The Osmolality of Sugarbeet Press Juices

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In an investigation of the relationship between non-sugar chemicals and sugar in beets, we found that the calculated osmolality of press juice was remarkably constant (3)[2]. If there is a physiological limit to beet cell osmotic pressure one millimole of sodium chloride (59 mg) could displace about two millimoles of sucrose (648 mg). This would help to explain why the nutrition of beets is so important to the sugar content. It seemed worthwhile to examine other beet populations in an attempt to determine whether the osmolality of press juice samples is constant or is correlated in any way with the sugar content of beets.

Materials and Methods

Harvest Conditions—In this study no deliberate attempts were made to collect beet samples at the same time of day or under the same moisture stress.

Field Beets 1963—Twenty mature beets were selected from a field near Davis, California. Ten showed a positive reaction to Johnson's petiole nitrate test with diphenylamine-sulfuric acid, and ten showed a negative reaction (7).

Analysis of the 1963 field beets has been previously reported (3). Individual beets were reduced to brei and pressed to expell juice. Purified juice was prepared by the liming and phosphation of Carruthers and Oldfield (2), and sodium, potassium, total nitrogen and sugar by polarization (Pol) determined on the purified juice.

The total osmotic concentration of the 1963 beets was calculated from the N, K and Na concentrations expressed on the basis of press juice, and Pol measured on the press juice. We assumed that the non-sugar concentration is approximately the sum of the equivalents of nitrogen plus twice the equivalents of sodium and potassium.

Field Beets 1964—Thirty beets were collected from two fields near Clarksburg, California, representing three planting dates

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[2] Numbers in parentheses refer to literature cited.

and two levels of nitrogen fertilization. In Field A, three planting dates were represented in one small area, and beets were taken which had been planted about 8, 12 and 17 weeks earlier. Several weeks of cool weather following the two earlier plantings delayed the emergence and growth of the 17- and 12-week old beets. In Field B, the interior rows of beets gave a negative reaction for petiole nitrate but the end rows of beets had received additional applications of nitrogen and gave a positive reaction.

The 1964 field beets were ground to a brei in a vegetable chopper and pressed in a hydraulic press. Refractometric dry solids (RDS) and sucrose by Pol were measured on a sample of the press juice. The remainder of the press juice was protected from evaporation, clarified by centrifugation at 33,000 *g*, frozen in small plastic tubes, and stored at -30° C.

Pot Beets—Brei from sixteen pot-grown beets representing three harvest dates was kindly supplied by Dr. Albert Ulrich, University of California, Berkeley. The beets were grown in pots, with adequate plant nutrients, at 20° C, with a 16-hour photoperiod at 3200 ft-c supplied by a combination of fluorescent and incandescent lighting. The beets were harvested after 9, 13 and 17 weeks. Sucrose was determined by Pol immedately, and 26-gm samples of brei were held frozen in plastic bags for approximately one year before receipt at this laboratory (8). Press juice was prepared from the quickly thawed brei in a hydraulic press. The press juice was clarified and frozen as described above.

Osmolality Measurements—The osmotic concentrations in the press juices from pot-grown beets and 1964 field-grown beets were measured with a Vapor Pressure Osmometer (Model 301A Mechrolab Inc., Mountain View, California). Measurements were made at 37.00° C, with sucrose solutions as standards. The osmolality values reported are the average of duplicate determinations on separately frozen samples of processed juice. The standard deviation of the observation was 12.8 milliosmoles per liter.

Results and Discussion

Table 1 is a comparison of press juice sucrose and calculated osmolality for the 1963 beets. There was no correlation between sucrose and calculated osmolality in this population. Furthermore the lower coefficient of varition for calculated milliosmoles indicates that the osmotic concentration is less variable than the sucrose concentration.

Table 2 and Figure 1 compare the press juice sucrose and actual osmotic concentration of the 1964 field beets. The meas-

Table 1.—Press juice sucrose and calculated osmolality of 1963 beets.

