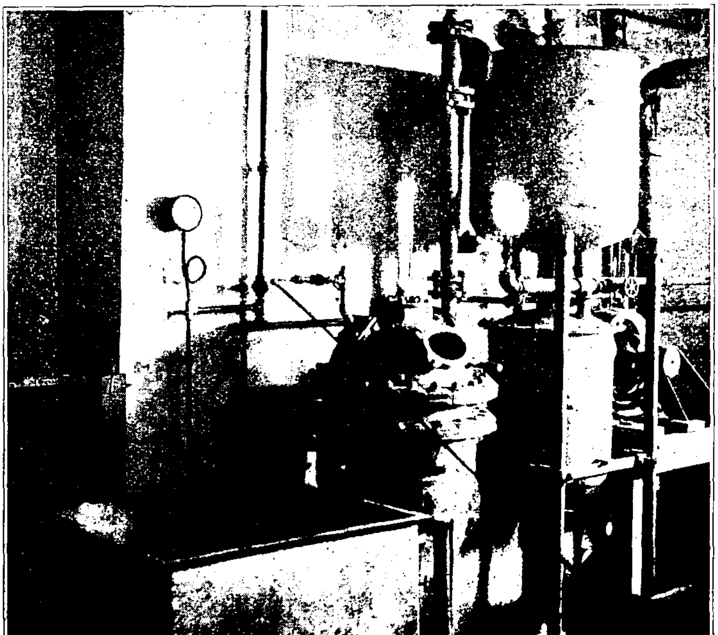
UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION

CORNSTALK SIRUP INVESTIGATIONS

J. J. WILLAMAN, G. O. BURR, AND F. R. DAVISON
DIVISION OF AGRICULTURAL BIOCHEMISTRY



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CORNSTALK SIRUP INVESTIGATIONS[1]

By J. J. Willaman, G. O. Burr, and F. R. Davison

From the time of the Aztecs to the present many attempts have been made to develop a sugar industry with cornstalks as the raw material. An interesting review of the trade in corn sugar in colonial days is given by Collier in his book on sorghum sugar (8). He considered maize stalks to be very promising material for sugar manufacture, but inferior to sorghum. During the last thirty years reports from various parts of the world have been published on the crystallized sugar obtainable from cornstalks. (See bibliography.) The general conclusion from these reports is that sugar can be obtained, but that it varies considerably from day to day and from one period of maturity to another, and that the yield is low because of the low purity of the juice. As a source of sirup, however, the cornstalk has been given very little attention. The writers have met several people who made sirup in a small way several years ago; but they have been unable to find any published reports of sirup investigations except a casual one in a report of the National Academy of Science on sorghum sugar (15). In 1921 the Minnesota State Canners' Association[2] induced the writers to undertake a study of the sirup making possibilities of sweet-corn stalks as a cannery by-product. This bulletin is a report of these investigations.[3]

The work divides itself more or less readily into three parts: (1) Progressive development of the constituents of the juice; (2) manufacture of sirup; and (3) economic considerations. Each of these phases will be considered separately.

[1] A brief resumé of this work was presented before the convention of the American Chemical Society, Milwaukee, Wis., Sept. 13, 1923.

[2] Frank Rabak, of the Bureau of Plant Industry, U. S. Dept. of Agr., first called the attention of C. D. Geidel, of the Minn. State Canners' Lab., to the sirup possibilities of sweet-corn stalks, and the latter brought the proposition to the authors.

[3] The authors' sincere thanks are due to the Wells Canning Co., of Wells, Minn., for housing the sirup plant and furnishing the materials for the investigations.

I. PROGRESSIVE DEVELOPMENT OF THE CONSTITUENTS OF THE JUICE

METHODS OF ANALYSIS

Extraction of juice was accomplished by milling the stalks in a three-roll mill, the rolls being 12 by 15 inches. Double milling was practiced, as it was thought that this would give juice more nearly comparable to that obtained by heavy pressure in multiple mills.

Density of the juice was ascertained by the use of Brix hydrometers.

Preservation of the juice for future analyses was effected by mixing 400 cc. of juice with 600 cc. of 95 per cent alcohol, boiling the mixture a few minutes, and transferring it to bottles. This alcoholic preparation was filtered. The precipitate was washed, dried, and weighed, and was called the *alcoholic precipitate.* The nitrogen in the alcoholic filtrate was called *non-protein* nitrogen. This filtrate was also used for the determination of *ash*; of *total solids* during the first season by drying an aliquot in vacuum at 70 degrees C. and adding the weight of the alcoholic precipitate; and of *sugars* during the first season. The latter were determined by the picrate colorimetric method, with several modifications (29) in conjunction with the polarization value of the juice, according to the formula given by Browne (6, p. 488).

Color of the juice was judged from the alcoholic extracts, arbitrary values from 1 to 4 being assigned in order of increasing color.

During the second season, the *total solids* were determined on the fresh juice by means of the Abbe refractometer, and *sugars* from the fresh juice.

Acidity was measured in the fresh juice, and is recorded as cc. of 0.1 N alkali required per 100 cc. of juice.

Total nitrogen was obtained by preserving 20 cc. of fresh juice in 35 cc. concentrated sulfuric acid, and digesting later according to the Kjeldahl-Gunning method.

MATERIAL

In 1921 Crosby sweet corn and Silver King field corn were the only varieties that could be obtained at Wells. Therefore Golden Bantam and Narrow Evergreen were obtained at Owatonna, Minn., and Stowell's Evergreen and Country Gentleman at Lake Mills, Iowa. As this entailed hauling the stripped stalks 40 and 30 miles, respectively, very often they could not be milled until the next day. The age of the samples is given in each case in Table I. In 1922 Crosby, Stowell's Evergreen, Country Gentleman, and Minnesota No. 13 field corn were obtained at Wells, and were milled immediately in all cases.

EFFECT OF REMOVING THE EARS

One of the principal points to be determined in the study of the development of the composition of the juice was the effect of removing the ears at the canning stage. Since Stewart (22), in 1906, obtained his patent for the process of increasing the sugar content of cornstalk juice by removal of the ears at this time, many investigators have tested the procedure. In most cases Stewart's claims were corroborated (2, 3, 7, 9, 11, 16, 18, 24, 25). In this work it was necessary to make a further test in order to see the performance of the plants under Minnesota conditions. In each field several rows were left untouched, while the rest were harvested for the cannery at the usual time, leaving the de-eared stalks standing in the field. Both groups were then sampled at intervals, and are described as "ears on" and "ears off."

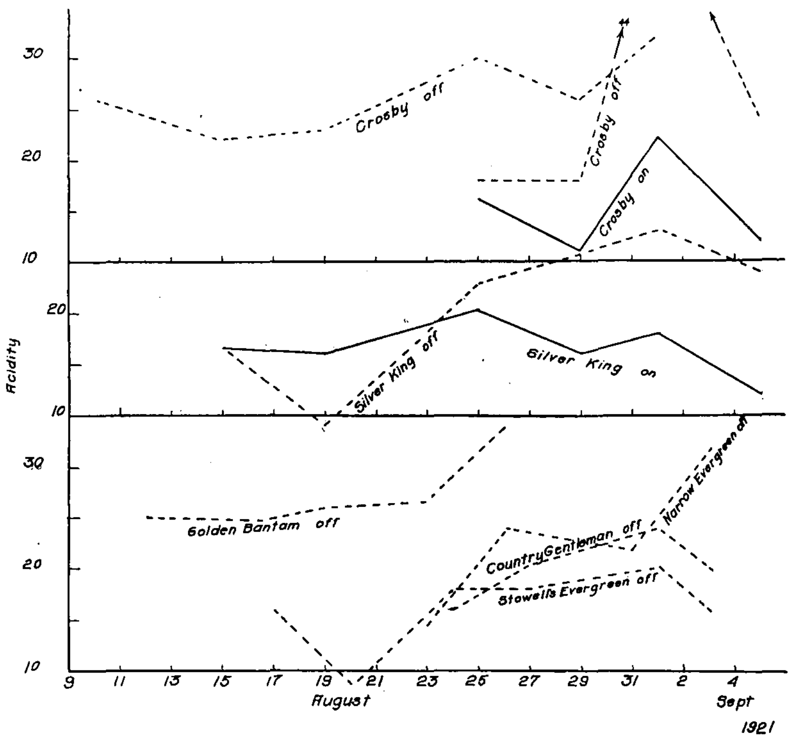

Fig. 1. Development of Acidity of Cornstalk Juice in 1921

TABLE I

ANALYSES OF CORNSTALK JUICES, CROP OF 1921

A	B	C	D	E	F	G	H	K	L	M	N	O	P	Q	R	S	T	U
Sample No.	Date	Time from canning stage	Age of sample	Extraction	Acidity 0.1 N per 100 cc. juice	Color	Brix	Sugars				Purity $\frac{K}{H} \times 100$	Total nitrogen	Non-protein nitrogen	Protein nitrogen, of total	Alcohol precipitate	Total solids	Ash
								Total	Sucrose	Glucose	Fructose							
		days		per cent	cc.			gms.	gms.	gms.	gms.		gms.	gms.	per cent	gms.	gms.	gms.
								Crosby, Ears off (Wells)										
2	Aug. 10	0	Fresh	47	26.0	1	10.5	7.89	4.00	2.0	1.9	75	.0909	.0491	46	0.797	9.46	.373
4	" 15	5	"	47	22.0	1	13.0	9.25	5.99	2.0	1.3	71	.1171	.0919	22	0.988	11.15	.410
9	" 19	8	12 hrs.	45	23.0	4	15.5	12.69	6.98	3.2	2.5	81	.1630	.1211	26	0.939	14.05	.298
21	" 25	14	Fresh	44	30.0	3	13.8	9.59	5.93	3.2	0.5	69	.1925	.1404	27	0.888	9.80	.433
30	" 29	19	"	45	26.0	2	14.7	10.89	8.14	2.1	0.6	74	....	.1547	..	1.244	13.61	.560
34	Sept. 1	21	"	45	32.0	3	17.9	13.79	9.69	1.4	2.7	77	.2559	.2534	1	1.197	16.54	.712
								Late Crosby, Ears on (Wells)										
19	Aug. 25	0	"	50	16.0	1	9.1	7.78	3.72	2.1	2.0	85	....	.0589	..	0.479	8.05	.463
28	" 29	4	"	47	11.0	2	8.8	6.91	4.59	0.8	1.5	79	.0768	.0539	30	0.564	8.07	.426
35	Sept. 1	6	"	50	22.0	4	12.2	9.15	3.81	2.2	3.1	75	.1208	.1118	8	0.599	10.53	.527
45	" 5	10	"	..	12.0	3	10.5	6.79	4.10	1.6	1.1	65	.1879	.1172	38	0.557	9.04	.547
								Late Crosby, Ears off (Wells)										
20	Aug. 25	2	"	50	18.0	1	10.2	8.56	4.62	2.0	1.9	85	....	.0641	..	0.644	9.35	.382
29	" 29	6	"	44	18.0	2	12.1	9.28	6.53	1.7	1.1	77	....	.1031	..	0.988	11.09	.435
36	Sept. 1	9	"	50	44.0	2	15.5	11.77	3.60	5.0	3.2	76	.2082	.1651	21	0.851	12.43	.414
44	" 5	13	"	..	24.0	2	13.5	8.87	6.38	1.9	0.6	65	.1640	.1115	32	1.041	11.98	.220
								Silver King, Ears on (Wells)										
5	Aug. 15	0	"	44	16.3	1	10.5	8.87	6.46	0.8	1.6	84	.0662	.0552	17	0.571	8.06	.320
10	" 19	4	"	50	16.0	1	11.0	8.38	5.29	1.6	1.5	76	.0700	.0540	23	0.404	9.29	.460
17	" 25	10	"	44	20.2	1	10.2	7.41	5.47	1.0	0.9	74	.0598	.0386	35	0.456	8.91	.510
27	" 29	14	"	40	16.0	2	10.1	7.68	5.54	1.0	1.2	77	.0713	.0526	26	0.421	9.15	.444
33	Sept. 1	17	"	46	18.0	2	11.2	8.09	3.42	2.2	2.5	72	.0668	.0508	24	0.403	9.61	.451
47	" 5	21	"	..	12.0	2	13.0	8.65	5.56	2.1	1.0	67	....	.0651	..	0.641	11.26	.383

Silver King, Ears off (Wells)																			
5	Aug.	15	0	"	44	16.6	1	10.5	8.87	6.46	0.8	1.6	84	.0662	.0552	17	0.571	8.96	.320
11	"	19	4	"	44	8.6	2	12.5	11.06	6.70	1.1	3.3	88	.0614	.0384	38	0.347	12.08	.307
18	"	25	10	"	55	22.8	2	13.7	11.65	8.48	1.9	1.3	85	.0986	.0580	41	0.890	12.97	.320
26	"	29	14	"	43	26.0	2	14.7	11.34	9.10	1.8	0.4	77	....	.1291	..	0.777	13.73	.411
32	Sept.	1	17	"	43	28.0	2	18.0	13.40	8.56	2.4	2.4	74	.2548	.1812	29	1.014	15.49	.438
46	"	5	21	"	..	24.0	2	16.6	14.00	10.64	1.3	2.1	84	.1955	.1441	26	1.113	15.40	.400
Golden Bantam, Ears off (Owatonna)																			
1	Aug.	9	4	24 hrs.	33	30.0	2	15.0	10.66	3.81	..	..	71	....	.1315	..	0.982	13.24	.404
3	"	12	8	18 "	59	25.0	1	14.0	11.52	5.85	2.6	3.1	82	.1720	.1641	19	0.615	12.40	.367
6	"	16	12	Fresh	40	24.6	1	13.8	9.18	6.84	1.0	1.3	66	.2021	.1345	34	0.945	11.34	.563
8	"	19	15	12 hrs.	46	26.0	2	15.1	11.93	8.42	2.5	1.0	78	....	.1732	..	0.989	13.95	.508
13	"	23	19	12 "	45	26.8	2	13.7	9.31	6.19	2.1	1.0	69	....	.2295	..	0.686	10.73	.437
22	"	26	22	12 "	37	33.6	2	14.9	11.63	8.65	2.1	0.9	78	....	.2259	..	0.434	14.31	.441
Evergreen, Ears off (Lake Mills, Iowa)																			
7	"	17	0	18 "	46	16.0	2	12.0	8.92	5.42	1.9	1.6	74	.0831	.0655	21	0.513	9.75	.243
12	"	20	3	18 "	44	8.6	1	12.5	9.17	3.50	3.4	2.2	73	.0768	.0652	15	0.490	9.99	.367
15	"	24	7	18 "	51	18.0	3	13.2	11.85	7.22	1.6	3.0	89	....	.1052	..	0.663	12.32	.343
24	"	27	10	18 "	44	18.0	3	15 2	12.86	6.56	3.3	3.0	85	.1779	.1559	12	0.556	15.13	.340
38	Sept.	1	14	24 "	21	20.0	3	15.0	11.34	6.64	2.4	2.3	76	.1908	.1593	16	0.974	13.08	.348
42	"	3	16	16 "	..	16.0	1	14.9	11.12	8.31	2.0	0.8	75	.1891	.1491	22	0.819	13.68	.337
Narrow Evergreen, Ears off (Owatonna)																			
14	Aug.	23	1	16 "	47	15.0	1	10.9	8.06	3.54	2.3	2.2	74	....	.0967	..	0.459	9.64	.437
23	"	26	4	16 "	48	24.0	1	13.1	10.97	5.97	2.6	2.5	84	.1397	.1153	17	0.951	11.43	.473
31	"	31	9	16 "	42	22.0	2	15.2	11.76	6.50	2.7	2.6	78	.1868	.1029	45	1.099	13.48	.219
43	Sept.	3	12	16 "	..	32.0	3	17.5	13.00	9.17	3.0	0.8	74	....	.1164	..	1.311	15.96	.675
Country Gentleman, Ears off (Lake Mills, Iowa)																			
16	Aug.	24	0	16 "	57	16.0	1	12.5	10.31	7.96	0.5	1.8	82	....	.0639	..	0.600	11.50	.601
25	"	27	3	16 "	50	20.4	2	14.5	11.16	5.41	3.8	2.0	77	.1287	.0961	25	0.781	13.15	.542
37	Sept.	1	8	48 "	31	24.0	3	16.6	13.42	6.26	4.0	3.2	81	.1627	.1211	26	0.708	15.21	.580
41	"	3	10	12 "	..	20.0	1	15.0	10.53	8.88	1.3	0.3	70	.1580	.1106	30	0.705	13.68	.392

