Sodium and Potassium Content of Sugar Beet Varieties in Some Western Beet Growing Areas

C. W. DOXTATOR AND F. R. CALTON[1]

Breeding for improvement of sugar beets in the past has been largely confined to the factors of yield, sucrose percentage and disease resistance, since these characters were of first importance in American-developed varieties. Recently however, non-sugars in beet juice have commanded attention since high purity in beets is essential to maximum extraction of sugar.

The literature contains numerous references to non-sugars but very little data which are related directly to a breeding program. Contributions such as those of Zitkowski et al (6)[2] and of Ness (3) have established average values for the various non-sugar constituents with respect to average sugar beet varieties. Wiklund (5) gives a very detailed discussion of the effect of various non-sugars on factory operations with numerous references. All of these indicate the need for improving beet quality. Smolenski and Zalenski (4) have investigated differences in the chemical composition of high sugar and high tonnage type beets; and Dahlberg (1) has reported results of breeding for high purity type varieties.

Early in 1949 plans were made by the American Crystal Sugar Company to enlarge its breeding program with the objective of further improving the purity of juice in sugar beet varieties. A study of sodium and potassium was chosen to initiate the work since, in spite of the importance of these minerals, practically no direct information was available. To a large extent this lack of information could be traced to the expense involved in sodium and potassium determinations by conventional methods. Now, however, with the advent of flame spectrophotometry involving low temperature excitation and direct photometric measurement, such analyses can be placed on a routine basis in the hands of only semi-skilled analysts. Also an analysis is rapid enough so that sufficient data can be obtained for interpretation by the conventional statistical methods commonly used in breeding programs.

This paper reports the results to date on Na and K content between and within varieties tested in different areas.

MATERIALS AND METHODS

Sample Preparation

The samples tested fall into two groups with respect to preparation for analysis: A. Those from widely separated areas which could not very well be shipped in a wet form, and, B. those from a single area where the mineral analysis could be made parallel with the usual sucrose determination.

[1] Plant Breeder and Experimental Chemist, respectively, American Crystal Sugar Company, Rocky Ford, Colo.

[2] Numbers in parentheses refer to literature cited.

Plot and strip test samples were prepared as follows: 5 gms. of freshly rasped pulp were weighed rapidly on a watch glass, transferred into a 1-oz. wide mouth bottle, dried at 105° C. for 4-8 hours, capped with screw caps having vinylite liners, labelled and shipped to the central laboratory. The bottles had been washed, then soaked in dilute HC1, rinsed with distilled water and dried before use; the caps were rinsed with distilled water. In almost every instance the pulp dried to a hard mass on the bottom of the bottle.

In the central laboratory the dried pulp was softened in the bottle by covering with about 10 ml. of distilled water and allowing to soak for several hours. Contents of the bottle were then transferred quantitatively to a 50-ml. flask and made to volume with distilled water. After mixing, allowing to stand for about an hour and then remixing, the sample was filtered and the extract tested in a flame photometer.

When all samples making up a particular test were rasped at the central laboratory, the customary normal weight sugar solution could be used. According to this procedure 26 gms. of freshly rasped pulp were weighed rapidly into a capsule, 177.0 ml. of distilled water and approximately 0.6 gm. of Horne's dry lead added, the capsule covered, shaken, allowed to stand 30 minutes, shaken again and filtered. To each filtrate was added 2 drops of glacial acetic acid prior to testing in the flame photometer.

Sample Analysis

All samples as prepared above were tested for both sodium and potassium using the Beckman flame spectrophotometer (2) . Instrument settings were as follows: (a) for sodium, wave length 589 m mu, slit .15 mm, sensitivity about 1½ turns from full clockwise position, red-sensitive phototube, gas 4 cm., oxygen 42 inches, air 25 lbs. per square inch (b) for potassium, wave length 767 m mu, slit .02 mm, sensitivity about 3 turns from full clockwise position, red-sensitive phototube, gas 4 cm., oxygen 36 inches, air 25 lbs. per square inch. Because this instrument sprays the sample into the flame after first drawing the sample up through a fine capillary it was very important that all samples be free from suspended particles.

In actual operation the transmission scale was set to read 100 for an 80-ppm. sodium solution by adjusting the sensitivity dial slightly; then checked against a 40 ppm. sodium solution to insure conformance with calibration curve characteristics; and finally a group of samples run. Six samples were usually run consecutively before the instrument was rechecked. After rechecking against the 80 and 40 ppm. sodium solutions, the last sample in the previous group was tested again; if the difference in transmission exceeded two transmission scale units, the previously tested samples were retested in reverse order until a check was obtained. In all instances, difference in reading could be traced to restricted flow through the capillary and could usually be corrected quickly by blowing air back through the capillary. For potassium the reference standards were 300 ppm. and 150 ppm. Both the sodium and potassium standards were in the chloride form.

