Some Agronomic Factors Affecting Processing Quality of Sugarbeets[1]

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The recovery of sucrose from the beet depends not only on the sucrose but also on the non-sucrose impurities that interfere with its extraction, thus both must be known to estimate recovery. By 1962 a relatively simple, rapid, and reliable laboratory method had been devised to obtain juice which simulated factory thin juice. Thus, the effect of variety and cultural practices on juice quality could be evaluated in detail.

Powers, *et al.* (6)[3] reported that sugarbeet varieties differed in their content of chemical constituents and in their response to nitrogen (N) fertilization. These differences were genetically controlled. Also, certain constituents (e.g. betaine) in a given variety varied markedly from year to year. Thus, the environmental influence on quality can be very pronounced.

Quality of sugarbeets has been investigated at the Michigan Sugarbeet Research Laboratory, Saginaw, Michigan since 1963. A cooperative effort of personnel (involving growers, processors, and research personnel in Michigan, Ohio, and Ontario, Canada (amassed a large volume of data between 1964 and 1966. The more significant findings are presented herein.

Methods and Materials

Samples were harvested between September 20 and November 20 each year, approximately spanning the commercial harvest. Most samples comprised 10 uniformly topped beets. They were washed and allowed to drain before rasping. Beets from Michigan and Ohio were rasped through the longitudinal center approximately perpendicular to the grooves from which the lateral roots protrude. The Ontario beets were rasped using a multiple-bladed saw.

A sample of juice was obtained by squeezing the brei sample through muslin (4) and the following analyses were made: Percent sucrose in beet (4), clarified juice purity (CJP) (4), alpha-amino N (3), potassium (K) and sodium (flame photometry using clarified juice), betaine (3), and chloride (1).

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[3] Numbers in parentheses refer to literature cited.

"Apparent Total Impurities", the complementary value of apparent CJP, was used because it better reflects the magnitude of changes in juice quality. The individual and total impurities were expressed as mg per 100 g of apparent sucrose (pol not corrected for rotation effects of reducing sugars and raffinose). The mg of elemental N obtained in the alpha-amino N analysis was multiplied by the factor 9.5 to approximate closely the mg of impurities designated as amino acids.

The milli-equivalents (meq) of K plus sodium divided by the meq of amino-N gives a ratio which is helpful in estimating the alkalinity factor of the juice (3). In Michigan, Ohio, and Ontario, the quantity of sodium naturally present in the clarified juice is so small that it usually is not reported as a separate entity, but it was included in the calculation of the alkalinity factor.

Data and Discussion

Varietal versus environmental influence on quality

A 26-variety screening test was grown in 1965 at East Lansing, Michigan. An eight-variety agronomic test was grown in 1965 on the Miller Farm, Marlette, Michigan. Data from these two tests (Table 1) are compared with the environmental influence on a single variety (SL129 x 133) ms x SP5822-0, grown in 1965 at seven locations in Michigan and Ohio. The environmental influence across many locations exceeded the varietal influence found in typical variety tests. Hogaboam[4] examined environmental or location variability versus varietal variability associated with clarified juice purity of 8 x 8 variety tests in Michigan and Ohio. Locations usually contributed much more variability than did varieties.

Although the smaller variety tests, e.g. the agronomic test in Table 1, generally have less variation between varieties, statistically significant differences for sucrose, total impurities, amino acids, K, and betaine are not uncommon.

Expressing the individual impurities as a percentage of the total impurities (lower part of Table 1) has very limited usefulness because the percentages are similar, yet total impurities and the values for the individual impurities varied about threefold.

