Sugar Beet and Purified Juice Quality in Relation to Non-Sugar Constituents

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All soluble chemicals present in thin juice after carbonation lower juice quality. These include ash, nitrogen compounds, some organic acids, alkali metal ions, and others. The actions of these substances are additive but not necessarily equal in effect. Carruthers and Oldfield developed a method to assess beet quality (1)[4]. They prepared a clarified extract from brei, determined some of the specific non-sugars, and summarized the non-sugar effects in a "purity value." Heimann and Ratner studied the influence of sodium and the sodium-potassium ratio on the quality of Israeli beets (3). Powers and Payne studied the relation between nitrogen, sodium, and potassium in both petioles and purified juice (5). Other reports, too numerous to summarize, have dealt with effects of genetics, climate, salts, fertility levels, and other factors and their interactions on over-all beet quality (2).

It seemed worthwhile to attempt to evaluate separately and interrelate some effects of sodium and potassium with nitrogen, chloride, and other specific chemicals of purified beet juice prepared from individual beets selected for a wide range of petiole nitrate content grown in the same field. Data from Israel offer a comparison with beets grown in another climate in a more saline soil.

Collection of Sugar Beets—A fertilizer test plot at Davis, California, had been planted on June 7, 1963, with variety 202-H sugar beets (Spreckels Sugar Company) with application of 200 pounds of nitrogen per acre as ammonium sulfate. On October 10, 1963, beets within a few feet of each other were selected to represent a wide range of size and petiole nitrate contents (as indicated by the diphenylamine-sulfuric acid test (4)). The tops were removed immediately, and the beets and tops were taken to the laboratory for analysis.

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[4] Numbers in parentheses refer to literature cited.

Preparation and Analysis—Petiole nitrates were determined by the method of Johnson and Ulrich (4). The beets were scrubbed free of soil, the crowns were removed, and each beet was numbered for identification. Brei was prepared in a vegetable chopper and two samples taken for analysis, for sugar by polarization (Pol), and for sodium and potassium by flame photometry. Juice was pressed from the brei through a nylon cloth in a hydraulic press. Sucrose in the juice was measured by polarization and total solids by refractometer (RDS). The remainder of the juice was purified by the lime-phosphoric acid method of Carruthers and Oldfield (1) and preserved for analysis by quick freezing.

Pol sugar of the purified juices was measured on 26 g of clarified juice diluted to 200 ml with water. Apparent purity was calculated from RDS and Pol sugar. Total nitrogen including nitrate was measured by the Kjeldahl method. Chloride was determined with an Aminco-Cotlove chloride titrator. Betaine isolated by ion exchange according to the method of Carruthers and Oldfield was precipitated as the reinickate and determined colorimetrically (1). Sodium and potassium were measured by flame photometry.

Measurements of "anions" to include pyrrolidone carboxylic acid (PCA) were as follows: After the limed-phosphated juice at pH 11.2 was heated and filtered, a sample was heated in a boiling water bath for 1 hour to convert glutamine to PCA. "Anions" were determined on this converted juice by passing 20 ml through a column containing 20 ml of Dowex 50 (H) ion exchange resin then titrating to pH 8.6 with 0.05 *N* sodium hydroxide. "Anions" should be determined after conversion of glutamine to PCA because this conversion is usual in factory operation.

Results and Discussion

Table 1 shows the results on beets and press juices for individual roots, arranged in order to decreasing sugar content of the press juice. Samples with plus signs showed a positive reaction to the petiole nitrate test. Low petiole nitrate is associated with high sugar content. There is usually a positive relation between beet weight and nitrogen fertilization, but in this case, beets were selected to have a wide range in sizes within a selected nitrate classification. The wide range of petiole nitrate is typical when beets are sampled by the petiole nitrate test.

Table 2 shows analyses of the purified juices. These samples are also arranged in decreasing order of the sugar content of the press juice. The purity values of the low nitrogen beets, samples 1 to 9 and 11, are unusually high and may reflect careful topping in the laboratory. Sample 12, one of the group of low-nitrogen beets, falls into the grouping of high nitrogen samples; it is not unusual to have overlapping in sample groups like these.

Table 1.—Analyses of beets for weight, Pol, and RDS and petioles for nitrate[1].