Although instrument reference points were relative to solutions of the pure salts, actual calibration curves were prepared from data for mixed salt-

sucrose solutions which more nearly approximated the sample extract. For sodium, the calibration curve solutions contained 40 ppm. calcium as $Ca(NO_3)_2$,40 ppm. magnesium as $Mg(NO_3)_2$,300 ppm. potassium as KC1 and 2% sucrose plus varying amounts of sodium as NaCl; for potassium the calibration curve solutions contained 40 ppm. calcium, 40 ppm. magnesium and 2% sucrose as before, plus 80 ppm. sodium as NaCl and varying amounts ofpotassium as KC1. Choice of 80 ppm. sodium and 300 ppm. potassium for the 100° transmission scale settings was based on average data obtained by Zitkowski (6) .

EXPERIMENTAL RESULTS

Differences Between Varieties

The first results obtained in the 1949 season were from a 4-variety non-replicated strip test west of Fowler, Colorado. Five samples, each of 15 beets, were taken from each variety strip at uniform distances down the field. Average percentages of sucrose, sodium and potassium by variety for this test are given in Table 1.

Table 1.—Sucrose, sodium and potassium percentages of 4 varieties grown in strip tests at Fowler, Colo., in 1949.

Variety	Sucrose	Na in Beet	K in Beet
	%	%	%
5-414-0	17.48	.0384	.2072
Amer. 1 Com'l	17.46	.0424	.2076
Amer. 3 LSR	16.40	.0606	.2038
3-428-0 (Check)[1]	13.56	.1352	.1986

[1] R & G Old Type, American increase

Due to the severe *Cercospora* leaf spot conditions, only resistant varieties produced a high sucrose percentage. Differences in Na percents were also very large with the most resistant variety lowest in sodium. There were no appreciable differences in K percent.

Tests for Na and K were next conducted on an 8-variety test planted in Latin square arrangement. Two samples from each plot were used for the tests. Yield data along with percentage of sucrose, sodium and potassium are given in Table 2.

Table 2.—Yield and quality of 7 domestic varieties and 1 European variety in a Latin square test, Rocky Ford, Colo., in 1949.

Variety	Tons Beets per Acre	% Sucrose	% Na	% K
1	25.80	14.59	.100	.234
2	25.46	14.69	.094	.247
3	25.59	14.52	.090	.270
4	23.77	14.97	.090	.222
5	24.97	14.01	.111	.272
6	24.00	14.43	.106	.209
7 (European)	24.45	13.70	.120	.258
8	22.39	14.74	.090	.209
Sign.Diff.(19.1)	1.67	.61	.019	.022
F value	3.78[2]	3.60[2]	2.89[1]	10.75[2]

[1] Significant beyond 5% point.
[2] Significant beyond *1*% point.

Statistical analysis of the data indicates that reliable differences between varieties were obtained for yield and for sucrose, Na and K percentages. Differences in Na percents ranged from .090 to .120, the high sodium value being found in the European variety, which has the lowest sucrose percent. Potassium percents ranged from .209 to .272, with the lowest value being found in the variety lowest in yield and above average in sucrose percent.

Differences Between Areas

In the 1949 variety testing program of the American Crystal Sugar Company, 16-variety, 6-replicate plot tests had been planted at Rocky Ford, Colo., Mason City, Ia., Chaska and East Grand Forks, Minn., all of which had a check variety, American 3 LSR. At Missoula, Mont., this variety was used as a check in a 12-variety, 6-replicate plot test. Percentages of Na and K were determined for this variety from all test plots at each factory location and the data analyzed statistically. Results as obtained for the different areas are given in Table 3.

Table 3.—Percentages of Sodium and Potassium in American 3 LSR at 5 factories (4 states)—1949.

Location	Na %	K %
Missoula	.044	.226
Rocky Ford	**.147**	**.185**
Mason City	**.016**	**.227**
Chaska	**.023**	**.195**
East Grand Forks	**.101**	**.198**
Significant difference (19:1)	**.027**	.028

The data obtained indicates very great variation in Na percents attributable to area of production. Lesser variation, but also significant, occurs in the K percent values. It is interesting to note that in the Mason City district the American 3 LSR variety, although extremely low in Na percent, is higher in K percent than in any of the other areas.