Effect of cultural practices on quality

Nitrogen effect: Some of the effects of N fertiliation on yield and quality have been previously summarized (7). More detailed data for these experiments follow. When N applied per acre was increased from 30 to 150 lb, sucrose decreased 1.4 (16.1

[4] Hogaboam, G. J. "Environmental versus varietal variability associated with clear juice purity" presented orally at 14th General Meeting of American Society of Sugar Beet Technologists, Minneapolis, Minn. 1966.

to 14.7%) and CJP 1.6 (94.6 to 93.0%). Total impurities in the clarified juice increased 32% (5,708 to 7,527 mg per 100 g sucrose); amino acids increased 55% (1,805 to 2,807 mg), K 11% (1,003 to 1,152 mg), sodium 67% (92 to 154 mg), and betaine about 6% (betaine concentration averaged 1,060 mg per 100 g sucrose).

Table 1.—Comparison of varietal versus environmental influence on quality of sugarbeets grown in the Great Lakes Region, in 1965. Impurities expressed as mg/100 g apparent sucrose.

Constituent	Varietal influence				Environmental influence[3]	
	Agronomic test[1]		Screening test[2]			
	Range	Range in %	Range	Range in %	Range	Range in %
Apparent sucrose percent on beet	13.1-14.2	8.4	12.0-15.5	29.2	12.1-16.0	32.2
Appar. total impur. mg	6,131-8,313	35.6	3,812-6,769	77.6	4,342-11,893	173.9
Amino Acids, mg	2,026-2,774	36.9	1,360-2,702	98.7	1,282-4,011	212.9
Potassium, mg	1,133-1,550	36.8	676-1,360	101.2	830-1,707	105.7
Betaine, mg	902-1,150	27.5	639-896	40.2	----	----
Meq ratio	1.79-2.45	----	1.38-3.98	----	1.57-2.44	----
Amino Acids as % total impur.	29.0-36.1	----	25.4-41.7	----	27.9-40.6	----
Potassium as % total impur.	16.8-19.0	----	14.4-23.2	----	12.4-20.4	----
Betaine as % total impur.	13.6-14.9	----	11.8-17.4	----	----	----

[1] Averages of 8 replications per variety.
[2] Averages of 6 replications per variety.
[3] Based on a single variety at seven locations, with 5-8 replications per location.

In experiments with three or four replications involving rates of applied N at 30 lb intervals, average values for apparent total impurities, as well as the individual impurities, for the successive increments of N did not align consistently in relation to the rate of N applied (see Table 2). When increments of applied N differed by at least 50 lb, the data aligned in a consistent manner.

Nitrogen-location effect: In 1964 two experiments within 15 miles of each other in the Bay City, Michigan area illustrated some of the more subtle differences in quality affecting the processing of beets. Yields on the Appold Farm ranged between 20.3 and 23.1 and on the Walraven Farm between 24.9 and 25.8 tons per acre. The comparative data (averages of three replications) in Table 2 reveal the following: 1) Beets which received 30 lb of applied N had the same quantity of impurities in the clarified juice, but average sucrose differed by 0.9. 2) Clarified juices having essentially the same quantity of impurities may have very large differences in individual constituents, e.g. those from the Appold Farm had about half the amino acids as those from the Walraven Farm. 3) Potassium was approximately the same in both experiments. 4) Betaine was much lower in the clarified juice of beets from the Appold Farm. 5) The meq ratios of the clarified juice from the Appold beets indicate that they would process better than the Walraven beets (3).

Table 2.—Comparison of sugarbeet quality at two locations near Bay City, Michigan in 1964.

Applied N lb/A	Apparent sucrose %	Total impurities mg/100 S	Amino acids mg/100 S	Potassium mg/100 S	Betaine mg/100 S	$\frac{K + Na}{NH_2—N}$ meq ratio
Appold Farm						
30	16.3	5,717	1,041	900	883	3.3
60	16.2	6,561	1,436	1,023	873	2.8
90	15.8	6,907	1,495	1,125	889	3.1
120	15.2	7,289	1,435	1,159	1,076	3.3
150	15.1	6,997	2,214	1,029	858	2.0
190	14.1	8,734	2,472	1,350	1,105	2.3
Walraven Farm						
30	17.2	5,737	2,150	873	1,487	1.5
60	16.7	6,565	2,518	935	1,362	1.3
90	16.5	7,875	3,326	1,041	1,504	1.1
120	16.7	7,735	2,894	1,016	1,699	1.3
150	15.6	9,880	4,624	1,230	1,737	1.0
190	15.7	9,356	4,100	1,106	1,800	1.0
230	14.6	11,375	5,375	1,312	2,014	0.9