TABLE II

ANALYSES OF *CORNSTALK* JUICES, CROP OF 1922, GROWN AT WELLS, MINNESOTA

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Sample No.	Date	Time from canning stage	Extraction	Acidity 0.1 N per 100 cc. juice	Color	Brix	Total solids by refractometer	Solids / Brix × 100	Sugars: Total	Sugars: Sucrose	Sugars: Glucose	Sugars: Fructose	Purity J / G × 100	Total nitrogen	Non-protein nitrogen	Protein nitrogen, of total	Alcohol precipitate	Ash
		days	per cent	cc.			gms.		gms.	gms.	gms.	gms.		gms.	gms.	per cent	gms.	gms.
								Evergreen, Ears on										
2	Aug. 15	0	48	21.0	2	10.5	9.3	88.5	8.40	3.82	2.71	1.87	80	.1095	.1050	4	0.634	1.2300
5	" 17	2	50	21.6	1	10.3	9.1	88.2	8.59	4.54	2.47	1.58	82	.0975	.0605	38	0.442	1.2312
11	" 19	4	57	22.5	2	10.8	8.9	82.5	7.46	4.62	1.35	1.49	69	.1215	.0935	23	0.511	1.2637
15	" 22	7	54	19.5	2	11.8	10.1	85.8	7.85	5.33	1.32	1.20	70	.1200	.0740	38	0.552	1.1712
24	" 24	9	50	19.1	1	10.9	9.7	89.0	8.18	4.82	1.95	1.41	75	.0945	.0515	46	0.442	1.0012
28	" 26	11	57	21.2	1	11.5	9.7	84.4	9.51	7.06	0.79	1.66	82	.1085	.0665	39	0.654	1.0087
34	" 29	14	52	22.5	1	11.6	10.7	92.0	10.06	7.02	1.23	1.81	87	.1080	.0995	8	0.566	1.0000
39	" 31	16	52	24.6	1	12.5	11.4	91.3	10.19	7.52	0.90	1.77	81	.1005	.0995	1	0.657	1.0210
47	Sept. 2	18	45	17.6	1	11.0	9.4	85.5	8.67	6.25	1.02	1.33	78	.0940	.0715	23	0.663	1.1750
50	" 5	21	44	16.8	3	11.8	10.4	88.3	10.95	8.76	0.11	2.08	92	.1160	.0925	20	0.631	1.1887
57	" 7	23	50	12.8	1	9.6	7.7	80.3	8.32	6.79	0.49	1.04	86	.1230	.0930	24	0.526	1.3162
60	" 9	25	48	16.4	3	10.5	9.0	85.7	7.95	6.43	0.23	1.29	75	.1300	.0925	28	0.600	1.3262
								Evergreen, Ears off										
2	Aug. 15	0	48	21.0	2	10.5	9.3	88.5	8.40	3.82	2.71	1.87	80	.1095	.1050	4	0.634	1.2300
6	" 17	2	44	27.2	2	11.2	9.5	83.0	8.76	4.31	2.87	1.59	77	.1240	.1135	12	0.465	1.5275
10	" 19	4	56	22.3	2	11.2	9.5	83.0	8.62	5.29	1.43	1.90	77	.1225	.0985	27	0.517	1.2687
28*	" 26	1*	57	21.2	1	11.5	9.7	83.0	9.51	7.06	0.79	1.66	87	.1085	.0665	39	0.654	1.0987
33	" 29	4	52	23.1	1	12.9	11.9	92.3	11.67	8.97	0.45	2.25	90	.1280	.0775	39	0.674	0.9775
38	" 31	6	55	26.3	1	13.5	12.0	89.0	11.37	9.03	0.63	1.71	84	.1220	.1215	1	0.747	1.1162
41	Sept. 1	8	48	35.9	3	15.5	14.7	95.0	11.82	7.99	2.62	1.21	76	.1370	.1105	19	0.759	1.1150
46	" 2	9	45	21.8	1	14.3	13.2	92.5	11.92	9.94	0.50	1.48	83	.1325	.1015	23	0.714	0.9950
51	" 5	12	45	18.2	2	12.9	11.5	89.2	10.12	7.82	1.19	1.11	78	.1645	.1300	21	0.921	1.1937
58	" 7	14	48	20.3	1	13.7	13.1	95.6	10.63	8.90	0.36	1.37	77	.1925	.1300	32	0.842	1.2162
61	" 9	16	45	19.7	1	13.8	13.0	94.2	10.65	8.32	1.54	0.79	77	.1685	.1300	22	0.842	1.1375

								Country Gentleman, Ears off										
40	Aug. 31	0	52	18.5	1	10.2	9.7	94.2	7.76	4.79	1.30	1.67	75	.0550	.0315	42	0.549	0.6425
45	Sept. 2	2	54	17.6	2	12.0	11.9	99.1	10.36	7.56	1.30	1.67	87	.0920	.0715	22	0.629	0.6262
52	" 5	5	48	18.5	2	13.5	12.9	95.5	11.82	8.11	2.02	1.69	87	.1475	.1065	28	0.734	0.9412
56	" 6	6	50	21.0	1	14.1	12.9	91.6	11.69	9.40	0.61	1.68	83	.1845	.1215	34	0.868	0.8787
59	" 8	8	44	18.7	2	14.2	13.4	94.5	11.92	9.32	1.28	1.32	84	.1535	.1275	17	0.825	0.8675
								Minnesota No. 13, Ears on										
1	Aug. 14	0	49	20.9	1	11.8	11.2	95.0	10.15	5.78	2.59	1.78	85	.0900	.0720	20	0.720	0.5637
3	" 16	2	38	27.0	1	11.8	10.5	94.0	10.41	4.32	3.84	2.25	88	.0865	.0520	40	0.554	0.5012
7	" 18	4	31	16.6	1	11.7	10.9	93.1	10.90	4.98	3.23	2.69	93	.0735	.0490	33	0.538	0.5887
14	" 21	7	50	18.5	2	10.4	9.1	87.7	9.35	4.40	2.38	2.57	90	.0520	.0250	52	0.451	0.5125
23	" 23	9	50	20.8	2	11.1	10.2	92.0	10.57	5.47	2.72	2.38	95	.0860	.0390	55	0.537	0.5675
25	" 25	11	50	18.2	2	10.3	9.6	93.2	8.72	5.67	1.36	1.69	92	.0765	.0215	72	0.565	0.5900
31	" 28	14	45	21.0	3	11.2	10.4	93.0	9.67	6.00	1.39	2.28	95	.0800	.0485	39	0.576	0.6712
36	" 30	16	52	23.7	2	10.3	9.3	90.5	8.46	5.49	1.06	1.91	82	.0405	.0175	57	0.476	0.7050
43	Sept. 1	18	50	21.8	2	9.9	7.9	80.0	7.15	3.81	2.00	1.34	73	.0515	.0255	51	0.576	0.5037
48	" 4	21	50	21.0	2	9.4	8.6	91.5	6.16	3.12	2.29	0.75	66	.0640	.0400	37	0.629	0.7087
								Minnesota No. 13, Ears off										
1	Aug. 14	0	49	20.9	1	11.8	11.2	95.0	10.15	5.78	2.59	1.78	86	.0900	.0720	20	0.720	0.5637
4	" 16	2	41	20.4	1	13.7	12.5	91.3	11.58	5.18	4.62	1.78	85	.1010	.0610	40	0.628	0.4962
8	" 18	4	44	21.6	2	14.4	13.5	93.7	13.87	7.39	3.41	3.07	96	.1017	.0605	41	0.844	0.6087
13	" 21	7	52	22.0	3	14.1	13.3	94.4	13.47	7.91	3.11	2.45	96	.1095	.0705	37	0.623	0.4737
16	" 22	8	52	28.1	2	14.1	12.7	90.1	13.38	9.48	1.27	2.63	95	.0915	.0515	44	0.864	0.5125
22	" 23	9	55	21.4	2	14.6	14.0	96.0	14.55	10.26	1.72	2.57	95	.1105	.0605	48	0.823	0.4887
26	" 25	11	46	26.0	3	14.8	14.3	96.6	12.69	9.97	1.37	1.35	86	.1513	.0895	41	1.220	0.5037
32	" 28	14	36	24.5	3	14.6	14.0	96.0	13.68	10.31	1.32	2.05	94	.1220	.0750	38	0.847	0.4362
37	" 30	16	52	25.2	2	16.5	16.1	97.5	15.43	12.60	0.74	2.09	93	.1340	.0815	39	1.160	0.4625
42	Sept. 1	18	43	26.6	2	16.7	16.0	95.7	13.81	11.02	1.24	1.55	83	.1580	.1095	41	1.292	0.5875
49	" 4	19	42	31.5	3	16.1	15.7	97.5	13.60	10.38	1.86	1.36	85	.1965	.1300	32	0.957	0.4838
55	" 6	21	44	36.3	2	17.1	16.7	97.7	13.59	10.27	2.64	0.68	80	.2270	.1300	43	1.334	0.5525
								Crosby, Ears off										
9	Aug. 18	1	42	19.5	4	11.3	10.6	93.8	10.84	3.74	3.98	3.12	95	.0700	.0440	37	0.569	0.5075
12	" 21	4	48	20.4	4	12.4	11.4	92.0	11.38	5.74	3.35	2.29	92	.0955	.0625	35	0.599	0.3862
21	" 23	6	50	24.3	4	13.1	12.7	97.0	13.81	7.24	3.04	3.53	105	.1107	.0625	44	1.159	0.3662
27	" 25	8	45	18.0	4	12.6	12.5	99.2	11.18	6.48	2.50	2.20	89	.1300	.0750	43	0.844	0.3725
30	" 28	11	40	23.5	4	13.9	13.8	99.3	13.05	7.89	2.11	3.05	93	.1650	.1050	36	1.039	0.5087
35	" 30	13	47	20.6	4	14.1	13.9	98.6	15.12	10.45	1.20	3.47	107	.1325	.0870	34	0.835	0.5012

* Samples 2, 6, and 10 were taken before the canning stage of ripeness; therefore a new series was started with No. 28.

The data for 1921 are presented in Table I, and those for 1922 in Table II. The values given are in terms of 100 cc. of juice, and not, strictly speaking, in per cent. Each item can best be considered separately.

Acidity.—The acidity of cornstalk juice is considerably higher than that of sorghum juice or of sugar cane juice. On the average, in corn juice it is approximately 20, in sorghum 12, and in sugar cane 15 cc. 0.1 N per 100 cc. Figures 1 and 2 indicate that there is a somewhat greater acidity in the samples without ears. This difference, however, may be a secondary effect of the increased density in the latter case. This is shown in Figure 3, in which the Brix readings and the acidities of the 1922 samples are plotted against each other. There is a slight but constant positive correlation between the two values, altho the number of samples did not warrant calculating the correlation coefficient.

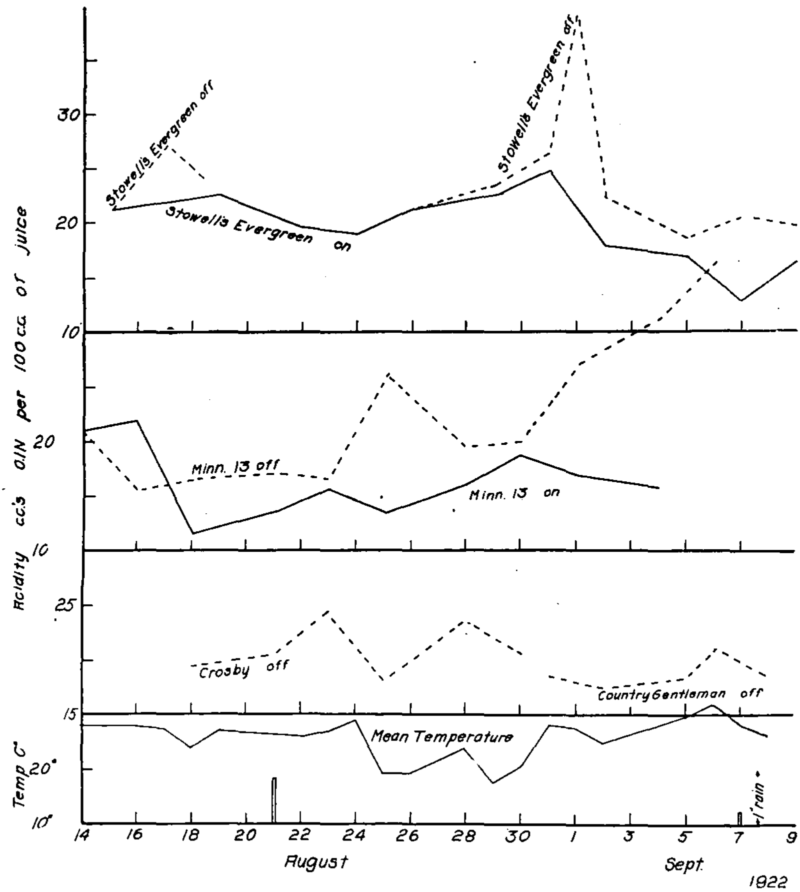

Fig. 2. Development of Acidity of Cornstalk Juice in 1922

Density.—Figures 4 and 5 indicate that there is very little if any increase in density in the juice of normal corn plants left to mature with the ears on. Collier (8) found only a slight increase in most of his varieties. When the ears are removed, however, the density almost always increases markedly, the only exception being Golden Bantam. This increase in density after the removal of the ears is the most conspicuous fact brought out in any of the charts. It is so marked as to indicate the impracticability of making sirup from anything but stalks from which the ears have been removed. The time of maximum density is probably the point at which the cane should be harvested for sirup, unless at some other stage the quality of the juice is better. This point of maximum density is reached at from 2 to 3 weeks after removing the ears. To what substances this increase in density is due will be discussed below. At the bottom of Figure 5 are the temperature and rainfall data for the season of 1922. There is no evident relation between these and the density, perhaps because neither of the rains was heavy.

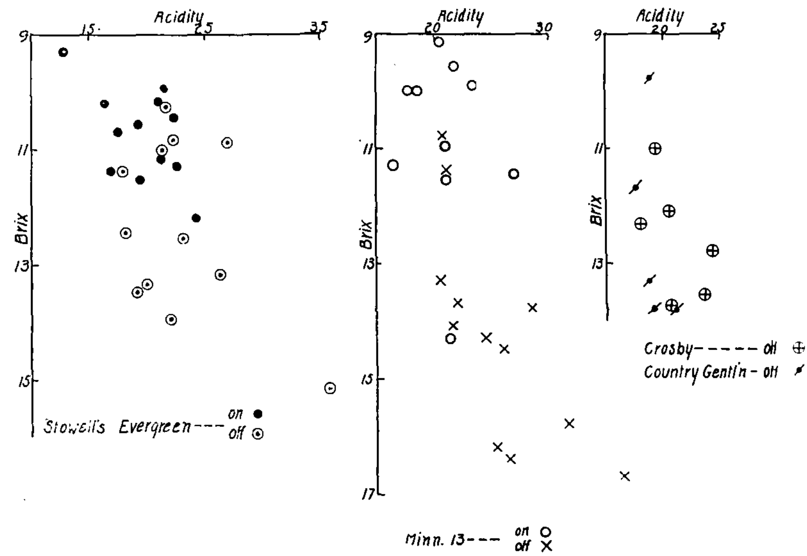

Fig. 3. Acidities Plotted Against Brix, 1922 Samples, to Show the Positive Correlation Between These Two Factors

Through the courtesy of Prof. E. D. Holden, of the University of Wisconsin, the writers were able to secure some data on the density of the juice of early Evergreen grown at Madison, Wis. The data are given in Table III. The densities are about the same as those given for the Minnesota samples, and show further that at the canning stage these densities are too low for sirup making.

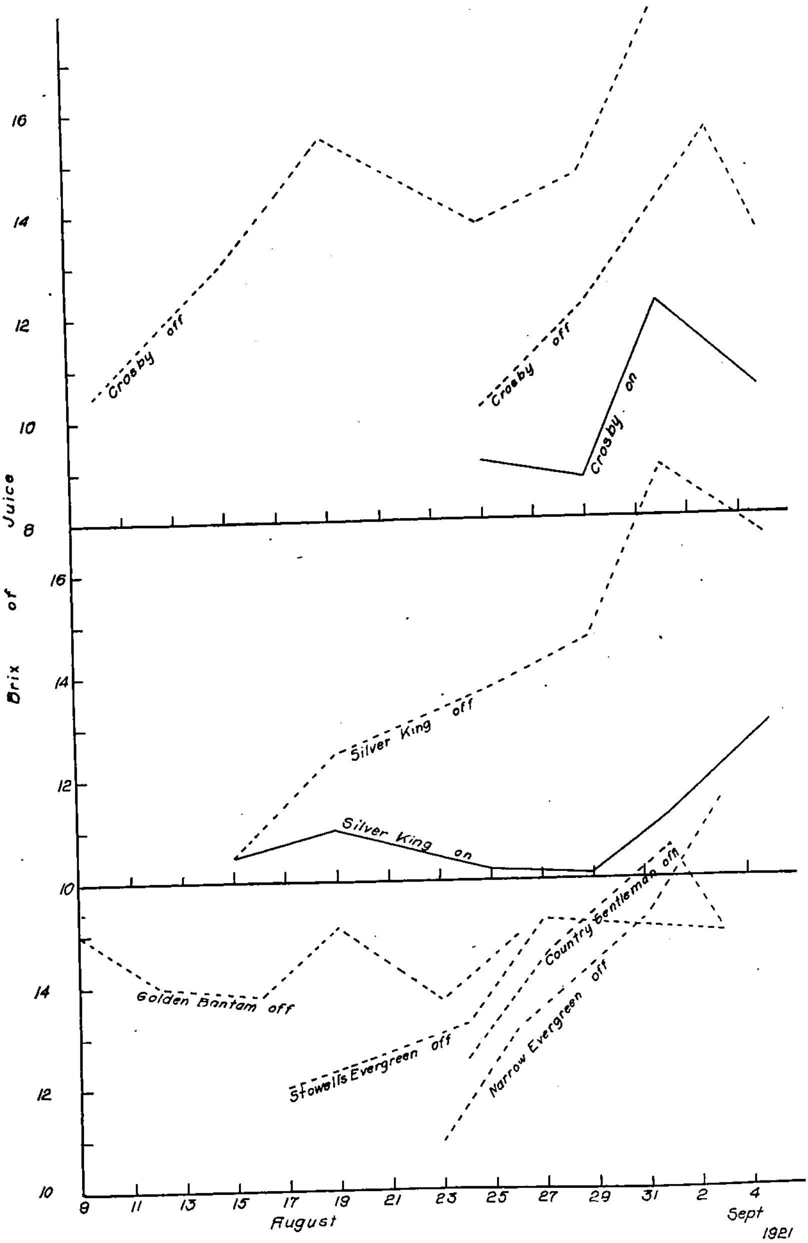

Fig. 4. Development of Density of Juice (in Degrees Brix) of Cornstalks in 1921

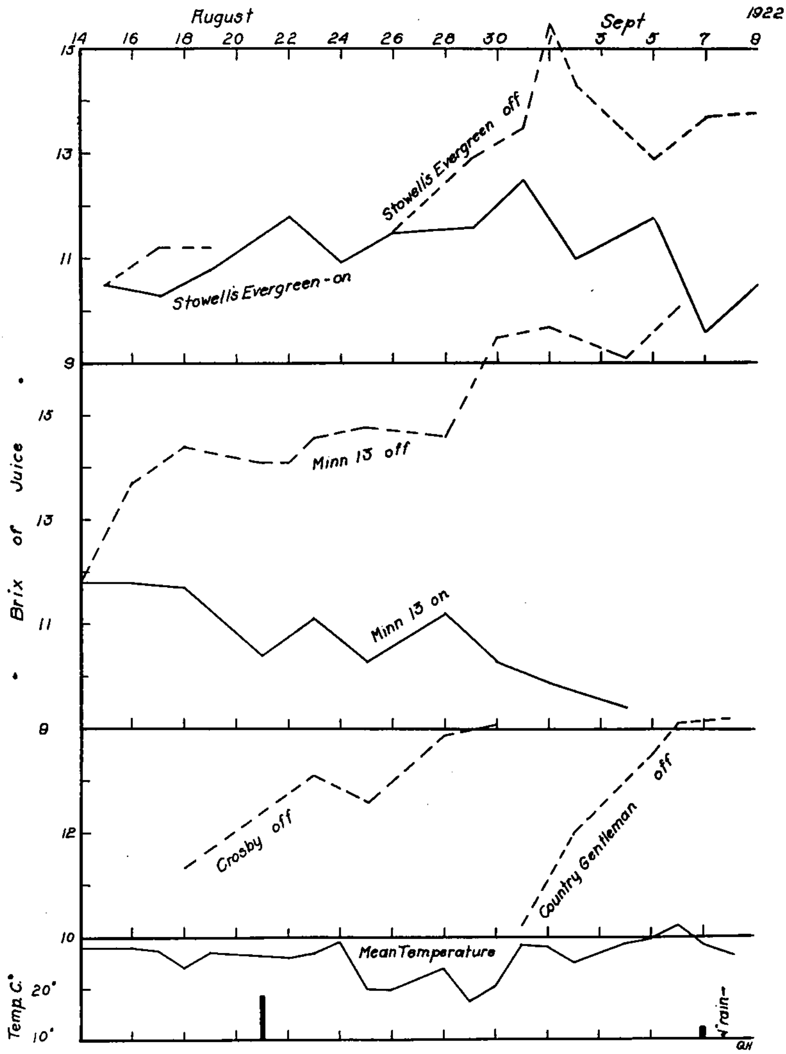

Fig. 5. Development of Density of Juice (in Degrees Brix) of Cornstalks in 1922

TABLE III

DEGREES BRIX OF JUICE OF EARLY EVERGREEN GROWN AT MADISON, WISCONSIN, IN 1921

Sample No.	Date	Stage of maturity	Degrees Brix
1	July 31	Just previous to canning stage	11.1
2	July 31	Just previous to canning stage	11.2
3	July 31	Early canning stage	9.3
4	August 5	Early canning stage	10.2
5	August 5	Early canning stage	11.0
6	August 11	Canning stage	9.5
7	August 17	Late canning stage	11.8

