp. 43 and 47.

Means:

	Per cent.
Sucrose	8.38
Glucose	4.09
Total solids	14.06

The part of the cane ground from September 29 to October 4 was of an exceptionally poor quality. Its analysis is given separately.[1]

	Per cent.
Sucrose	6.73
Glucose	6.16
Purity co-efficient	50.00

A separate study of the mill juices was also made from October 16 to November 21.[2]

Following are the means of these analyses:

	Per cent.
Sucrose	9.04
Glucose	4.08
Total solids	14.81

Analyses of diffusion juices obtained from the same lot of cane and at the same time showed the following composition:[3]

	Per cent.
Sucrose	4.95
Glucose	2.42
Total solids	8.02

Analyses were also made of canes grown in Indiana.

The canes were cut and prepared as follows:[4]

These canes were cut, the leaves and tops left undisturbed, the cut surface covered with melted wax, and the whole wrapped carefully in paper and sent by express to the laboratory here for analysis.

Nos. 1 and 2 were cut in the afternoon of October 1 and analyzed October 4, having been three days on the road.

No. 1 was a sample of eight selected canes. No. 2 was a sample of sixteen canes taken seriatim from an average row, and represents the cane as a whole. It seems to have deteriorated very little in transit, and the analyses of the sirup go to show that the average of the whole patch was about a mean of the results of Nos. 1 and 2. No. 3 was cut at 4 p. m. October 1 and analyzed October 6, at 9 a. m., an interval of four days and seventeen hours.

Following are the results of the analyses:[5]

Indiana canes and sirups.

No.		Sucrose.	Other sugars.
		Per cent.	*Per cent.*
1	Sample of eight selected canes	13.25	2.30
2	Sample of sixteen average canes	10.73	3.71
3	Cane cut October 1	8.54	5.99

[1] *Op. cit.*, p. 43.
[2] Bull. No. 2, p. 32.
[3] *Op. cit.*, p. 31.
[4] Bull. No. 3, p. 52.
[5] *Op. cit.*, p. 53.

Analyses were also made of canes from the Rio Grande plantation, New Jersey. These canes were prepared for shipment in the manner just described.

Analyses of juice from eight volunteer canes, ripe and in first-class condition:

	Per cent.
Sucrose	10.68
Glucose	3.25
Not sugar	2.48
Total solids	15.36

Analyses of six canes from field fertilized with salt muck:

	Per cent.
Sucrose	12.78
Glucose	1.77
Not sugar	3.23
Total solids	17.78

Analyses of twenty-five canes taken from carrier representing fairly well the canes ground on September 22, 1883:

	Per cent.
Sucrose	9.32
Glucose	4.99
Not sugar	0.96
Total solids	15.27

In 1884 some small plats of sorghum were grown on the Department grounds. These varieties were Early Amber, Early Orange, Link's Hybrid, and Honduras. These plats had a dressing of well decomposed stable manure and an application of superphosphate equal to 400 pounds per acre.

Following is a description of the method of preparing the canes for analysis: [1]

The seed-heads, as they appeared, were cut off of a large number of canes at intervals along the row. A like number of canes was left to mature in the usual way. To protect the forming seeds of these against the depredations of the English sparrows they were covered with a cap of tarlatan; but in spite of this precaution the seeds did not mature. The hungry birds would hang upon the netting and gradually pick them off. To this extent the object of the trial was defeated; but the results show that the removal of the seed, either before or after flowering, does apparently increase the percentage of sucrose in the juice. This is shown from the fact that the percentage of sucrose in canes deprived by the birds of their seed is much greater in the juices analyzed in 1884 than in those of 1883, when the seed matured. On the other hand, it does not appear that the removal of the panicle immediately on its appearance tends to give a materially greater percentage of sucrose than is obtained by allowing the birds to remove the seeds after they have begun to form.

In Table 1 are given the results of the analyses of canes whose panicles were cut as soon as they could be seen. These canes were stripped and pressed in a small mill. The percentage of juice expressed was noted. The bagasse was now passed a second time through the mill, and the percentage of second juice calculated on the first weight of the cane.

[1] Bulletin No. 5, Division of Chemistry, Department of Agriculture, pp. 139, 140.

Means of analyses of canes whose seed-heads had been removed.[1]

	Per cent.
First juices:	
Sucrose	14.90
Glucose	1.32
Not sugar	3.71
Total solids	19.90
Purity co-efficient	74.80
Second juices:[2]	
Sucrose	14.83
Glucose	1.25
Not sugar	4.99
Total solids	20.96
Purity co-efficient	70.50

Analyses of canes whose seeds were allowed to ripen.[3]

	Per cent.
First juices:	
Sucrose	14.72
Glucose	1.22
Not sugar	3.58
Total solids	19.59
Purity co-efficient	74.93
Second juices:[4]	
Sucrose	14.60
Glucose	1.18
Not sugar	4.77
Total solids	20.67
Purity	70.54

Analyses of juices from stripped and unstripped canes.[5]

	Canes with seed heads cut.		Canes with seed heads uncut.	
	Stripped.	Unstripped.	Stripped.	Unstripped.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sucrose	15.73	14.48	15.89	15.05
Glucose	1.57	1.99	1.36	1.99
Not sugar	3.37	2.84	3.32	2.79
Total solids	20.68	19.41	20.58	20.00
Purity co-efficient	75.99	74.52	77.02	75.22

I add the following observations:[6]

JUICES OF 1884 COMPARED WITH THOSE OF 1883.

The most surprising phase of the experimental work as exhibited in the tables given is the great difference which it shows between the composition of juices analyzed and those analyzed during 1883:

	1883.	1884.
Mean percentage sucrose	8.38	14.72
Mean percentage reducing sugars	4.09	1.24
Mean percentage albuminoids	.1544	.961

[1] *Op. cit.*, p. 141.
[2] *Op. cit.*, p. 142.
[3] *Op. cit.*, pp. 142, 143.
[4] *Op. cit.*, p. 144.
[5] *Op. cit.*, pp. 148, 149.
[6] *Op. cit.*, p. 150.

The chief points of interest in this comparison are the increase in sucrose, the decrease in reducing sugars, and the increase in albuminoids. It is difficult to explain why the same varieties of cane grown in the same locality, with the same kind of culture and fertilizing, and in seasons not markedly different, should yield juice of such different composition. Sorghum is one of the most capricious of plants, and the above comparison brings some of its moods into strong contrast.

During the season of 1884 the Department made an extensive series of analyses at Helena, Wis.[1]

The variety of cane was Early Amber, and it was grown in a light, sandy soil without fertilizers. I visited the plantation during the progress of the work. The cane, though small, looked well and was mostly ripe.

Following are the means of the analyses for the whole season:[2]

	Per cent.
Sucrose	7.85
Glucose	5.00

The proprietors of the plantation, Messrs. Williams & Flynn, even after the discouraging results of the above analyses, were not without hope that sugar-making could be profitably undertaken in Wisconsin. To this opinion I was not able to subscribe, as will be seen from the following quotation:[3]

In spite of the conviction of Messrs. Williams & Flynn that sorghum sugar can be made profitably in Wisconsin, I am far from being convinced of the justness of that expectation, unless, indeed, it be in some small way. In view of the disasters that have overtaken attempts at sorghum-sugar making further south I think it would be unwise to encourage like enterprises in regions where at best not more than four weeks of an average milling season can be expected.

In 1885 additional analyses were made of sorghum grown near Ottawa, Kans.[4]

The juices from the two mills used in grinding the cane were collected in a common tank and the samples for analysis taken from time to time from this tank. These samples, therefore, represent the mean constitution of the juice from several thousand tons of cane. The samples were taken from September 9 to October 14, inclusive:

Means of the analyses.

	Per cent.
Sucrose	9.23
Glucose	3.04
Not sugar	2.87
Total solids	15.07

ANALYSES OF CANES USED IN DIFFUSION.

During the progress of the diffusion experiments at Ottawa, Kans., October 8, 1885, three samples of cane were taken at different times

[1] *Op. cit.*, pp. 151, *et seq.*

[2] *Op. cit.*, p. 154.

[3] *Op. cit.*, p. 156.

[4] Department of Agriculture, Division of Chemistry, Bull. No. 6, 1885.

during the day, and the juice, expressed on a small hand-mill, subjected to analysis. The following results were obtained:[1]

	First analysis, 10 a. m.	Second analysis, 11 a. m.	Third analysis, 11.30 a. m.
	Per cent.	*Per cent.*	*Per cent.*
Total solids....	17.00	15.60	15.20
Sucrose........	11.24	9.62	9.83
Glucose.......	2.44	2.85	3.41
Not sugar	3.32	3.13	1.96

ANALYSIS OF DIFFUSION JUICES.

The diffusion juices obtained in the above experiment were analyzed with the following results:[1]

	First sample.	Second sample.
	Per cent.	*Per cent.*
Total solids....	10.84	9.70
Sucrose........	6.19	5.90
Glucose........	2.32	2.00
Not sugar......	2.23	1.80

Composition of canes used in second diffusion experiment at Ottawa.[2]

No.	Hour.	Sucrose.	Glucose.	Not sugar.	Total solids.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	10 a. m.	10.23	2.11	2.82	15.16
2	3 p. m.	8.64	2.95	2.81	14.40
3	4.30 p. m.	8.54	3.11	2.89	14.54
4	5.30 p. m.	8.81	2.61	2.98	14.40

Composition of diffusion juices from above canes.[3]

No.	Sucrose.	Glucose.	Not sugar.	Total solids.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1............	4.86	1.69	1.78	8.33
2............	5.94	2.00	2.20	10.14
3............	4.99	2.31	1.64	8.94
4............	4.76	2.25	1.55	8.56
5............	3.91	2.16	1.63	7.70
Means......	4.89	2.08	1.76	8.74

Composition of juices from canes topped and suckered, topped and not suckered, and untouched, Ottawa, 1885.

MEANS.

	Topped and suckered.	Topped and not suckered.	Normal canes.
	Per cent.	*Per cent.*	*Per cent.*
Sucrose.........	12.45	12.46	12.15
Glucose.........	1.99	2.09	2.06
Not sugar	2.82	2.76	2.56
Total solids.....	17.26	17.31	16.77

[1] *Op. cit.*, p. 8. [2] *Op. cit.*, p. 10. [3] *Op. cit.*, p. 12.

COMPOSITION OF CANES AND JUICES AT FORT SCOTT, SEASON OF 1886.

During 1886 the Department analyses were continued at Fort Scott, Kans.[1]

Mean composition of juices of canes expressed by hand-mill.

	Per cent.
August 30 to October 1, 1886:[2]	
Sucrose	10.49
Glucose	4.01
Total solids	17.56
October 1 to 26:	
Sucrose	8.70
Glucose	4.15
Total solids	16.60

MEAN COMPOSITION OF DIFFUSION CHIPS.

These chips were taken from each cell and, after thorough mixing, sampled for analysis. The extractions were made in closed bottles.[3]

	In the cane.	In the juice.
September 8 to October 1, 1886:	*Per cent.*	*Per cent.*
Sucrose	8.85	9.73
Glucose	3.32	3.65
Total solids	14.69	16.15
October 1 to 28:		
Sucrose	7.01	7.71
Glucose	4.15	4.56
Total solids	14.90	15.99

COMPOSITION OF JUICES FROM DIFFUSION CHIPS.

Samples taken as just described and the chips passed through small mill.

Means from October 15 to 28.[4]

	Per cent.
Sucrose	7.28
Glucose	3.74
Total solids	14.80

Composition of the canes calculated from the mill juices for the entire season.[5]

	Total solids.	Sucrose.	Glucose.
	Per cent.	*Per cent.*	*Per cent.*
Before October 1	15.63	9.34	3.57
After September 30	14.77	7.74	3.79
After October 14	13.17	6.48	3.31
Means	14.56	7.85	3.52

[1] Bulletin No. 14, Division of Chemistry, Department of Agriculture, 1887.

[2] *Op. cit.*, p. 15.

[3] *Op. cit.*, p. 16.

[4] *Op. cit.*, p. 17.

[5] *Op. cit.*, p. 31.

MEAN COMPOSITION OF THE DIFFUSION JUICES FOR THE SEASON OF 1886.

Sampling.—From each cell as it was withdrawn a measured quantity of the diffusion juice was taken until an entire circuit of the battery had been made. The mixed samples was then subjected to analysis.[1]

Mean composition of diffusion juices.

	Per cent.
September 9 to October 1:	
Sucrose	5.75
Glucose	2.32
Total solids	11.77
September 30 to October 28:	
Sucrose	4.90
Glucose	3.39
Solids	11.34

(*b*) WORK NOT DONE BY THE DEPARTMENT OF AGRICULTURE.

D. J. Browne[2] says the juice of sorghum grown in France contained from 10 to 16 per cent. sugar, a third part of which is sometimes uncrystallizable.

C. T. Jackson[3] analyzed samples of sorghum canes sent him by the Department, and obtained from 9 to 12 per cent. saccharine matter to weight of stalk.

From samples grown in Massachusetts he obtained from 10.6 to 14.6 per cent. saccharine matter. He made no attempt to separate the different sugars in the juice.

In same volume, p. 313, is given an analysis made at Verrieres, France, showing 16 per cent. sugar, of which 10.33 is sucrose and 5.67 glucose.

C. T. Jackson reports further analyses in Agricultural Report, 1857, pp. 185 *et seq.*, in which the per cent. of saccharine matter varied from 9.36 to 16.6, and the sucrose from nothing to a large quantity, the exact amount of which was not determined. Dr. Jackson made no determinations of the sugar in the juice, but calculated the saccharine matter from the specific gravity.

J. Lawrence Smith[4] made several analyses of sorghum, from which he concludes that "the sorgho contains about 10 per cent. crystallizable sugar.[5]

[1] *Op. cit.*, pp. 18, 19.

[2] Department of Agriculture. Report 1856, pp. 309–313.

[3] *Op. cit.*, p. 308.

[4] Agricultural Report 1857, pp. 192 *et seq.*

[5] *Op cit.*, p. 196.

Dr. C. A. Goessmann[1] gives the following as the means of his analyses of the ripe canes:

	Per cent.
Water	78.94
Soluble matter	10.22
Of which sucrose	9.25
Of which cellulose	8.20
Of which other substances	2.64

Joseph S. Lovering[2] found the following per cent. of sucrose in the juices of sorghum in several experiments, viz, 5.01, 5.57, 7.29.

Stansbury reports[3] that the juice of sorghum, as examined in France, contains from 10 to 16 per cent. of sugar, a third part of which is uncrystallizable. In respect of the manufacture of sugar, he says:

In so far as the manufacture of sugar is concerned, in a domestic way, this plant appears to have but little chance of success in a high northern climate, as a large proportion of that which is uncrystallizable is not only a loss to the manufacturer, but an obstacle to the extraction of what is crystallizable. It must not be understood, however, that the produce of this plant is unprolific or difficult to obtain, but that, all things being equal, its nature renders it more abundant in alcohol or sirup than in sugar.

Hippolyte Leplay[4] found a percentage of sucrose varying in ripe sorghum from 9.35 to 17.81.

Leplay[5] shows a total content of both sugars from 7.81 to 11.81 per cent.

ANALYSES GIVEN BY F. L. STEWART.[6]

Stewart states that sorghum juices show an average density of 11° B., with 18° saccharine matter, nearly all of which is cane sugar.

After clarification this specific gravity is reduced to 9.5° B.[1]

Average results for juice of ripe cane grown on good upland soil are given as follows:[1]

Specific gravity	1.085
Specific gravity of clarified juice	1.070
Total sugars (per cent.)	17.00

Of which nearly all is sucrose.

Stewart quotes the analyses of Dr. C. T. Jackson as follows:

Specific gravity	1.062
Calculated total sugar (per cent.)	15.5
Obtained sugar (nearly all sucrose), per cent	16.6

The figures given in the Agricultural Report, already quoted for Dr. Jackson's analyses, are claimed by Stewart to be erroneous.

[1] Contributions to the Knowledge of the Nature of the Chinese Sugar-Cane, 1862, p. 21.

[2] Experiments on the Sorghum Saccharatum, 1857, pp. 7 and 14.

[3] Chinese Sugar-Cane, 1857, p. 10.

[4] Culture du Sorgho sucre, pp. 33 and 34, Toulouse, 1858.

[5] Manuscript sent to author.

[6] Sorghum and its products, 1867, pp. 171 *et seq.*

The reliability of the observations of Mr. Stewart may be called in question by the fact that he gives an illustration of a thin section of sorghum cane which shows an abundance of cane sugar crystals of a triangular shape. I will allow Mr. Stewart to describe these crystals in his own words:[1]

An incontrovertible evidence of the presence of cane sugar almost exclusively in the juice of sorghum is afforded in the fact that thin sections of the fresh stalk of the plant under the microscope exhibit the cells filled with innumerable minute crystals of pure white sugar, which by their form and other criteria are shown to be cane sugar only. Scarcely a trace of any other substance is found in the cells. This is well represented in the engravings.

The means of analyses of Early Amber cane made by Professor C. A. Goessmann at the Agricultural College of Massachusetts in 1878 are as follows:[2]

	Per cent.
Sucrose	5.00
Glucose	6.35
Total solids	14.42

An analysis of the juice of the Amber cane at Berkeley, Cal., was made in 1879 by Professor Hilgard. It gave the following results:[3]

Specific gravity		1.0605
Total solids	per cent..	14.8
Sucrose	do....	10.1

Weber and Scovell[4] give the results of numerous analyses of Amber and Orange sorghum. Following are the figures:

Composition of juice.

No.	Sucrose.	Glucose.
	Per cent.	*Per cent.*
1	10.75	3.34
2	4.90	5.70
3	12.48	2.47
4	7.12	6.19
5	11.42	2.13
6	9.13	5.00
7	11.02	2.79
8	9.76	4.11
9	10.06	2.47
10	13.11	1.82
11	9.67	2.94
12	11.41	4.02
13	3.55	14.66
Means	9.61	4.43

Weber gives the mean composition of the juice of orange cane as follows:[5]

	Per cent.
Sucrose	9.77
Glucose	3.00
Water	76.58
Starch	4.12

[1] *Op. cit.*, p. 186.

[2] Department of Agriculture, Report 1881 and 1882.

[3] Report California College of Agriculture, 1879, p. 58.

[4] Illinois Agricultural Report, 1880, pp. 425 *et seq.*

[5] *Op. cit.*, p. 427.