Nitrogen-plant spacing effect: (1964 experiment by Canada Department of Agriculture and Canada and Dominion Sugar Co., Ltd. personnel at Woodslee, Ontario), The experiment, planted in April, consisted of four replications of plants spaced at 4, 8, 12, and 16 in. intervals in 24-in. rows with rates of applied N of 0, 80, 160, and 240 lb per acre. Since the chemical-constituent values for the 8, 12, and 16 in. spacings tended to be very similar, only values for the 4 and 16 in. spacings are given. Values for the chemical constituents were very similar for 0 and 80 lb per acre of applied N and were averaged together. Those for 160 and 240 lb of N were similar and also were averaged.

Wide spacing in the row reduces quality, but higher rates of applied N are much more detrimental (Table 3). Thus, reducing the spacing between plants in the row cannot overcome the adverse effects of high N on quality. With low N (0-80 lb applied), increasing the spacing between plants in the row from 4 to 16 in. increased the total impurities 19%; but with high N (160-240 lb), the increase in spacing increased total impurities 27%. At the 4 in. spacing, increasing the N increased the total impurities 47% and at the 16 in. spacing 57%.

Table 3.—Effect of nitrogen fertilization and spacing in the row on sugarbeet quality at Woodslee, Ontario in 1964. Impurities expressed as mg/100 g apparent sucrose.

Lb N per acre	Plant spac. in.	Apparent sucrose %	Total impur. mg	Amino acids mg	Potassium mg	Betaine mg	K + Na / Amino—N meq ratio
0-80	4	20.0	3,950	753	759	1,280	3.6
	16	19.3	4,712	902	969	1,373	4.0
160-240	4	19.2	5,820	1,559	902	1,575	2.1
	16	18.2	7,411	2,192	1,195	1,694	2.2

Row width-plant spacing effect: 1964 experiment, details of design reported in (2). Data for the widest and narrowest row and plant spacings are given in Table 4. Increasing the row width from 12 to 30 in. increased total impurities 25%, whereas increasing the spacing in the row from 6 to 12 in. increased impurities only 7%.

Table 4.—Effect of row width and spacing in the row on sugarbeet quality at Woodslee, Ontario in 1964. Impurities expressed as mg/100 g apparent sucrose.

Row width in.	Apparent sucrose %	Total impur. mg	Amino acids mg	Potassium mg	Betaine mg	K + Na / Amino—N meq ratio
12	15.4	9,769	3,503	1,585	1,816	1.8
30	14.2	12,233	3,759	2,139	1,964	2.2
Plant spac. in.						
6	15.1	10,742	3,579	1,745	———	1.9
12	14.3	11,483	3,619	1,960	———	2.2

Nitrogen-row width-plant spacing effects: 1965 experiment, details of design, yield, sucrose, and CJP were reported previously (2). The additional quality data were used for regression analyses. The three spacings of plants within the row had very little effect on total impurities, therefore the in-row data were combined to determine the effect of row width. The effects of row width and N fertilization on total impurities, amino acids, and K are graphed in Figures 1, 2, and 3, respectively. Other calculations indicate that one additional inch of row-width contributed about the same amount of total impurities as applying 5 lb of N per acre. One additional inch of row-width increased the amino acids about the same amount as applying 4 lb of N per acre. Potassium in the clarified juice increased nearly 2% for each additional inch of row-width.

Analysis for betaine were obtained on only 119 of the 144 beet samples. For each row-width, the betaine values were an average of 27 to 32 samples (36 samples for complete data). The approximate betaine values were 765 mg per 100 g sucrose for the 12-in. and 935 mg for the 30-in. row-width. When the spacing-within-the-row and the rate-of-nitrogen-applied data were averaged together, betaine increased about 1% for each additional inch of row-width.