Sugars.—The 1921 values for sucrose, glucose, and fructose are given in Table I, but they are not charted, as it was thought that some inversion might have taken place during the heating with alcohol. However, polarizations of normal solutions of the 1921 juices are given in Figure 6. All sugar data for 1922 are given in Figures 6 to 10.

The total sugars in the juice of the normal plant with ears left on increased but slightly. The 1921 samples showed no increase. Evergreen in 1922 showed a small increase, and the field corn a decrease from 11 per cent to 6 per cent. All three sugars contributed to these changes. With the ears removed, however, there was a marked increase in total sugars, amounting to at least 50 per cent in most cases. Most of this increase was due to sucrose, as glucose and fructose usually decreased. A total sugar content of 13 per cent was almost always attained by the varieties used, and 15 per cent was reached in several cases. The ratio of glucose to fructose fluctuated continually, neither sugar being consistently in excess of the other. This is different from sorghum (31), in which glucose is always in excess of fructose. The two sugars considered together always varied inversely with the sucrose, which, of course, is usual in plants.

One unusual thing about the carbohydrates of cornstalk juice is the absence of starch. It has not been found in any of the samples of sirup tested. This is especially interesting in view of Sherwood's recent observations on the universal occurrence of starch in sorghum juice (21). The low viscosity of the sirup, discussed in Part III, is explainable by this lack of starch.

Purity.—The sucrose purities are not given in the tables, but they vary between 55 and 70, showing the infeasibility of making sugar from this material. For the manufacture of sirup the sucrose purity is of little consequence, the "total sugar purity" being of more significance. This quotient is given in Table I, Column O, and Table II, Column N. It varied erratically from day to day, but was appreciably higher in the samples with the ears removed. It was higher in 1922 than in 1921, and in Minnesota No. 13 field corn than in any of the sweet corn varieties.

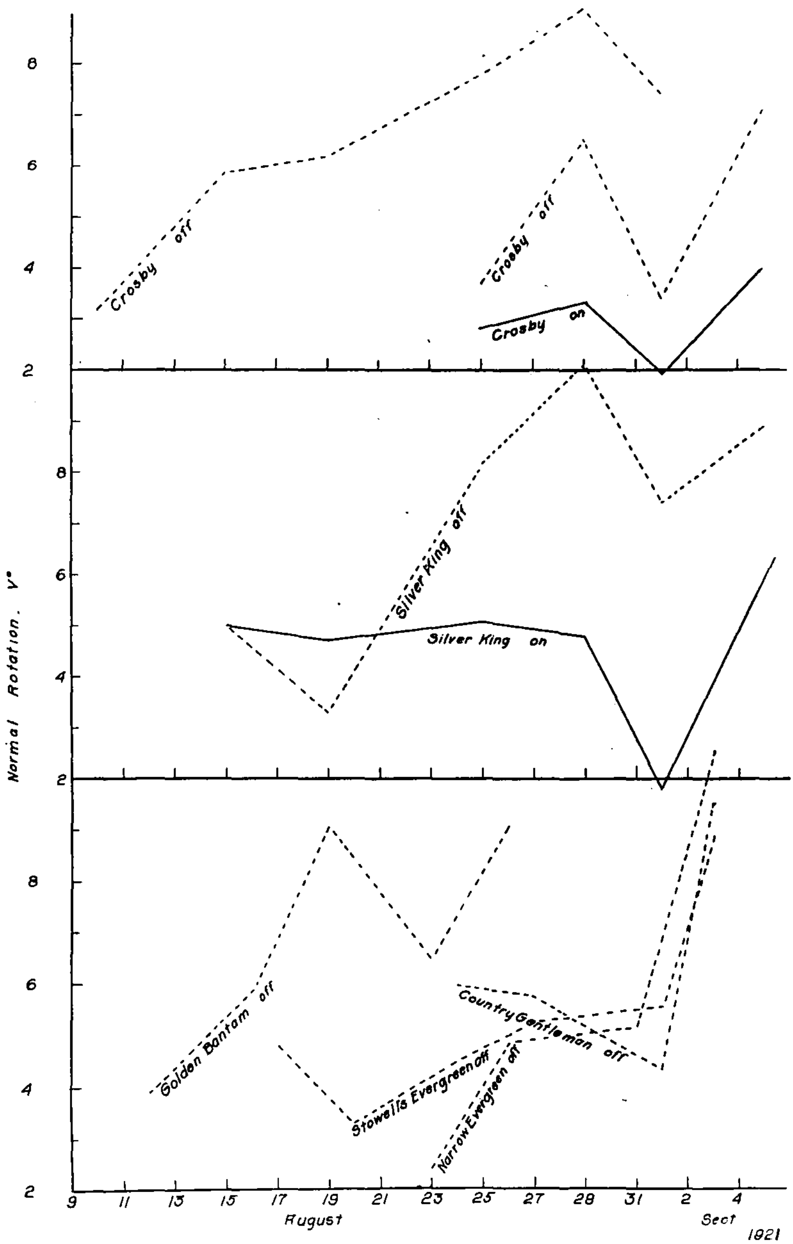

Fig. 6. Normal Rotations of Cornstalk Juices in 1921

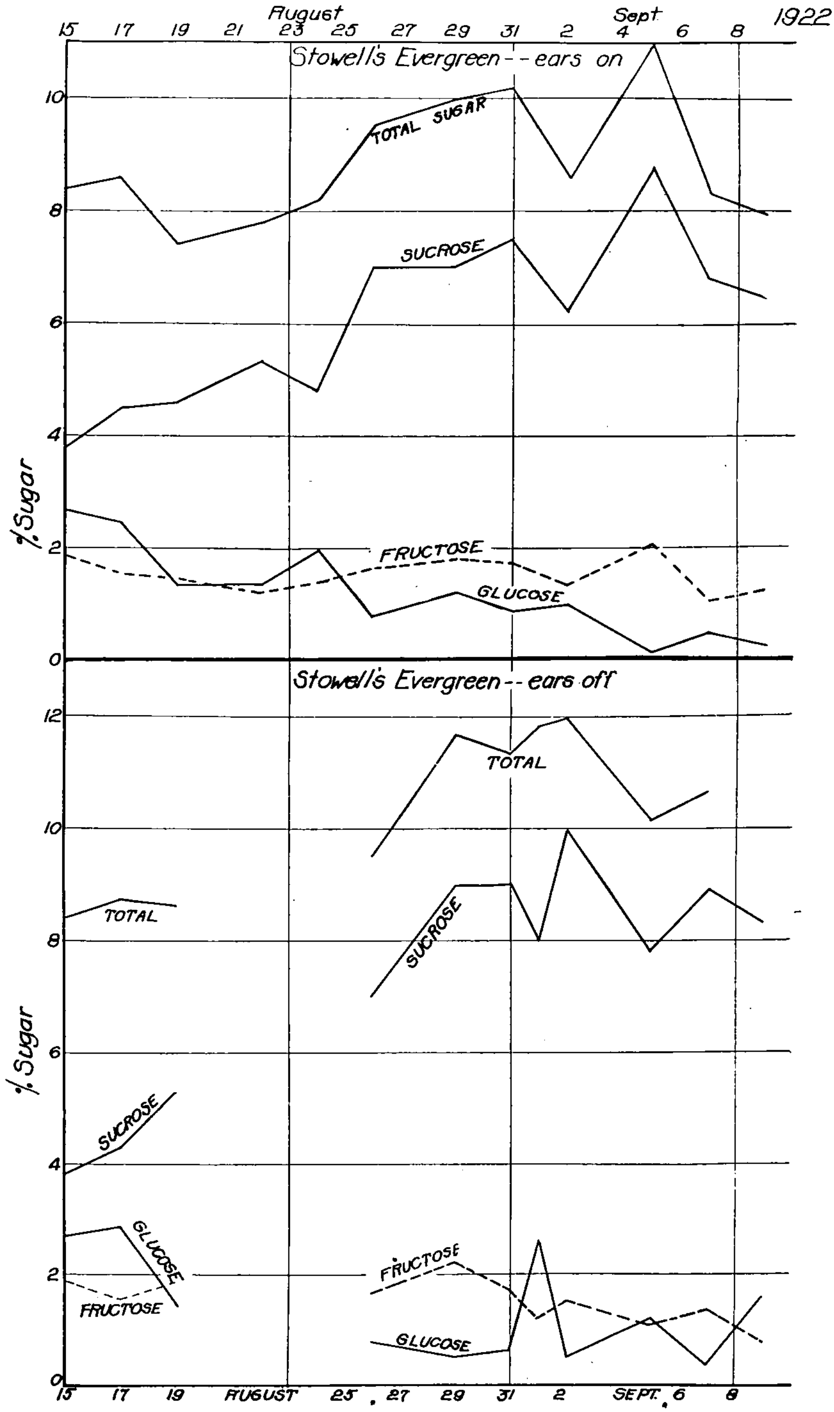

Fig. 7. Percentages of Various Sugars in Cornstalk Juices, 1922

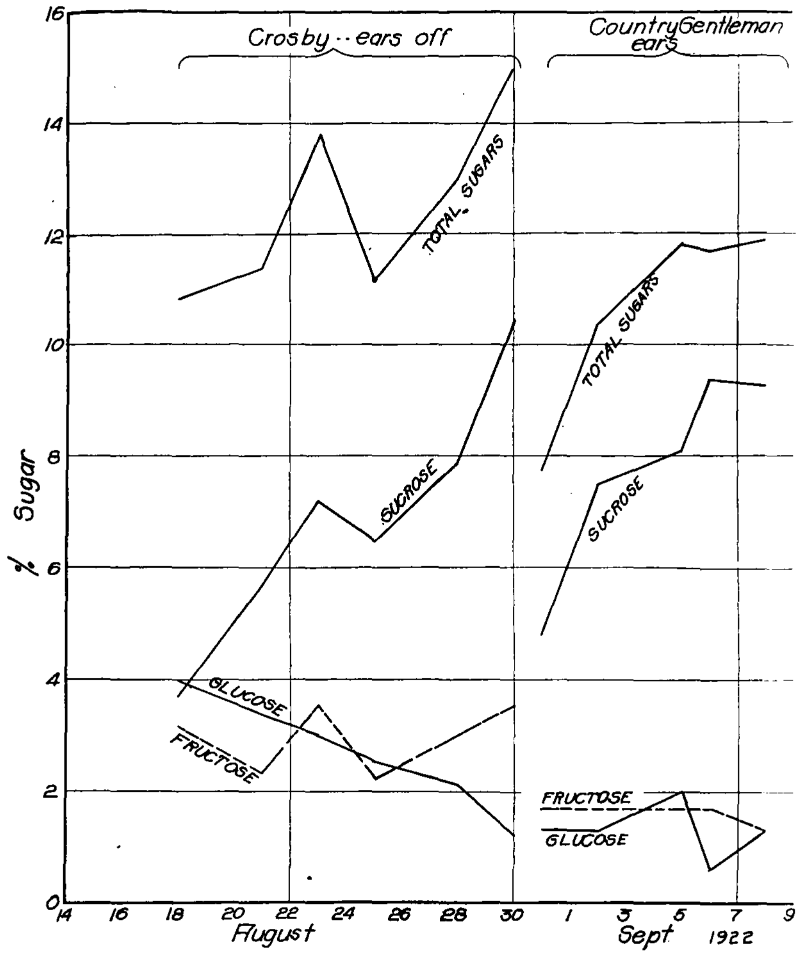

Fig. 8. Percentages of Various Sugars in Cornstalk Juices, 1922 (Continued from Figure 7)

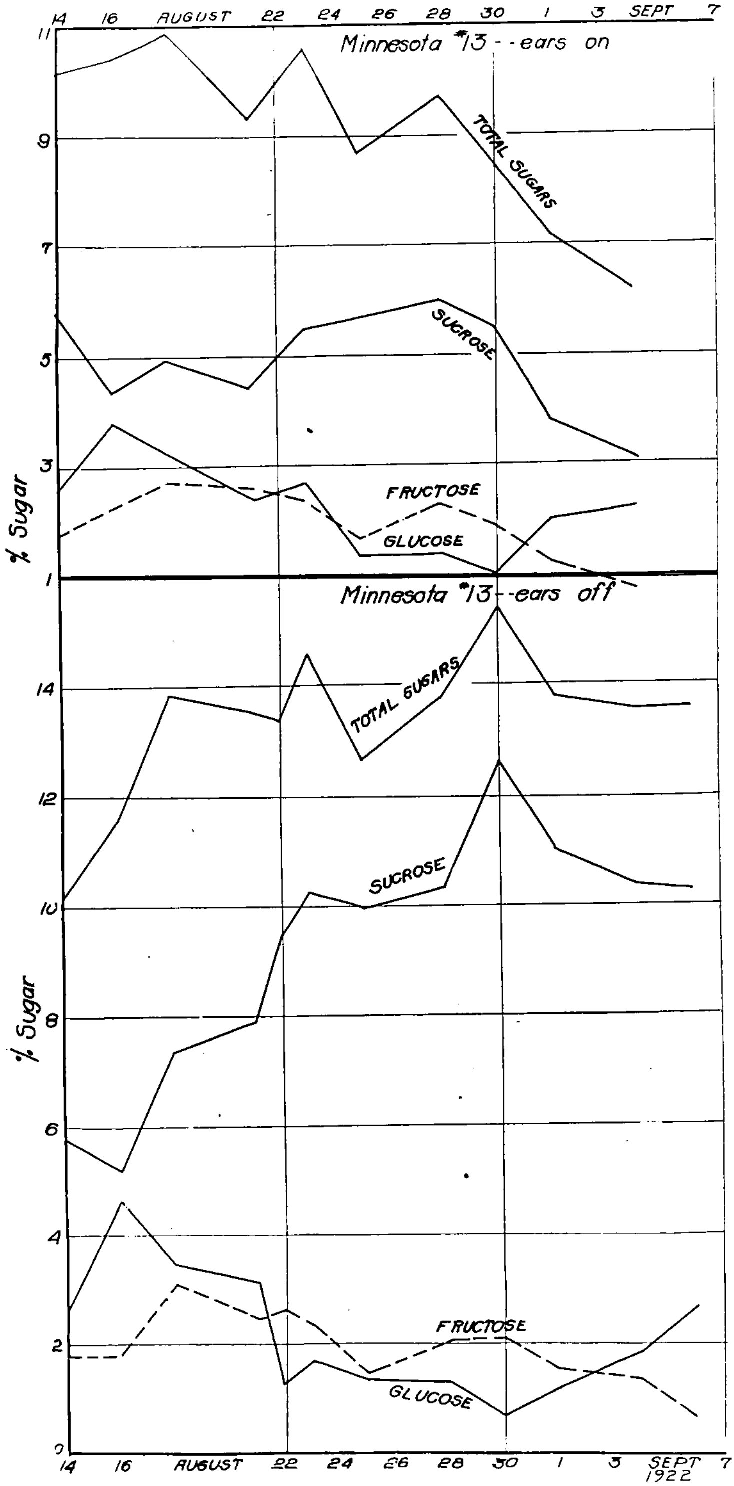

Fig. 9. Percentages of Various Sugars in Cornstalk Juices, 1922
(Continued from Figures 7 and 8)