Five samples of sorghum juice examined by Professor Hilgard, of Berkeley, Cal., in 1880, showed the following mean composition:[1]

Specific gravity		1.081
Total solids	per cent	19.65
Sucrose	do	11.89
Purity		66.82

In 1881 Weber and Scovell continued their analyses.[2]

The means of three series of determinations of sucrose and glucose were found to be:

Series.	Sucrose.	Glucose.
	Per cent.	*Per cent.*
First	8.56	4.84
Second	11.95	3.21
Third	11.18	2.85

Weber and Scovell[3] give the following as the mean composition of the juice of Amber cane for 1881:

Specific gravity		1.070
Sucrose	per cent	12.08
Glucose	do	2.47

ANALYSES AT EXPERIMENTAL FARM OF WISCONSIN FOR 1881.[4]

The mean composition of the juice for 1881 at Madison, Wis., was—

	Per cent.
Sucrose	9.5
Glucose	3.2
Not sugar	2.3
Water	85.0

Analyses of Early Amber, Early Orange, and Honduras canes gave the following mean results:[5]

In the juice.	Early Amber.	Early Orange.	Honduras.
	Per cent.	*Per cent.*	*Per cent.*
Sucrose	10.63	10.50	7.00
Glucose	2.68	4 95	4.20

CANES FROM DIFFERENT PARTS OF THE STATE.

The mean composition of the juice from canes grown in different parts of the State of Wisconsin and sent to experimental station for analysis is as follows:[6]

	Per cent.
Sucrose	8.07
Glucose	5.12

[1] College of Agriculture, California, Report 1880, p. 41.

[2] Illinois Agricultural Report, 1881, p. 497.

[3] Encouragement to the Sorghum and Beet Sugar Industry, Department Agriculture, 1883, p. 12.

[4] Report National Academy Sciences on Sorghum, p. p. 80 *et seq.*

[5] *Op. cit.*, p. 86.

[6] *Op. cit.*, p. 89.

Weber and Scovell give the following as the mean composition of Amber cane for 1882.[1]

Specific gravity		1.060
Sucrose	per cent	8.20
Glucose	do	3.66

For the best cane raised by them in 1882 the following mean composition of the juice is given:[2]

Specific gravity		1.060
Sucrose	per cent	10.17
Glucose	do	2.48

Swenson[3] gives the analyses of juices from plots of fertilized canes grown at the experimental farms of the University of Wisconsin.

Following are the means of sixteen analyses:

	Per cent.
Sucrose	10.75
Glucose	3.09

Professor Swenson reports the mean percentage of sucrose in the juice of three lots of cane used for sugar making as follows:[4]

	Per cent.
Lot 1	9.89
Lot 2	12.10
Lot 3	11.20

Twenty-six varieties of sorghum grown on the experimental farm of Wisconsin in 1882 and analyzed by Professor Swenson showed the following composition of the juice:[5]

	Per cent.
Sucrose	9.84
Glucose	2.35

Twenty-three varieties grown with fertilizers at same place gave a juice of the following composition:[6]

	Per cent.
Sucrose	10.79
Glucose	2.81

Swenson also reports[7] another set of canes which had a juice on October 13 of the following composition:

	Per cent.
Sucrose	10.59
Glucose	2.85

[1] Encouragement to the Sorghum and Beet Sugar Industry, Department of Agriculture, 1883, p. 12.

[2] *Op. cit.*, p. 16.

[3] *Op. cit.*, p. 19.

[4] Encouragement to Sorghum, etc., Department of Agriculture, 1883, p. 20.

[5] Experiments with Amber Cane, Madison, Wis., 1882, p. 7.

[6] *Op. cit.*, p. 8.

[7] Encouragement to Sorghum, etc., Department of Agriculture, 1883, p. 21.

Three days later the juice had the following composition:

	Per cent.
Sucrose	9.50
Glucose	5.00

At Modena, Italy, during the same year, further experiments were carried on by Professor Pirotta.[1]

The experiments were divided into four series. Following are the mean results for each series. In each series are given the means of twelve analyses of sorghum juices:

First series:		
Specific gravity		1.0712
Sucrose	per cent	8.20
Glucose	do	6.53
Second series:		
Specific gravity		1.0946
Sucrose	per cent	14.84
Glucose	do	5.14
Third series:		
Specific gravity		1.0997
Sucrose	per cent	15.10
Glucose	do	5.81
Fourth series:		
Specific gravity		1.1039
Sucrose	per cent	18.01
Glucose	do	4.17

In 1882 I made numerous analyses of juice from a large cane-mill at La Fayette, Ind. The analyses represent 50 acres of cane, the greater part of which was stripped and ripe.[2]

The means of the analyses are as follows:

Sucrose	per cent	7.52
Glucose	do	5.80
Specific gravity		1.0586

Fifteen varieties of sorghum were also grown on the experimental farm of Purdue University during the same year. The whole of the plots was cut and passed through the mill, and the analysis represents the composition of the entire juice.

The means are as follows:

Sucrose	per cent	7.17
Glucose	do	5.15
Specific gravity	do	1.059

Prof. Giulio Monselise[3] gives the result of numerous analyses of sorghum juices. Following are the means of forty-one analyses made on canes planted in April, 1882:

	Per cent.
Sucrose	11.35
Glucose	5.78
Total solids	18.60

[1] Annali di Agricoltura sul Sorgho Ambrato, 1883, pp. 28 *et seq.*, Roma.

[2] Report Agricultural College of Indiana (Purdue University), 1882, pp. 244-245.

[3] L'ambra primiticcia o Sorgho Zuccherino del Minnesota, Manitova, 1883, Facicolo Quorto; table opposite p. 192.

In 1882 experiments were made at the Zootechnic school in Reggio, Italy, by Professors Zanelli and Spallanzani. The means of the analyses made by them are as follows:[1]

	Per cent. in the juice.
First series:	
Sucrose	13.99
Glucose	4.97
Second series:	
Sucrose	11.55
Glucose	7.82

Two samples of sorghum juice (early amber) examined by Professor Hilgard, of the University of California, showed the following mean composition:[2]

Specific gravity		1.070
Total solids	per cent..	17.00
Sucrose	do....	8.10
Purity		45.40

A sample of juice from sugar-cane also grown in California showed the following composition:

Specific gravity		1.076
Total solids	per cent..	18.4
Sucrose	do....	16.9
Purity		92.93

Professor Hilgard adds the following observations:[3]

The above analyses exhibit, first, the superiority of the true sugar-cane over the sorghum in respect to purity as well as total sugar contents, although in both respects the former is here shown below the quality to which it attains in tropical countries. There can be no doubt that wherever the tropical sugar-cane can be grown to advantage within the reach of intelligent labor and perfected appliances, it is superior to the sorghum as a sugar-producing plant.

Remarkable results were obtained by using special fertilizers in the New Jersey experiments.

In sixteen experiments the percentages of sugar in the cane were as follows:[4] 15.05, 13.13, 12.97, 11.74, 11.40, 12.50, 15.01, 11.79, 12.70, 15,20, 12.59, 13.57, 15.42, 15.93, 16.09, 15.37. Mean calculated for juice, 15.16 per cent.

In 1883 two samples of sorghum juice were analyzed by Dr. H. P. Armsby, chemist of the Wisconsin Agricultural Experiment Station.

The results are given in the first annual report of the station, p. 79:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Sucrose	6.15	7.85
Glucose	3.32	3.22
Total solids	12.00	13.50

[1] Annali di Agricoltura sul sorgho Ambrato, Roma, 1883, pp. 20 *et seq.*

[2] College of Agriculture, University of California, report, 1882, p. 61.

[3] *Op. cit.*, p. 61.

[4] New Jersey Experiment Station, Bull. No. XXX, p. 7.

Swenson[1] says the average percentage of cane sugar in sorghum grown by him on the Wisconsin farm was 10.5 to 12.5.

Weber[2] reports the following as the general average of all the cane juices manufactured at Champaign during the year 1883:

Specific gravity		1.059
Sucrose	per cent	7.78
Glucose	do	4.76

The means of seventy analyses made of Amber canes at Hutchinson, Kans., during the season of 1883, by Prof. M. Swenson, are as follows:[3]

	Per cent.
Total solids	14.2
Sucrose	9.3
Glucose	2.8

The means of thirteen analyses of the cane juices from the large mill at Hutchinson, Kans., give the following numbers:[4]

	Per cent.
Total solids	15.7
Sucrose	11.1
Glucose	3.3

The means of thirteen analyses of Orange cane at Hutchinson during 1883 are as follows:[4]

	Per cent.
Total solids	13.1
Sucrose	8.7
Glucose	3.5

Seven analyses of the juices of Link's Hybrid cane, made at same place in 1883, are as follows:[4]

	Per cent
Total solids	13.2
Sucrose	10.3
Glucose	2.13

Means of two analyses of the juices of Honduras cane, made at the same time and place, are as follows:[5]

	Per cent.
Total solids	15.2
Sucrose	10.2
Glucose	3.4

The means of fifty-six analyses of the juices of sorghum, chiefly Amber, made by Prof. M. A. Scovell, at Sterling, Kans., in 1883, are as follows:[6]

	Per cent.
Sucrose	7.45
Glucose	3.8[illegible]
Not sugar	3.13

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[1] Third Annual Meeting Wisconsin Cane-Growers' Association, February, 1883, p. 16; edited by J. A. Field, Saint Louis, Mo.

[2] Department of Agriculture, Division of Chemistry, Bull. No. 3, p. 62.

[3] *Op. cit.*, p. 64.

[4] *Op. cit.*, p. 65.

[5] *Op. cit.*, p. 66.

[6] *Op. cit.*, pp. 67, 68.

The means of nine analyses of Early Amber cane juice, made by Prof. G. H. Failyer, of the Kansas State Agricultural College, at Manhattan, in 1883, are as follows:[1]

	Per cent.
Total solids	15.35
Sucrose	11.72
Glucose	1.45

The means of six analyses made by the same person, at the same place, of the juices of Link's Hybrid cane, are as follows:[1]

	Per cent.
Total solids	11.12
Sucrose	6.13
Glucose	2.83

Means of four analyses of Kansas Orange cane juice, made by the same person at same place and time, are as follows:[1]

	Per cent.
Total solids	14.91
Sucrose	11.28
Glucose	1.06

One analysis of Honduras cane, made at the same time and place by Professor Failyer, gave—

Sucrose	per cent..	9.76
Glucose	do....	3.29
Specific gravity		1.061

The means of sixteen analyses reported by F. L. Stewart are as follows:[2]

Specific gravity		1.068
Sucrose	per cent..	12.50
Glucose	do....	2.23

Prof. W. A. Henry[3] reports the analyses of twenty-one samples of sorghum juices from different varieties.

The mean results are as follows:

	Per cent.
Sucrose	8.93
Glucose	2.34

In 1885 further analyses were made of field samples at the Rio Grande factory by the chemist of the New Jersey station, Dr. Neale.

All the samples except the last one named had been fertilized. The quantity of sugar in the cane of the several samples was as follows:[4]

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[1] *Op. cit.*, pp. 68, 69.

[2] Fourth Annual Report New York State Sugar-Growers' Association, p. 44.

[3] Second Annual Report Wisconsin Agricultural Experiment Station, p. 33

[4] New Jersey Experiment Station, Bull. No. XXXVIII, p. 10.

7.18, 7.56, 7.48, 6.57, 7.29, 7.14, 7.50, 6.26, 7.50, 8.19, 8.30, 7.54, 7.46, 6.46, 6.17. Mean calculated for juice, 7.96.

After the experiments above mentioned all the canes of the experimental plots were cut and passed through the large mill, and the expressed juices sampled and analyzed.

The respective percentages of sucrose in these juices were as follows:[1] 8.69, 8.23, 9.96, 8.89, 9.70, 9.48, 9.96, 9.12, 11.30, 11.21, 11.38, 11.16, 11.03, 8.87, 9.18. Mean, 9.88.

Twenty-six tons of early orange cane was found by another analysis to contain 7.25 per cent. sucrose:[2]

Composition of sorghum juices from large mill at Rio Grande, N. J., for the four seasons from 1882 to 1885, inclusive.[3]

SUCROSE.

[Averages for each week.]

1882.[4]	1883.[5]	1884.[6]	1885.[7]
Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
10.35	9.70	9.90	6.60
11.33	10.37	9.64	8.03
11.81	8.56	9.16	8.39
11.56	9.22	10.96	8.70
10.68	9.50	11.10	8.94
11.58	9.70	12.60	10.64
10.85	10.36	10.25	10.00
11.00	10.74	10.33	....
10.56	9.95	9.90	....
11.38	9.42	8.70	....
11.11[8]	9.75[8]	10.25[8]	8.76[8]

[4] From Sept. 4 to Nov. 6.
[5] From Sept. 10 to Nov. 12.
[6] From Sept. 8 to Nov. 10.
[7] From Sept. 2 to Oct. 12.
[8] Mean.

For 1886 the mean percentage of sucrose in the cane as reported by the New Jersey Experiment Station was 114 to 120 pounds per ton.

Mean in cane (pounds)	117
Mean per cent, sucrose in cane	5.85
Mean per cent. sucrose in juice	6.54

The general average content of sucrose in the mill juices at Rio Grande for the five years is 9.28 per cent.

The means of ninety-eight analyses made in 1886 by Professor Stubbs, director of the experiment station at Kenner, La., were as follows:[4]

	Per cent.
Sucrose	11.92
Total solids	16.34

[1] *Op. cit.*, p. 10.
[2] *Op. cit.*, p. 15.
[3] MS. from Mr. H. A. Hughes, superintendent.
[4] Louisiana Sugar Experiment Station, Kenner, La., Bull. No. 5, pp. 6 and 7, 1886.

In 1886 the New Jersey station continued its analyses at Rio Grande. The percentage of sucrose in the cane varied from 114 to 120 pounds per ton.[1]

COMPARISON OF MILL AND DIFFUSION JUICES FOR 1886.

At Rio Grande the chemist of the New Jersey station made analyses for the purpose of comparing mill and diffusion juices.[2]

The means are as follows:

	Mill juice.	Diffusion juice
	Per cent.	*Per cent.*
Sucrose	8.93	7.59
Total solids	12.99	11.56
Purity	68.75	65.57

A mean of eight experiments made by J. F. Willcox, of New York,[3] in 1886 shows 9 per cent. sucrose in sorghum juice.

ANALYTICAL DATA FROM THE EXPERIMENTS AT THE NEW JERSEY AGRICULTURAL STATION.

The systematic investigations made by Dr. Geo. H. Cook, director of the New Jersey Agricultural Experiment Station, have already been quoted in the data given. These experiments were commenced in 1881 and have been continued every year since. The chemical work has been in charge of Dr. A. T. Neale. The results of these experiments have been so interesting and instructive that I have grouped them together.

In 1881 fourteen varieties were planted, of which only five matured.[4] The sucrose in the juice of these five matured varieties was as follows: Per cent., 8.58, 7.28, 6.50, 7.60, 14.06. Mean, 8.80 per cent.

The same season[5] sixteen plots of Early Amber were treated with various fertilizers, and the yield of sugar calculated per acre.

The percentages of sucrose in the juice of the several plots were as follows: 9.70, 9.43, 9, 9.27, 9.68, 9.94, 10.51, 11.65, 11.43, 9.84, 9.57, 11.61, 9.73, 9.44, 12.01. Mean, 10.16.

In respect of the experiments Dr. Cook makes the following report:[6]

After a struggle, which has now lasted more than twenty-five years, sorghum to-day does not occupy its true position among sugar-producing plants. Its advocate-justly claim that this is due to our lack of information, not only in regard to the manufacture of sugar from it, but also in respect to its proper cultivation. For some time past authorities have felt that the hope of having a small sugar-house on each farm must be abandoned, and that our attention must be turned towards the more rational

[1] Prof. G. H. Cook, Rural World, July 7, 1887.

[2] Seventh Ann. Report New Jersey Agricultural Experiment Station, 1886, p. 130.

[3] MS. communication to author.

[4] Second Ann. Report New Jersey Experiment Station, p. 43.

[5] *Op. cit*, pp. 44, 45.

[6] *Op. cit.*, pp. 46, 47.

plan of thoroughly equipped manufactories, in which the sorghum grown on neighboring farms can be worked quickly and economically by skilled operatives.

The result of the season's experiments is decidedly encouraging, considering the unfavorable circumstances. There has been a drought of unprecedented severity and length, so that the corn crop on the college farm was not more than one-quarter its usual amount. And yet the results of sorghum growing on the same farm, as given in the above table, are respectable. With a season having the average rain-fall a crop weighing from two to three times as much as that of the present one may safely be calculated on.

In 1882 experiments were made on two plots on autumn and spring plowed ground. Each plot was divided into sixteen sections, on which different fertilizers were employed.

The mean percentages of sucrose in the juice for the two plots are as follows:[1]

First plot	13.16
Second plot	12.2

The season was again reported as unfavorable.[2]

The plants came up quickly and grew rapidly from the first, so that no special trouble was experienced in hoeing or cultivating it. It came forward with strong and stout canes until near the middle of August, when a very severe drought set in. The growth of the cane was entirely stopped for some weeks, when it was about 6 feet high. Finally stunted-looking seed-heads partially developed in irregular patches and streaks over the field; most of the seed was blasted, and many of the stalks failed to head out. The height of the crop was 2 or 3 feet below the normal growth. When the rains came in September new shoots forked out from the upper joints and unfolded slender heads, but it was too late in the season, and no seeds ripened on them.

We judge that the crop of cane was not half what it would have been in a favorable season, and that of the seed not one-third of a full crop. The percentage of juice in the canes was also much lower than is natural in properly-grown sorghum.

The effects of the drought were irregular on the field, not following any of the lines which marked the plots and fertilizers, so that we can draw no satisfactory conclusions from the experiments on fertilizers either in the production of cane and seed or on the quality and amount of the juice or sugar.

Our uniform course is to record our failures as well as our successes, and this is published, though it is a disappointment and a failure which we could not avoid.

In 1883 the results of the experiments were still more encouraging.

The means of the percentages of sucrose in the juice of sixteen samples from as many different plots was 15.16.[3]

The average quantity of sugar produced per acre, based on the above analyses, was 3,963 pounds.

Some of the conclusions derived from the above set of experiments are of a remarkable character.[4]

Even when a mill expresses from 50 to 60 per cent. of juice from stripped and topped cane, it may yet leave more than one-half of the sugar in the bagasse. This fact can be best shown by an example. The cane on plot 11 contained 4,119 pounds of sugar per acre. Of this the mill expressed 1,983 pounds, leaving in the bagasse 52 per cent. of the sugar which the cane contained. This result is the most favorable in the experiment. The other extreme is found on plot 10, where nearly 70 per cent. of the sugar was

[1] Third Annual Report New Jersey Agricultural Experiment Station, pp. 64, 65.

[2] *Op. cit.*, pp. 61, 62.

[3] Fourth Annual Report New Jersey Experiment Station, p. 70.