Sample	Root wt, g	Petiole NO_3 - N, ppm	Beet Pol, %	Press juice Pol, %	Press juice RDS, %	Press juice Purity, %
1	633	211	16.69	18.26	19.84	92.0
2	513	177	16.50	17.90	19.81	90.4
3	693	253	15.70	17.43	19.29	90.4
4	965	211	15.42	16.77	18.51	90.6
5	681	422	15.27	16.76	18.51	90.5
6	721	177	15.14	16.36	17.72	92.3
7	752	270	15.08	16.28	17.74	91.8
8	1,017	160	15.07	16.24	17.83	91.1
9	875	245	14.92	16.22	17.76	91.3
10+	1,042	1,820	14.96	16.07	18.48	87.0
11+	915	4,480	14.79	16.00	18.08	88.5
12	868	118	14.02	15.02	16.89	88.9
13+	732	6,550	12.72	14.10	16.60	84.9
14+	1,626	7,640	12.94	13.85	16.14	85.8
15+	1,673	4,940	12.94	13.78	16.70	82.5
16+	691	8,990	12.48	13.54	15.84	85.5
17+	467	10,900	11.40	12.45	14.76	84.3
18+	2,099	9,160	11.70	12.19	15.37	79.3
19+	1,478	13,800	10.75	11.60	13.71	84.6
20+	1,782	7,260	10.34	10.95	13.13	83.4

[1] Arranged in order of sugar content of press juice.

Table 2.—Composition of purified juice.[1]

Sample	Percent Sugar	Percent RDS	Percent Purity	N, miligrams per 100 g beet Total	N, miligrams per 100 g beet Betaine	Milliequivalents per 100 g beet Anions	Milliequivalents per 100 g beet Cl	Milliequivalents per 100 g beet Na	Milliequivalents per 100 g beet K
1	14.15	14.66	96.5	36	24.4	1.77	1.03	0.35	3.75
2	14.01	14.68	95.4	49	26.1	2.85	1.62	0.56	5.40
3	13.80	14.34	96.2	50	30.2	3.24	1.29	0.69	2.78
4	13.30	14.04	94.7	42	24.4	3.00	1.50	0.86	4.38
5	12.83	13.41	95.7	34	21.4	2.48	0.87	0.61	4.48
6	12.99	13.60	95.5	30	20.3	2.85	1.38	0.30	4.12
7	13.10	13.61	96.3	28		1.90	0.71	0.71	3.12
8	13.12	13.81	95.0	44	20.7	2.92	1.00	0.45	4.82
9	12.59	13.31	94.6	36	20.6	2.88	1.49	0.78	4.98
10+	12.75	13.94	91.5	94	30.6	2.75	0.63	1.29	4.08
11+	12.63	13.50	93.6	78	24.1	4.56	0.56	1.27	4.79
12	11.86	12.82	92.5	75	24.3	3.36	1.88	0.72	6.78
13+	11.26	12.35	91.2	116	—	4.79	1.13	3.14	4.75
14+	10.83	11.82	91.6	89	26.2	5.31	1.54	3.58	6.45
15+	10.92	12.28	88.9	155	37.2	3.86	1.29	1.19	6.60
16+	10.47	11.51	91.0	82	23.2	4.33	0.79	3.84	4.15
17+	9.51	10.66	89.2	86	18.3	5.89	0.99	6.59	3.62
18+	9.74	10.97	88.8	123	30.8	7.55	1.99	4.15	6.70
19+	9.04	10.00	90.4	93	19.1	7.47	1.10	4.74	3.40
20+	8.30	9.48	87.6	91	20.2	9.00	3.20	5.31	6.83

[1] Arranged in order of sugar content of press juice.

Table 3.—Correlations between some constituents of beets, press juice, and purified juice.

	y^1	x^1	r^2	Regression equation
a	Juice purity	Beet Pol	0.910	$y = 1.39x + 74.5$
b	Juice purity	Press juice Pol	0.922	$y = 1.24x + 74.1$
c	Juice purity	Na	−0.813	$y = -1.20x + 95.3$
d	Juice purity	K	−0.518	
e	Juice purity	Na + K	−0.912	$y = 1.06x + 100.1$
f	Juice purity	K/Na	0.680	
g	Juice purity	Cl	−0.404	
h	Juice purity	Anions	−0.898	$y = 1.30x + 98.2$
i	Juice purity	Betaine	N.S.	
j	Juice purity	Total N	−0.871	$y = -0.071x + 97.90$
k	Na	Total N	0.550	
l	K	Total N	0.509	
m	Na + K	Total N	0.694	
n	Na	Anions	0.935	$y = 0.915x - 1.73$
o	K	Anions	0.398	
p	Na	Petiole NO_3-N	0.922	$y = 0.000405x + 0.48$
q	K	Cl	0.668	
r	Beet Pol	Press juice RDS	0.979	$y = 0.995x - 3.08$
s	Beet Pol	Petiole NO_3-N	−0.897	$y = -0.000383x + 15.43$
t	Press juice sugar[3]	2(Na + K) + N	−0.902	$y = -0.809x + 648$