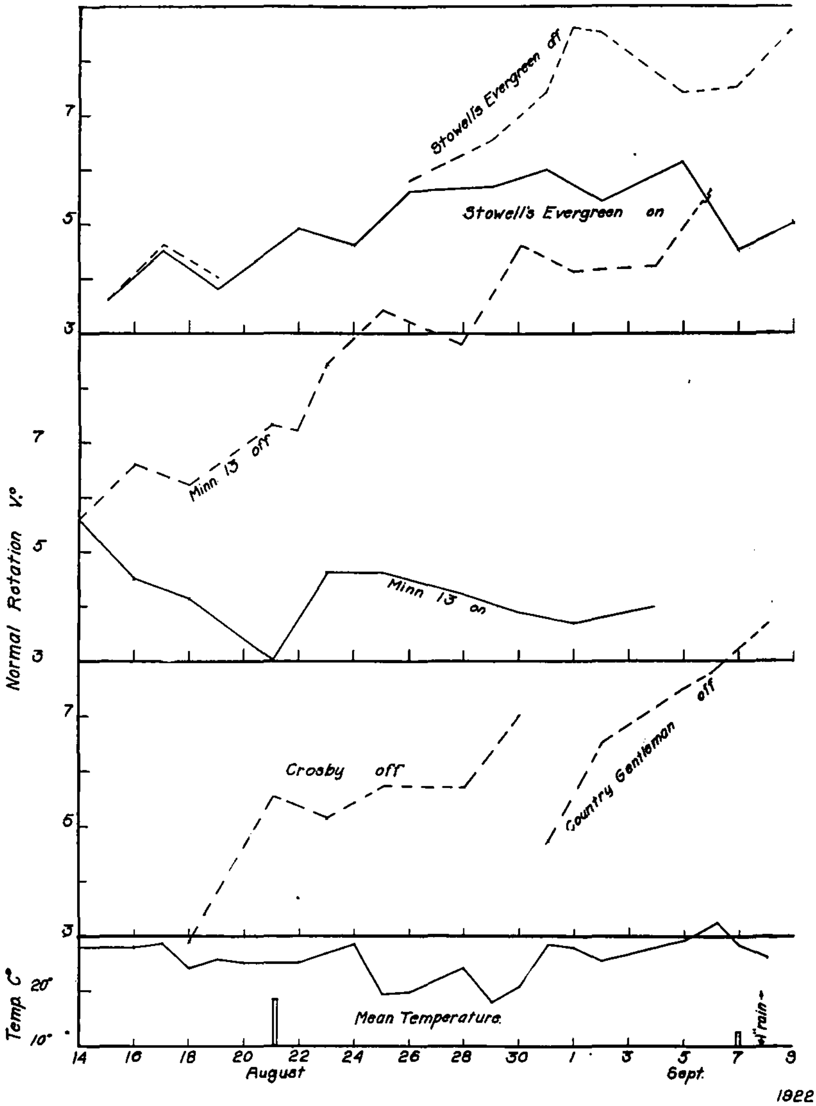

Fig. 10. Normal Rotations of Cornstalk Juices in 1922

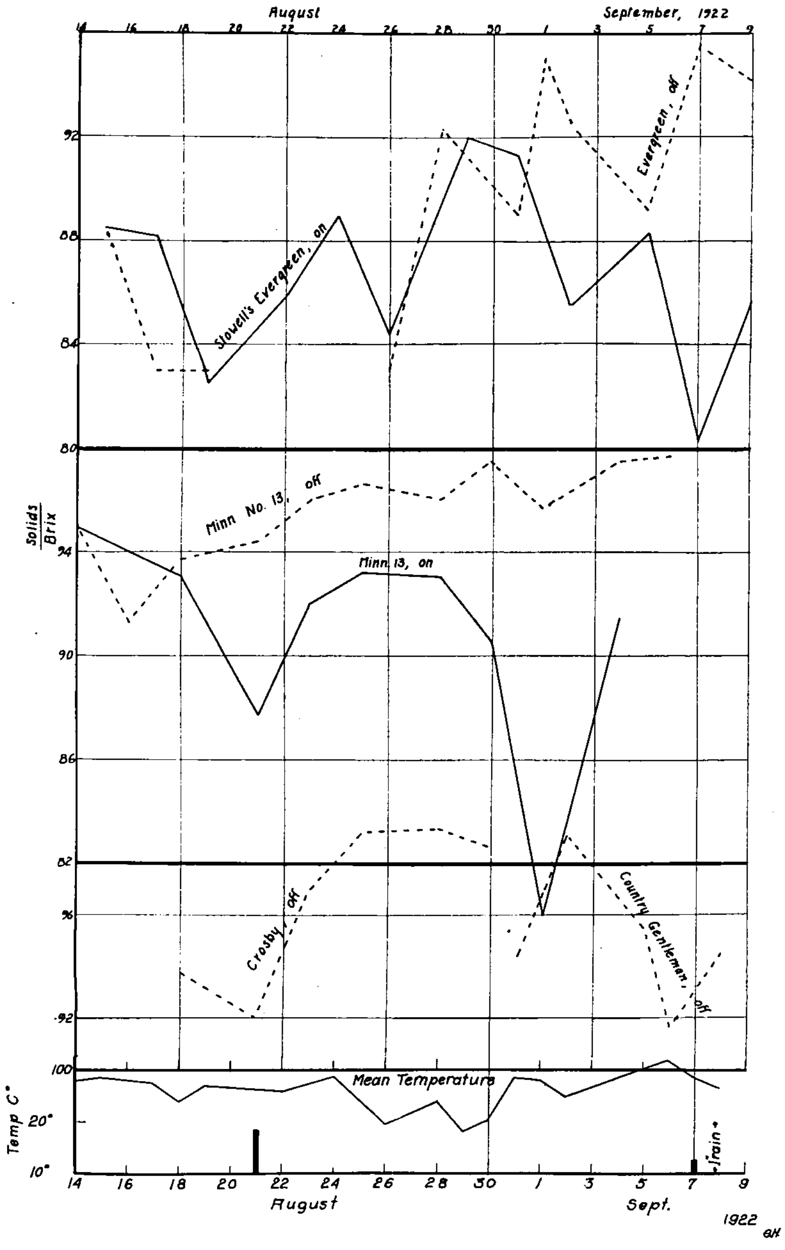

Fig. 11. Development of Purity Quotient (Solids-over-Brix) of Cornstalk Juices in 1922

Another purity quotient that was calculated is the total solids as determined by the Abbe refractometer divided by the degrees Brix. This instrument has frequently been shown to give an accurate estimation of the total solids in plant extracts (6, 10), while the Brix reading usually gives results that are too high. This difference is due to the fact that the index of refraction averages about the same for sugars, minerals, and organic acids, especially such of those substances as are met with in plant juices; while the specific gravity is much higher for each unit of mineral substances in solution than for the sugars. Thus, as the ratio of sugars to non-sugars increases, the index of refraction does not change appreciably, but the specific gravity becomes relatively lower. Therefore, the less the difference between the Brix reading and the refractometer total solids, the greater is the total sugar purity.

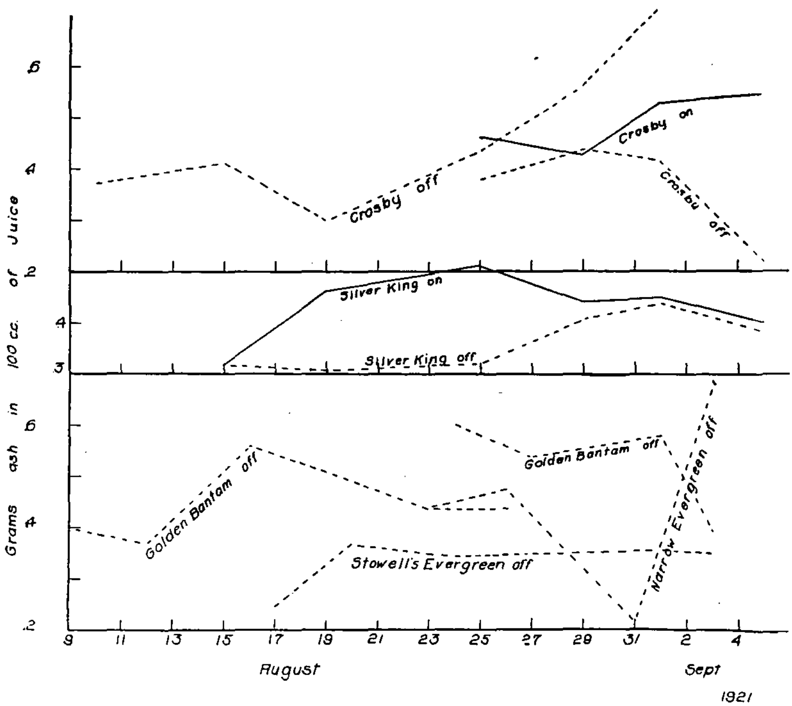

Fig. 12. Development of Ash in Cornstalk Juices in 1921

The quotients of these two readings for the 1922 samples are given in Column I, Table II, and in Figure 11. Refractometer readings were not obtained in 1921. It will be seen that the quotient is higher in the case of the samples with ears removed, and that in general the quotient increases with the maturity of the plant.

Figures 12 and 13 show that there is only a small lowering of the ash content when the ears are removed; hence the changes in the quotient must be due mostly to changes in the sugar content.

Another way of showing the relation between this quotient and the degrees Brix is to plot them against each other. This has been done in Figure 14. It will be seen that in all varieties except Country Gentleman the Brix increases as the quotient increases, or as the purity increases. The correlation is more marked in the samples with the ears off, which again argues for the belief that during the period following the removal of the ears sugars are the principal constituents laid down in the juice. A little further information is furnished by some of the samples of juice obtained for sirup making, and described in Part II of this paper. They are shown in Figure 15.

Another significant fact is the much lower quotients among the samples of Stowell's Evergreen, and likewise the much higher ash content of these juices. The sirups from these juices had a very unpleasant flavor. The cause of this was found to be a large amount of potassium nitrate in the juice; so large, in fact, that it crystallized from the sirups. This will be discussed further in Part II and is mentioned here in order to show how the refractometer-over-Brix coefficient is affected by such abnormalities. It is believed that this coefficient can be made a very useful index of the quality of juices for sirup making. It may have application to other plant juices, and the writers intend to make a further study of its use.

Nitrogen content.—The total nitrogen, non-protein nitrogen, and percentage of total as protein nitrogen are shown in the tables, and in Figures 16, 17, and 18. By protein nitrogen in this case is meant the nitrogen removed by boiling the juice in about 60 per cent alcohol and filtering. An inspection of the curves will show that when the ears are left on the stalks to mature there is no change in the total nitrogen or in the protein nitrogen of the juice. With removal of the ears, however, there is an enormous increase in total nitrogen, accompanied by a well marked increase in protein nitrogen. The percentage of the total in the form of protein nitrogen remains fairly constant, however. This is significant from the standpoint of defecation, since it is the protein compounds which are removable by heat, and which occlude other non-sugar substances in the process. From this standpoint there would be no better defecation in the samples with ears removed.

The *alcoholic precipitate* represents proteins, starch, pectin, and the so-called gums in general. Calculations not shown in the tables indicate that the proteins of the juice (protein nitrogen $\times$ 6.25) constitute from a third to a half of the amount of the alcoholic precipitate.

The curves for the latter, in Figures 19 and 20, have the same general trend as the curves for total protein nitrogen in Figure 17, indicating a very considerable increase in the period following the removal of the ears. Undoubtedly, therefore, protein constitutes a considerable proportion of the alcoholic precipitate. Gummy substances are rather low in cornstalk juice, as is evidenced by the low viscosity of the finished sirup. This will be discussed in Part II.

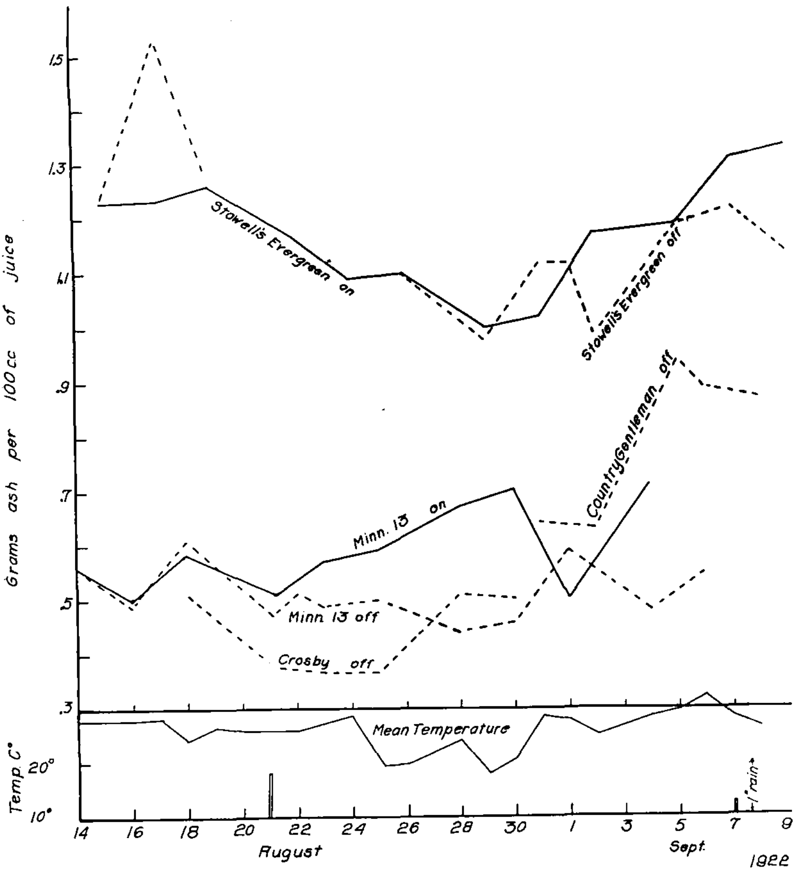

Fig. 13. Development of Ash in Cornstalk Juices in 1922

The *ash* content of cornstalk juices has been mentioned in connection with its effect on the purity quotient. Figures 12 and 13 show that there is less ash in the juices when the ears are off. This is in accord with the increased purity. This is shown further in Figure 21, where the Brix and the ash are plotted against each other. A negative correlation is apparent. Figure 13 shows how greatly the ash content of Evergreen exceeded that of the other varieties in 1922.

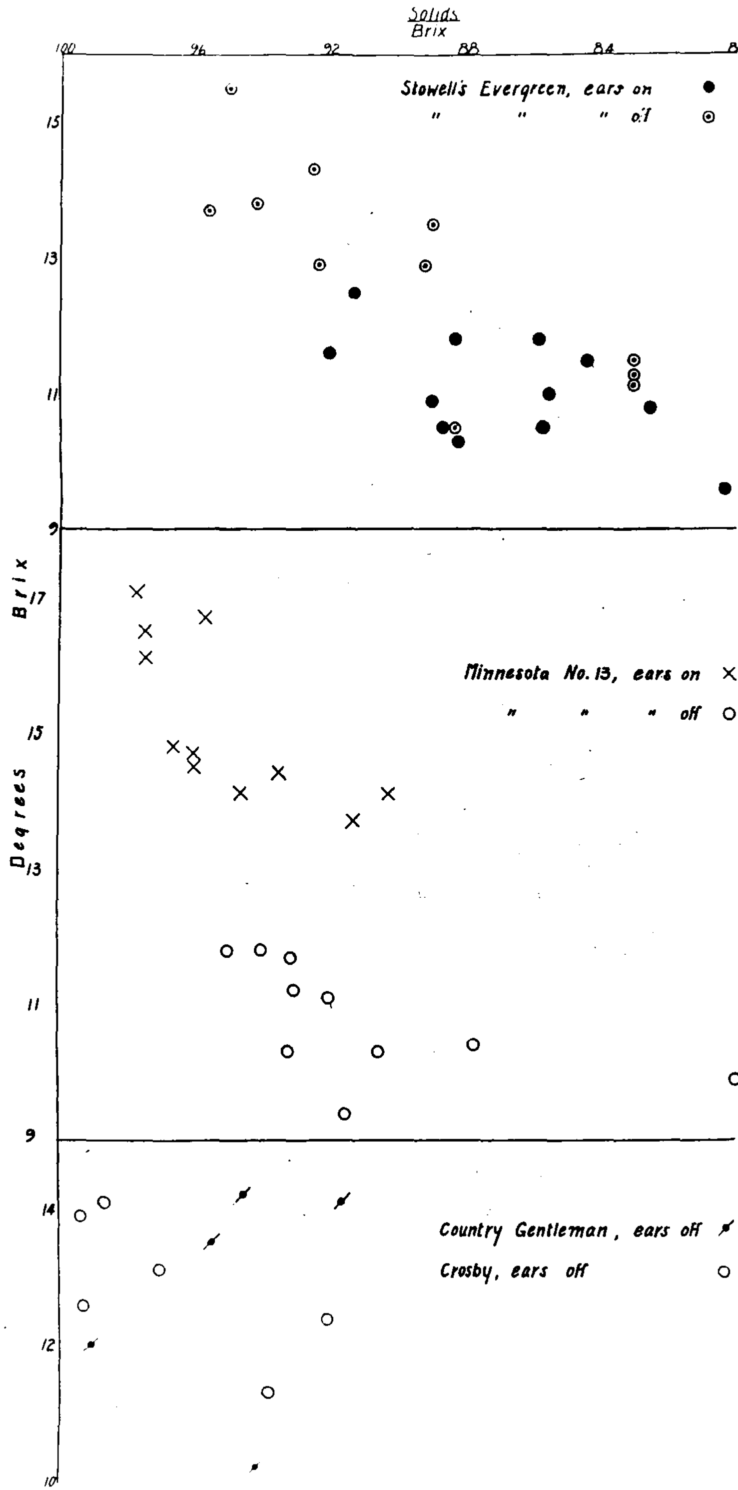

Fig. 14. Purity Quotient Plotted Against Degrees Brix, to Show Increase in Purity with Increase in Brix

As already mentioned, this was due to a large accumulation of potassium nitrate. The Evergreen was grown in a different plot from the other varieties, and probably had at its disposal an unusually large amount of nitrate in the soil.