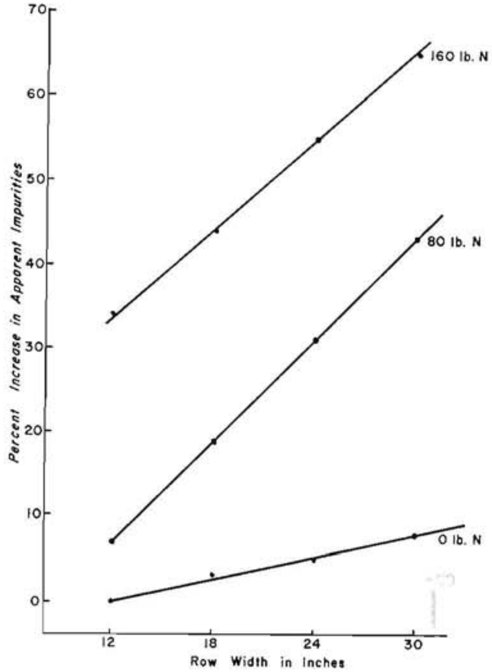

Figure 1.—Effect of row width and nitrogen applied per acre on total impurities in clarified juice of sugarbeets grown at Woodslee, Ontario in 1965.

In the quest for high quality beets, the concept of prorating the N applied per acre according to the growing period should be valuable. In the Great Lakes region, the planting of sugarbeets may vary as much as a month because of wet conditions. Data from 20 rate-of-nitrogen fertilization experiments in Michigan indicate that applied N should be reduced 5 to 10 lb for each week that is lost from the growing season. In the Thumb area of Michigan, 27 weeks is about the maximum length of the growing season. With a late planting and harvest begun two weeks early, the growing period may not exceed 22 weeks.

The data indicate clearly that reducing the width of row and spacing between plants in the row is no panacea for controlling beet juice quality, but these must be coordinated with proper N fertilization.

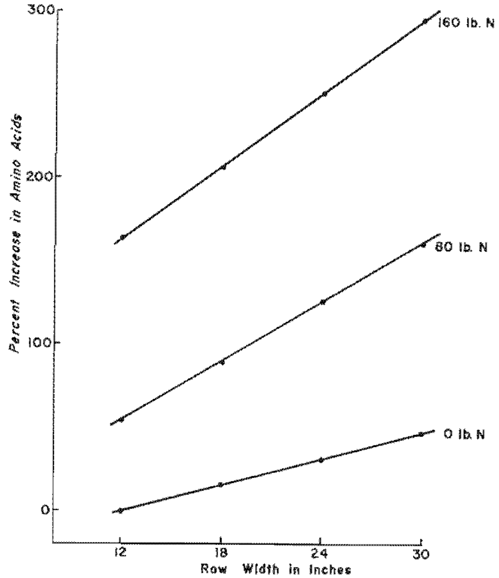

Figure 2.—Effect of row width and nitrogen applied per acre on amino acids in clarified juice of sugarbeets grown at Woodslee, Ontario in 1965.

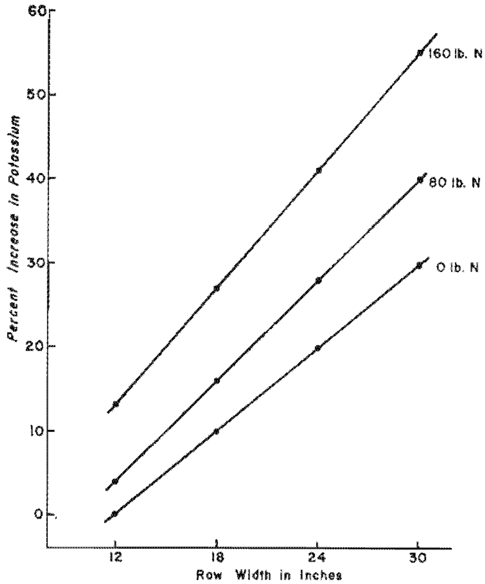

Figure 3.—Effect of row width and nitrogen applied per acre on potassium in clarified juice of sugarbeets grown at Woodslee, Ontario in 1965.