[4] *Op. cit.*, pp. 67, 68.

wasted. In eleven other cases the loss exceeds 60 per cent. Apparently the greener the cane the smaller the loss of sugar by the milling process.

To explain this loss it is necessary to assume that a considerable portion of the sugar is stored in the cane in a solid state, either as pure crystallized sugar or in some combination easily decomposed or dissolved in water. It is claimed that the microscope has shown crystals of sugar in the cells of the sorghum; if this is true, it is irrational to attempt the perfect separation of sugar from the cane fiber by mechanical means. For attaining this end the process of diffusion seems to be the most practical and promising method. It has been thoroughly tested and generally adopted by the beet-sugar industry, and experiments thus far reported indicate that it is also applicable to the sorghum and tropical cane.

Mr. H. B. Blackwell states in the Boston Journal of Chemistry that by following this process he was able without difficulty to make 13 pounds of crystallized sugar and 6 pounds of good sirup from 100 pounds of Amber cane.

In my opinion natural crystals of sugar never exist in healthy sorghum canes. In 1883 I had this subject thoroughly examined.[1]

Six hundred sections of sorghum and sugar canes failed to show a single crystal of sugar. In very dry seasons the juice of sorghum has been known to exude through perforations made by an insect and to crystallize on the outside of the stalk. A sample of very pure cane sugar formed in this way was sent to me last year (1886) by Mr. A. A. Denton, of Kansas.

In 1884 the following data were obtained as the result of the experiments at the station.[2]

There were sixteen plots Early Amber all fertilized but two. The percentage of sucrose in the cane was 8.53 and in the juice 9.39. The average total sugar per acre for the sixteen plots was 1,752 pounds. Two additional plots were planted in Amber and Orange canes respectively, no fertilizers being used.[3]

The total sucrose in the Amber plot was, for the cane 9.20 per cent., and for the juice 10.12 per cent.

For the Orange the numbers were: for the cane 6.57 per cent., and for the juice 7.22 per cent.

A plot of amber cane, from seed sent by Professor Henry, of Wisconsin, showed in the same conditions as above:[4]

	Per cent.
Sucrose in cane	8.63
Sucrose in juice	9.49

The intensely hot weather following May 14, the date of planting, was decidedly unfavorable for sorghum. The soil "baked" hard, the Amber seed germinated slowly, the "moping" period appeared to be unusually prolonged, and the plants in many hills perished, especially upon plots 12 to 16, inclusive. For a long time the experiment was regarded as a failure, and received comparatively little attention. Later the development was remarkable, and the yield of cane from several of the plots was above the average; in quality, however, in all cases it fell far below previous results.[5]

[1] Department of Agriculture, Division of Chemistry, Bull. No. 2, p. 6.

[2] Fifth Ann. Report New Jersey Agricultural Experiment Station, pp. 84, 85.

[3] *Op. cit.*, p. 79.

[4] *Op. cit.*, p. 80.

[5] *Op. cit.*, p. 81.

In 1885 comparative experiments were made with native Amber seed, Amber seed from Prof. W. A. Henry, and native Orange seed.

The percentages of sucrose in the three kinds of canes were as follows:[1]

	In the cane.	In the juice.
	Per cent.	*Per cent.*
Native Amber	8.98	9.87
Wisconsin Amber	10.40	11.44
Native Orange	7.38	8.11

Sixteen plots all fertilized save two were planted in Early Amber and the following data were obtained:[2]

Mean sucrose in canes	per cent..	9.37
Mean sucrose in juice	do....	10.30
Average weight sugar per acre	pounds..	2,372

Another set of experiments was made at Rio Grande with the co-operation of Mr. George C. Potts and Mr. H. A. Hughes. The following data were obtained. Early Orange cane, sixteen plots, all fertilized but one:[3]

Mean percentage sucrose in juice		9.88
Total weight sugar per acre	pounds..	2,508

In reviewing the operations of the Rio Grande factory for the past five years, Professor Cook says:[4]

> The records of this plantation for the past five years show that upon the average 7.7 tons of unstripped and untopped cane only have been grown per acre, while the average yield of merchantable sugar per ton of cane has not exceeded 40 pounds.
>
> To compete successfully with other sources of cane sugar, therefore, the average tonnage of good cane per acre should be at least doubled, while the quantity of merchantable sugar secured per acre should be increased many fold.

In 1886 the experiments at Rio Grande were continued. Sixteen plots all fertilized but one were planted in Early Orange Cane. The following data were obtained:[5]

Cane (leaves and seed) per acre	pounds..	13,383
Clean cane per acre	do....	10,448
Sucrose in clean cane	per cent..	7.95
Total weight sugar per acre	pounds..	905

Professor Cook makes the following remarks on the results of the season:[6]

> Three years ago it was clearly seen that the Rio Grande Company failed to secure one-half of the total amount of sugar present in its sorghum crops, and since that time all energies have been directed toward the substitution of diffusion for milling.

[1] Sixth Annual Report New Jersey Agricultural Experimental Station, p. 109.

[2] *Op. cit.*, p. 111.

[3] *Op. cit.*, p. 126.

[4] *Op. cit.*, p. 119.

[5] Seventh Annual Report New Jersey Experimental Station, p. 151.

[6] *Op. cit.*, p. 141.

The obstacles to this change, met at the very beginning, have at last been overcome, and 70 per cent. of the sugar in the cane has this year been extracted and sold. Information has also been gained which shows how 90 per cent. of the total sugar may be secured in the future.

It still remains to be demonstrated that this industry can be made a financial success.

The chemical analysis of cane, showing its percentage of sugar only, is far from reliable information on this question if unaccompanied by the actual weight of crop per acre.[1] A normal evaporation of water from a crop, for instance, may cause an apparent improvement in its quality, but as this evaporation is accompanied by a corresponding loss of weight, it leaves the absolute amount of sugar per acre unchanged. Again, the percentage of sugar in the juice may remain constant while the quantity of juice to be secured from an acre of cane may be steadily decreasing, involving thereby a loss in the absolute amount of sugar.

During the period October 9–23, 728 tons of unstripped and untopped sorghum were diffused, and an average yield per ton of 80 pounds of 100° test sugar thereby secured. Of this 80 pounds, 55.7 pounds crystallized and 24.3 pounds remained in the molasses. This cane was grown principally upon banked meadows, and although it may have passed its best stage as regards sugar production, it was not considered "dried up" or pithy.

On the 1st, 2d, and 3d of November 241 tons of unstripped and untopped cane were diffused, and an average yield per ton of 50 pounds of 100° test sugar thereby secured, of which 30 pounds crystallized and 20 pounds remained in the molasses. This cane was grown upon upland which had been heavily dressed with stable manure. Early in the fall it was considered a first-class crop, and, as it was within easy reach of the sugar-house, it was held in reserve to be used in case any emergency made it difficult to secure the necessary supply from more distant fields. This sorghum affords an unusual example of an over-ripe, pithy crop.

The green cane yielded 80 pounds and the pithy cane 50 pounds of 100° test sugar per ton. If, therefore, this loss of sugar was accompanied by losses in tonnage as heavy as farmers claim, then milling wastes at once sink into comparative insignificance. For if one-half of the tonnage disappears, and if at the same time that portion of the crop which remained depreciates 40 per cent. in value to the sugar boiler, it follows that two-thirds of the sugar formed in the plant may be wasted by delays in field-work.

This reasoning rests upon claims and assumptions which can be easily and thoroughly investigated; it indicates that the most important question now awaiting solution is, "At what stage in its growth should sorghum be harvested?"

MANUFACTURE OF SUGAR.

EXPERIMENTAL.

The first sorghum sugar made in this country appears to have been in an experiment by Dr. Battey, of Rome, Ga., in the laboratory of Dr. Booth in Philadelphia.[2]

We will give further results of experiments made at the South, and quote from the Southern Cultivator for October, 1856: "In the winter of 1844–'45[3] the junior editor of this journal obtained from Boston a few ounces of seed of this plant (Chinese sugar-cane), then newly imported from France. It came very highly recommended as a sugar-producing and forage plant; but, having a vivid recollection of many pro-

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[1] *Op. cit.*, pp. 153 *et seq.*

[2] The Chinese Sugar-Cane, by James F. C. Hyde, New York, 1857, pp. 46 *et seq.*

[3] This is probably a mistake and means 1854–'55.

vious disappointments with new-fangled notions, we concluded to test it cautiously and moderately. Passing by it one day, when the seeds were nearly or quite ripe, we concluded to test the sweetness of the stalk; so cutting a moderate-sized cane and peeling its hard outside coat, we found an exceedingly sweet and pleasant flavor, wholly and entirely unlike anything of the corn-stalk family that we had ever tasted. It was, in fact, ready-made candy.

"Fully satisfied by this time that it was valuable, at least for the production of soiling, forage, and dried fodder, we next turned our attention to its saccharine properties, and fortunately induced our friend, Dr. Robert Battey, of Rome, Ga., who was at that time pursuing the study of experimental chemistry in the well-known laboratory of Professor Booth, of Philadelphia, to test it. As the result of his experiment Dr. Battey sent us three small phials, one containing a fine sirup, one a very good sample of crude brown sugar, and the other a very good sample of crystallized sugar. This we believe to be the first crystallized sugar made in the United States from the juice of the sorgho-sucré."

Experiments were made by Joseph S. Lovering at Oakhill, near Philadelphia, in 1857, in the manufacture of sugar from sorghum. The first experiment was made September 30. In view of the voluminous literature on this subject in the thirty years that have passed since this experiment was made, I give Mr. Lovering's own description of it:[1]

The fact of the presence of crystallizable sugar in the cane being established, I proceeded to cut and grind 20 feet of a row, and passed the thirty canes which it produced three times through the rollers; about one-fourth of the seed had changed to a dark glistening brown color, but was still milky; the remainder was quite green; ground six to eight of the lower joints, which together yielded 3½ gallons of juice, weighing 9° Beaume; neutralized the free acid by adding milk of lime; clarified with eggs and boiled it down to 240° F.

This first experiment looked discouraging and unpromising at every step; its product was a very dark, thick, viscid mass, apparently a *caput mortuum*; it stood six days without the sign of a crystal, when it was placed over a flue and kept warm four days longer, when I found a pretty good crop of soft crystals, the whole very similar to the "melada" obtained from Cuba, but of darker color.

Lovering's fourth experiment was made on one-fiftieth of an acre. It yielded 18.56 pounds of sugar and 23.73 pounds molasses.[2]

Calculated to 1 acre this gives 928 pounds sugar and 98.87 gallons molasses.

A foot-note informs us:[3]

Neither the scales in which this juice was weighed nor the quart measure in which it was measured were sufficiently delicate or accurate to give precise results, and as they form the basis of these calculations, the percentages are probably not absolutely exact, but they are sufficiently so for all practical purposes.

Three other experiments were made by Mr. Lovering, but with results less favorable than No. 4.

The fashion in excuses for failure in sorghum-sugar making was early set by Mr. Lovering.

In the fifth experiment[4] he observed "a very sudden and unfavorable change in the working of the juice," which he ascribes to the weather "becoming and continuing very warm."

The sixth experiment, November 27,[5] was made after warm Indian summer weather, with heavy rains, also very cold weather, making ice 2 inches in thickness, thermome-

[1] *Op. cit.* p. 7.
[2] *Op. cit.*, p. 16.
[3] *Op. cit.* p. 17.
[4] *Op. cit.*, p. 19.
[5] *Op. cit.*, pp. 20–21.

ter having varied from 16° to 60°. To try the effect of these changes, I cut one-hundredth part of an acre, which produced 11.15 gallons of juice only, instead of 19 or 20 gallons, as before. It had, however, regained its former weight of full 10° B., but was much more acid, rank, and dark-colored than previously. It clarified without difficulty, but raised a much thicker and denser scum, and, when concentrated, was very dark and molasses-like; it, however, produced good, hard, sharp crystals, but the quantity being much reduced, there was no inducement to pursue it further. This experiment proves, however, that this cane will withstand very great vicissitudes of weather without the entire destruction of its saccharine properties.

On page 21 Mr. Lovering announces as a fundamental principle a rule of analysis which he followed, which, unfortunately, has not characterized all subsequent investigations. He says:[1]

The foregoing are all actual results produced by myself (the polariscopic observations having been taken on the spot, under the supervision of my partner, Mr. William Morris Davis), with no object in view but the truth and a desire to contribute whatever useful information I could towards the solution of this interesting and important question.

But even thus early he was led into the error of making sorghum sugar on paper, a process which for ease and profit is far superior to making it from canes, and which, unfortunately, has been largely practiced since these days of initial experiments. Taking only his experiment No. 4, he figures a yield of 1,466.22 pounds of sugar and 74.39 gallons molasses per acre, adding[2]

Further, it will be observed that my acre produced but 1,847 gallons of juice. I have, however, seen published accounts of far greater yields than this—one for instance, in this county, apparently well authenticated, reaching 6,800 gallons per acre, which, according to my *actual* results would produce 4,499 pounds of sugar and 274 gallons of molasses, and according to the foregoing *probable* results, would yield 5,389 pounds of sugar and 274 gallons to the acre.

Mr. Lovering was also the first one to show (on paper) that sorghum was quite as fine a sugar-making crop as the sugar-cane in Louisiana. He makes the following comparison:[3]

	Louisiana.	Pennsylvania.
Yield of juice per acre .... gallons..	2,236	1,847
Density of juice (Baumé).........., degrees..	8.44	10.00
Yield of sugar per gallon of juice ... pounds ..	.76	.66
Yield of sugar per acre:		
Actual .... pounds ..	1,704	1,221.85
Probable ....do ...	....	1,612.00
Yield of molasses per acre:		
Actual .. .. gallons..	102	74.39
Probable ....do	....	81.83

As a result of the study of all his experiments, he arrives at the following conclusions:[4]

(1) That it is obvious that there is a culminating point in the development of the sugar in the cane, which is the best time for sugar making. This point or season I consider to be when most if not all the seeds are ripe, and after several frosts, say when the temperature falls to 25° or 30° F.

[1] *Op. cit.*, pp. 21 and 22.
[2] *Op. cit.*, pp. 23-24.
[3] *Op. cit.* p. 25.
[4] *Op. cit.*, pp. 26, 27.

(2) That frost, or even hard freezing, does not injure the juice nor the sugar, but that warm Indian summer weather, after the frost and hard freezing, does injure them very materially, and reduces both quantity and quality.

(3) That if the cane is cut and housed, or shocked in the field when in its most favorable condition, it will probably keep unchanged for a long time.

(4) That when the juice is obtained the process should proceed continuously and without delay.

(5) That the clarification should be as perfect as possible by the time the density reached 15° Baumé, the sirup having the appearance of good brandy.

(6) That although eggs were used in these small experiments, on account of their convenience, bullock's blood, if to be had, is equally good, and the milk of lime alone will answer the purpose; in the latter case, however, more constant and prolonged skimming will be required to produce a perfect clarification, which is highly important.

(7) That the concentration or boiling down, after clarification, should be as rapid as possible without scorching, shallow evaporators being the best.

With these conditions secured, it is about as easy to make good sugar from the Chinese cane as to make a pot of good mush, and much easier than to make a kettle of good apple-butter.

EXPERIMENT BY PROF. C. A. GOESSMANN.

In 1857 Professor Goessmann obtained from 1,440 grams of sorghum juice, by two crystallizations and washing the crystals with alcohol, 120 grams of sugar.[1] Professor Goessmann says:[2]

As I before mentioned, J. S. Lovering obtained in practice 7 to 8 per cent. of sugar without estimating the amount left in the molasses. I found from 9 to 9½ per cent. in the juice; and Mr. Wray, an Englishman, who examined several species of sorghum at Cape Natal, on the southeastern coast of Africa, found the percentage almost equal to that of the real sugar cane, 18 per cent. I mention these facts to show what may be expected when the sorghum shall have received the attention of our farmers and have become acclimatized on a suitable soil. The transplantation of a plant to a new and perhaps less congenial climate and soil invariably exerts at first an injurious influence on the vital principle and its products. When the beet root was first cultivated for the manufacture of sugar it contained only 7 to 8 per cent. of sugar, but by the application of proper care to the cultivation and to selecting the best specimens for seed the percentage was increased to from 11 to 12 in some species. Should it be possible to increase the percentage of sugar in the sorghum in the same ratio, its successful cultivation would become an accomplished fact; and our farmers, aided by their superior skill, more perfect machinery, and many other advantages afforded by this country, would be able to compete successfully with the planters of the West Indies.

Between the dates of the experiments recorded above and 1878 hundreds of successful attempts to manufacture sorghum sugar as a by product of molasses were made in the United States. I say successful in the sense that they demonstrated beyond any doubt the possibility of making sugar, although they threw no light on either the scientific or economic problems involved. I therefore omit any further discussion of them here.

Numerous experiments were made by Dr. Collier, chemist of the De-

[1] Sorghum Saccharatum, republished from Transactions N. Y. State Agricultural Society, 1861, p. 21.

[2] *Op. cit.*, pp. 26, 27.

partment of Agriculture in 1878, in the production of sugar from sorghum and maize stalks.[1]

Dr. Collier says of these experiments:[2]

The point which these experiments have fully settled is, that there exists no difficulty in making from either corn or sorghum a first-rate quality of sugar, which will compare favorably with the best product from sugar-cane grown in the most favorable localities.

The experiments here given clearly indicate the probability that sugar may be thus made at a profit, and it is desirable that nothing be spared in continuing an investigation giving such fair promise of success.

The experiments in the production of sugar were continued by the Department of Agriculture in 1879.[3] The sugar was not separated from the molasses except in one case, but the percentage of sucrose in the melada is given.

The melada from Chinese sorghum gave 54.7 per cent. sugar.[4] Some of the analyses seem to show a loss of glucose, and in one instance this loss is given at 144.5 per cent.[5]

On this point Dr. Collier says:[6]

The presence of the same relative proportions of crystallizable and uncrystallizable sugar in a sirup to those present in the juice from which this sirup has been prepared by no means implies that there has been no inversion of the crystallizable sugar; for the destructive action of an excess of lime upon glucose is well known and is not unfrequently made available in the production of sugar. Hence, it not unfrequently happens that the relative quantity of crystallizable sugar in the sirup may be greatly in excess of that present in the juice, even after a large quantity of the crystallizable sugar has been destroyed by inversion.

He adds:[7]

There is no doubt but that when the present industry shall have secured the employment of the capital and scientific ability which has developed the beet-sugar industry, even these results, which may appear extravagant to many, will be assured.

EXPERIMENTS AT THE ILLINOIS INDUSTRIAL UNIVERSITY, CHAMPAIGN, IN 1880.