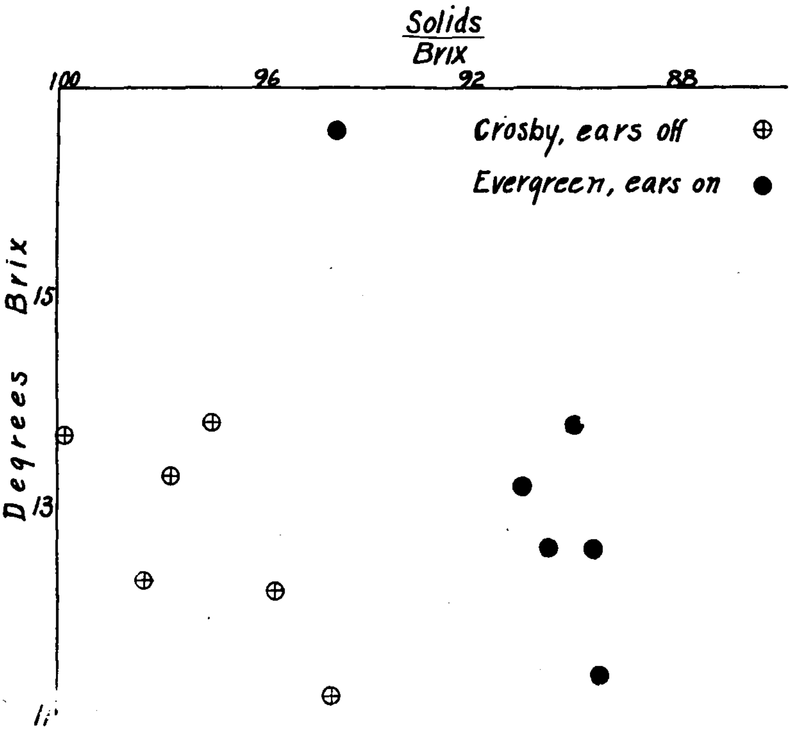

Fig. 15 Purity Quotient Plotted Against Degrees Brix (Continued from Fig. 14)

CLIMATIC EFFECTS

In 1922 a record of temperature and rainfall was kept in the hope that the effect of these factors could be seen in some of the changes noted in the juice. The data obtained are plotted in the various charts for the 1922 samples. The only charts in which any relation is apparent between the weather and conditions in the plant are Figures 11 and 13, containing the purity quotients and the ash contents, respectively. At both ends of the season there was hot weather, with a cool spell in the middle. This cool spell followed the only good rain of the season, when 0.84 of an inch fell. Thus the latter part of the season was characterized by hot, dry weather. The curves for ash content parallel the temperature curve, while the purity curves are the reverse.

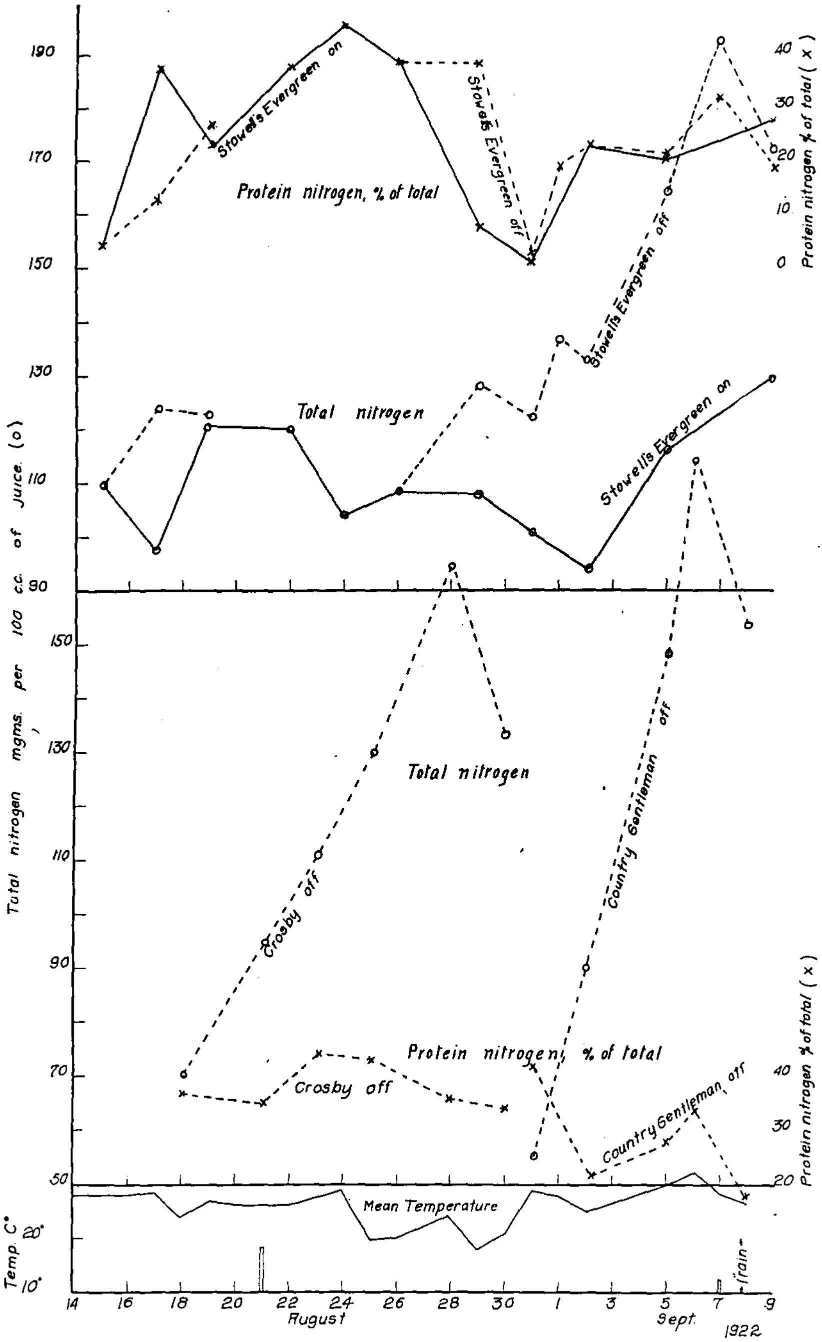

Fig. 16. Development of Total Nitrogen and of Protein Nitrogen in Cornstalk Juices, 1922

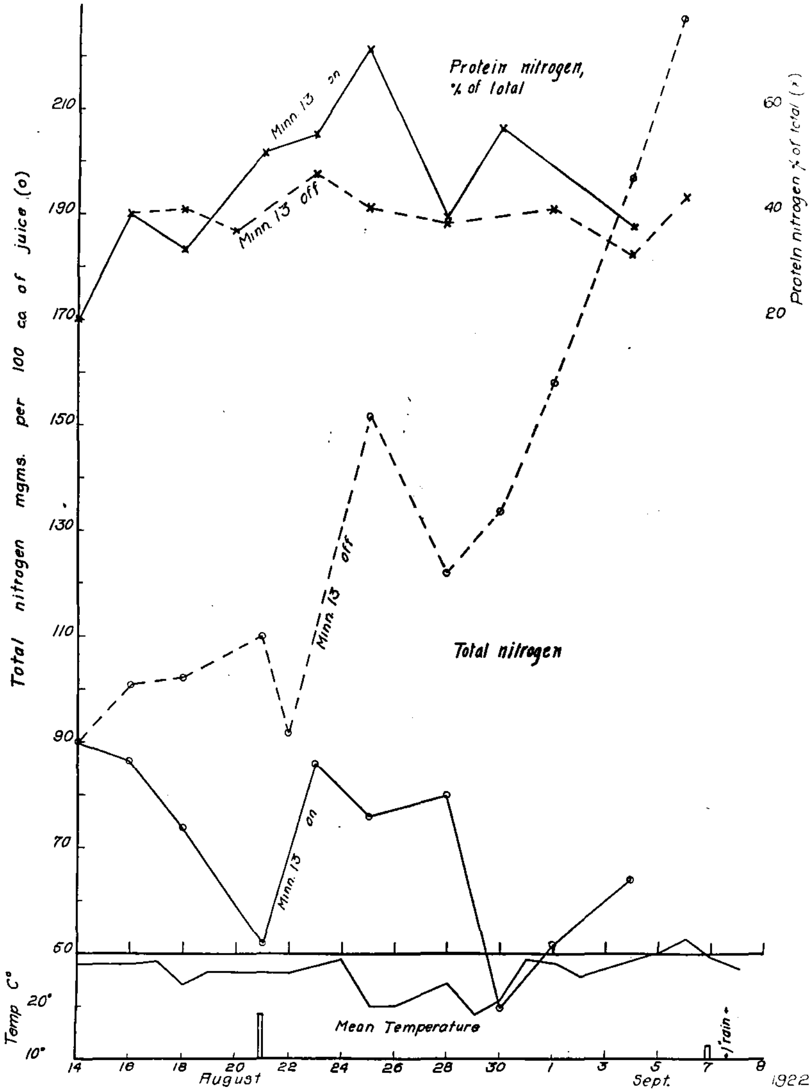

Fig. 17. Development of Total Nitrogen and of Protein Nitrogen in Cornstalk Juices, 1922 (Continued from Figure 16)

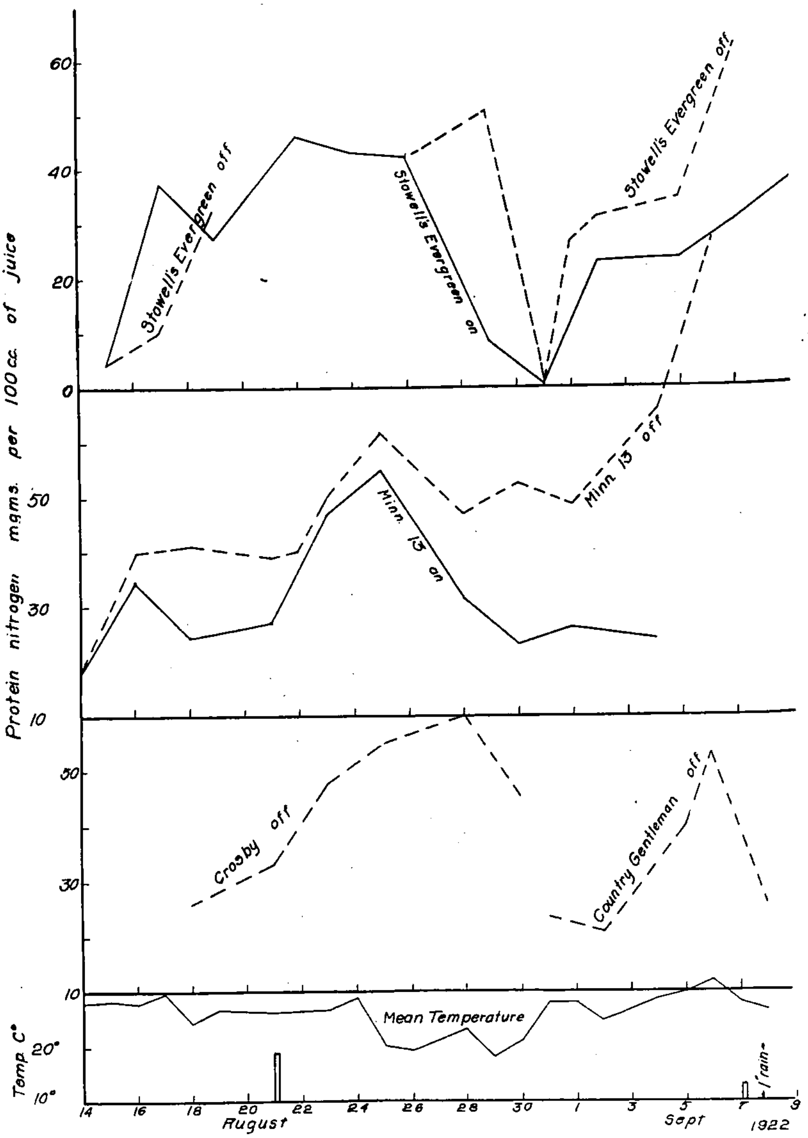

Fig. 18. Development of Total Nitrogen and of Protein Nitrogen in Cornstalk Juices, 1922 (Continued from Figures 16 and 17)

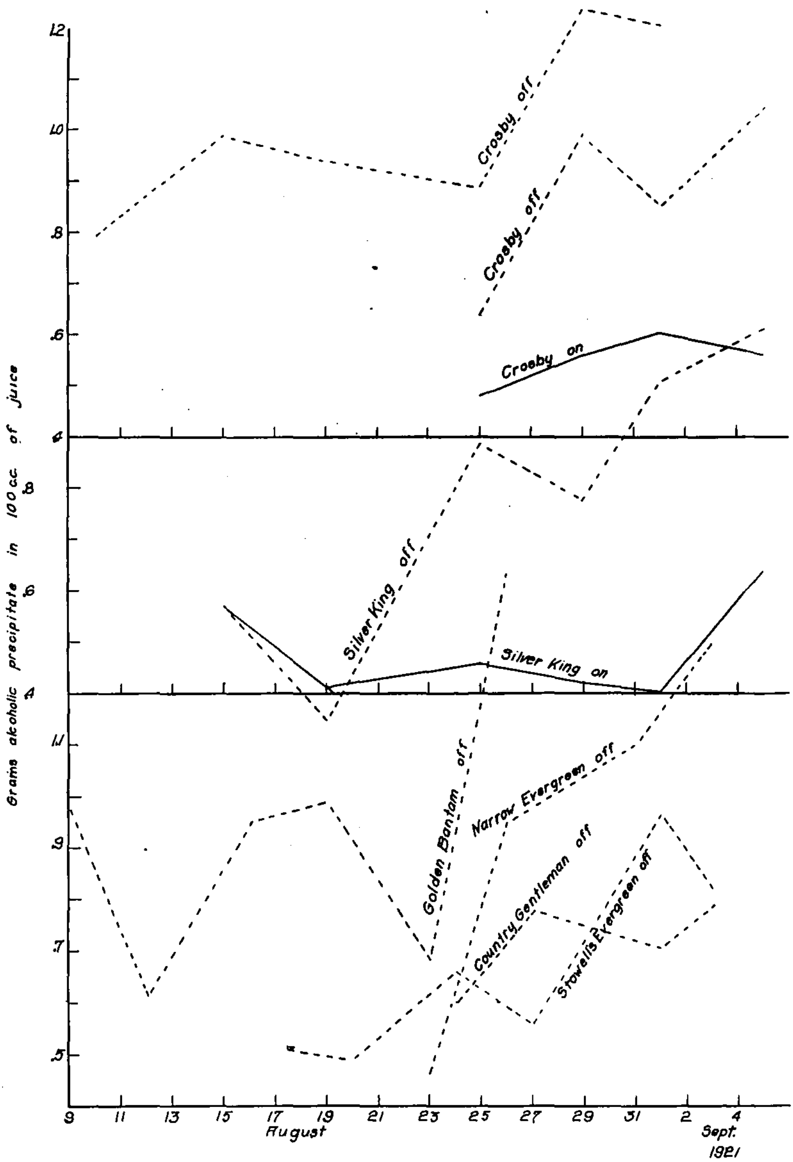

Fig. 19. Development of Alcoholic Precipitate in Cornstalk Juices, 1921

When the temperature was low and the soil moist, the stalks were replete with water, the ash content was relatively low, and the purity quotient high. (It should be kept in mind that a low quotient indicates a high sugar purity.) During the subsequent hot, dry weather, water was scarcer in the stalks, the minerals were higher, carbohydrate formation was retarded, and the purity quotients were decreased. Sufficient data are not at hand to make any sweeping conclusions in this respect, but it is believed that the above interpretation of the curves is correct.

VARIETAL DIFFERENCES

From the standpoint of quality of juice for sirup making, all the varieties studied, including the two of field corn, are about equally good. The juice densities attained are about the same, except that in the smaller varieties, as Crosby and Golden Bantam, desiccation of the stalks may give high densities; but in such cases, of course, the extraction becomes too low for practical purposes. The yields of sirup per ton and per acre will be discussed later.

All varieties responded markedly to the removal of the ears, the field corn varieties possibly showing a greater effect than the others. The time required to attain maximum density of juice varied somewhat, but the manufacturer would have no difficulty in ascertaining the proper time to harvest the stalks for sirup. If two weeks were always allowed, a good average would be struck, altho further investigations on a greater number of plots might show that it would pay to test samples of cane at intervals in order to catch the point of maximum development of sugar.

EFFECT OF TIME OF DAY WHEN SAMPLED

It was thought desirable to ascertain whether corn varies in composition from one part of the day to another. Therefore samples of 2 varieties were taken at 8 a.m. and at 4 p.m. and milled and analyzed immediately. The results are given in Table IV. The afternoon samples show a somewhat greater acidity, Brix, and total nitrogen, but the differences are not great, and more samples would have to be examined before definite conclusions could be drawn. The data do show, however, that successive sampling from the same plot gives comparable results, and that the method of sampling and analysis used throughout the work was such as truly to represent the plots in question.