Potassium and complementary anion effect: In all experiments involving a given uniform application of K to the soil, the K in the clarified beet juice always increased as the rates of N applied to the soil increased (See Figure 3).

A 1965 experiment on the effect of K, with the experimental design and yield, was reported previously as location 1 (5). The loam soil (ammonium acetate extractable soil test, 240 lb K per acre) received either 83 or 166 lb of applied K per acre. The higher rate of applied K increased the K in the clarified juice by 2.7%.

In 1965 at location 1 (5), about 9% less K was found in the clarified juice from beets fertilized with K_2SO_4 than in juice from beets fertilized with KCl. At location 2, previously published as Table 3 (5), clarified juice from beets fertilized with K_2SO_4 had a statistically significant reduction (25%) of K as compared with beets fertilized with KCl. Thus, the anion of the K-carriers appears to influence the uptake of K.

Environmental influence on betaine: In 1964, 177 analyses for betaine from seven experiments in Michigan and Ontario, Canada averaged 1,591 mg per 100 g of sucrose. In 1965, 850 analyses from 23 experiments in Michigan, Ohio, and Ontario averaged 818 mg, ranging from a low average of 634 in one experiment in Michigan to a high average of 1,203 mg in one in Ohio. Thus, the environmental effect between years, as well as within a given year, significantly alters the quantity of betaine. In 1964 betaine ranged from 13.5 to 27.8% of the total impurities in the clarified juice, and in 1965 from 11.2 to 18.0%.

Chloride and sodium in clarified juice: Chlorides ranged between 3.4 and 4.8% of the total impurities (See Table 2) and between 3.7 and 6.5%, while sodium ranged between 1.1 and 2.3% and between 0.4 and 0.7% for the Appold and Walraven experiments, respectively. Similar percentages for sodium were obtained for the Woodslee, Ontario experiments in 1964.

The higher concentration of chloride compared to sodium in the clarified juice probably is the result of applying K as KCl. In recent years no sodium has been applied to soil on which beets are grown in Michigan.

Correlations

Correlation data were used to determine the consistency of certain relationships under differing environmental conditions in the same year and in different years. Correlation coefficients (r) were calculated for each location or experiment, for each year's data, and for the combined data for 1964, 1965, and 1966.

The associations among the chemical constituents in the clarified juice of these beets varied considerably (Tables 5 and 6). For example, the percentage of sucrose in the beet did not correlate well with any of the major quality indices of clarified juice, such as CJP or total impurities, amino acids, K, or betaine. Since CJP and total impurities are complementary, they have the same correlation coefficient, but with opposite sign. Although the percentage sucrose in the beet did not relate closely with total impurities, it usually tended to increase a total impurities decreased. Particularly for sucrose in the beet, the r-values may vary rather widely from year to year. Betaine did not correlate well with total impurities or any other chemical constituent analyzed.

Table 5.—Correlation coefficients for apparent sucrose in beet and some of the chemical constituents in clarified sugarbeet juice. Data for 1964, 1965, and 1966.

	Year	Total impur.	Amino acids	Potassium	Amino + K + Na	Betaine
Sucrose in beet	64-66	—0.40	—0.47	—0.55	—0.54	——
	1964	—0.69	—0.65	—0.60	—0.70	—0.34
	1965	—0.47	—0.51	—0.56	—0.58	—0.11
	1966	—0.31	—0.28	—0.32	—0.33	——
Total impur.	64-66		0.89	0.74	0.92	——
	1964		0.86	0.76	0.90	—0.50
	1965		0.90	0.76	0.92	—0.25
	1966		0.93	0.77	0.96	——
Amino acids	64-66			0.66	0.98	——
	1964			0.65	0.97	0.61
	1965			0.66	0.98	0.37
	1966			0.62	0.99	——
Potassium	64-66				0.79	——
	1964				0.81	0.44
	1965				0.78	0.19
	1966				0.74	——

1964—518 samples, except 177 for betaine. All significant at 1% level.
1965—2,030 samples, except 850 for betaine. All significant at 1% level.
1966—751 samples. All significant at 1% level.
1946-66—3,274 samples. All significant at 1% level.