These experiments were all directed by Professors Weber and Scovell. They undertook a series of experiments to determine the possibilities of manufacturing sugar from sorghum.[8] Twelve experiments with amber and orange cane were made from September 17 to October 2.

In experiment No. 5 the sugar obtained, calculated to 1 acre, amounted to 710.67 pounds.

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[1] Agricultural Report, 1878, pp. 98 *et seq.*

[2] *Op. cit.*, p. 99.

[3] Agricultural Report, 1879, p. 53.

[4] *Op. cit.*, p. 56.

[5] *Op. cit.*, p. 61.

[6] *Op. cit.*, p. 60.

[7] *Op. cit.*, p. 56.

[8] Transactions Department of Agriculture, Illinois, 1880, pp. 423 *et. seq.*

Quantitative determinations were not made in the other experiments. As a result of their work the experimenters were led to make the following statement:[1]

From the results above given it appears that crystallized sugar can be obtained from sorghum of as good a quality as that of the ordinary brown sugars found in the market. A portion of this brown sugar was re-dissolved and the solution passed through boneblack. On evaporation it yielded a white sugar, which had no trace of sorghum taste or smell.

From the proximate analysis of the cane, it appears that 1 acre of sorghum produces over 2,500 pounds of cane sugar. Of this amount we obtained 710 pounds in the form of good brown sugar, and 265 pounds in the molasses drained from the sugar. Hence 62 per cent. of the total amount of sugar was lost during the process of manufacture. This shows that the method of manufacture in general use is very imperfect.

The 710 pounds of sugar at 8 cents per pound would bring $56.80. The molasses is worth 25 cents a gallon, or the products of an acre of sorghum would bring $75.55. There is no doubt that, with proper care and apparatus, the above yield can be doubled.

From our experiments, it seems that about one-half of the sugar remains in the bagasse. This could, no doubt, in part be recovered by the process of percolation, as is sometimes done in the manufacture of beet-root sugar. Experiments will be made this coming season to determine the feasibility of recovering this great loss of sugar.

In 1880 Mr. H. A. Hughes manufactured some sirup from early amber cane near Cape May, N. J. This sirup was sent to a Philadelphia refinery and manufactured into sugar.[2]

EXPERIMENTS AT THE AGRICULTURAL STATION IN WISCONSIN IN 1881.

These experiments were conducted by Profs. W. A. Henry and M. Swenson.[3] Two plots each of two-thirteenths acre area furnished the canes for experiments. On plot A there was made 142 pounds of sugar. On plot B there was made 109½ pounds sugar.

Calculated for an acre, plot A would make 923 pounds, and plot B would make 997½ pounds.

In regard to the character of the season, Professor Henry[4] says:

I would state upon the whole that the season has not been a very favorable one * * * Had sugar been the object with our manufacturers this season, it would have been a very unfavorable one.

Weber and Scovell[5] continued their work and made some very instructive experiments in the manufacture of sugar.

Experiment 1 (August 22):[6]

Weight of cane crushed ....pounds..	1,560.00
Weight of juice obtained ....do....	687.50
Per cent. of juice	43.40

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[1] *Op. cit.*, pp. 431–2.

[2] Fifth Ann. Report N. J. Agricultural Experiment Station, p. 86.

[3] Report National Academy Sciences on Sorghum, p. 85.

[4] *Op. cit.*, p. 92.

[5] Transactions Dept. of Agriculture, Ill., 1881, pp. 500 *et seq.*

[6] *Op. cit.*, pp. 500, 501.

The juice was carefully neutralized with milk of lime and brought to the boiling point in the defecating pan. A very heavy green scum rose, and this being removed, the juice was seen to be full of a green, light flocculent precipitate, which did not subsequently rise to the top in any considerable quantity. The juice was now drawn off into a tub, where it was allowed to repose twelve hours. At the end of this time only about one-half of the juice could be drawn off clear, the precipitate being still suspended in the remainder. It was found impossible to filter this portion, and it was, therefore, thrown away. The clear juice, after being passed through bone-black, was evaporated in a copper finishing pan to the crystallizing point. The melada had a very unpleasant, saltish taste, owing to the presence of salts of ammonia. The sugar crystallized very readily, and although it looked well, it still retained somewhat of this saltish taste after being separated from the molasses.

Experiment 2 (August 25):		
Yield sugar per acre	pounds..	608.7
Yield sugar per ton	do....	77.2
Experiment 3:		
Weight of cane	pounds..	1,440
Weight of melada obtained	do....	145.8
Weight of sugar not given.		
Experiment 4:		
Weight cane	pounds..	1,161
Weight melada from juice	do....	95.5
Weight sugar from juice	do....	41.5

The authors add the following observations:[1]

(1) Seed should be planted as early as possible.

(2) The proper time to begin cutting the cane for making sugar is when the seed is in the hardening dough.

(3) The cane should be worked up as soon as possible after cutting. Cane which cut in the afternoon or evening may safely be worked up the following morning.

(4) The manufacture of sugar can be conducted properly only with improved apparatus, and on a scale which would justify the erection of steam sugar-works, with vacuum pans, steam defecators and evaporators, and the employment of a competent chemist to superintend the business. The same is true for the manufacture of glucose from the seed. Our experiments were made with the ordinary apparatus used in manufacturing sorghum sirup, and any person who desired to work on a small scale could use the methods with good results, provided he had acquired the necessary skill in neutralizing and defecating the juice and in the treatment of the bone-black filters. The manufacture of glucose on a small scale is entirely out of the question. Five hundred to a thousand acres of sorghum would be sufficient to justify the erection of steam sugar-works, and this amount could easily be raised in almost any community within a radius of 1 or 2 miles from the works."

Fourteen quantitative experiments were made by the Department of Agriculture in 1882 in the production of sugar. These experiments are described by Dr. Collier as follows:[2]

In the fourteen experiments which were made, quantitatively, eleven of the sirups were a solid mass of crystals; in two of them two-thirds of the sirups were mush sugar, and in the remaining sample the sirup contained a few crystals of sugar, but the analysis showed that this one had not been evaporated quite to the point of good crystallization.

[1] *Op. cit.* 502, 503.

[2] Investigations of Sorghum, Special Report, 1883, pp. 55 *et seq.*

EXPERIMENTS FOR WHICH AN AWARD OF $1,200 WAS MADE BY THE COMMISSIONER OF AGRICULTURE.

(1) CHAMPAIGN, ILL.

The Champaign Sugar and Glucose Manufacturing Company in 1882 submitted a report of its operations to the Commissioner of Agriculture, of which the following is a summary: [1]

Number tons cane worked for sugar	1,723.99
Number acres cane	185.8
Pounds sugar manufactured	86,603.00
Pounds sugar per ton	50.3
Pounds sugar per acre	465.5

A part of the crop was so poor in sucrose that it was worked for molasses only. The climatic conditions attending the experiments are described as follows: [2]

The weather during this year, so far as planting, cultivating, maturing the crop, and the development of cane sugar in sorghum in this section of the country has been the most unfavorable of any year within our knowledge, and we are informed by those who have grown sorghum and broom-corn that this year has been the most unfavorable season for upwards of twenty years in this section for those crops.

Further difficulties in manufacture are also described.[3]

The company were unfortunate in not having a crystallizing-room, capable of being heated to the proper temperature for the best results in crystallization, and the subsequent purging of the sugar. The room was so cold that the melada was too stiff to arrange itself evenly in the centrifugal without the addition of warm water in the mixer, and even then it was often found impossible to purge without washing with warm water. We took the trouble to make experiments to see how much or what proportion of sugar was being washed down with and into the molasses by reason of the cold. It was done by taking a certain weight of melada, 120 pounds, which was carefully warmed and then swung out. The yield was 56 pounds of dry sugar. The same amount of melada from the same car was swung in the usual way, and the yield was 38 pounds of dry sugar, or a loss of 18 pounds of sugar in a purge, by reason of the cold. We had but a few days of favorable weather, and the results from it compared favorably with the above experiment.

Upon that basis we find that there was uselessly washed away 27,799 pounds of sugar. Add sugar obtained, 86,603, and, with a suitable crystallizing-room kept at a temperature of from 98° to 100°, the sugar product would have amounted to 114,402 pounds. This would have made the yield per ton of 66.3 pounds; yield per acre, 615.7 pounds.

This sugar was actually made, and was lost in separation by reason only of the fact that it could not be kept at the proper temperature. This difficulty can be overcome by having a crystallizing-room and having it kept properly heated.

In the next place sorghum requires hot summer weather for its proper development. As shown in our report, the average temperature during the part of the past season fell far below the usual summer temperature in this section, and was an average of 6° below the average of the same months of last year.

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[1] Encouragement to sorghum, etc., 1883, p. 13.

[2] *Op. cit.*, p. 11.

[3] *Op. cit.*, pp. 17, 18.

(2) REPORT OF PROFESSOR SWENSON.

Magnus Swenson[1] reports three experiments:

	Stripped cane.	Sugar.	Yield per ton.
	Pounds.	*Pounds.*	*Pounds.*
Three and three-fifths acres gave	75,262	2,116.5	56.3
Two acres gave	28,974	1,008	70
One and one-fourth acres gave	17,112	594	69

Owing to the very backward season the growth of the cane was exceedingly slow.[2]

In respect of the purity of the juice Professor Swenson says:[3]

I do not believe that the average juice from the sorghum cane is of sufficient purity to allow of its being boiled to grain in the vacuum pan. I obtained a much coarser sugar by allowing the crystallization to take place in small tanks, and it was consequently much more easily separated.

Compare this with the statement of Professor Weber:[4]

During our season's work in running the vacuum pan for sugar we did not fail at any time to produce crystals therein of proper quantity and desirable size.

(3) REPORT OF MR. PAUL STECK, OF SAN FRANCISCO, CAL.[5]

Four hundred acres of cane were planted. Mr. Steck puts his daily expenses, aside from the cost of cane, at $235.50. His premium of $1,200 therefore only paid his running expenses for a little over five days.

I give below that part of his report where we might expect to find a statement of the quantity of sugar made.[6]

I manufactured from 600 to 650 gallons of sirup per day; average market price 50 cents per gallon. The reason why I could not manufacture sugar in quantity was on account of the juice not crystallizing in the vacuum pan, as cane sugar should do, so I was compelled to let the sirup run into tanks for crystallization. The sirup which I manufactured from this sorghum was superior to any in the market, both in color and taste. The time required in making the alterations necessary and the putting in of large tanks, and other changes which I would have to make, was too short, so I converted the crop into sirup, as above stated. The sorghum sirup has a very slow crystallization, and the room in which it is kept should have a temperature of not less than 105°. It is a very important point in manufacturing sugar from sorghum not to bring the juice to boiling-point, as it checks the crystallization; therefore it should always be evaporated in vacuum pans (what we call single, double, and triple effect), and also the cane brought to the mill should be manufactured into sugar or sirup within twelve to fifteen hours, as the longer it is exposed to air the more sucrose will turn to glucose. There should not be more cane cut in the field than can be worked at the mill each day.

[1] *Op. cit.*, pp. 19 *et seq.*
[2] *Op. cit.*, p. 20.
[3] *Op. cit.*, p. 23.
[4] *Op. cit.*, p. 15.
[5] *Op. cit.*, pp. 23 *et seq.*
[6] *Op. cit.*, p. 25.

In the summary of his report, however, we have the following curious information: [1]

Number of acres of sorghum brought to the mill	300
Number of tons of cane manufactured	3,600
The yield of sorghum per acre ....tons	15
The amount of sugar manufactured (about) ....tons	5
The amount yielded per ton of cane (about) ....pounds	80 to 90

Mr. Steck, it seems, had equal difficulty in making sugar and computing yield per ton. Had heavy floods and frosts not occurred, and the factory had been large enough, Mr. Steck states that he would have made 288,000 pounds.[2] The loss of 278,000 pounds is therefore to be attributed to the unfriendliness of nature.

Mr. Steck closes his report with a promise which he has never performed, viz:

My intention next year is to manufacture sugar from sorghum, knowing the exact process necessary to its manufacture.

(4) REPORT OF NELSON MALTBY, GENEVA, OHIO.[3]

Mr. Maltby makes the following statement of his work: [4]

I worked up cane from 17½ acres; the weight of the cane was 167 tons and 824 pounds, yielding a little over 9½ tons per acre. I made 1,466 gallons sirup not to be granulated. I made 1,095 gallons of sirup for sugar, weighing 12 pounds per gallon, all of which grained well. I made 4,380 pounds good dry sugar from the same. From some cane I made 72 pounds sugar and 112 pounds sirup per ton. The average was 62 pounds sugar and 124 pounds sirup per ton.

(5) REPORT OF DRUMMOND BROS., WARRENSBURGH, MO.[5]

The number of tons of cane manufactured was 243, an average of 9⅙ tons per acre. The greater part of this product did not crystallize.

The sugar obtained was wholly from the Early Amber variety, and amounted to 1,464 pounds, being an average of 50 pounds per ton. Calculated on the whole quantity of cane, however, it is not quite 7 pounds per ton.

Drummond Bros. make no complaint of the unfavorableness of the season.

(6) REPORT OF A. J. DECKER, OF FOND DU LAC, WIS.[6]

Mr. Decker, in competing for the prize of $1,200 for sorghum-sugar making, naïvely remarks in his summary of operations:

	Gallons.
Full amount of sirup made this year	3,600
Vinegar	800
Sugar (not yet swung out).[7]	

[1] *Op. cit.*, p. 25.
[2] *Op. cit.*, p. 26.
[3] *Op. cit.*, pp. 26 *et seq.*
[4] *Op. cit.*, p. 27.
[5] *Op. cit.*, pp. 28 *et seq.*
[6] *Op. cit.*, pp. 31 *et seq.*
[7] *Op. cit.*, p. 36.

The date of Mr. Decker's report is not given. He says, however:[1]

On September 22 and 23 there was a sharp frost. The cane was mostly in blossom and the juice tested 5° B. Three months later it tested less than 6° B. There is, therefore, internal evidence that the report was written later than December 23.

This failure to separate the sugar may have been due to the small capacity of the centrifugal, which[2] "was small, 24 inches in diameter, 6 inches deep, with a capacity of 500 pounds per day."

In respect of the weather we learn:[3]

The season has been the most unfavorable of any known in this locality since the introduction of this crop.

Mr. Decker closes with a number of observations to which the preceding part of his report gives great emphasis:[4]

There are a number of points requisite to the development of sugar from sorghum as well as the process of manufacturing. First, is ripe cane; second, proper appliances; third, "the know how." The long-continued high degree of heat required in open-pan boiling destroys nearly all the sugar long before the required density is reached, and under the most favorable circumstances not more than one pound of sugar to the gallon can be expected from open-pan work, and that does not deserve to be called sugar making yet. I believe with the use of the vacuum pan and the skill to run it, sugar in the West is as certain as making flour from wheat.

(7) REPORT OF WILLIAM FRAZIER, ESOFEA, VERNON COUNTY, WIS.[5]

The weight of cane manufactured by Mr. Frazier was nearly 259 tons, grown on a little more than 41 acres. Mr. Frazier's success in sugar making can not be properly appreciated save in his own words:[6]

My report on this subject can not be what I would like. I am able, however, to send you what I believe to be a pretty fair sample of crude sugar; it was dried from sirup made of Mr. Brigg's cane, dried by draining the sirup through a coarse cloth. Allow me to state here that my object has been sirup, with a view of making sugar in the near future. The most of my sirup was thoroughly grained one week after it was made. Had it granulate in the coolers frequently. My coolers are 8 inches deep and hold 40 gallons each.

On two occasions there was about an inch in the bottom of the second cooler so completely grained that it would not run out, although the melada was quite warm. I now have about 2,500 pounds of sugar in the bottom of sirup tanks, which I intend to throw out in the spring.

Mr. Frazier also finds fault with the weather:[7]

But the expected spring rains failed to come. It continued very dry until the 24th day of June, when nearly 4 inches of rain fell in one day, many heavy rains following, making it impossible to work our crops until the season was far advanced. I re-planted my cane twice, but owing to the cold, dry spring and to the ravages of the grub worm, failed to get half a stand on the 19-acre piece.

(8) REPORT OF THE JEFFERSON SUGAR COMPANY, JEFFERSON, OHIO.

We manufactured 33,250 pounds of melada from the 190 tons of cane worked. We have not separated all of it in the centrifugal as yet; but it is running about 4 pounds per gallon (or for every 12 of melada), from the first granulation. We expect on re-

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[1] *Op. cit.*, pp. 31 and 32.
[2] *Op. cit.*, p. 35.
[3] *Op. cit.*, p. 31.
[4] *Op. cit.*, p. 36.
[5] *Op. cit.*, pp. 36 *et seq.*
[6] *Op. cit.*, p. 38.
[7] *Op. cit.*, p. 41.
[8] *Op. cit.*, p. 46.

boiling twice to raise the figures to 7 pounds. Last year we got 6 pounds in every 12, with two boilings, from some of the best cane. If we do not succeed in getting more than 6 pounds per gallon, we will have from the above figures 16,625 pounds sugar. This would be nearly 90 pounds sugar per ton of cane, and about 700 pounds per acre of land. We feel assured of this much from the yield of that already separated; but we hope to obtain an average of 7 pounds per gallon from all of the cane worked for sugar during the present season. If cane had fully matured we should not want to stop with less than 8 pounds per gallon.

The weather, as usual, was bad:

The last two seasons have been the most disheartening ones for developing this new industry that our country has seen for years.[1]

(9) REPORT OF THE OAK HILL REFINING COMPANY, EDWARDSVILLE, ILL.[2]

The report says:[3]

And now we must state plainly that we have not manufactured sugar *on a business scale* this season. That is, we have simply made a small quantity as samples of our work, and contented ourselves with turning out the greater part of our products as sirup. We did this for several reasons.

In the first place, during the two previous years the juice, at its best (and seldom so), had been on the ragged edge; that is, scarcely enough sugar to crystallize under the most favorable circumstances. In 1880–'81 the best "quotient of purity" (*i. e.*, polarization divided by solid contents) was about equal to the lowest boilings in a sugar refinery, where a vacuum pan is needed, and three weeks' storage in a "hot room" to insure a yield of 25 per cent. in sugar, and afterwards a bone-black filtration to give the sirup a salable color. In 1881–'82 the cane, if anything, was poorer; we had fine-looking ripe cane, the stalks of which were sticky with exuded juice; it had been in the society of the chinch-bug, and the juice polarized from 1 to 2 per cent. This year the chinch-bug had been hard at work improving the time as far as possible, and we knew what to expect.

As to the weather, etc., the report says:[4]

The past three years the chinch-bugs have been very troublesome in this section. They have done great damage to the cane crop, especially severe in dry seasons, as the past three have been.