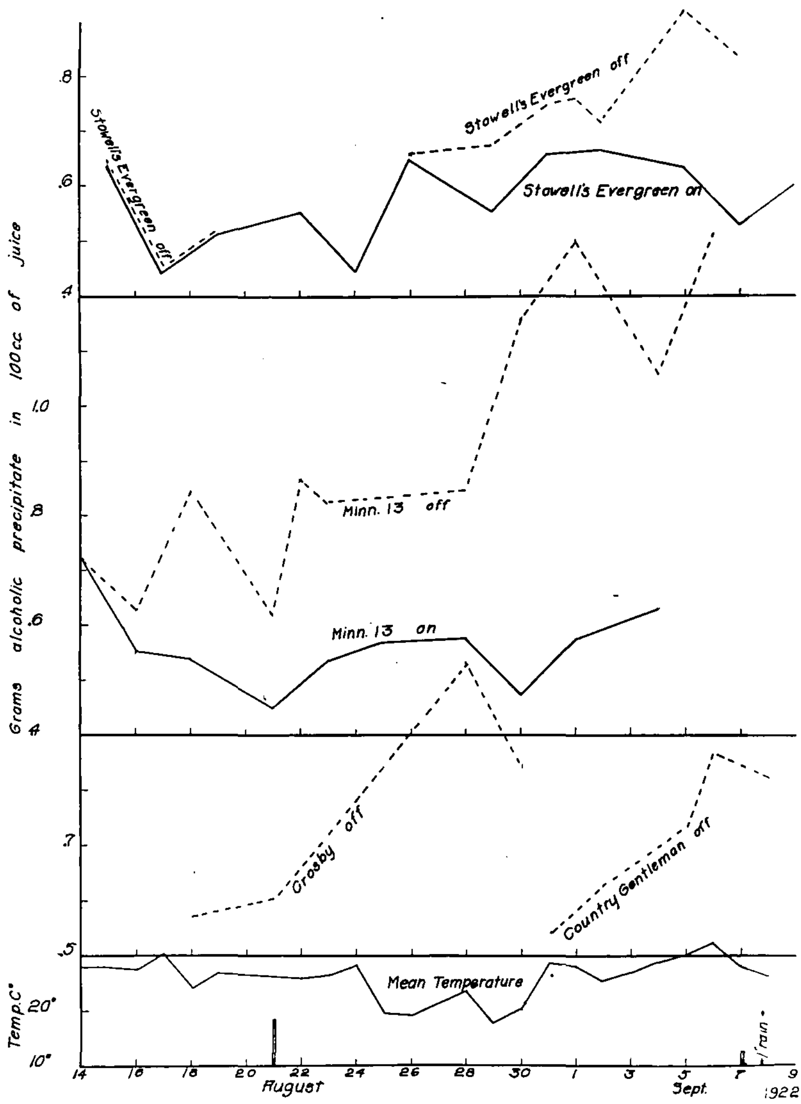

Fig. 20. Development of Alcoholic Precipitate in Cornstalk Juices, 1922

TABLE IV

Composition of Cornstalk Juices as Affected by Time of Day When Sampled, and by Standing in the Shock Two Days

A Sample No.	B Date when cut	C Treatment	D Extraction	E Acidity 0.1 N per 100 cc.	F Color	G Brix	H Total solids by refractometer	I $\frac{\text{Solids}}{\text{Brix}} \times 100$	J Sugars: Total	K Sugars: Sucrose	L Sugars: Glucose	M Sugars: Fructose	N Purity $\frac{J}{G} \times 100$	O Total nitrogen	P Non-protein nitrogen	Q Protein nitrogen, of total	R Alcohol precipitate	S Ash
			per cent	cc.			gms.		gms.	gms.	gms.	gms.		gms.	gms.	per cent	gms.	gms.
							Minnesota No. 13, Ears off 21 Days											
53	Sept. 6	Cut at 8 a.m., milled immediately	47	32.1	2	16.5	16.3	98.8	13.59	10.39	2.3	0.9	82	.192	.130	32	1.384	0.591
55	Sept. 6	Cut at 4 p.m., milled immediately	44	36.3	2	17.1	16.6	97.2	13.54	10.24	2.4	0.9	79	.227	.130	43	1.334	0.553
							Country Gentleman, Ears off 6 Days											
54	Sept. 6	Cut at 8 a.m., milled immediately	50	16.8	1	13.3	12.1	91.0	10.53	8.63	0.5	1.4	79	.140	.109	22	0.878	1.022
56	Sept. 6	Cut at 4 p.m., milled immediately	50	21.0	1	14.1	12.9	91.5	11.70	9.40	1.2	1.1	83	.184	.122	34	0.868	0.879
							Minnesota No. 13, Ears off 8 Days											
16	Aug. 22	Milled immediately	52	28.1	2	14.1	12.7	90.0	13.38	9.48	2.6	1.3	94	.092	0.52	43	0.864	0.513
17	Aug. 22	Milled after standing 1 day	41	30.6	3	15.1	14.5	96.0	14.20	5.30	4.4	4.5	94	.128	.071	44	0.575	0.629
18	Aug. 22	Milled after standing 2 days	38	25.0	3	16.5	16.0	97.0	15.46	8.16	3.3	4.0	93	.110	.083	25	0.594	0.466
							Stowell's Evergreen, Ears off 6 Days											
38	Aug. 31	Milled immediately	55	26.3	1	13.5	12.0	89.0	11.33	9.03	0.7	1.6	84	.122	.120	2	0.747	1.116
41	Aug. 31	Milled after standing 1 day	48	35.9	3—	15.5	14.6	94.3	11.79	7.99	2.3	1.5	76	.137	.111	20	0.759	1.115
44	Aug. 31	Milled after standing 2 days	42	39.9	3	16.9	15.6	92.3	14.74	10.24	2.4	2.1	87	.139	.122	12	0.802	1.044

EFFECT OF STANDING IN SHOCKS

It was often necessary to keep the harvested cane for a day or longer before milling. In order to see how rapidly the juice was affected by this treatment, two lots of stalks were cut, stripped of leaves, stood in shocks, and analyzed after one day and two days.

The results are given in Table IV. In both cases the extraction steadily decreased, owing to evaporation, and the density of the juice correspondingly increased. The solids extracted decreased somewhat, but this might be overcome if the bagasse is macerated. The solids-over-Brix purity (Column I) decreased in both varieties, while the total sugar purity (Column N) remained constant. No explanation is offered for these results. In both cases the sucrose decreased during the first day and increased by the second day. From these tests it may be concluded that cane may be shocked for at least two days before milling with no serious disadvantage.

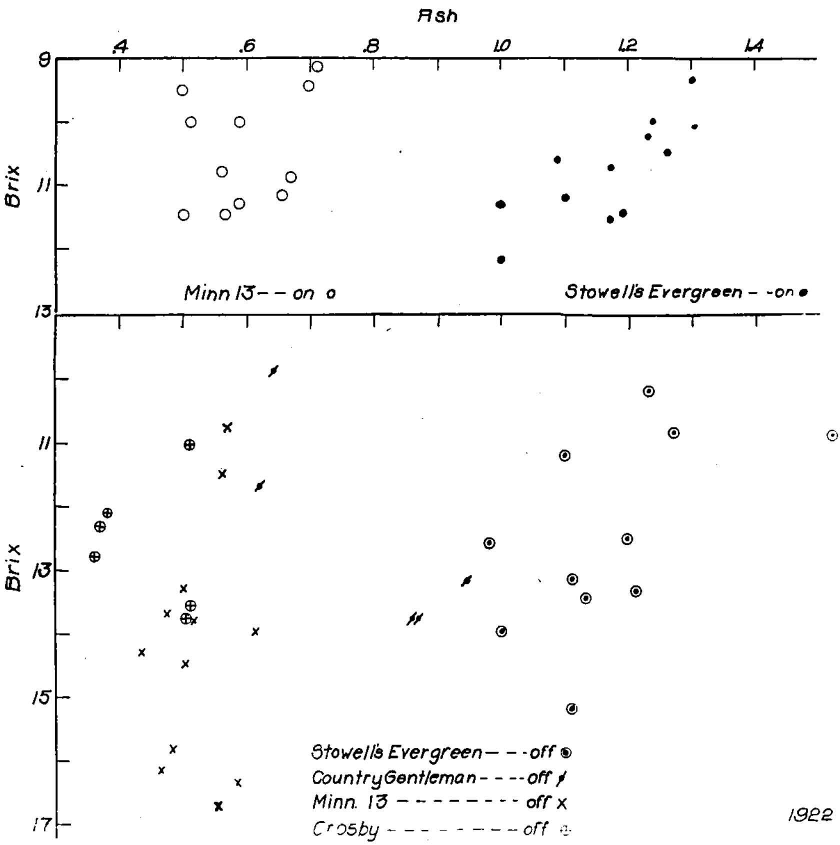

Fig. 21. Ash Plotted Against Degrees Brix of Cornstalk Juices, to Show the Negative Correlation Between These Two Factors

SUMMARY

1. The juice of the stalks of sweet corn at the canning stage has a density of from 9 to 11 degrees Brix, and hence is not suitable for sirup making. If, however, the stalks are allowed to stand in the field from 10 to 20 days after the ears are removed, there is an increase in density up to 13 or even 17 degrees Brix. The best stage for sirup making is during this period.

2. During this period of ripening after the removal of the ears, there is a slight increase in acidity of the juice; a large increase in total nitrogen and in protein nitrogen, but no change in the proportion of protein nitrogen; a large increase in substances precipitable by alcohol, of which a third to a half is protein; no change in mineral content; a large increase in sugars, most of which is due to sucrose, the glucose and fructose remaining rather constant; and an increase in purity, as measured by the refractometer solids-over-Brix quotient.

3. The general phenomenon indicated by these changes is that after removal of the ears the organic substances, but not the inorganic, are shunted from the ears to the juice.

4. The purity quotient, refractometer-over-Brix, is a valuable index of the quality of the juice for sirup making.

5. The sucrose purities of cornstalk juices are always very low.

6. There is some evidence that during cool, moist weather the mineral content of the juice is low and the purity high; and that the reverse holds during hot, dry weather.

7. The characteristics of cornstalk juice summarized are common to all the varieties of sweet and field corn examined. Apparently varietal differences affect the quantity but not the quality of sirup. The exception to this was one lot of Evergreen, the juice of which became loaded with potassium nitrate, owing to excessive quantities available in the soil. It is believed that all varieties would do this, altho data are not at hand to prove it.

8. Cornstalks may stand in the shock at least two days without seriously imparing the quality of the juice.

II. MANUFACTURE OF SIRUP

When the samples were taken for chemical analysis, as described in Part I, larger samples were also taken for making sirup. The object was to make sirup from all available varieties, at various stages of maturity, and by all available processes. A series was run on Silver King field corn in 1921 and on Minnesota No. 13 field corn in 1922 for comparison with the sweet corn varieties.

EQUIPMENT

The stalks were pressed in a three-roll mill, the rolls of which were 12 by 15 inches and the capacity about one ton of cane per hour. Two 100-gallon galvanized iron tanks with steam coils in the bottom served as defecators. Filtration was accomplished in a plate-and-frame filter press, with leaves 16 inches square. Usually only five leaves were used. The press was fed either by a small rotary pump or by a centrifugal. During the first season an open evaporator was used, consisting of a trough 1 foot wide and 8 feet long, lined with tinned copper, and provided with steam pipes on the bottom. Fresh juice was admitted at one end, and the finished sirup was continuously withdrawn from the other end, a thermometer being used to indicate the density of the sirup. Appropriate pumps and storage tanks, and a laboratory for making chemical analyses, completed the outfit. In 1922 a glass enamel-lined vacuum evaporator, with an evaporating capacity of 7 gallons of water per hour, was used.

The *color* values are comparable among themselves only, all the samples being segregated into 6 groups, No. 1 being the lightest and being equivalent to about No. 6 on the scale used for sirups (27).

The *flavor* ratings were established by placing the samples in three groups, No. 1 being the best. Three judges agreed on the classifications.

All the analyses were made according to the methods outlined in Part I.

PROCESS OF MAKING EXPERIMENTAL LOTS OF SIRUP

The clean stalks, with ears, leaves, and tassels removed, were milled once. It was found that enough juice could not be obtained by a second milling to pay for the trouble, and any difference in quality of juice due to heavier pressing in commercial mills was taken care of in the analytical samples described in Part I, which were milled twice. From 15 to 30 gallons of juice was used for a single lot of sirup. Frequently a larger batch was milled, and then aliquoted for different treatments. The juice was heated to boiling, the scum was allowed to form and then removed by skimming to simplify the filtration. The juice was then treated, if desired, with lime, kieselguhr, and carbon, and filtered.

Sometimes the carbon was added after filtration, and then the juice was filtered a second time. The clarified juice was then ready for evaporation. Only the data for 1922 are shown, when the vacuum evaporator was used, as the data for these samples are much more complete, and represent commercial practice better than those obtained by open evaporation. The finishing point of the sirups was judged by the refractometer, from 73 to 76 per cent of solids being desired.

DISCUSSION OF RESULTS

Many modifications of the above outline of the process were followed. The results are given in Table V. The data include the condition and treatment of the cane before milling; the extraction in per cent of clean cane; the polarization of a normal solution of the juice; the degrees Brix, the refractometer total solids, and the acidity of the juice; the treatment with kieselguhr and with decolorizing carbon; the density, color, and flavor of the sirup; and the purity quotient of both juice and sirup, as described in Part I, and obtained by dividing the total solids by the degrees Brix.

It will be simplest to discuss each factor separately.

Variety of corn.—As was shown in Part I, all varieties develop a fairly satisfactory sugar content in the juice, especially when allowed to remain in the field after removing the ears, the so-called Stewart process (22). The usual density of juice was from 12 to 14 degrees Brix. Evergreen showed consistently a rather high density, but the flavor of the sirups from this variety was always very disagreeable. In fact these sirups were in a class by themselves, having a nauseating taste. It will be noted that the purity quotients shown in the last two columns of Table I are much lower for the samples from this variety than for those from any other. This would indicate a rather high content of non-sugar solids in the juice and sirup, as a lower quotient indicates a more impure juice, as was discussed in Part I. When the sirups were examined after standing several weeks, it was found that the Evergreen samples contained considerable amounts of a crystalline deposit. This proved to be potassium nitrate. It was undoubtedly the cause of the bad flavor, and also of the low purity coefficient, as solutions of this salt have a higher density and a lower index of refraction than other salts found in plant juices.

The question naturally arises as to whether Evergreen always produces a juice high in potassium nitrate. It probably does not, for in 1921 the sirups from this variety were as good as the others. Furthermore, Tables I and II show that the ash content of the Evergreen samples in 1922 was far higher than that of any other variety, but that was not the case in 1921. The writers believe the explanation of the whole matter lies in the plot of ground on which the Evergreen was grown in 1922. The accumulated manure in the pasture caused a very heavy, rank growth of the Evergreen, most of it being more than 7 feet high. Nitrification no doubt took place very rapidly, which resulted in loading up the sap of the corn with nitrates.

Purity coefficient.—The quotients solids-over-Brix for both juice and resultant sirup are given in the last two columns of Table V. As the clarification process removes non-sugar material primarily, it is of interest to examine the quotients to see whether there is any apparent purification. Out of 21 samples for which values for both juice and sirup are available, 13 show an increased quotient, 6 show a decreased, and 2 do not change. Thus in two-thirds of the cases an increase in purity is shown by this test. In most cases the difference is only one or two points.

There appears to be some relation between the flavor of the sirup and the purity quotient. Sirups having flavor values of 2 and 3 have lower quotients than those having a value of 1. This is brought out rather strikingly by arranging the purity quotients of the sirups against their flavor ratings. This has been done in Table VI, in which the numbers are the numbers of the sirup samples in Table V. It will be noted especially that all the Evergreen samples fall in the columns of low quotients. It was suggested that the high mineral and nitrate content of these samples was due to the soil on which they were grown, and that thus any variety might show this phenomenon. If this is so, it would behoove any manufacturer of cornstalk sirup to ascertain the condition of the juice before making it into sirup. For this purpose it is believed that the refractometer and the Brix scale furnish the simplest means. It is tentatively suggested that any juice with a quotient of 94 or less be regarded as unsuitable for sirup making. It is further suggested that this method might be found advantageous with other plant materials as an index of their quality for a particular purpose.

TABLE V

ANALYSES OF SIRUPS, CROP OF 1922

Sample No.	Date	Days since canning stage when cut	Ears on or off when cut	Field treatment	Extraction	Juice: Polarization	Juice: Brix	Juice: Refractometer solids	Acidity: Initial	Acidity: Final	Treatment: Kieselguhr	Treatment: Carbon	Sirup: Brix	Sirup: Refractometer solids	Sirup: Color	Sirup: Flavor	Solids/Brix × 100: Juice	Solids/Brix × 100: Sirup
					Per cent						Per cent	Per cent		Per cent			Juice	Sirup
				Minnesota, No. 13														
24	Aug. 15	0	on	Milled fresh	34*	..	9.4	...	19.0	7.0	2	0.5	...	85.0	6	1	....	...
32	" 23	8	off	" "	37	..	14.1	13.8	31.0	19.5	1	0.5	74.3	73.4	6	1	98.0	98.8
37	" 28	13	off	" "	31	8.4	17.0	17.0	29.5	(a) 20.0	1	0.5	71.1	70.6	4	1	100.0	99.3
										(b) 9.0			75.5	74.8	6	1		99.1
39	" 31	16†	on	" "	50	3.7	11.9	11.3	18.5	7.0	1	0.5	76.6	74.4	6	1	95.0	97.2
26	" 17	0	on	Stacked without leaves 2 days	30	..	12.0	...	15.0	7.5	1	0.5	75.5	73.4	4	1	....	97.2
27	" 18	0	on	" " " 3 "	28	..	13.8	...	20.0	11.0	1	0.5	81.1	78.5	4	1	....	97.0
				Crosby, Plot 1														
25	" 17	0	on	Milled fresh	43	..	11.1	...	15.0	6.0	1	0.5	74.9	73.2	6	1	....	97.8
33	" 24	8	off	" "	48	..	12.3	12.1	31.5	8.0	1	1.0	74.3	73.1	5	1	98.3	98.5
34	" 25	9	off	" "	42	..	13.3	13.0	...	(a) 15.0	1	0.5	74.0	73.0	2	1	97.8	98.6
										(b) 6.0	1	0.5	72.8	71.5	4	1		98.2
38	" 30	14†	on	" "	32	2.7	11.5	11.4	20.5	12.5	1	0.5	76.2	73.2	4	2	90.0	96.0
28	" 19	1	on	Stacked without leaves 2 days	35	..	12.9	...	14.0	(a) 7.0	1	0	73.8	72.5	3	2	....	98.2
										(b) 6.0	1	0.5	77.7	75.9	6	1		97.7
29	" 21	1	on	" " " 4 "	35	..	11.7	...	15.0	(a) 14.0	1	0	76.1	74.3	3	2	....	97.7
										(b) 10.0	1	0.5	74.6	72.7	5	2		97.3
30	" 21	3	off	Shocked with leaves 2 days	32	..	12.8	...	16.4	(a) 14.5	1	0	74.7	73.5	3	2	....	98.6
										(b) 9.0	1	0	76.2	74.8	5	2		98.3
31	" 22	2	off	" " " 4 "	50	..	13.7	13.8	20.0	(a) 12.0	1	0	75.4	74.4	3	2	100.0	98.7
										(b) 11.5	2	0	75.3	74.3	4	2		98.7
										(c) 7.4	1	1.0	76.5	75.1	4	2		98.2