Variety Differences in Different Areas

It has been a general observation covering many years experience and testing that varieties often do not perform the same in different areas. Since a number of varieties were in replicated plot tests in several of the five factory district plot tests, it was possible to compare these varieties in more than one area in order to determine whether interaction between variety and area reached significance.

Three varieties, representing a wide range of *Cercospora* leaf spot resistance, were in test at both the Mason City and Chaska factory districts in 1949. At Stewart, Minn., (near Chaska) severe leaf spot occurred, while only a trace of leaf spot was found at Mason City. Performances of these varieties in each area with respect to yield, and sucrose, sodium and potassium percentages are given in Table 4.

The results of these tests show significant differences between varieties, and between areas, for all four characteristics. The only non-significant result in all the data is in sucrose percent at Stewart where only minor differences were obtained. F values computed in the analysis of variance for the variety

—area interaction were not significant for yield, sucrose, Na and K, indicating that the varieties performed similarly in both areas.

Table 4.—Comparison of tonnage yield, sucrose, sodium and potassium percentages of 3 varieties tested at Mason City, la., and Stewart, Minn.—1949.

Variety	Location	Tons Beets per Acre	% Sucrose	% Na	% K
7-401a	Mason City	16.9	18.6	.016	.231
7-401a	Stewart	11.7	16.8	.025	.187
Amer. 3 LSR	Mason City	18.2	17.6	.016	.227
Amer. 3 LSR	Stewart	14.0	16.5	.023	.195
3-428-0	Mason City	15.9	15.5	.032	.287
3-428-0	Stewart	11.8	16.0	.052	.207
(a) Significant Difference (odds 19:1)		2.20	1.04	.008	.029
Averages:	Mason City	17.0	17.2	.021	.248
	Stewart	14.8	16.5	.034	.196
(b) Significant Difference (odds 19:1)		1.27	.60	.005	.017
Averages:	7-401a	14.33	17.72	.021	.209
	Amer. 3 LSR	16.08	17.08	.020	.211
	3-428-0	13.87	15.73	.042	.247
(c) Significant Difference (odds 19:1)		1.55	.73	.006	.020

A second test of variety performance in different areas was possible in the plot tests of East Grand Forks and Missoula. Three varieties widely different in origin were used in this experiment. The results are given in Table 5.

Significant differences were obtained between varieties for yield, and for Na percents. Both areas produced similar yields, but significant differences between areas were obtained for sucrose, Na and K percents. Although variety performance was slightly different in each area it was not of high enough level to be satistically significant, and hence it can be assumed that the performance of the varieties was relatively the same in each area.

Table 5.—Comparison of tonnage yield, and of sucrose, sodium and potassium percentages of 3 varieties tested at Missoula, Mont., and East Grand Forks, Minn., in 1949.

Variety	Location	Tons Beets per Acre	% Sucrose	% Na	% K
7-801	Missoula	18.1	15.2	.053	.133
	East Grand Forks	19.0	15.9	.128	.248
U.S. 33	Missoula	12.9	15.4	.046	.137
	East Grand Forks	12.5	16.2	.107	-269
Amer. 3 LSR	Missoula	14.4	15.3	.044	.226
	East Grand Forks	16.0	16.3	.101	.198
(a) Significant Difference (odds 19:1)		2.5	.56	.025	.042
Averages:	Missoula	15.13	15.29	.047	.165
	East Grand Forks	15.86	16.11	.111	.238
Significant Difference (odds 19:1)			.32	.014	.024
Averages:	7-801	18.57	15.55	.090	.190
	U. S. 33	12.72	15.76	.075	.203
	Amer. 3 LSR	15.20	15.79	.072	.212
Significant Difference (odds 19:1)		1.76		.017	

Variations within Varieties

Since differences between varieties had been observed in several areas, attention was directed to differences between beets within varieties. For this study the Elite stock 7-40la was used. This variety had been subjected to a medium severe *Cercospora* leaf spot epidemic at Rocky Ford, Colorado,