(10) REPORT OF C. BOZARTH, CEDAR FALLS, IOWA.[5]

Mr. Bozarth introduces his report as follows:[6]

I want to preface by stating that I have been in the business twenty-four years, and this has been the worst year for cane that we have had for sixteen years. We had a very cold, wet, backward spring. The cane was four weeks coming up, after which there were a number of hard frosts, the weather continuing cold and wet up to July, which so delayed the crop that it was not much past the bloom when frost came again on the 22d of September, leaving the cane poor in sweetness and weight, both marking only 6° to 8° Baumé and averaging not more than 7°. I have made but little sugar this season, hardly enough to pay for running through the centrifugal machine, and inasmuch as the sirup is a good price I have not thought best to put it through for the little that is in it, although there is a considerable granulation through all my sirup, fully as much this year as I could expect, and more, considering the quality of cane. Last year I had 5,000 pounds that sold in the market for

[1] *Op. cit.*, p. 43.
[2] *Op. cit.*, pp. 47 *et seq.*
[3] *Op. cit.*, p. 51.
[4] *Op. cit.*, pp. 55.
[5] *Op. cit.*, pp. 57 *et seq.*
[6] *Op. cit.*, p. 57.

8½ cents per pound, and the year before 15,000 pounds that sold for 8 cents per pound. I raised this year on my own farm 85 acres, which was all worked without stripping.

The introduction contains all there is in this report concerning the production of sugar.

The results of the experiments just abstracted are appropriately preceded by a summary made by the Commissioner of Agriculture of the experiments which had been made up to that time by the Department of Agriculture in the production of sugar from sorghum. He says:[1]

On assuming the duties of my office in 1881 I found 135 acres of sorghum, containing fifty-two varieties, which had been planted in Washington for the use of the Department. On being informed that the time had arrived for manufacturing sirup and sugar, I engaged the services of an expert in sugar-making who had been highly recommended for the position of superintendent, and operations were commenced on September 26 at the mill erected by my predecessor on the grounds. These operations were continued with slight interruptions until the latter part of October, at which time the supply of cane became exhausted. Forty-two acres of the crop were overtaken by frost before being sufficiently ripe for use, and this portion of the crop was so badly damaged as to be unfit for manufacture. The yield of cane per acre on the 93 acres gathered was 2½ tons; the number of gallons of sirup obtained was 2,977, and the number of pounds of sugar was 165. The expense of raising the cane was $6,589.45, and the expense of converting the cane into sirup and sugar was $1,667.69—an aggregate of $8,557.04.

To recapitulate the results of the ten experiments I give the following table:

Sugar made.	Pounds.
No. 1	86,603
No. 2	3,718.5
No. 3 (about)	10,000
No. 4	4,380
No. 5	1,461
No. 6	0,000
No. 7	0,000
No. 8 (estimated)	10,000
No. 9	0,000
No. 10 ("a little")	....
Total sugar	116,165.5

Amount of premium given, $12,000. Amount per pound (nearly), 10.3 cents.

BY THE DEPARTMENT OF AGRICULTURE.

PRACTICAL.

Attempts were made in 1881 by the Department of Agriculture to manufacture sugar at Washington. Cane from 93.5 acres was crushed. From the official report it does not appear that any success attended these efforts.

The causes of failure are thus set forth by Dr. Collier:[2]

Briefly stated, the several chief sources of failure are as follows:

(1) The immaturity of the sorghum at the period when it is cut and worked. This may be due to late planting, as in our experience the past season, or to the selection

[1] *Op. cit.*, p. 3.

[2] Agricultural Report, 1881–2, pp. 509 *et seq.*

of a variety which requires more time for its complete maturity than the season in any given latitude may give. The importance, then, of selecting only such varieties as will mature sufficiently long before frosts, so as to give a reasonable time to work up the crop, can not be overestimated.

(2) Another frequent cause of failure is due to allowing the sorghum to remain some time after being cut up before it is worked at the mill. That such a course may be pursued in certain seasons and in certain localities without producing an unfavorable result has been established beyond much doubt, but the climatic conditions which render such a procedure possible are imperfectly understood at the present, and repeated experiments have demonstrated that after being cut up the juices are subject to chemical changes which speedily result in the destruction of the crystallizable sugar. For the present, then, the only safe course to pursue is to work up the cane within at most twenty-four hours after it is cut up.

(3) A third cause of failure exists in an imperfect method of defecation of the juice. The object of defecation and the method by which it is accomplished should be carefully studied and as thoroughly understood by the sugar-boiler as is possible, for, although somewhat complex in its details, the general principles which underlie this important step are few and easily comprehended.

The report of the engineer in charge of the work, Mr. J. H. Harvey, gives the following summary :[1]

Cane crushed	pounds..	458,444
Juice obtained	gallons..	26,794
Sirup obtained	do....	2,977
Sugar made	pounds..	165

Mr. Peter Lynch, sugar expert, makes the following statement concerning the work:[2]

Peter Lynch, who had the general management of the sorghum business, superintending its manufacture into juice, sirup, and sugar, says that he has had fifteen years' experience as a sugar-boiler with Cuban molasses, cane sugar, grape sugar, etc.; that of the 206½ gallons of light sirup obtained October 5 and 6, 1881, there were from 175 to 200 pounds of sugar obtained—nearly 1 pound per gallon. It was good sugar, worth 8 to 9 cents a pound, wholesale; would polarize between 96 and 98. No special means were used to obtain this result. It was boiled to a proof that would granulate. The juice from which this was made contained on an average from 2.8 to 3½ per cent. of glucose and from 11 to 13½ per cent. of cane sugar.

The mill worked excellently, and every particle of juice possible was extracted. Had this same quality prevailed with all the season's juice, the same average quality of sugar would probably have been obtained every day.

The only canes really worth anything were those worked that day. On other days the proportion of glucose was greater, owing to bad cane. Do not think the quality of sirup made this year as fair an average as might be expected with fair soil, fair climate, etc. Good soil ought to raise from 16 to 18 tons of stripped stalks.

For the results of the season's work no blame can be attached to the machinery or anything else. The only cause for failure to make sugar was that the cane was not sufficiently ripe.

In 1883 572,350 pounds of sorghum cane were worked for sugar by the Department at Washington. The machinery employed was that used by Dr. Collier in the work of 1881.

The quantity of sugar made was 7,160 pounds, or 1.24 per cent. of the cane worked, or 24.8 pounds per. ton.[3]

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[1] *Op. cit.*, p. 522.

[2] *Op. cit.*, p. 523.

[3] Department of Agriculture, Division of Chemistry, Bulletin No. 3, p. 43.

Forty-two tons of clean cane grown in Indiana were also worked for sugar. The quantity made was 2,860 pounds, or 3.39 per cent., equal to 67.8 pounds per ton.[1]

Further attempts were made by the Department in Ottawa, Kans., in 1885 to manufacture sugar from sorghum. The process of diffusion was employed. Expensive machinery was provided and one satisfactory trial was made. Unfortunately the actual number of tons of cane used could only be estimated. The estimate was based on the weight of *masse cuite* obtained, and is without doubt very nearly correct. The quantity of sugar made was 1,420 pounds, estimated at 95 pounds per ton.[2] A subsequent trial failed to produce any sugar.[3]

Further attempts were made by the Department in 1886 to manufacture sugar from sorghum at Fort Scott, Kans. The diffusion process was employed. The average weight of *masse cuite* was 12 per cent. of the weight of the cane used.[4] The weight of cane worked for sugar was 2,322 tons.[5] The weight of sugar made was 50,000 pounds.[6] Weight sugar per ton, 21.6 pounds.

MANUFACTURING TRIALS WITHOUT THE DEPARTMENT.

I could not give here all the incidental attempts at making sugar which have been made in connection with the manufacture of molasses from the time of the introduction of the sorghum plant into this country to the present time. I will confine myself to a brief review of the attempts which have been made to produce sugar.

CRYSTAL LAKE, NEAR CHICAGO.

I believe the first attempt to make sugar from sorghum on a large scale in this country was at Crystal Lake, near Chicago. The factory was under the direction of Mr. J. B. Thoms. According to the report of the National Academy of Sciences on sorghum—[7]

> In 1879, with a "miserable mill," he obtained juice of 8½° B. (specific gravity 1,060), and from a gallon of sirup weighing 11 pounds got a yield of about 4½ pounds to the gallon. He obtained from 15 to 23 gallons of sirup to the ton of cane, weighing 11½ pounds to the gallon, the sirup yielding 4½ pounds sugar, polarized 53°. Of amber cane, which is the only sort he has worked, has known as high as 21 tons cut to an acre, and states 12 tons as an average. He sold of the crop of 1879 over 50,000 pounds of good C sugar, which was tested in Boston and New York, and polarized 96½ per cent. of sugar. In 1880 his crop of about 300 acres was nearly all destroyed by a hurricane and the product of about 30 acres of damaged cane was all made into sirup, which polarized only 42 per cent.

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[1] *Op. cit.*, p. 52.

[2] Department of Agriculture, Div. of Chemistry, Bul. No. 6, p. 9.

[3] *Op. cit.*, p. 13.

[4] Department of Agriculture, Div. of Chemistry, Bul. No. 14, p. 36.

[5] *Op. cit.*, p. 35.

[6] *Op. cit.*, p. 36.

[7] Report Nat. Acad. of Sciences, p. 36.

Further data concerning operations at Crystal Lake and Hoopeston I give in quotations from the communication of Mr. Thoms to the committee of the National Academy:[1]

In the first place let me state to you I am a practical sugar refiner; spent some eight years in the West Indies making sugar from cane. So you will perceive I came here well armed in the knowledge of the business of sugar making. In August, 1879, I saw sorghum for the first time, and although the works were put up by inexperienced persons, besides being so near the time for grinding the cane, we had not much chance to make the necessary alterations, so had to get along as well as we could; and as the cane was new to me, and I had little or no faith in its sugar-producing qualities, I resolved to treat it with as much delicacy as a mother would her sick child.

In consequence of the vacuum-pan boiling the sugar so hot, and not being familiar with the juice, and wishing to get as large a yield of sugar as possible, I boiled it rather stiff, which made the grain finer than I wished it, but to the experienced that did not detract one iota from its strength. I continued to run until I had made over 50,000 pounds of sugar.

In 1880 we had made alterations in order to do some pretty good work; planted about 300 acres of cane, and a month before it matured it was struck by a hurricane and damaged to such an extent that we received only the product of 30 acres; that, mixed with dead cane, rendering the juice so bad that the sirup only polarized about 42 per cent. Boiled some for sugar, but finding it very gummy abandoned the idea and made only sirup. Thus ends the chapter for 1880. In 1881 the spring was so backward our cane hardly matured, and the sirup from it polarized about the same as the previous year (42½ per cent). Having such bad luck the past two years at Crystal Lake, Ill., where the above experiments were tried at the works of F. A. Waidner & Co., we have concluded to abandon any further work at the above place. I should here state that Crystal Lake is the most elevated section in the State of Illinois which makes raising a crop there rather uncertain; although the old residents of the place say they never experienced two such years with sorghum as 1880 and 1881; indeed, that is the general verdict throughout the country. Crystal Lake is situated about 44 miles north of Chicago. I am interested in a large works at Hoopeston, Ill., which is attached to a corn-canning establishment erected for the purpose of utilizing corn-stalks. That we found was no go, as the stalks had but little juice; could not produce enough sirup to pay expenses. I consider the corn-stalks had a thorough test. We found only about a foot or a foot and a half of the stalk to contain juice; the rest was a dry pith. At the time the corn was in the roasting-ear. The corn-stalks were tested in 1880. In 1881 we cultivated 500 acres of sorgo, and the drought was so severe we only got about 2½ tons to the acre, instead of from 10 to 20. Cane was very thin and in some instances not over 2 or 3 feet long, sirup only polarizing 40; did not attempt to make sugar. This year we are putting under cultivation at Hoopeston 1,000 acres. We sold all of our product last year by the car-load in this city at 50 cents per gallon.

Notwithstanding I have been here three seasons I have not had a single day's fair trial of sorgo juice. With the plant of machinery we have at Hoopeston now to work up juice such as I had in 1879, I am sure the results I could produce would astonish the country.

I am satisfied of one thing, that the cultivation of the cane is not thoroughly understood. One great drawback here has been the want of proper machinery and a knowledge how to treat the juice. They imagine all that is necessary is to boil out the water and let nature do the rest.

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[1] *Op. cit.*, pp. 119, 120.

I have been a very careful student for the last three years, and consider myself now familiar with the juice, and just want one fair chance. They were thirteen years in Louisiana before they could successfully make sugar from ribbon cane. We did it here in six weeks."

I will add that the further attempts to make sugar at Hoopeston were total failures, and both factories have been abandoned and dismantled.

FARIBAULT, MINN.

In 1879 a factory was built at Faribault, but no sugar was made.[1] In 1880 5,000 pounds sugar were made.[2] In 1881 there are several conflicting reports of the amounts made. Blakeley reports 7,000 pounds.[3] He also reports the amount at 11,000 pounds.[4] The total amount made during the season is also given at 15,000 pounds.[5]

The manufacture of sugar having proved financially unsuccessful further operations were abandoned and the factory closed.

CHAMPAIGN, ILL.

A large factory was built at Champaign, Ill., in 1882. This factory was under the immediate supervision of Professors Weber and Scovell. Professor Weber says:[6]

As a result of the experiments carried on by the writers in the seasons of 1880 and 1881 the Champaign Sugar and Glucose Company, of Champaign, Ill., was organized. The object of the company was to carry out on a commercial scale the production of sugar and glucose from sorghum, as was indicated by our laboratory experiments. The company was organized with a capital stock of $25,000. The total expenditure for building the works and raising the crop, however, exceeds $30,000.

The committee of the National Academy[7] say:

In 1882 the results of the sugar mill at Champaign, Ill., are reported as being very satisfactory to owners.

Several hundred thousand pounds of white sugar were made in that and the two following seasons. The venture, not proving profitable, was abandoned.

HUTCHINSON, KANS.

This factory was built in 1882, but the first year failed to produce any sugar. In 1883 about 200,000 pounds of sugar were made, but at a heavy loss.

In 1884, 250,000 pounds of sugar were made, but still with a loss. Further attempts were then abandoned and the factory has been dismantled.

STERLING, KANS.

The first season's work of this mill, 1882, resulted in the production of a very small quantity of sugar. In 1883, 170,000 pounds were made.

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[1] Blakeley, Report Nat. Acad. Sciences on Sorghum, p. 35.

[2] *Op. cit.*, p. 35.

[3] *Op. cit.*, p. 36.

[4] Third Ann. Meeting Wis. State Cane-Growers' Association, p. 33

[5] Report Nat. Acad. of Sciences on Sorghum, p. 30.

[6] *Op. cit.*, p. 78.

[7] *Op. cit.*, p. 34.

In 1884 a little over 100,000 pounds sugar were manufactured and the business was then abandoned as unprofitable.

FRANKLIN, TENN.

The disasters which attended the fortunes of this company, 1883–'84, were not softened by the production of sugar. The young sugar-boiler at first secured a few crystals in his pan. Each day, however, the results were poorer, "and at the end of one week no trace of sugar could be found, and in mortification he left without notice and has not yet been heard from."[1]

OTTAWA, KANS.

A large glucose factory here was converted into a sorghum-sugar factory. Sugar was made in considerable quantities in 1884 and 1885, and the house was then shut up, the business being attended with financial loss.

RIO GRANDE, N. J.

This factory is the most extensive and thoroughly equipped of any sorghum-sugar house ever built in the United States.

For five successive seasons from 1882 it was conducted with the highest skill. With the aid of a State bounty of $1 per ton for the cane and 1 cent a pound for the sugar, the company was able to hold together financially. With the close of 1886 the State bounty expired and the factory has now been closed and dismantled, since it could only be run at a loss without the bounty. In all nearly 1,500,000 pounds of sugar have been made by this company.

In speaking of the operations of the large factories the committee of the National Academy says:[2]

> One signal success, on a large scale, obtained by intelligent attention to the results of experimental research and skillful culture, opens the way to a repetition of like results.
>
> It is from the States of New Jersey and Illinois that we are able to cite examples of success on so large a scale and attended with such a satisfactory result as fairly puts to rest any doubts as to the production of sugar, on a great scale, in a northern climate with a commercial profit.

How sadly the members of the committee suffered themselves to be deceived the financial ruin of the above two "successes" has attested.

At the present time, May, 1888, there remains only one sorghum-sugar factory on a large scale in the country, viz, at Fort Scott, Kans. One is building at Topeka and one at Conway Springs, Kans. Col. Cunningham, Sugar Lands, Tex., is also preparing to make sorghum sugar in connection with the sugar-cane.

DISCUSSION OF THE DATA.

Having thus collected from every available source the results of the analyses of sorghum juices made by different investigators, except those

[1] Department of Agriculture, Div. of Chemistry, Bull. No. 5, p. 165.
[2] Report National Academy of Sciences on Sorghum, pp. 30, 31.

recorded in Bulletin 17 and Professor Stubbs's Bulletin No. 12, it ought to be possible to weigh them justly and to form some approximately accurate idea of the value of sorghum as a sugar producer.

First of all, it will be necessary to divide the analytical data into two classes, viz: (1) Data derived from the analyses of small samples, in other words, experimental data, and (2) those obtained from analysis of large quantities of material entering in the process of manufacture; in other words, manufacturing data.

I have collected below all the mean analyses of experimental samples, and have obtained therefrom a general average of the character of all the juices which have been analyzed in a small way.

BY THE DEPARTMENT.