				Crosby, Plot 2														
35	Aug. 26	1	off	Milled fresh	45	..	11.2	10.6	18.5	(a) 5.0	1	0.5	82.8	78.4	5	2	94.7	94.7
										(b) 7.5	1	0.5	77.2	73.2	4	2		94.7
36	" 28	2	off	Stacked without leaves 2 days	50	..	12.2	11.7	21.5	6.0	1	0.5	75.3	72.0	4	2	95.8	95.6
41	Sept. 1	8	off	Milled fresh	40	7.6	13.8	13.4	21.5	7.0	1	0.5	76.3	74.8	4	1	97.0	98.1
				Stowell's Evergreen														
40	Aug. 31	0	on	Milled fresh	38	4.5	11.4	10.2	19.5	8.0	1	0.5	78.4	72.0	1	3	89.5	91.0
46	Sept. 5	6	off	" "	42	7.2	14.3	13.3	25.5	(a) 21.0	1	0.5	74.4	69.8	1	3	93.0	93.8
										(b) 6.0	1	0.5	79.0	74.4	2	3		94.0
52	" 9	10	off	" "	39	8.6	14.3	13.4	27.5	6.5	1	0.5	80.7	75.8	1	3	93.7	94.0
43	" 2	0	on	Stacked without leaves 2 days	39	5.4	12.6	11.4	23.5	8.0	1	0.5	80.6	73.8	1	3	90.5	91.5
44	" 4	0	on	" " " 4 "	39	5.5	13.2	12.0	22.0	6.3	1	0.5	79.4	72.9	1	3	91.0	92.0
47	" 6	0	on	" " " 6 "	41	6.1	13.8	12.4	21.5	8.0	1	0.5	79.2	73.0	1	3	90.0	92.2
42	" 2	0	on	Shocked with leaves 3 days	42	5.7	12.6	11.3	24.0	8.5	1	0.5	79.4	72.0	1	3	89.6	90.8
45	" 4	0	on	" " " 5 "	39	5.7	13.3	11.6	26.0	10.5	1	0.5	78.5	71.2	1	3	97.3	90.6
48	" 6	0	on	" " " 7 "	30	7.8	16.7	15.8	49.0	...	..	..	...	...	..	..	94.6	...
				Country Gentleman														
49	" 7	0	on	Milled fresh	34	5.6	13.4	13.2	15.0	10.5	1	0.5	74.5	72.0	2	2	98.6	96.6
50	" 8	4	off	" "	32	5.5	13.3	12.7	18.0	5.5	1	0.5	75.6	72.3	5	2	95.6	95.6
51	" 8	0	on	Stacked without leaves 3 days	22	5.3	14.5	13.3	24.5	6.5	1	0.5	77.8	73.4	5	2	91.8	94.5

* Mill rolls set too far apart for high extraction.

† Ears in hard dent stage.

TABLE VI

RELATION BETWEEN PURITY QUOTIENT (SOLIDS-OVER-BRIX) AND FLAVOR OF CORNSTALK SIRUPS

The numbers are those of the samples in Table I.

Flavor Ratings	$\frac{\text{Solids}}{\text{Brix}} \times 100$								
	99	98	97	96	95	94	93	92	91
	32	34b	39						
	33	25	26						
1	37a	28b							
	37b	41							
	34a								
	31a	31c	29b	50	35a				
2	31b	28a	49	38	35b				
	30a	29a		36	51				
		30b							
						46a	43	40	42
3						46b		44	45
						52		47	

Field treatment.—The principal items to be observed under this heading are the effect of shocking in the field several days, of stacking without the leaves, and of removing the ears. In Part I it was shown that when the ears are removed at the canning stage and the stalks are left standing in the field, there is a more or less rapid rise in the density of the juice for the next 10 to 20 days, and that there is some tendency for the purity to increase during this period. The data in Table V show that the flavor of the sirup is not appreciably affected by the removal of the ears. The yield of sirup becomes greater as the density of the juice increases, of course, but the purity is not affected sufficiently to make any improvement in the flavor. Furthermore, stacking the stripped stalks for 2 to 4 days does not affect the sirup-making qualities, altho it does in most cases increase the acidity and the density of the juice, mostly because of loss of moisture from the stalks.

Polarizations show nothing of significance regarding sirup quality.

The low *extractions* shown in Table V are misleading. Tables I and II show that extractions of from 50 to 60 per cent were obtained in most cases when double milling was employed. In the sirup samples only a single milling was employed, and the mill was not a heavy one. That the low extractions are due to the mill and not to the character of the cornstalks was shown by the fact that a good sample of stripped sorghum cane yielded only 33 per cent of its weight as juice, whereas with a large commercial mill the extraction would have been at least 60 per cent. The stalks of all varieties of corn were remarkably juicy, considering that they are generally known to be merely pithy in character.

Acidity.—It was found by experience that an acidity of 6 to 8 degrees (cc. of 0.1 N alkali per 100 cc. of juice) in the clarified juice was the most desirable. A higher acidity gave a sharp-tasting sirup, while a lower gave a dark sirup because of the nearness to an alkaline reaction. Lime in the form of the hydrate was used for neutralizing. At first the titre of the raw juice was taken and the calculated amount of lime was added. It was soon found, however, that the neutralizing effect of a unit of lime was not always the same. Therefore the juice was defecated by heat first, then the titre was taken and lime added. Even then irregular results followed, so it was decided to make a more detailed study of the acidity changes that take place during the various steps of clarification. The results are incorporated into Table VII, altho in Table V also the initial and final acidities are given.

In columns E, F, G, and H "raw" juice is that which is fresh from the mill, before heating; "defecated" juice is that which has been brought to the boiling point and the scum removed; "treated" means adding kieselguhr and carbon and then filtering; "limed" means the addition of lime and a second filtering. All these stages were not followed in each case.

In Column I are assembled the differences in titre betwen the raw and the defecated juice, and these figures show the changes in acidity brought about by heat alone. The changes are considerable, ranging from 1 to 8.5 degrees. Column J gives the changes due to the addition of kieselguhr and of carbon, and these changes are even greater than those shown in the preceding column, ranging from 0 to 15. Column K gives the total change from raw to treated juice. That both the carbon and the kieselguhr affect the acidity is shown by a closer examination of the data. In samples Nos. 28 a and b, 29 a and b, and 31 a and c, in which the carbon was omitted from one pair, it is shown that the carbon has considerable effect in reducing the acidity. Samples 31 a, b, and c show that the kieselguhr alone also reduces the acidity.

TABLE VII

DATA SHOWING THE CHANGES IN ACIDITY IN CORNSTALK JUICE DUE TO VARIOUS FACTORS

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Sample No.	Days since canning stage when cut	Ears on or off	Field treatment	Acidity of juice 0.1 N per 100 cc. of juice: Raw	Defecated	Treated	Limed	Changes in acidity: E-F	F-G	E-G	G-H	Treatment: Kieselguhr	Carbon	$Ca(OH)_2$ per 100 lbs. juice	$Ca(OH)_2$ required / $Ca(OH)_2$ theoretical
				cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	per cent	per cent	gms.	
							Minnesota No. 13								
24	0	on	Milled fresh	19.0	...	1.5	...	...	...	17.5	...	2	0.5	...	...
32	8	off	Milled fresh	31.0	25.0	19.5	19.5	6.0	5.5	11.5	0	1	0.5	0	...
37	13	off	Milled fresh	29.5	22.5	20.0	(a) 20.0	7.0	2.5	9.5	0	1	0.5	0	...
							(b) 9.0				11.0	1	0.5	16.1	0.88
39	16*	on	Milled fresh	18.5	16.7	12.0	7.0	1.8	4.7	6.5	5.0	1	0.5	7.3	0.89
26	0	on	Stacked without leaves 2 days	15.0	...	7.5	7.5	...	...	7.5	0	1	0.5	0	...
27	0	on	Stacked without leaves 3 days	20.0	...	...	11.0	...	...	...	...	1	0.5	0	
							Crosby, Plot 1								
25	0	on	Milled fresh	15.0	...	6.0	6.0	...	...	9.0	0	1	0.5	0	
33	8	off	Milled fresh	31.5	23.0	8.0	8.0	8.5	15.0	23.5	0	1	1.0	0	
34	9	off	Milled fresh	...	19.5	15.0	(a) 15.0	...	4.5	...	0	1	0.5	0	
							(b) 6.0				9.0	1	0.5	18.9	1.28
38	14*	on	Milled fresh	20.5	16.0	12.5	12.5	4.5	3.5	8.0	0	1	0.5	0	
28	1	on	Stacked without leaves 2 days	14.0	...	(a) 7.0	7.0	...	...	7.0	0	1	0	0	
						(b) 6.0	6.0			8.0	0	1	0.5	0	
29	1	on	Stacked without leaves 4 days	15.0	...	(a) 14.0	14.0	...	...	1.0	0	1	0	0	
						(b) 10.0	10.0			5.0	0	1	0.5	0	
30	3	off	Shocked with leaves 2 days	16.4	14.0	14.0	(a) 14.0	2.4	0	2.4	0	1	0	0	
							(b) 9.0				5.0	1	0	7.3	0.89
31	2	off	Shocked with leaves 4 days	20.0	16.5	(a) 12.0	12.0	3.5	4.5	8.0	0	1	0	0	
						(b) 11.5	11.5		5.0	8.5	0	2	0	0	
						(c) 7.4	7.4		9.1	12.6	0	1	1.0	0	

							Crosby, Plot 2								
35	1	off	Milled fresh	18.5	16.5	14.0	5.0	2.0	2.5	4.5	9.0	1	0.5	13.0	0.89
36	2	off	Stacked without leaves 2 days	21.5	20.5	15.0	6.0	1.0	5.5	6.5	9.0	1	0.5	14.5	0.98
41	8	off	Milled fresh	21.5	16.7	14.0	7.0	4.8	2.7	7.5	7.0	1	0.5	9.4	0.82
							Stowell's Evergreen								
40	0	on	Milled fresh	19.5	16.7	13.5	8.0	2.8	3.2	6.0	5.5	1	0.5	9.1	1.01
46	6	on	Milled fresh	25.5	23.5	21.0	(a) 21.0	2.0	2.5	4.5	0	1	0.5	0	...
							(b) 6.0				15.0	1	0.5	21.5	0.87
52	10	off	Milled fresh	27.5	26.0	21.5	6.5	1.5	4.5	6.0	15.0	1	0.5	22.4	0.91
43	0	on	Stacked without leaves 2 days	23.5	18.5	15.0	8.0	5.0	3.5	8.5	7.0	1	0.5	12.0	1.04
44	0	on	Stacked without leaves 4 days	22.0	20.5	15.5	6.3	1.5	5.0	6.5	9.2	1	0.5	13.2	0.87
47	0	on	Stacked without leaves 6 days	21.5	19.5	16.2	8.0	2.0	3.3	5.3	8.2	1	0.5	14.7	1.09
42	0	on	Shocked with leaves 3 days	24.0	21.0	16.7	8.5	3.0	4.3	7.3	8.2	1	0.5	14.4	1.09
45	0	on	Shocked with leaves 5 days	26.0	23.5	20.0	10.5	2.5	3.5	6.0	9.5	1	0.5	19.2	1.23
							Country Gentleman								
49	0	on	Milled fresh	15.0	14.0	10.5	10.5	1.0	3.5	4.5	0	1	0.5	0	
50	4	off	Milled fresh	18.0	16.7	13.0	5.5	1.3	3.7	5.0	7.5	1	0.5	9.3	0.76
51	0	on	Stacked without leaves 3 days	24.5	23.5	20.5	6.5	1.0	3.0	4.0	14.0	1	0.5	19.4	0.85

* Ears in hard dent stage.

These facts explain the irregular action of lime on the raw juice. When the lime effect is segregated from the others, it is found to be rather consistent in its neutralizing power. This is shown in the last two columns of Table VII. The ratio of the actual to the theoretical amount of lime is close to 1.0. This is quite contrary to the findings of Anderson (1) with sorghum juice, in which 2.2 times the theoretical amount of lime is necessary to produce neutrality. Furthermore, the lime was more effective when added before heating the juice. In order to see whether the acidity of sorghum juice behaves like that of corn juice under the action of heat and of kieselguhr, some experiments were run at a sorghum sirup factory after the close of the corn sirup season. No change in the titre occurred either during the heating of the juice or by the addition of kieselguhr. Furthermore, kieselguhr in any concentration had no appreciable effect on the acidity of solutions of tartaric, citric, and hydrochloric acids, showing that it is not a question of a contained alkali. It is therefore believed that the above acidity changes in cornstalk juices are due to colloid adsorption phenomena, and that the proper colloids are lacking in the sorghum juice. Whatever the explanation, these changes have to be watched carefully in making cornstalk sirup if the proper acidity of the sirup is to be obtained.

Effect of kieselguhr and of carbon.—Besides the neutralizing effect of the kieselguhr as already discussed, it has very valuable filtering properties, as has been repeatedly shown for other products. One per cent of it on the basis of the weight of the juice filters very readily, builds a thick cake, and produces a brilliant filtrate. Altho in most of the present experiments the scum was removed from the juice prior to filtering, there is no doubt that this amount of kieselguhr would be ample for good filtration without the removal of the scum. Cornstalk juice filters much more easily than does sorghum.

Two brands of decolorizing carbon[4] were used during the investigations, altho in the experiments listed in Tables V and VII but one kind was used. As regards the decolorizing action of the carbons on cornstalk juice, the results were very disappointing. It will be noted in the tables that as often as not the use of carbon resulted in a darker sirup. Many combinations of acidity and quantity of carbon were tried, but no satisfactory decolorizing action could be obtained. Color, however, is of less importance than flavor, as all these sirups have satisfactory color for cooking sirups, and as flavor is the deciding factor in sirup quality. The carbons did not affect the flavor to any appreciable extent. If, as the evidence seems to indicate, the flavor

[4] The writers' thanks are due the Carbrox Company, Inc., and to the General Norit Company, Ltd., for generous samples of Carbrox and of Norit, respectively.

in these sirups is largely dependent on the ratio of sugars to mineral matter, perhaps no great effect from the carbon should be expected.

Suggested process of manufacture.—The processes and machinery that should be employed for the successful manufacture of cornstalk sirup on a commercial scale must now be considered. The general process outlined for the experimental lots of sirup is essentially the same as would be used on a large scale, and is practically the same as the best accepted process of making sorghum sirup (28, 30).

The following brief description of the method of manufacture recommended will suffice:

Harvesting.—After the ears are picked off for canning, the stalks should be allowed to stand in the field for from 10 to 20 days, in order to develop the maximum sugar content in the juice, thus following essentially the Stewart process (22, 23). It will be found highly desirable to test samples from each field with a Brix hydrometer from time to time in order to ascertain the period of greatest density. If a refractometer is available, the solids-over-Brix quotient should be determined, as this gives a good idea of the quality of the juice. Any juice with a quotient of 94 or lower is probably unfit for sirup making. When the stalks are ready for harvesting, they should be cut with a corn binder and either brought to the factory immediately and there shocked for a few days, or allowed to dry on the ground for one or two days and then brought to the factory for immediate milling. The object of the partial drying of the leaves is to facilitate handling in the cleaning machine. The calculations in the preceding tables are based on the freshly cut stalks. If the stalks are allowed to dry for a day or two before weighing at the factory, the price per ton should be increased about 20 per cent to allow for the shrinkage.

Cleaning and milling.—The leaves must not be milled with the stalks, as they absorb juice and contribute impurities. As removal of the leaves by hand in the field is out of the question for economic reasons, a cleaning machine at the factory is necessary. This removes the leaves and tassels and leaves the clean stalks ready for milling.[5] A 6-roll mill, preferably with crusher attached, should be used. Maceration increases the efficiency of extraction.

Defecation and filtration.—The juice from the mills is heated by steam in defecators just to the boiling point. The juice is then titrated[6] and lime added to reduce the acidity to about 12 degrees, counting on the kieselguhr treatment to reduce it further to from 7 to 9 degrees, which is the desired acidity. After liming, kieselguhr is

[5] The Waconia Sorghum Mills, Inc., of Waconia, Minn., is the only company, to the writer's knowledge, that makes a cleaning machine suitable for this purpose.

[6] For directions for titration, see reference 30, p. 40.

added to the amount of about one per cent of the weight of the juice. The juice is then thoroly stirred and immediately pumped through a filter press, the cloths of which have been precoated with kieselguhr. The juice filters readily and becomes sparkingly clear. The use of decolorizing carbon is not recommended, as the writers' results with it were not satisfactory.

Evaporation of the juice should be done in a vacuum evaporator, because of the better quality of sirup produced and the economy in fuel. A density of 75 to 78 degrees Brix is desirable in cornstalk sirup. From the evaporator the sirup should be pumped through a cooler to the storage tank.

By-products.—The bagasse can best be used for fuel. If the milling is well done, the bagasse will have a moisture content of about fifty per cent, and will burn directly if the proper kind of grate and furnace are used, or at least with a small amount of coal in addition. The leaves from the cleaner can be ensiled with the husks and cobs from the cannery, or they can be dried and baled, as already discussed. In some cases it might be found profitable to dry both bagasse and leaves and bale them together for feed. Conservation of all possible useful products is quite necessary for the economical operation of a combined cannery and sirup factory.

The Stewart process (22) of removing the ears at approximately the canning stage in order to increase the sucrose content of the juice may be involved in the process outlined. Altho this patent is entitled, "Method of making maize sugar," Stewart apparently had sirup in mind also, for in all his claims in connection with the clarified juice he speaks of "reducing it to sugar or sirup." A prospective manufacturer of cornstalk sirup would have to give consideration to this, altho the other items in Stewart's treatment are not recommended, as they are believed by the writers to be unnecessary. The Stewart patent expires Jan. 30, 1926.