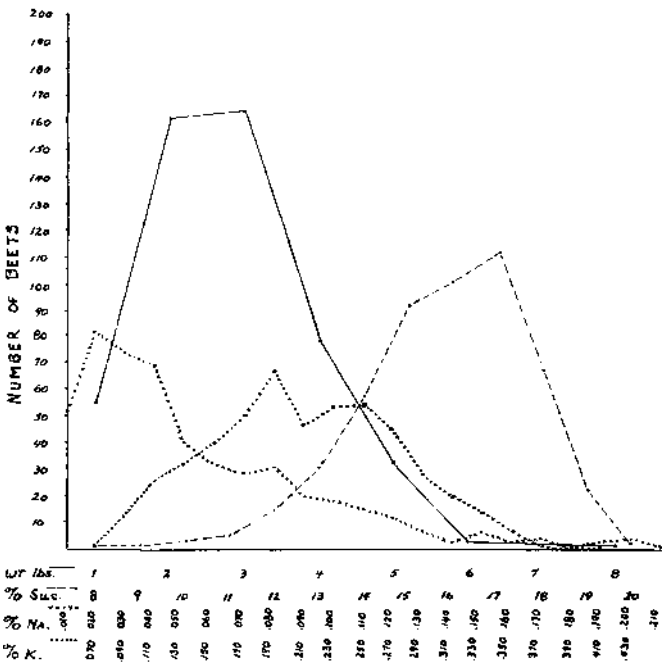

Figure 1. Frequency distributions for weight per beet, percent sucrose, percent sodium and percent potassium as determined from 500 beets of elite stock **7-40la.**

and field selections of mother beets were made of those plants most resistant to the disease. Five hundred beets were used on which weights, together with sucrose, Na and K percentage data were obtained. Frequency distributions were set up for all four characters, as shown in Figure 1.

The frequency distributions obtained indicate that there were sizable differences between beets of this variety for percent Na and percent K. In Na, the range is from .010 to .210 percent; and in K the range is from .070 to .430 percent. As a result of these tests two groupings, each of 25 beets, were made for seed production as follows:

	Average Weight, lbs.	% Sucrose	% Na	% K
Poorest	2.60	13.2	.107	.274
Best	3.88	17.8	.015	.140

A test of the progenies will be made to determine in 1950 what improvement can be made by the mass selection method of breeding.

Association of Na and K with Yield and Sucrose

In the improvement of sugar beet varieties it is important to know the degree of association between those characters being studied. Accordingly, correlation coefficients were calculated using yield, percent sucrose, percent Na and percent K in all possible pair combinations. Three sets of data were used: (a) 8-variety plot test (Table 2) analyzed by the co-variance method, (b) 500 beets of Elite Stock 7-401 a selected at Rocky Ford and (c) 52 beets of American 5 selected at Clarksburg, California. Values of "r" with significance levels are given in Table 6.

Table 6.—Correlation coefficients (r) showing the relationship of weight, and of sucrose, Na and K in all possible pairs, as calculated from an 8 variety test, and individual roots of two varieties.

	Rocky Ford		Clarksburg
	S-variety Test	7-401 a (500 Beets)	Amer. 5 (52 Beets)
Weight x Percent Sucrose	—.194	—.2596	—.2664
Weight x Percent Sodium	+ .140	+ .3160	+ .2855
Weight, x Percent Potassium	+ .674	+ .4457	+ .1532
Percent Suciose x Percent Sodium	—.731	—.7379	—.4296
Percent Sucrose x Percent Potassium	—.567	—.5312	+ .0226
Percent Sodium x Percent Potassium	+ .337	+ .4662	+ .1492
Significance level (19:1 odds)	.666	.088	.275

High yield and high Na and K content were positively associated in these tests. Sucrose percent was negatively associated with Na and K content. There was also a positive association of Na and K beyond the significant level in the data from 500 beets of the 7-401 a variety.

Summary

Preliminary to work on breeding for higher purity sugar beet varieties was a study of the technique necessary for accurate determination of sodium and potassium in beet samples by the spectrophotometer method. After a standard technique had been set up, pulp samples from varieties in one strip test and one 8 x 8 variety plot test were analyzed for sodium and potassium at Rocky Ford, Colo. One variety in pulp samples of field test in replicated plots in five areas was tested to determine area differences. Three varieties were tested in each of two factory areas to determine (a) variety, (b) area, and (c) variety-area differences, with respect to yield and sucrose as well as sodium and potassium.

Differences between beets of the same variety were determined on two varieties for yield, sucrose, sodium and potassium, and the relationships as measured by correlation coefficients determined for these distributions. An 8 x 8 variety plot test was given similar study. The results obtained indicate that major differences between varieties exist for sodium and potassium content as well as for yield and sucrose, and likewise, major differences exist in these characters between areas. Varieties performed similarly in different areas. It was also observed that domestic varieties generally were lower in sodium content than foreign check varieties included in the tests.

Tests of mother beets from two varieties indicated good possibilities for further improvement in sodium and potassium content because of the wide differences in amounts of these minerals found among the individual beets.

The relationships between yield and between sucrose, sodium and potassium percentages as measured by correlation coefficients indicate that sodium and potassium contents are associated to some degree with high yield, and are associated negatively with sucrose percent. Sodium and potassium percentages were associated positively in these tests.

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