Authority.	Sucrose.	Glucose.	Total solids.
	Per cent.	*Per cent.*	*Per cent.*
Wetherell	4.29	6.08	....
	4.13	7.00	....
	6.19	3.65	....
Erni	10.31	2.07	....
Antisell	11.10	8.90	....
	7.86	4.38	....
	5.94	3.60	....
Collier	14.60	....	....
	13.80	....	....
	13.80	....	....
	14.60	....	....
	10.83	2.44	....
	12.41	2.47	....
	13.17	2.14	18.41
	10.95	2.95	17.08
	9.89	3.85	....
	8.45	2.90	....
	9.88	2.17	....
	10.48	1.33	....
	11.45	1.20	....
	12.25	1.12	....
	12.63	1.45	....
	10.29	3.21	15.34
	14.64	1.87	18.05
	11.79	1.15	15.97
	13.31	0.93	17.52
	12.44	1.23	16.35
	14.35	2.85	20.18
Wiley	9.04	4.08	14.81
	13.25	2.30	....
	10.73	3.71	....
	8.54	5.99	....
	10.68	3.25	15.36
	12.78	1.77	17.78
	9.32	4.99	15.27
	14.90	1.32	19.90
	14.83	1.25	20.96
	14.72	1.22	19.59
	14.60	1.18	20.67
	14.48	1.99	19.41
	15.73	1.57	20.68
	15.89	1.36	20.58
	15.05	1.99	20.90
	11.24	2.44	17.00
	9.62	2.85	15.60
	9.83	3.41	15.20
	10.23	2.11	15.16
	8.64	2.95	14.40
	8.54	3.11	14.54
	8.81	2.61	14.40
	12.45	1.99	17.26
	12.46	2.09	17.31
	12.15	2.06	16.77
	10.49	4.01	17.56
	8.70	4.15	16.60
Averages	11.34	2.80	17.37

ANALYTICAL DATA OBTAINED WITHOUT THE DEPARTMENT

Authority.	Sucrose.	Glucose.	Total solids.
	Per cent.	*Per cent.*	*Per cent.*
Browne	7.00	3.00	....
	11.00	5.00	....
Jackson	10.33	5.67	....
Smith	11.00	2.20	....
Goessmann	10.94	....	....
Lovering	5.01	....	....
	5.57	....	....
	7.29	....	....
Leplay	9.35	....	....
	17.81	....	....
Goessmann	5.00	6.35	14.42
Hilgard	10.10	....	14.80
Weber & Scovell	9.61	4.43	....
Weber	9.77	3.00	....
Hilgard	11.89	....	....
Weber & Scovell	8.56	4.84	....
	11.95	3.21	....
	11.18	2.85	....
	12.08	2.47	....
Henry & Swenson	9.50	3.20	15.00
	10.63	2.68	....
	10.50	4.95	....
	7.00	4.20	....
	8.07	5.12	....
Weber & Scovell	8.20	3.66	....
	10.17	2.48	....
Henry & Swenson	10.75	3.09	....
	9.89	....	....
	12.10	....	....
	11.20	....	....
	10.59	2.85	....
	9.50	5.00	....
Pirotta	8.20	6.53	17.14
	14.84	5.14	22.60
	15.10	5.81	23.50
	18.01	4.17	24.50
Wiley	7.17	5.15	14.70
Monselise	11.35	5.78	18.60
Zanelli & Spallanzani	13.99	4.97	....
	11.55	7.82	....
Hilgard	8.10	....	17.00
Armsby	6.15	3.32	12.00
	7.89	3.22	13.50
Swenson	9.30	2.80	14.20
	8.70	3.50	13.10
	10.30	2.13	13.20
	10.20	3.40	15.20
Scovell	7.45	3.83	14.41
Failyer	11.72	1.45	15.35
	6.13	2.83	11.12
	11.[illegible]2	1.06	14.91
	9.76	3.29	15.00
Stewart	12.50	2.23	16.50
Henry	8.93	2.34	....
Neale	7.96	....	....
	9.88	....	....
	7.25	....	....
Stubbs	11.92	....	16.34
Neale	8.93	....	12.99
Willcox	9.00	....	....
Cook & Neale	8.80	....	....
	10.16	....	....
	13.16	....	....
	12.20	....	....
	15.16	....	....
	9.39	....	....
	10.12	....	....
	7.22	....	....
	9.49	....	....
	9.87	....	....
	[illegible].44	....	....
	8.11	....	....
	10.30	....	....
	9.88	....	....
	7.95	....	....
Averages	10.00	3.83	15.99

Means of the two sets of data:

	Per cent.
Sucrose	10.67
Glucose	3.32
Total solids	16.68

The means of the above means of experimental analyses show that, taken as a whole, even small quantities of sorghum have not been particularly suitable for sugar-making.

If, however, we study the analyses in detail, it will be seen that the sorghum often develops a surprisingly high content of sucrose, an amount in fact which, could it always be produced and kept long enough to allow of its manufacture, would place sorghum in the front rank of sugar-producing plants.

ANALYSES OF JUICES EMPLOYED IN MANUFACTURE.

We turn with lively interest from the experimental laboratory to the large factory.

Unfortunately the promises of a laboratory experiment are not always performed in actual practice, and in the case of sorghum sugar-making this fact is emphasized.

Following are the means of the analyses of samples of large quantities of sorghum juices entering into the defecating pan.

The lessons which these mean analyses teach us of the nature of sorghum juice when produced on a large scale for manufacturing purposes are far more valuable from a practical point of view than the teachings of an experimental laboratory.

The mean analyses are taken from the data already given. Those from Weber and Scovell and Weber are from the factory at Champaign, Ill.; those marked Scovell from the factory at Sterling, Kans.; those marked Swenson from the Hutchinson factory; those marked Collier from the large operations conducted by the Department of Agriculture at Washington; those marked Neale and Hughes from the factory at Rio Grande, N. J., and those marked Wiley from the large operations carried on at Washington, Helena, Wis., Ottawa and Fort Scott, Kans.

The means of these analyses show as accurately as possible the character of sorghum grown on a large scale in the United States from 1880 until the present time.

These are figures which do not deal with the future and the ideal, but set forth in a convincing light what has actually been accomplished in the growing of sorghum as a sugar-producing plant on a large scale.

I believe I have incorporated in these general means the average numbers representing the composition of all the sorghum juices which have entered into manufacturing on a large scale of which analyses have been made:

Means of analyses of sorghum juices manufactured into sugar.

Analysts.	Sucrose.	Glucose.	Total solids.
	Per cent.	*Per cent.*	*Per cent.*
Collier	6.94	6.38	15.22
Wiley	8.38	4.09	14.06
	6.73	6.16	....
	7.85	5.00	....
	9.23	3.04	15.07
	9.73	3.65	16.15
	7.78	4.56	15.99
	7.28	3.74	14.80
	7.52	5.80	14.50
Weber	7.78	4.76	....
Swenson	11.10	3.30	15.70
Hughes	11.11	....	....
	9.75	....	....
	10.25	....	....
	8.76	....	....
Neale	6.54	....	....
Averages	8.54	4.59	15.19

We come, therefore, to the somewhat surprising result that the mean percentage of sucrose in the juices of sorghum grown on a large scale and entering into the manufacture of sugar in the United States during the past six years is only 8.54 per cent.

The mean co-efficient of purity of these juices is 56.2 and the per cent. of available sugar on the basis of difference between per cent. sucrose and sum of the percentages of other solids, 1.89. Allowing an average extraction of 60 per cent. of the weight of cane, the theoretical yield per ton for the time indicated, supposing there was no loss in manufacture, would be 22.68 pounds. By diffusion extracting 93 per cent. of the sugar, and calculating available sugar as sucrose less glucose multiplied by 1.4, the theoretical yield per ton would have been 35.5.

These figures need no comment. They show beyond any question that the failure to make sorghum sugar profitably in this country has not been due alone to defective machinery nor lack of skill, but chiefly to the quality of the cane which has been used.

These practical results are strongly in contrast with the conclusions of the committee of the National Academy of Science, who, basing their statements on the results of the analyses of small samples of carefully cultivated cane, reached results which in no manner represent the actual data of experience. The committee says:[1]

> These analyses have shown the constitution of the juices of each variety at the successive stages in the development of the growing plant. They not only confirm the well-known fact of the presence of sugar in the juices of these plants in notable quantity, but they also establish beyond cavil what seems surprising to those who have not examined the facts, that the sorghum particularly holds in its juices, when taken at the proper stage of development, about as much cane sugar as the best sugar-cane of tropical regions.

[1] Report National Academy of Sciences on sorghum, p. 43.

It is particularly unfortunate that such a fallacious conclusion should have been published on such high authority, not so much because of the harm it has done and will do, but chiefly because it is constantly used by unscrupulous persons to bias the minds of those who have not time to investigate this matter for themselves, thus hindering the knowledge of the truth.

A strenuous effort has been made in certain quarters to convey the impression that nothing has been learned about sorghum since the report of the Academy was published and that any person who calls in question its infallibility is unworthy of public confidence.

But what shall we think of the care exercised by the committee in forming its conclusions on this matter when we find it at the same time indorsing the corn-stalk sugar theory in the following terms? [1]

By reference to the tables it will also be seen that of the eight varieties of maize examined in 1881, seven of which were of common field and one of sweet corn:

	Per cent. of cane sugar.
3 analyses of 3 varieties gave over	13
9 analyses of 7 varieties gave over	12
22 analyses of 7 varieties gave over	11
29 analyses of 7 varieties gave over	10
35 analyses of 7 varieties gave over	9

Of ten varieties of maize grown in 1880, the following results were obtained:

	Per cent. of cane sugar.
124 analyses of 10 varieties gave over	9
90 analyses of 10 varieties gave over	10
59 analyses of 9 varieties gave over	11
24 analyses of 9 varieties gave over	12
8 analyses of 4 varieties gave over	13
2 analyses of 1 variety gave over	14
1 analysis of 1 variety gave over	15

In 1880 over 62,000,000 acres of our land were in maize, or 38 per cent. of all the cultivated land of the United States. The amount of sugar thus apparently lost, calculated on the results obtained at the Department of Agriculture in the last three years, is equal to the present product of the entire world. It is premature to say that the profitable extraction of sugar from corn-stalks is demonstrated, but such a result may yet be possible.

The only trial on a large scale for extracting sugar from corn-stalks of which we have record will be found in the statement of J. B. Thoms, of date April 10, appended to this report (p. 119), and was not a success. *It is possible that if the maize had been allowed to mature, in place of being cut when the ear was in an immature state fit for canning, the result might have been different.*

I have taken the liberty of italicizing the last sentence, since it is one of the most remarkable scientific generalizations that has ever met my view.

I will add that the committee were extremely modest in limiting the corn-stalk sugar to the whole sugar production of the world. Sixty-four million acres of maize would give not less than 640,000,000 tons of corn-stalks. The mean per cent. of sucrose as given by the committee is 11.6. The total quantity of sugar which is, therefore, annually wasted

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[1] *Op. cit.*, pp. 44 *et seq.*

in our corn stalks is 74,240,000 tons. Since the annual production of sugar for the whole world is only 6,000,000 tons, it is seen that by a failure to utilize the means of wealth which were so carefully pointed out we waste a quantity of sugar twelve times larger than the whole product of the world.

But this is a theoretical computation. Let us take the actual yields which the committee found had been obtained:[1]

It will be seen that in successive years there was also obtained from the stalks of common maize, *after the ripened grain had been plucked*, at the rate of 900 pounds of sugar to the acre. It also appears from the correspondence submitted that many parties have practically secured results nearly equal to these in their work.

At 900 pounds per acre 64,000,000 acres would give 57,600,000,000 pounds, or 28,800,000 tons.

Those of us who have been brought up on a farm and know by experience the exceptionally juicy and saccharine character of the corn stalk when the ears are fully ripe can appreciate the explanation which the committee makes of Mr. Thoms' failure to secure sugar from the stalks. *Credat Judæus Apella.*

The above opinions show the danger of forming conclusions which from insufficient data or from data which are partial, are not safe guides to the whole truth.

It is evident, therefore, that the committee of the academy, having now before them the data derived from the attempts at manufacture on a large scale, to which I have referred, would compile a summary wholly different from that given in their report.

There is one fact, however, which is emphasized in the analytical data which demands careful attention. It is seen by numerous analyses of the juices of a single or a few stalks of sorghum that they are capable of furnishing a large yield of sugar.

The question therefore arises, "May not a whole crop of this kind be produced?"

Without referring to the analyses which were made before, it will be sufficient to cite those made by the Department at Fort Scott, Kans.

I call attention first to some analyses made of the juices of a few canes expressed by a small "hand-mill":[2]

Date.	Sucrose.	Glucose.	Total solids.
	Per cent.	*Per cent.*	*Per cent.*
Sept. 19	13.54	2.97	20.00
Sept. 22	14.50	2.77	21.20
Sept. 24	13.53	2.41	18.70
Sept. 30	12.39	3.76	17.80
Oct. 2	14.50	1.77	20.20
Oct. 3	14.37	2.16	20.70
Oct. 5	13.20	2.37	19.70
Means	13.72	2.60	19.76

[1] *Op. cit.*, p. 48.

[2] Department of Agriculture, Div. of Chemistry, Bul. No. 14, p. 15.

With such cane juices, although they are not as pure as the average sugar-cane juice in Louisiana, it would not be difficult, in my opinion, to make sugar profitably. The data which I give are easily duplicated in those of former years, but this point is so well settled that I will not dwell longer on it here.

In contrast with this I will cite an equal number of analyses made in the same circumstances:[1]

Date.	Sucrose.	Glucose.	Total solids.
	Per cent.	*Per cent.*	*Per cent.*
Sept. 16	7.04	7.80	19.00
Sept. 23	3.60	11.36	20.30
Oct. 1	8.37	4.95	15.50
Oct. 5	9.95	4.88	18.80
Oct. 9	4.55	9.62	18.30
Oct. 12	6.65	4.72	14.40
Oct. 13	5.71	11.41	21.50
Means	6.56	7.82	18.26

It seems almost incredible that two sets of analyses so entirely different in their results could have been made on samples taken in identically the same manner. This remarkable fact discloses the great difficulty which the sugar maker working on sorghum has to encounter, viz, the unreliability of his raw material.

This difference between seven of the best analyses and seven of the poorest ones, made during the same season, is not more remarkable, however, than the differences between two sets of such experiments made under similar conditions by the New Jersey station.

In the data already quoted we find:

	1883.	1886.
Sucrose in juice..........per cent..	15.16	7.95
Total sugar per acre......pounds..	3,963	9.05

These two illustrations set forth in a most striking form the tendency to acute and extensive variations which the sorghum plant has shown ever since its introduction into this country.

The worker in sugar cane and sugar beets is reasonably sure of his material. What it is to-day it will likely be to-morrow and so continue sensibly until the end of the season. Unhappily the sorghum-sugar worker has no such assurance. The same variety of cane, in the same degree of maturity, will show the most surprising differences in the sugar content of its sap.

Prof. Hippolyte Leplay has noticed this variation especially, from year to year, and has ascribed it to the process of degeneration. He says:[2]

The culture and distillation of sorghum cane had given such important results in Algiers that Mr. Hardy, director of the Central Government nursery at Algiers, announced, as results of his experiments, that from 1 hectare (2.47 acres) of sorghum,

[1] *Loc. cit.*

[2] MS. to author, p. 5 *et seq.*

when the price of alcohol was 171 francs per hectoliter (26.40 gallons), he could realize a profit of 8313 francs, and with the price of alcohol as low as 70 francs per hectoliter, the profit from 1 hectare would be 3340 francs.

Under the influence of these encouraging results, the question as to the culture and distillation of sorghum could not be doubtful.

The most important establishments were able to distill from 8,000,000 to 10,000,000 kilograms of sugar cane in the districts of Haute-Garonne, Pyrénées-Orientales of Vaucluse, and in Algiers.

Five years later, that is to say, in 1862, all this grand agricultural and industrial movement had disappeared, all the large and small distilleries had closed, with great losses, and the culture of sorghum cane was almost entirely abandoned.

What have been the causes of these great reverses after the grand success of the beginning so generally and so well established?

Certain circumstances have led the author of this article to occupy himself personally in the culture of sorghum, mostly with a view to its industrial utilization. He took an active part in the grand movement of which sorghum was the object in 1856 to 1862; he has followed all the phases of its prosperity and of its decadence as propagator and as victim; he has been able to study the causes of the failure and the means of avoiding it, but the discouragement from all sides became too great for him to examine with coolness and mature thought or to attempt new efforts. In 1863 he finally abandoned sorghum, which every one else had already given up, as the captain abandons his ship at last, when it sinks under his feet, and the distillery "St. Michel," at Avignon, was, like the other establishments, closed up and abolished. Since that time, and until within the last few years, sorghum has given no signs of life and no further publications upon the subject have been made; but generations pass, the defeats of the past lose their intensity, prejudice is dissipated, and there is born of these disasters a new breath of youthfulness which creates new projects.

We have studied much into the details and the causes of this failure in France in many manufactories established in the south for the distillation of the cane using several millions of kilograms of stalks each season. The first year the production in alcohol was, from 100 kilograms of stalks, 7.50 liters or quarts, or 22 pounds.

The second year the production from the same amount of stalks was 6 liters; the third year, 4.50 liters; the fourth year, 2 liters.

It was discovered that the cause of this reduction in the quantity of alcohol, and consequently in the quantity of sugar, was due to the fecundation of the sugar cane by the broom cane, or *Sorghum vulgare*, which is cultivated in great quantities in the same localities. The crossing is caused by the pollen from the broom cane being carried by the winds to the sugar cane, and the consequence of this fecundation was that the seeds which had received this attaint, when resown, produced stalks full of white pith without juice, like the stalks of broom corn, or stalks half pithy, which, instead of containing 90 per cent. of juice, contained only 15 or 20 per cent., and this juice was of a quality which produced a small quantity of sugar.

All means employed to overcome this imperfection were without success. One could distinguish by the peculiarities of the spike those stalks which had not been tainted by the pollen from the broom corn, but this influence was invisible in the seed, which had been fecundated by the pollen to such an extent that, although taken from stalks containing 15 per cent. sugar and sown the following season, would produce only degenerated cane.

We have seen stalks of sorghum cane produced from the planting of seeds from the same spike, of which the primitive stalk contained 16 per cent. of sugar, give bunches of seeds and single seeds presenting such entirely different characteristics that they would serve to constitute as many different varieties, more or less rich in sugar, and which in reality were only the product of a degeneracy under the influence of a crossing more or less pronounced in each seed.

Such an experience for several years was disastrous, and it is upon this hybridizing of the sorghum cane and the broom cane that all the responsibility must be thrown. Now that which is true in France should also occur in America, and the causes for the failure in the sugar cane must be the same in the two countries.

There is no doubt of the truth of M. Leplay's ideas in respect of the admixture of sorghum with broom corn, but such an admixture can be avoided, and if this were the only cause of deterioration we would have little to fear.

Horace Piper[1] says:

The natural cross-breeding of different varieties with those of inferior qualities is a very frequent cause of deterioration. This is often observed in gramineous and leguminous and cucurbitaceous plants, which are raised annually from their seeds. All the varieties of maize are very liable to deteriorate in this way. Those of the *Sorghum saccharatum* intermix so freely that cultivators have found it almost impossible to obtain pure seeds. From the same cause it is extremely difficult to preserve any of the varieties of the melon pure for any considerable time.

No one can have any security of obtaining pure seeds unless they are planted many rods from all others, and the *perfect* flowers from which seeds are to be raised are covered with small tents of gauze of sufficient size to inclose each and protect it from insects. The judicious cross-breeding, however, of individuals of the same variety, when taken from a distance, will, as has before been observed, have a tendency to improve it.

The rapid deterioration of the juice of the cane when cut has been noticed by every one who has had anything to do with sorghum. This deterioration, however, is independent of the natural variations above mentioned.