SUMMARY

1. The stalks of all varieties of sweet corn and two varieties of field corn gave satisfactory sirup, with the exception of Stowell's Evergreen in 1922, which contained an excessive amount of potassium nitrate.

2. The purity coefficient solids-over-Brix of the juice and of the sirup proved to be a very useful criterion of quality. It is suggested tentatively that any juice with a quotient of 94 or less be considered unsuitable for sirup making.

3. Stalks at all ages after removal of the ears made sirup of good quality. The purity did not appreciably increase as the density of the juice increased.

4. Shocking the stalks with the leaves on, or stacking them with the ears removed, for periods up to 4 days, did not affect the sirup-making qualities, altho the acidity and density of the juice increased in most cases.

5. Altho in the present experiments low percentages of juice were obtained, this was due more to the character of the mill than to the lack of juice in the stalks.

6. The titratable acidity of the juice always decreased during defecation by heat. It decreased further by the addition of kieselguhr and of activated carbon. These changes have to be taken into consideration in controlling juice acidity. Calcium hydrate exerted almost theoretical effect in neutralizing juice acidity.

7. Activated carbons had practically no value in decolorizing cornstalk juices, and very little in removing objectionable flavor.

8. Kieselguhr proved to be an excellent filter aid, and the juices filtered very satisfactorily with one per cent of their weight of this material.

9. A brief outline of the process of manufacture recommended for commercial practice is given. It differs from the manufacture of sorghum sirup only in the treatment in the field and in the control of the acidity.

10. The leaves can be used dry as baled feed or can be ensiled with the husks and cobs from the cannery. The bagasse can be burned, or it can be dried and baled with the leaves.

III. ECONOMIC CONSIDERATIONS

YIELD AND COST OF STALKS

As the primary object of the investigation was to discover a more valuable use of the sweet-corn stalks near canneries than that of forage, it was necessary to study the probable cost of making sirup from the stalks. Most of the stalks in Minnesota are fed standing; some are ensiled, and some are not used at all. Thus the cannery would have to compete against these other needs for the raw material for sirup manufacture.

As corn is usually not considered to have a saccharine juice in the ordinary sense, it becomes of special interest to examine the data concerning the yield of sirup obtainable from the varieties tested. The data were obtained during the collection of the samples discussed in Parts I and II. Altho only a few hundred pounds of sirup were obtained at each sampling, it is believed that the tonnage figures are fairly accurate, as in most cases several lots of each variety were obtained, representing different stages of maturity after removal of the ears.

The data are given in Tables VIII and IX. The samples presented were selected from a large number; they include only the "ears off" samples of the sweet corn and mostly the "ears on" samples of the field corn, as these are the ones of interest from the commercial standpoint. The yields of stalks are given in terms of the fresh stalks, with the ears removed but with leaves and tassels on. The clean cane represents about 60 per cent of this weight. The extraction figures given are those actually obtained from the clear cane, and not from the whole stalks. The calculated extraction of 60 per cent is on the same basis, and was made in order to give a more accurate comparison with what could be expected in larger multiple mills. The sirup figures are in terms of a sirup weighing 11.5 pounds to the gallon and containing 75 per cent of solids.

TABLE VIII

YIELD DATA FOR THE VARIETIES OF CORN

Sample No.	Date	Time since removing ears	Yield of stalks per acre	Extraction	Degrees Brix	Yield of sirup per acre: Found	Yield of sirup per acre: Calculated for 60 per cent extraction	Sirup per ton of cane, 60 per cent extraction
		days	pounds	per cent		gallons	gallons	gallons
		Stowell's Evergreen, 1921, ears off						
7*	Aug. 17	0	21,100	46	11.5	79	102	
12*	" 20	3	16,600	44	12.0	61	84	
15	" 24	7	17,660	51	12.7	80	93	
24	" 27	10	20,360	44	14.7	92	125	
		Average	19,000	48	13.7	86	109	11.5
		Stowell's Evergreen, 1922, ears off						
28*	Aug. 26	1	21,600	57	11.2	96	101	
33*	" 29	4	21,600	52	12.6	99	114	
38	" 31	6	18,500	55	13.2	89	98	
41	Sept. 1	8	17,500	48	15.2	89	111	
46	" 2	9	14,600	45	14.0	65	86	
51	" 5	12	13,300	45	12.5	53	71	
58	" 7	14	16,600	48	13.4	75	93	
61	" 9	16	16,160	45	13.5	71	94	
		Average	16,160	47	13.6	73	92	11.4
		Country Gentleman, 1921, ears off						
41	Sept. 3	10	22,500	..	14.5	..	138	12.1
		Country Gentleman, 1922, ears off						
40*	Aug. 31	0	15,830	52	9.9	57	65	
45*	Sept. 2	2	11,160	54	11.7	49	55	
52	" 5	5	9,000	48	13.2	40	50	
56	" 6	6	13,860	50	13.8	67	80	
59	" 8	8	9,000	44	13.9	38	52	
		Average	10,660	49	13.6	47	61	11.4
		Narrow Evergreen, 1921, ears off						
23	Aug. 26	4	15,000	48	12.6	64	79	10.5
		Crosby, 1922, ears off						
9	Aug. 18	1	6,000	42	10.0	17	25	
12	" 21	4	5,830	48	12.1	24	30	
27	" 25	8	6,000	45	12.3	26	31	
30	" 28	11	6,330	40	13.6	24	36	
35	" 30	13	5,660	47	13.7	26	32	
		Average	6,000	44	13.2	25	33	11.0
		Golden Bantam, 1921, ears off						
23	Aug. 26	22	6,830	48	14.4	33	41	12.0
		Silver King, 1921, ears off						
26	Aug. 29	14	17,330	43	14.2	74	103	11.9

TABLE VIII—*Continued*

Sample No.	Date	Time since removing ears	Yield of stalks per acre	Extraction	Degrees Brix	Yield of sirup per acre: Found	Yield of sirup per acre: Calculated for 60 per cent extraction	Sirup per ton of cane, 60 per cent extraction
		days	pounds	per cent		gallons	gallons	gallons
			Silver King, 1922, ears on, hard dent Aug. 24					
27	Aug. 24	..	12,330	40	9.6	33	50	
33	Sept. 1	..	12,000	45	10.7	40	54	
		Average	12,160	43	10.2	37	52	8.5
			Minnesota, No. 13, 1922, ears off					
1*	Aug. 14	0	15,160	49	11.5	59	73	
4*	" 16	2	14,660	41	13.3	57	82	
8	" 18	4	15,660	44	14.1	68	93	
13	" 21	7	18,000	52	13.7	89	103	
22	" 23	9	14,500	55	14.3	79	87	
26	" 25	11	16,000	46	14.5	74	97	
32	" 28	14	15,500	36	14.3	56	92	
37	" 30	16	14,160	52	16.2	83	96	
42	Sept. 1	18	15,160	43	16.4	75	105	
49	" 4	21	15,830	42	15.8	73	105	
		Average	15,660	46	14.9	74	97	12.5
			Minnesota No. 13, 1922, ears on, hard dent Sept. 1					
36	Aug. 30	..	11,660	53	10.2	45	50	
43	Sept. 1	..	13,000	47	9.9	42	54	
48	Sept. 4	..	12,500	50	9.4	41	49	
		Average	12,500	50	9.9	42	51	8.3

* Not included in averages.

TABLE IX
Cost Data for Cornstalk Sirup

	Weight of whole cane per acre	Sirup per acre 60 per cent extraction	Sirup per ton of cane 60 per cent extraction	Cost per gallon at $3 per ton	Value per acre at $3 per ton
	pounds	gallons	gallons		
Stowells' Evergreen, 1921	19,000	109	11.5	$0.26	$28.50
" " 1922	16,160	92	11.4	0.26	24.00
Country Gentleman, 1921	22,500	138	12.1	0.25	33.75
" " 1922	10,600	61	11.4	0.26	16.00
Crosby, 1922	6,000	33	11.0	0.27	9.00
Golden Bantam, 1921	6,830	41	12.0	0.25	10.20
Silver King, 1921, ears off	17,300	103	11.9	0.25	26.00
" " " " on	12,160	52	8.5	0.35	18.20
Minn. No. 13, 1922, ears off	15,600	97	12.5	0.24	23.40
" " " " " on	12,500	51	8.3	0.36	18.75
Narrow Evergreen, 1921	15,000	79	10.5	0.28	22.50

It will be noticed that the tonnage varies from about three for Crosby and Golden Bantam to about nine for Evergreen and the field corns. For comparison, it might be mentioned that sweet sorghum in Minnesota yields from 10 to 20 tons per acre. From Table II it is evident that the smaller varieties do not have any appreciable value per acre. The arbitrary figure of $3 a ton for whole cane delivered at the factory was chosen because, in conversation with farm economists and with farmers who grew corn for canneries, the writers found that this would be considered a fair price, and an inducement to bring the stalks to the factory. Such a price would bring the farmer from $9 to $33 per acre. This is undoubtedly more than the stalks are worth as forage. The price the cannery would have to pay would vary in different localities, depending on the abundance of feed and on the labor demand at the time of hauling the cane. It is believed that the above estimate would be found fairly correct for most places.

The next point to consider is the cost of the sirup at the above price for cane. On the assumption that 60 per cent of the cane as bought would be clean cane, and that 60 per cent of this would be extracted as juice, each ton would yield 720 pounds of juice. This, multiplied by the Brix and divided by 8.6 (the solids per gallon of sirup) gives the gallons of sirup per ton. Therefore, the yield per ton is dependent on the density of the juice; hence the great difference in yield between the "ears on" and "ears off" samples. These calculations will be in error because the larger varieties of corn will usually give higher extractions than the smaller, and the juiciness of stalks, and hence the extraction, varies from time to time irrespective of the density of the juice. But the figures in the table represent as close an approximation as can be made at present. It will be seen that the yield per ton is between 11 and 12 gallons of sirup, excluding the "ears on" samples as well as samples taken within a few days after removing the ears. At $3 per ton, the cost of cane per gallon of sirup is between 25 and 27 cents.

Against this charge for raw material must be credited the value of the trash, including the leaves, tassels, and bagasse. Ordinarily the bagasse would be burned as fuel, and would probably be as valuable for this purpose as for feed, altho local circumstances would decide this in each case.

There are two possible ways of utilizing the leaves; one, drying and baling; the other, ensiling them with the husks and cobs from the cannery.

According to figures given above, about 40 per cent, or 800 pounds, of each ton of stalks purchased would consist of leaves and tassels. At 25 per cent dry matter, this material would make 220 pounds of fodder at 10 per cent dry matter. From its similarity to timothy hay in composition, it is estimated that it would be worth $6 a ton. The cost of drying and baling should not be over $1.50 a ton. The net value of this material handled in this way would thus be about 5 cents per gallon of sirup.

If the leaves were ensiled, they would be worth from $1.50 to $2 per ton, or from 60 to 80 cents per ton of stalks purchased. This would allow 6 or 7 cents per gallon of sirup.

From the above figures, the cost of the raw material for the manufacture of cornstalk sirup would be between 18 and 21 cents per gallon. The cost of manufacturing would be about 30 cents per gallon, making a total cost of 48 to 51 cents and a wholesale price of approximately 68 cents.

At the present time molasses for cooking purposes is wholesaling at from 55 to 60 cents per true gallon in 10-pound units. Sorghum is sold at from 75 to 85 cents on the same basis. Therefore cornstalk sirup at 68 cents should be able to compete with these other sirups.

SIZE OF SIRUP PLANT NEEDED

In addition to the cost of manufacture, another essential consideration is the volume of sirup obtainable at a cannery and the size of the equipment required to make it.

The product from an average of 700 acres is required for a one-line cannery in Minnesota; from 260 acres for a two-line cannery. The stalks from only 500 and 900 acres, respectively, could probably be obtained for sirup making. If a product of 7 tons per acre is assumed, the total tonnage ground would be 3500 and 7000, about 100 and 200 tons per day of 24 hours, for the season, about 35 days. At 11 gallons of sirup per ton, the seasonal output would be 38,500 and 77,000 gallons; the daily output, 1100 and 2200 gallons.

The smallest sirup plant that can be economically operated, with a reasonable chance of financial success, is one making 1000 gallons a day, or about 40,000 gallons per season. This is approximately the capacity required by the smaller of the two canneries discussed. Therefore when the managers of a cannery contemplate the manufacture of sirup, they should first assure themselves that they can obtain as a minimum the material for 40,000 gallons per season; and the greater the volume of manufacture, the greater the chances of success. The data in Tables VIII and IX show that the variety of corn, the heaviness of the growth, and the density of the juice all have an effect on the yield of sirup from a given number of acres. The larger varieties of corn are much better adapted for sirup manufacture than the smaller ones.

The writers believe that a dual purpose corn could be produced one that would meet all the requirements of the cannery, and at the same time have a large stalk that would develop a juice of high density and of high quality for sirup. None of the varieties so far tested meets this dual requirement to the extent that is probably possible.

COST OF SIRUP FACTORY

The installation of a sirup plant in connection with a cannery would involve an entirely separate set of machinery and buildings. Nothing in the cannery can be used for both canning and sirup making with the exception of the power plant, and usually this would not take care of the extra load. At the present time it would cost about $60,000 to erect a sirup plant wtih a capacity of 100 tons of cane daily; and about $90,000 for one with a capacity of 200 tons.

DESCRIPTION AND USES OF THE SIRUP

The sirups made during the present investigations were usually clear; only a few became cloudy during evaporation. In color they ranged from a light amber, similar to good grade maple sirup, to a dark brown, similar to molasses.

These color variations are discussed in Part II. The viscosity of the sirups was about that of maple sirup of the same density. This low viscosity is probably due to the lack of starch. The flavor, of course, is difficult to describe. Many people pronounced it very similar to that of sorghum, altho in opinion of the writers they were not at all alike. Most of the samples made had a mild, agreeable flavor; less pleasing than that of high grade sorghum but more so than that of molasses. Some of the samples made from cane grown in soil unusually rich in nitrates and other minerals had a very disagreeable flavor, and even deposited crystals of potassium nitrate after standing, as was discussed in Part II. Such sirups are unfit for food, but their occurrence would probably be unusual and could be predicted by watching the purity quotient of the juices, as suggested above.

The cornstalk sirups so far produced are not suitable for table use, but are well adapted for cooking. The writers have submitted samples of the sirups to a great many individuals for use in the home; to a class in experimental cookery; to a cafeteria for use on a large scale; to an experienced buyer of sirups and molasses; and cookies made from these sirups, from sorghum, and from molasses to several groups of people for comparison. The general opinion of these various observers was that cornstalk sirup is equal to the best grade of sorghum and molasses, and much superior to the lower grades, for all cooking purposes. One objection was that the sirups do not impart as dark a color to the products as molasses does, but such an objection probably would not be general. The flavor of the products is not so pronounced as with molasses, but this difference seemed to be acceptable to the great majority of the judges.

From this evidence the writers consider cornstalk sirup to be a competitor of high grade molasses and sorghum.

SUMMARY

1. The smaller varieties of sweet corn yield 3 or 4 tons of stalks to the acre; the larger varieties of sweet corn and field corn, 8 to 10 tons. At an estimated value of $3 per ton, only the larger varieties have an appreciable value per acre.

2. Most varieties, allowed to stand for two or three weeks after removing the ears, yield from 11 to 12 gallons of sirup per ton of whole cane. If used when the ears are removed the yield may be as low as 8 or 9 gallons.

3. At $3 per ton of whole cane, the cost of the raw material per gallon of sirup is between 18 and 21 cents, after subtracting 6 or 7 cents for the value of the leaves as feed.

4. Placing the cost of manufacturing the sirup at 30 cents, the total cost of the sirup would be 48 to 51 cents. It should thus wholesale at about 68 cents.

5. The average one-line corn cannery in Minnesota uses about 700 acres; a two-line, 1200 acres. Of this, probably only 500 and 900 acres, respectively, would be available for sirup. These acreages would yield about 38,000 and 77,000 gallons of sirup, and would require sirup plants of about 100 and 200 tons of cane daily capacity.

6. Cornstalk sirup is usually clear, of a reddish amber color, and has a mild, agreeable flavor. It is not a table sirup, however, but a cooking sirup with characteristics and uses very similar to those of sorghum and molasses.

IV. GENERAL SUMMARY AND CONCLUSIONS

The possibility of manufacturing sirup from sweet-corn stalks as a cannery by-product has been investigated for two seasons under Minnesota conditions.

A one-line cannery has available about 500 acres of stalks, or 4000 tons, a year, which would give about 1100 gallons of sirup per day or 38,000 per season.

Five varieties of sweet corn and two of field corn were used. The density of the juice at the canning stage of the ears is from 9 to 11 degrees Brix; if the stalks are allowed to stand in the field from 10 to 20 days after removal of the ears, the density increases to a maximum of 13, 14, or even 17 degrees Brix, these facts corroborating the claims in a patent covering this field treatment. The proper stage for sirup making is at this period of maximum density, because of both yield and quality of juice. A new purity quotient, solids-over-Brix in the juice, has been used as an index of juice quality.

Cornstalk sirup should be manufactured by essentially the same process as sorghum sirup, using controlled defecation, filtration, and vacuum evaporation. A careful use of the by-products, bagasse and leaves, would be necessary in commercial practice.

Cornstalk sirup is clear, reddish amber in color, with a pleasant flavor. It is not a table sirup, but is an excellent cooking sirup, rivalling the best grades of sorghum and molasses.

The possibilities of the successful commercial manufacture of cornstalk sirup are not yet altogether bright. In the present estimates of cost, it is assumed that $3 per ton of fresh stalks would be a price satisfactory to the grower. This would amount to from 18 to 21 cents per gallon of sirup. The cost of manufacture is estimated at 30 cents. The total cost is thus about 50 cents per true gallon, and could wholesale at about 68 cents and compete with the best grade of sorghum sirup. Assuming a capital outlay of $60,000 the returns at this price for sirup would be about 11 per cent. These figures allow for the utilization of bagasse and leaves. It would be difficult to say whether these costs could be materially reduced in actual practice, and whether the profits as indicated would make the venture attractive.

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