[1] Expressed in the units used in Tables 1 and 2.
[2] $r = 0.378$ for 10%, 0.443 for 5%, and 0.561 for 1% level of significance.
[3] Millimoles per liter in the press juice.

Table 3 shows some correlation coefficients and regression equations derived from the variables analysed in this study. The concentrations of individual constituents in the purified juices were calculated back to their concentration in the original beet by assuming no loss of sugar in the purification procedure. If concentrations are expressed relative to the sugar content, spurious negative correlations may be found which are due only to variations in sugar content. If a constituent B occurs in the beet at a constant concentration, and the purity of the juice is compared with B per unit of sugar, there is a built-in negative correlation between S/A and B/S. For the beets in this study, if betaine is expressed per unit of beet, the correlation with purity is −0.15, but if betaine is expressed per unit of sugar, the correlation rises to −0.67, which is significant at the 1% level.

As expected, purified juice purity correlates highly with the sugar content of beets (a) and press juice (b). Juice purity correlates negatively with the non-sugars, Na (c), Na + K (e), anions (h), and total N (j). In this series of beets, Na correlates with anions (n) and with petiole nitrate (p), potassium with chloride (q), and Na + K with total N (m). The high negative correlation of petiole nitrate with beet Pol (s) has been observed in all other tests. The high positive correlation between sugar in beets and RDS of press juice, 0.979 (r) suggests that for some purposes an RDS measurement of beet press juice used with the regression equation would serve as an adequate measurement of the sugar content of beets. Further attention should be given to this possibility. Item (t) shows that the calculated total moles of non-sugars is negatively correlated with the moles of sugar. Furthermore, the regression equation indicates a reduction of one mole of sugar for each increase of 1.2 moles of non-sugar. This indicates that the total solute content of beet press juice is relatively constant, when expressed as the number of particles in solution.

If beet cells have a constant number of molecules and ions per unit volume, and thus a constant osmotic concentration, the accumulation of sucrose would be limited by the presence of non-sugars. One mole of sodium chloride (59 grams) would displace two moles of sugar (648 grams). Total concentration of solutes (osmolality) of beet juices will be reported in a future communication.

Table 4.—Analytical values of pressed juice from Israeli beets compared with Davis, California beets.

Number of samples	Sugar %	Avg. sugar %	Purity	Avg. milliequivalents/100 g sucrose Na	K	K/Na
		Haifa, Israel beets				
13	above 18.0	19.0		15.3	25.2	1.6
31	16.6-18.0	17.5	86 6	18.3	28.0	1.5
26	15.0-16.5	15.8	82.0	22.2	30.4	1.4
33	below 15.0	13.8	.	39.9	40.5	1.0
		Davis, California beets				
4	16.6-18.0	17.2	90.5	4.4	27.5	6.3
7	15.0-16.5	16.0	90.1	5.3	31.6	6.0
8	below 15.0	12.9	84.2	36.4	44.8	1.2

Table 4 compares the beets in Table 1 with beets grown near Haifa, Israel, in an area of saline soil irrigated with saline waters. The purity of the factory juices from Israeli beets is lower than the purity of the laboratory juice from the Davis beets at comparable sugar contents. Israeli beets contain more sodium than the Davis beets, but the total Na + K values are similar. The ratio of K/Na for the various populations are very different although for each population sugar and purity decrease as the ratio decreases. The purity drop does not seem to be related directly to excess salts but appears to be due to some other factor.

Summary

Beets grown in the same field selected for high and low petiole nitrate contents and size within each population were processed into brei, pressed juice, and purified juice. Sugar and

non-sugar constituents were determined, and the influence of these constituents on juice quality was assessed. Correlations between some constituents of the beets, pressed juice and purified juice were highly significant. Data from Israeli beets, briefly reported, show some similarity and some variation.

Reference to a company or product name does not imply approval or recommendation of the product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

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