The gradual failure of the sucrose in the juice is also noticed when there has been no admixture with broom corn, as pointed out by Mr. Leplay. This has been unmistakedly illustrated at Rio Grande, N. J. The sugar in the amber cane there has been failing since the first until the year 1886, when the juice of this cane from several hundred acres was so poor that no attempt was made to convert it into sugar.

My own observations on this inconstancy of sorghum have been published more than once.

In speaking in a previous publication of the difficulties of successful sugar-making, I said:[2]

A careful study of the foregoing data will not fail to convince every investigator that the manufacture of sugar from sorghum has not yet proved financially successful.

The men who have put their money in these enterprises seem likely to lose it, and intending investors will carefully consider the facts herein set forth before making final arrangements. The expectations of the earlier advocates of the industry have not been met, and the predictions of enthusiastic prophets have not been verified. It would be unwise and unjust to conceal the fact that the future of the sorghum-sugar industry is somewhat doubtful. In the first place, the difficulties inherent in the plant itself have been constantly undervalued. The success of the industry has been based on the belief of the production of sorghum with high percentages of sucrose and small amounts of reducing sugar and other impurities.

But the universal experience of practical manufacturers shows that the average constitution of the sorghum-cane is far inferior to that just indicated. Taking the

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[1] Ann. Report, U. S. Department of Agriculture, 1867, p. 315.

[2] Department of Agriculture, Division of Chemistry, Bull. No. 5, pp. 155, *et seq.*

mean of several seasons as a safe basis of computation, it can now be said that the juices of sorghum as they come from the mill do not contain over 10 per cent. of sucrose, while the percentage of other solids in solution is at least 4.

Another difficulty with which the industry has had to contend has been found in the crudeness and inefficiency of the machinery which has been in use.

Successful sugar-making depends more on the efficiency of the machinery used than almost any other kind of manufacturing. It is safe to say that should the sugar-makers of Europe attempt to make beet sugar with machinery as imperfect as that used in the sorghum-sugar manufacture the attempt would end in disastrous failure.

The working of sorghum juices will be found as difficult as those of beets, and true success can not be hoped for until the processes used for the one are as complete and scientific as for the other. It is not meant by this that the processes and machinery are to be identical.

The chemical as well as mechanical treatment of the two kinds of juice will doubtless differ in many respects. And this leads to the consideration of the third difficulty, viz, the chemical treatment of sorghum juice. It has taken nearly three-quarters of a century to develop the chemistry of the beet-sugar process, and even now the progress in this direction is great. The chemistry of the sorghum-sugar process is scarcely yet a science. It is only an imitation of what has been done in other fields of work. Sorghum will have to develop a chemistry of its own. This will not be the work of a day or a year, but it will be accomplished sooner or later.

Careful study of climate and soil, joined with experience, will gradually locate those areas most favorable to the growth of this plant and its manufacture.

This is an all-important point in the problem, and is now occupying seriously the attention of the thoughtful advocates of the sorghum-sugar industry. One thing is already clear, *i. e.*, that the area of successful sorghum culture is not nearly so extensive as it was thought to be a few years ago. I would urge a further investigation in this direction as a work peculiarly within the province of the Department, and one which would prove of immense benefit to the country. Five million acres of land suitable to the purpose will produce all the sugar required for this country for several years to come. It is therefore certain that the sugar industry will be confined to the most favorable localities. If a thorough scientific study of all the soil and climatic conditions does not point out this region, bitter experience and the loss of hundreds of millions of dollars will gradually fix its boundaries. Last of all, the sorghum industry has suffered from the general depression which has been felt by the sugar industry of the entire world. Low prices have caused loss where every other condition has been favorable. It is hardly probable that the price of sugar will rise again to its maximum of the years passed. Only war, pestilence, or disaster would produce this effect. It is best, therefore, for the sugar-grower to accept the present price as final, and make his arrangements accordingly. But low prices will produce increased consumption, and thus even with a smaller profit the sugar-grower by increased production may find his business reasonably remunerative if not as enriching as before. The sorghum-sugar grower will be injured or benefited with the growers of other kinds of sugar by these economic forces. Hence there should be no enmity between the grower of the sorghum, the sugar-beet, and the sugar-cane, but all should work in harmony for the general good.

It is true that the present outlook is discouraging. But discouragement is not defeat. The time has now come for solid, energetic work. Science and practice must join improved agriculture, and altogether can accomplish what neither alone would ever be able to achieve. It is not wise to promise too much, but this Bureau would fail short of its duty were it either to suppress the discouraging reports of this industry or fail to recognize the possibility of its success. The future depends on the persistence and wisdom of the advocates of sorghum. The problem they have to solve is a most difficult one, but its solution is not impossible.

Again, in speaking of the necessity of systematic field experiments insecuring a sorghum suitable for sugar making, I said:[1]

Such a series of experiments carried on under uniform conditions over the whole country would do more in five years to determine these great agricultural problems than fifty years of spasmodic and disjointed work could accomplish.

Much of the success of the beet-sugar industry of Europe has been due to a wise selection and improvement of the seed, by which the sugar contents of the beet, in some instances, has been nearly doubled. There is no reason to doubt that a similar improvement (but not, perhaps, to the same extent) could be made in Northern cane. Such an improvement station could be established at small cost; but, to be effective, must be continued through, series of years. The seed of those canes showing the highest sugar content should be planted and the selection continued until a maximum of sugar is obtained. If in this way a variety of cane could be produced which would give an average result in analyses of only 2 per cent. uncrystallizable sugar and 10 per cent. of sucrose, it would prove of the greatest value to the country.

In another place, referring to the lessons which were taught by the Fort Scott experiments, I said:[2]

The chief thing to be accomplished is the production of a sorghum plant containing a reasonably constant percentage of crystallizable sugar.

Recently in a public address I said:[3]

It is easily seen from the foregoing figures that in four years I have never found a large field of sorghum, judged by the juice obtained, which was rich enough to make sugar economically.

On the other hand, intensive culture, like that given to a garden, has produced sorghum which, with the improved processes which have been introduced, would easily make 150 pounds of sugar per ton.

The sorghum enthusiast has been abroad in the land, and, in his wake, has closely followed the crank. Fairy tales of the richness of sorghum have been told everywhere, and have often obtained credence. Fictions of the imagination, and often, I am sorry to say, fictions without any imagination, have portrayed the glowing future of sorghum—a future full of triumph and glory. Sorghum has been extolled as the one great savior of the country, furnishing alike its bread, its sweets, its meats, and its drinks.

The hope for sorghum is not in new methods and new machinery; it is in the skill and patience of the agronomist.

Wise selection of seed, intensive culture, judicious fertilization—these are the factors that can make the sorghum sufficiently saccharifacient.

Still more recently, having collected various data concerning the instability of sugar in sorghum, I presented them to the Indiana Academy of Sciences.

From this paper I make the following quotations:[4]

ON THE CAUSES OF THE VARIATIONS IN THE CONTENTS OF SUCROSE IN SORGHUM SACCHARATUM.

For some years I have been investigating the Sorghum saccharatum in respect of its adaptability to the production of sugar.

During this time many difficulties have been encountered, and these troubles have all been overcome with one exception. The chief obstacles to successful sugar-mak-

[1] Department of Agriculture, Report 1883, pp. 413, 414.

[2] Department of Agriculture, Division of Chemistry, Bull. 14, p. 42.

[3] Bulletin No. 2, Chemical Society of Washington, pp. 28, 29.

[4] Botanical Gazette, Vol. XII, No. 3, pp. 54 *et, seq.*

ing have been, first, unfavorable climatic conditions; second, imperfect methods of extracting the sugar; third, improper treatment of the extracted juice; fourth, variations and rapid changes in the sucrose of the juice. All of these problems have been successfully solved save the last. It is proper to say, however, that certain methods of cultivation and certain methods of selecting seeds tend to produce maximum contents of sucrose in the cane, and these methods are not yet fully developed. A proper conception of the variations to which the sucrose in sorghum is obnoxious can not be had unless we study briefly the method of its formation, how it is stored, and the physiological functions in which it takes part.

Vegetable physiologists have taught us that a carbohydrate can be formed by a certain retrogressive change in protoplasm, by which the cell envelope, in other words cellulose, is produced. The carbohydrates which appear in the embryo of a plant are developed at the expense of the stores of material in the seed. After the appearance of the chlorophyll cells in the plant the production of carbohydrates takes place with their aid, CO_2 being absorbed from the air and free oxygen being eliminated.

It would be easy to explain the production of carbohydrates by supposing that the chlorophyll cell exerted a reducing influence[1] on the CO_2 which, with the assimilation of water, produced, for instance, starch by the formula $6CO_2 + 5H_2O = C_6H_{10}O_5 + O_{12}$. In the vast majority of plants it is found, in corroboration of this supposition, that the volume of the oxygen set free is sensibly the same as the carbonic dioxide absorbed. The carbohydrate which is generally formed in the chlorophyll cells is starch. This starch is removed from the leaf, and it is supposed that the carbohydrates which are formed in all parts of the plant are derived from this original substance.

In point of fact, however, the production of organic matter in a plant does not probably take place in the simple manner above described. It is more likely that the presence of a nitrogenous body is necessary and this proteid itself is the active principle in the production of new organic matter, by a certain decomposition it suffers, with the help of carbonic dioxide and water. Nor is it by any means certain that starch is the only organic matter formed by the chlorophyll cells; in fact, it is known that oil is often the product of this constructive and destructive metabolism.

But it seems reasonable to suppose that the different sugars are as likely to be formed in the leaf of the plant as starch.[2] When we remember how easily starch is detected in most minute quantities, and how easily sugar is missed even when present in much larger quantities, we do not wonder that vegetable physiologists have supposed that starch is the first carbohydrate formed in the leaf, and that all the others are derived therefrom. The explanation, which is made of the translation of the starch from the point of its formation to the localities where it is stored, is as follows:

Take, for instance, the formation of starch in the germ of cereals. We are taught that the starch first formed in the leaves is changed into sugar, and in this soluble state carried through the plant until it reaches the seed. This sugar, reaching the point where the seed is forming, is changed to starch again by the amyloplast.

Let us subject this theory of the translation of starch to a brief examination. There are two only known methods by which starch can be converted into sugar, viz: First, by the action of certain acids, and second by the action of certain ferments. The conversion of starch into sugar by acids even at a high temperature and with the stronger acids is very slow. It is simply incredible that such a conversion can take place at the ordinary temperature in the leaf of a plant, and by reason of the action of the extremely dilute weak vegetable acids which the leaf contains. In the same

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[1] It has lately been stated that this reduction is due to the action of electricity on the leaf—producing hydrogen—and this hydrogen is the active principle in the reduction of the carbonic dioxide. This statement appears to be purely theoretical.

[2] Meyer (Botanische Zeitung, 44, Nos. 5, 6, 7, 8) has lately shown that the leaf of the plant is incapable of forming starch out of sucrose, lævulose, etc., and calls especial attention to the fact that starch may not be the original substance formed.

way it must be conceded that the opportunity for the action of a ferment in the leaf is extremely limited.[1] Such action requires time and much more favoable conditions than can be found in the living leaf. In any case if sugar be formed from starch in either of the ways indicated it could not be sucrose.

In fact the reducing sugar which is found in plants is seldom starch sugar, *i. e.*, maltose or dextrose. This appears to be a fact which the vegetable physiologists have entirely ignored. The sugars of plants which reduce an alkaline copper solution are either derived from sucrose by inversion, or more probable are of independent formation. If they were derived from starch they would show dextro- if from sucrose, lævo-gyration. In point of fact they often show neither, as I long ago pointed out, when, in view of this optical inactivity, I proposed for them the name of anoptose. When they do show rotation, however, it is left-handed.

It seems to me that there is one fact that the physiologists forget, viz, that starch is not always insoluble. In my examinations of sorghum juices I have never failed to find soluble starch when I looked for it.[2] The existence of bodies when first formed in the soluble state, which when once made solid become insoluble, is not unknown. Certain forms of silica are illustrations of this. It seems much more reasonable to suppose that in the case of the sorghum, for instance, the starch which appears in the seed is partly transferred directly from the soluble nascent state to the seat of its final deposition. This, indeed, is hardly a theory in the light of the fact mentioned above—that the sap of the plant always contains soluble starch.

It is far more simple to suppose that the sucrose which we find in sorghum is produced directly by the decomposition of protoplasm in presence of carbonic acid, provoked by the katalytic action of the chlorophyll cell. At any rate there is no sort of evidence that it is ever made from starch, and no physiologist has ever invented any hypothetical saccharoplast to account for such a transformation.

This subject of the origin of sucrose is of great interest; but I have not yet finished my experimental studies of it, and so will not pursue it further at present.

The question now arises is the sucrose of sorghum a plastic material, reserve material, or waste? In respect of plastic material it is sufficient to call attention to the fact that the development of sucrose does not begin in the plant until it is far on the road to maturity. To this it may be objected that its accumulation does not begin until this period, and that what is formed earlier in its history is a really plastic material used in the development of other tissues. Had I time I might show, I think, conclusively, that the presence of the sucrose as a plastic material is not probable. Is it a reserve material? The sucrose which is deposited in the seeds of plants, in tubers like the sugar-beet, and in sugar-cane, doubtless is a true reserve material, and by its decomposition helps the growth of the succeeding plant. But the sucrose in sorghum seems to have no such function. It can in no way aid the incipient growth of the next plant, for that plant grows from a seed. As far as any use in the economy of the plant is concerned, it appears to be absolutely worthless. It is true that in the case of "suckering," the sucrose in the cane may suffer loss, but "suckering" is not always a natural growth; it is adventitious and is always detrimental to the proper maturity of a plant.

It seems, therefore, that the sucrose in sorghum is purely a waste material—as much so as an alkaloid or a resin.

In the cases where sucrose is a true reserve material, as in seeds, in tubers, and in sugar-cane, we find there is no tendency for it to disappear until the needs of the new plant require it. The sucrose remains, for instance, unchanged in the sugar-beet until the new growth begins. The same is true in a higher degree of the sucrose in seeds. The fact, therefore, that in sorghum all traces of sucrose may disappear in a few days shows that its office is radically different.

[1] The ferment which acts on the starch has been studied by Brasse and Schimper (Bied. Centralblatt, vol. 14, p. 169, vol. 15, pp. 310 and 473). It is called *amylase.*

[2] That is a body in solution which gives a blue color with iodine.

As a result of my investigations I will say that the development of sucrose in sorghum is an accidental function, or rather an adventitious function. It goes on usually *pari passu* with the formation of the starch in the grain and the content of sucrose in the plant, and its quantity is at a maximum at the time the starch formation is completed. In the sugar-cane the sucrose appears to be not only reserve, but also plastic material. In the upper part of the cane the content of sucrose is much less than in the lower, showing that in the region of most active growth the sucrose may suffer decomposition and help in the formation of proteid. (I wish to add here that the only way in which the plant can use sucrose for the formation of other bodies or for working it into living tissues is by thus getting it into protoplasm.) On the other hand, the content of sucrose in sorghum is sensibly the same in all parts of the cane, being just as great at the top near the place of most rapid starch storage, as it is near the base. It is not strange, therefore, if it be true that the production of sucrose is only the expression of the exuberant vitality of the leaf of the sorghum, that the greatest variations should be met with the content of sucrose. These variations are not confined to different varieties or to different fields, but are found in the same variety in different canes growing in the same hill, and which, therefore, have been subjected to precisely the same conditions of culture and weather.

In ten successive analyses of sugar-beets made two years ago, I found no greater variation than 1 per cent. in sucrose. The same was true of ten successive analyses of sugar-canes I made last month, November, 1886. On the other hand, any ten successive analyses of sorghum-canes, made last October, will show a variation of 6 per cent.

I have not the time here to cite all the instances I have noticed which illustrate the principles set forth above. They number hundreds. Without a record of these analyses, however, the fact clearly appears that the chief cause of variation is found in the accidental or adventitious nature of the formation of the sucrose; in other words, its independence of the life history of the plant. When, however, the sucrose has once been formed, as in a mature cane, it is subject to sudden variations. Sudden changes in the weather, severe frosts, followed by warm weather, or simply standing dead ripe, often cause a rapid disappearance of the sucrose. It is first converted into invert sugar and this quickly disappears by fermentation.

When the canes have been cut also, if they be expressed at a temperature of a warm September day, the sucrose is rapidly inverted. This inversion is not due to the action of the acids which the sap contains, but is produced by a special ferment, probably *invertin*, or some similar substance.[1]

These variations in the content of sucrose are, as I intimated at the beginning, the chief obstacles now in the way of the successful introduction of a sorghum-sugar industry into this country. The last one is easily avoided by promptly working the cane as soon as it is cut. The first one can only be overcome by the scientific agronomist, aided by the best practical botany and chemistry.

Since writing the above I have received the Revue Scientifique, of February 5, 1887, containing a notice of the observations of Girard on the production of carbohydrates in plants. This author definitely confirms my statements in respect of the independent formation of sucrose in leaves. The reviewer says:

"Les expériences de M. A. Girard mettent hors de doute que les limbes fabriquent alors des saccharoses et des sucres réducteurs."

M. Girard shows the possibility of leaves developing starch from sucrose, but there appears to be no evidence that the reverse of this operation takes place.

YIELD PER ACRE.

In the experiments of the New Jersey station we have already seen the theoretical yield of sugar per acre. It is a matter of considerable

[1] Duclaux, Compt. rend., 103, p. 881, has shown that sunlight is capable of inverting a solution of sucrose.

importance to know what the average yield of sorghum in clean stalks per acre is. Weber and Scovell[1] report yield of clean cane, equal to 15,766 pounds or 7.88 tons per acre. Professor Henry[2] gives the following as the yield of cane per acre:

	Pounds.
First plot	30,348
Second plot	23,550

In 1882 Henry found the following as a mean yield in clean cane of fifteen plots calculated to one acre:[3] Mean for fifteen experiments, 14,300 pounds=7.15 tons.

The yield per acre for the field crop[4] in the several fields was as follows:

First field	20,906 pounds = 10.45 tons.
Second field	14,487 pounds = 7.24 tons.
Third field	13,688 pounds = 6.84 tons.

In the field trial of cane by the Department at Washington in 1881 the average yield from 94 acres was 5,000 pounds[5]=2.5 tons.

The mean weight of clean cane per acre as determined at Champaign, Ill., in 1882, is seen from the following data.[6]

Number acres	244.59
Number tons	2,282.75
Tons per acre	9.33=18,660 pounds.

The average yield of 6.85 acres at the Wisconsin agricultural farm in 1882 was 16,200 pounds per acre, equal to 8.1 tons.