Sample	No. of beets	Sucrose average	v[1]	Milliosmoles average[2]	v[1]
High NO_3	10	13.45	12.7	777	4.9
Low NO_3	10	16.72	5.6	774	5.6
All	20	15.09	14.3	775	5.2

[1] Coefficient of variation as percent. $v = 100\left(\frac{s}{\bar{x}}\right)$

[2] Calculated. Milliosmoles = (mM sugar + mM nitrogen + 2 (mM sodium + mM potassium))

Table 2.—Press juice sucrose and osmolality of 1964 beets.

Sample	No. of beets	Sucrose average	v[1]	Milliosmoles average	v[1]
Field A, 8 weeks	3	8.79	13.4	676	7.9
12 weeks	3	13.17	8.4	785	4.9
17 weeks	4	14.00	13.1	789	3.2
Field B, high NO_3	10	15.39	12.3	792	4.1
low NO_3	10	19.32	4.6	830	7.0
All	30	15.63	22.5	792	7.6
All except 8 weeks	27	16.39	17.0	805	5.7

[1] Coefficient of variation as percent. $v = 100\left(\frac{s}{\bar{x}}\right)$

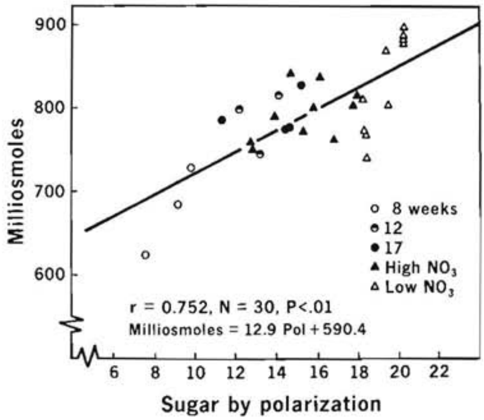

Figure 1.—Sugar content and osmolality of press juice from beets grown in 1964 at Clarksburg, California.

ured osmolality is very close to the calculated osmolality for the 1963 beets, but there is a highly significant correlation between sucrose and osmolality ($P < .01$). This correlation is due entirely to the beets with less than 10% or more than 19% sucrose in the press juice. Neglecting these beets, the correlation coefficient drops to 0.11, and the average milliosmoles is 787. Over

Table 3.—Beet sucrose and press juice osmolality for beets grown in pots.

Sample	No. of beets	Sucrose	v[1]	Milliosmoles average	v[1]
9 weeks	6	7.65	5.6	539	6.9
13 weeks	4	8.88	3.7	522	6.3
17 weeks	6	10.37	4.6	587	8.2
All	16	8.98	14.3	553	8.5

[1] Coefficient of variation as percent. $v = 100 \left(\frac{s}{\bar{X}}\right)$

a comparable range of sugar concentration, the results for the two years are in good agreement.

Table 3 compares beet sucrose and press juice osmolality for the pot-grown beets. They correlate significantly ($r = 0.583$, $P = 0.02$). The osmolality is much lower than for the field beets, even though the sugar content of the 13- and 17-week-old pot beets is higher than that of the 8-week-old field beets.

Plant physiologists have been studying the osmotic relations of plants for many years (1, 5, 6) and have developed much more refined methods than used in this study. The sap or press juice we obtained represents a mixture of contributions from all cells—active and non-active—in the beet root. At best, determination of osmotic pressure made on such juice represents no more than the average of the osmotic pressures of all the cells in the tissue. Even though the juices used were pooled fluids from different physiological structures, this study does show that the osmolality is less variable than the sugar content. It appears that there is no narrow physiological limit of osmolality of beet juices, as measured by the procedures used in these experiments.

It would be desirable to measure the osmotic pressure of the individual parenchyma cells that are involved in storage of sugar under the same moisture stress and without contamination of cell contents with free water from the vascular tissue and intercellular spaces. A new micro-technique has been reported that could determine the osmolality of beet cell sap with satisfactory precision (4). The preliminary results reported here indicate that the relation between osmolality and sugar content should be studied further.

Acknowledgments

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Reference to a company or product name does not imply ap-

proval 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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