Nelson Maltby obtained (mean of 17.5 acres) 9.5 tons per acre, equal to 19,000 pounds.[7]

Drummond Brothers report an average of 26.5 acres, at 9.17 tons, equal to 18,340 pounds.[8]

A. J. Decker[9] reports average yield of 45 acres at 6 tons, equal to 12,000 pounds.

William Frazier[10] states yield for 45 acres averaged 6 tons per acre, equal to 12,000 pounds.

A. L. Talcott[11] estimates yield per acre at 9.6 tons (226 acres), equal to 19,200 pounds.

Belcher and Schwarz[12] report yield for 191 acres at 3 tons per acre, 6,000 pounds.

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[1] Transactions Department of Agriculture, Illinois, 1881, p. 501.

[2] Experiments in Amber cane, 1881, p. 14.

[3] Second Annual Report, Amber cane, p. 8.

[4] *Op. cit.*, p. 14.

[5] Encouragement to Sorghum, p. 3.

[6] *Op. cit.*, p. 13.

[7] *Op. cit.*, p. 27.

[8] *Op. cit.*, p. 28.

[9] *Op. cit.*, p. 35.

[10] *Op. cit.*, p. 37.

[11] *Op. cit.*, p. 46.

[12] *Op. cit.*, p. 33.

Bozarth[1] from 85 acres reports a yield of 8.1 tons per acre, equal to 16,206 pounds.

In a field of 64 acres grown by the Department of Agriculture near Washington, in 1883, the yield was 746,250 pounds of clean cane, or 11,662 pounds per acre, equal to 5.83 tons.

At Rio Grande, according to the report of Professor Cook already cited,[2] it is shown that the average yield of that plantation for five years (about 1,000 acres per annum) was only 7.7 tons of unstripped and untopped canes, or of clean cane about 6 tons, equal to 12,000 pounds per acre.

TONNAGE PER ACRE DETERMINED BY THE EXPERIMENTS OF THE NEW JERSEY AGRICULTURAL STATION.[3]

In 1881 the average yield at the New Jersey experiment station[4] was 4.84 tons, equal to 9,741 pounds per acre.

In 1882, in fall-plowed land, the mean yield in sixteen experimental plots was 8.45 tons, equal to 17,110 pounds[5] per acre.

For the spring-plowed land the numbers are 9.84 tons per acre, equal to 19,680 pounds.[6]

For 1883 the mean yield of sixteen experimental plots was 14.4 tons, equal to 28,851 pounds per acre.[7]

In 1884 the mean yield of sixteen experiments was 10.30 tons, equal to 20,601 pounds per acre.[8]

In 1885 the mean yield of sixteen plots was 12.48 tons, equal to 24,965 pounds per acre.

In 1886[9] the mean weight of cane on fourteen fertilized plots calculated to 1 acre was of clean cane 10,443 pounds, equal to 5.22 tons.

I believe a perfectly fair average of the yield per acre of sorghum, taking into consideration all seasons and methods of culture and fertilizing, will be found by the investigation of the foregoing means.

[1] *Op. cit.*, p. 58.

[2] Sixth Ann. Report New Jersey Agricultural Experiment Station, p. 119.

[3] Ann. reports of station.

[4] *Op. cit.*, 1881, p. 45.

[5] *Op. cit.*, 1882, p. 64.

[6] *Op. cit.*, p. 65.

[7] *Op. cit.*, 1883, p. 70.

[8] *Op. cit.*, 1884, p. 84.

[9] *Op. cit.*, 1886, p. 151.

Summary.

Authority.	Yield per acre.
	Tons.
Weber and Scovell	7.88
Henry and Swenson	15.17
	11.77
Henry	7.15
	10.45
	7.24
	6.84
Harvey	2.50
Weber and Scovell	9.33
Henry and Swenson	8.10
Maltby	9.50
Drummond Bros	9.17
Decker	6.00
Frazier	6.00
Talcott	9.60
Belcher and Schwartz	3.00
Bozarth	8.10
Wiley	5.83
Hughes and Cook	6.00
	6.00
	6.00
	6.00
	6.00
Cook	4.87
	8.45
	9.84
	14.40
	10.20
	12.48
	5.22
General average per acre	7.97

We may, therefore, place the average crop of topped and stripped cane in round numbers at 8 tons per acre.

Practical farmers, chemists, and manufacturers have long recognized the imperative necessity of producing a better raw material for sorghum sugar making, but many of those who have gone into the business have not been impressed with such a necessity.

In many of our newspapers, in some official documents, and in the report of the Academy of Sciences, which has already been quoted, sorghum has been represented as the equal of Louisana sugar-cane, and therefore the great inferiority of it to that sugar plant has been first revealed by the crash of financial failure.

Among the methods which have been tried for increasing the sucrose in sorghum I will cite the

EFFECT OF REMOVAL OF THE SEED HEADS.

The question of the formation of sucrose in the sorghum cane has already been discussed.

Formerly, when it was considered that the starch was derived from the sucrose, it was supposed *a priori* that the removal of the panicle, thus preventing the formation of starch, would tend to increase the percentage of sucrose in the juice.

It is stated in Hyde's book [1] that—

[1] The Chinese Sugar-Cane, Hyde, pp. 23, 24.

The ripeness of the seeds does not appear much to lessen theproduction of sugar, at least in the climate near Paris, but in other countries where it matures when the weather is still warm the effect may be different. According to the report of M. de Beauregard, addressed to the "Comice de Toulon," the ripening of the sorgho in that latitude had no unfavorable effect; and he considers the seeds and the sugar as two products to be conjointly obtained. On the other hand, Mr. Wray says the Zulu-Kaffirs are in the habit of pulling off the panicles of the plant the moment they appear, in order to augment the quantity of saccharine matter in the stalks.

Mr. Leonard Wray[1] makes the same statement. In the direction for making sugar from sorghum printed in "The Working Farmer," and quoted in the book of Mr. Stansbury,[2] occurs the following sentence:

When the grower intends to make sugar, he should pinch off the seed heads before they are fully formed, or indeed as soon as they appear, thus causing the plant to give a larger yield of stronger juice.

In 1882 and 1883 experiments were made by Prof. H. A. Weber and Prof. M. A. Scovell, at Champaign, Ill., to determine the effect of the removal of the seed heads. Following is Professor Weber's report:[3]

The first experiment in topping cane was made in the season of 1882. It was suggested by the theory that the starch, which forms about 63 per cent. of the weight of the seed, could, by removing the top in time, be retained in the stalk in the form of cane sugar. The experiments in this direction fully proved the correctness of this theory. In the first experiment a portion of the heads was removed from a plat of Amber cane soon after they made their appearance and before there was any visible formation of seed. When the remaining cane had reached the hard-dough stage comparative analyses were made, with the following results:

	Topped.	Untopped.
Density, Baumé........	9.5	8.1
Cane sugar, per cent. ..	12.62	7.80
Grape sugar.... do.....	2.58	4.80

In the season of 1883 two more experiments were made in this direction. In the first one, a field of Kansas orange cane was chosen. Two rows lying side by side and of uniform growth were selected. One was topped as soon as the heads appeared. The first comparative analyses were made on September 19, when the upper half of the seed heads was in the hardening dough. The results are as follows:

	Topped.	Untopped.
Density, Baumé........	10.8	9.8
Cane sugar, per cent. ..	14.4	11.83
Grape sugar... do......	1.01	3.89

Two more comparative analyses of the same rows were made on October 2, after the seed was fully ripe.

[1] Agricultural Report 1854, p. 222.

[2] Stansbury, Chinese Sugar-Cane, p. 35.

[3] Department of Agriculture, Division of Chemistry, Bull. No. 5, pp. 145, 146.

The following table shows the results:

	Topped.	Untopped.
Density, Baumé........	13.3	9.4
Cane sugar, per cent...	14.82	11.53
Grape sugar... do......	2.82	3.53

The last test was made with a plat of Indian cane. The topping was done August 23, three days after the heads began to appear.

The comparative analyses were made October 6. At this date the seeds were perfectly ripe, and would drop from the head when shaken.

The results are given in the following table:

	Topped.	Untopped.
Density, Baumé........	10.2	8.3
Cane sugar, per cent...	13.04	10.06
Grape sugar... do......	1.54	2.46

These results show an increase of over 3 per cent. of cane sugar in favor of the topped cane.

Dr. Collier also was led to investigate the same subject.[1]

Two sets of analyses were made. In the first set of ninety-six pairs of analyses the results are as follows:

In the juice.

	Seed removed.	Seed on.
	Per cent.	*Per cent.*
Sucrose.................	12.66	9.96
Glucose.................	.97	1.40
Total solids............	16.61	14.31

In the second set of forty-two pairs of analyses the results were as follows:

	Seed removed	Seed on.
	Per cent.	*Per cent.*
Sucrose.................	11.34	12.08
Glucose.................	1.21	1.08
Total solids............	15.53	15.89

Dr. Collier makes the following observations on the results of these analyses:[2]

The practical conclusions from these results are, that there is no incompatibility between the maximum crop of ripe seed possible, and the maximum content of sugar in the juice of the stalks; and that, owing to the more rapid development of the cane

[1] Collier's Sorghum, pp. 138 and 241; Special Report, pp. 18 *et seq.*

[2] *Op. cit.*, p. 140.

from which the seed has been removed, the time necessary from planting to the maturity of the crop would be shortened from seven to ten days for each of the varieties, if the seed was removed early.

In 1884 I made a large number of experiments in the study of the effect of topping the canes.[1]

After having compared all the analyses the following conclusions were reached:[2]

The effect of cutting off the young heads in increasing the per cent. of sucrose was not as marked as had been expected, being a little less than .3 per cent.

Experiments on a much larger scale were made at Ottawa, Kans., in 1885, and these trials confirmed in every respect the results obtained at Washington the preceding years.

Following are the data:[3]

Means of ten analyses.

	Sucrose.	Glucose.	Total solids.
	Per cent.	*Per cent.*	*Per cent.*
Topped and suckered canes....	12.45	1.99	17.26
Topped canes, not suckered ..	12.46	2.09	17.31
Natural canes....................	12.15	2.06	16.77

From the above results it is seen that no appreciable increase of sucrose is obtained by topping and suckering the canes.

Even had experiments shown a notable increase in sucrose in the juices of those canes from which the seed heads had been removed the practical difficulties attending the process would prevent it from ever becoming more than an experimental study.

I think, therefore, we may at once dismiss all expectations of ever increasing the value of sorghum as a sugar producer by preventing the maturation of the seed.

THE FORT SCOTT EXPERIMENTS.

For the first time in the history of sorghum sugar making an opportunity was presented at Fort Scott in 1886 to try under identical conditions the relative merits of Louisiana sugar cane and Kansas sorghum as sugar-producing plants.

The light which this trial has thrown on the vexed problem has served to illuminate many points which were in obscurity. A candid study of the results of the experiments will set at rest all doubts in respect of the relative merits of these two sacchariferous plants.

In the Chicago Journal of Commerce of July 6, 1887, Dr. Collier makes a comparison of the analyses of juices of sorghum and sugar canes, which he submits as the teachings of years of experiment.

[1] Department of Agriculture, Div. of Chemistry, Bull. No. 5, pp. 139 *et seq.*

[2] *Op. cit.*, pp. 144, 145.

[3] Bull. No. 6, p. 16.

From these analyses he draws the following conclusions:

The average of the above (including two hundred and two analyses of sugar-cane juices grown on different plantations and in different years, and of three hundred and thirty-one analyses of many varieties of sorghum juices also grown in different years) gives for each ton of sugar cane 225 pounds total sugar, of which 179 pounds are theoretically available, and for each ton of sorghum cane a total of 261 pounds of sugar, of which 199 pounds are available.

In respect of the quality of the crop of sorghum at Fort Scott the same writer in the Journal of Commerce of the date mentioned, after quoting the results of a single analysis, makes the following observations:

Now, the above shows in each ton of cane 238½ pounds total sugar, of which 169 pounds were available.

Such was the average crop of cane according to the very best, and indeed the only method by which its value could be ascertained.

It is thus seen that it has been claimed that the sorghum crop at Fort Scott was not only equal to Louisiana cane, but, in fact, far superior to it in its sugar-making qualities.

The same authority says: [1]

The next question which arises is most naturally this: Granting that this sugar is found in the crop of cane, can it be recovered by processes similar to those employed on the sugar-cane plantations of the South or the best sugar factories of Europe? I reply with a decided yes to this most important practical question.

In the light of these statements the value of the actual comparison is greatly increased.

ABSTRACT OF EXPERIMENTS WITH SORGHUM AT FORT SCOTT, KANS., IN 1886.[2]

Mean composition of juices, seventy analyses, expressed from small quantities of sorghum canes during the entire season: [3]

	Per cent.
Sucrose	9.34
Glucose	4.10
Total solids	16.94
Purity co-efficient	55.14

The small samples of cane above mentioned were taken in such a way as to represent as nearly as possible the general character of cane entering the mill. It is idle to claim, however, that in nearly 3,000 tons of cane, varying in such a marked manner as has already been set forth, such a selection of samples could accurately represent the whole. They might give results better or worse than the average. Which of these was the case with the above samples will appear by studying closely the following data:

SAMPLES COLLECTED FROM CHIPS ENTERING EACH CELL AND AFTER MIXING PASSED THROUGH SMALL MILL.

Such samples represent much more accurately than those just studied the average composition of the canes entering into manufacture.

[1] Chicago Journal of Commerce, November 17, 1886.

[2] Department of Agriculture, Div. of Chemistry, Bull. No. 14.

[3] *Op. cit.*, pp. 14, 15.

They were taken on twelve different days, from October 15 to 27, and each sample represents the mean composition of 10 tons of cane. The means of the twelve samples are as follows :[1]

In the juice.

	Per cent.
Sucrose	7.28
Glucose	3.74
Total solids	14.80
Purity co-efficient	49.00

MEAN COMPOSITION OF THE DIFFUSION JUICES FOR THE WHOLE SEASON.

Following are the means of seventy-six analyses[2] extending over the whole season. The samples were taken (a measured quantity) from each cell when discharged. After ten samples were collected and mixed the analysis was made. The results of the analyses are, therefore, a true index of the diffusion juices for the entire season :[2]

	Per cent.
Sucrose	5.10
Glucose	3.07
Total solids	11.47
Purity co-efficient	44.4

There is one point in the above data to which I desire to expressly call attention. The juice which was actually worked for sugar at Fort Scott was the *diffusion juice*, of which the mean composition is given above. This juice, according to the methods of estimating its value in common use, not only would not yield crystallizable sugar, but, on the other hand, could have had a large quantity of pure sugar added to it before any could be obtained in the ordinary process of manufacturing.

The above is the actual character of the juices which Dr. Collier has stated had in each ton "238.5 pounds sugar, of which 169 pounds were available."

We now turn for comparison to the data obtained with identically the same processes employed at Fort Scott to make sugar from sugar cane.

The canes on which these trials were made were cut in Louisiana October 25 to 30, and subjected to diffusion at Fort Scott, November 6 and 7, 1886.

MEAN COMPOSITION OF THE JUICES IN THE CANE.

Samples of chips were taken from each cell until twelve were filled. These samples were passed through the small mill and the analyses made in the mixed juices.

Five sets of analyses were made, giving the mean composition of seventy-two tons of chips.

[1] *Op. cit.*, p. 17.

[2] *Op. cit.*, pp. 18, 19.

Following are the means of the results:

In juice.

	Per cent.
Sucrose	10.62
Glucose	1.78
Total solids	14.38
Purity co-efficient	73.8

COMPOSITION OF DIFFUSION JUICES FROM ABOVE CANES.

The samples were taken by withdrawing a measured quantity from each of the twelve cells and thoroughly mixing. Six sets of analyses were made.

Following are the means:

	Per cent.
Sucrose	7.16
Glucose	1.23
Total solids	9.86
Purity	72.6

In this connection it must be remembered, too, that the mean temperature used in the diffusion of sorghum chips was 70° C., while for sugar cane the diffusion took place at 90°. Therefore, a much greater inversion would be expected with the former than with the latter.

In point of fact, it has been clearly established that the sucrose in ripe and fresh sorghum canes undergoes no appreciable inversion during the process of diffusion at 70°, if that process is not delayed by faulty machinery or accidents. When inversion in the battery does take place, it is due to the fact that chips are used which are not in a fit state for sugar making, or by reason of some delay in the process.

Without discussing further the details of the experiments with sugar-cane, I desire to call your attention to the following points:

(1) Sorghum-canes manufactured at Fort Scott in 1886 gave a yield of 21.6 pounds sugar per ton.

(2) Louisiana sugar-cane, manufactured at the same place, by identically the same processes, and under identical conditions, save that the temperature in diffusion was 20° higher, gave 144 pounds sugar per ton.

The sorghum-cane, therefore, grown at Fort Scott was nearly seven times less valuable for sugar making than the sugar-cane. I am fully convinced of the fact, however, that had the machinery at Fort Scott in 1886 been perfect, so that the sorghum could have been promptly worked at maturity, the quantity of sugar it made would have been greatly increased. This fact I have emphasized in Bulletin No. 14.

It will be of interest in closing this brief review of our present knowledge concerning sorghum and sugar cane, to add to the summary given the results of the final experiments recorded in Bulletin No. 17. In the summary of the data for Louisiana this has already been done.

The mean composition of sorghum juices used for manufacturing sugar on a large scale up to 1887 and the means of the two stations at Rio Grande and Fort Scott for 1887 are as follows:

	Up to 1887.	Rio Grande, 1887.	Fort Scott, 1887.
	Per cent.	*Per cent.*	*Per cent.*
Sucrose	8.54	8.98	9.54
Reducing sugar	4.59	3.24	3.40
Total solids	15.19	14.02	16.14
Purity	56.22	64.05	59.11

It will be seen that the cane both at Rio Grande and Fort Scott was slightly better than the average of the recorded analyses up to that time. I see no reason to doubt, however, the possibility of producing in a few years a sorghum-cane, the purity of whose juice will average higher even than that at Rio Grande.

I am not one of those, however, who claim for sorghum a position above the sugar-cane, either at present or remotely. All such claims are based either purposely on a few selected analyses, or ignorantly on partial evidence, or on no scientific evidence whatever.

The work which has been done under my supervision has had a double purpose: (1) To determine the true average sugar content of sorghum when grown on a commercial scale; and, (2) to devise the best methods of securing the sugar in merchantable form.

I have not hesitated to state the facts as they were disclosed during the progress of the work, nor have I knowingly concealed any result which has had any apparent relation to the problem, whether of a favorable or unfavorable nature.

In conclusion, I will say that I have written this bulletin to bring into convenient shape for reference all the information which I have been able to collect concerning the sugar industry of this country.

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