Potassium has been suggested as a possible index of quality. Potassium in the clarified juice did not correlate very highly with total impurities or any of the constituents analyzed in these studies. The association of K with total impurities was lower than amino acids with total impurities.

The negative correlation between K in the clarified juice and sucrose in the beet was very similar to that for amino acids in the clarified juice and sucrose in the beet. This suggests that K and amino acids are equally detrimental to quality and that excesses of both K and N fertilization should be avoided. Powers *et al.* (6) obtained a similar association between sucrose in the beet and K only for beets fertilized with 200 lb per acre of N.

The correlation coefficients by locations (Table 6) indicate that the association between the chemical constituents for any

Table 6.—Extremes in correlation coefficients by locations for apparent sucrose in the beet and some chemical constituents in clarified sugarbeet juice. Data for 1964, 1965, and 1966*.

	Locat.	Total impurities			Amino acids			Potassium			Amino acids + K + Na		
		1964	1965	1966	1964	1965	1966	1964	1965	1966	1964	1965	1966
Sucrose in beet	All	—0.69	—0.47	—0.31	—0.65	—0.51	—0.28	—0.60	—0.56	—0.32	—0.70	—0.58	—0.33
	High	—0.93	—0.86	—0.69	—0.89	—0.77	—0.54	—0.88	—0.87	—0.86	—0.91	—0.88	—0.72
				+0.61			+0.36						
	Low	0.07	—0.01	—0.05	0.01	0.03	—0.09	—0.20	—0.02	—0.15	—0.28	—0.06	—0.002
Total impurities	All				0.86	0.90	0.93	0.76	0.76	0.77	0.90	0.92	0.96
	High				0.95	0.94	0.95	0.85	0.95	0.86	0.97	0.95	0.96
	Low				0.14	0.53	0.55	0.06	0.26	—0.06	0.16	0.66	0.45
Amino acids	All							0.65	0.66	0.62	0.97	0.98	0.99
	High							0.79	0.90	0.66	0.996	0.995	0.99
	Low							—0.003	0.15	0.10	0.85	0.31	0.90
Potassium	All										0.81	0.78	0.74
	High										0.86	0.94	0.81
	Low										0.19	0.31	0.28

* 21 location in 1964, 36 in 1965 and 12 in 1966.

given location can not be predicted with any degree of certainty. This situation may occur even when the r-value for all the samples may exceed 0.9 as shown for the association of total impurities versus amino acids for 1966. One location had an r-value as low as 0.55. The highest degree of association of sucrose in the beet and clarified-juice impurities for one location was +0.61 and for another location −0.69. Thus at the first location, sucrose in the beet increased as the impurities increased; but sucrose decreased as the impurities increased at the other. These data suggest caution in using correlation data for predicting the degree of association of chemical constituents in clarified juice of beets from any given experimental location or farm.

Summary

More than 3,200 samples of freshly harvested sugarbeets, grown in 69 experiments in the Great Lakes region, were analyzed for percent sucrose, clarified juice purity, alpha-amino nitrogen, potassium, and sodium. A smaller number of samples were analyzed for betaine.

The environment in which the beets grew altered the clarified juice quality more than the genetic differences of varieties grown at one location. Plant spacings of 12 in. or less in the row had relatively little effect on juice quality. Altering row width had a greater effect on juice quality. One inch of row-width contributed about the same amount of total impurities as applying 5 lb of nitrogen per acre. Potassium in the clarified juice increased nearly 2% for each additional inch of row-width. Manipulation of in-the-row spacing of plants and row-width cannot overcome the adverse effects of higher rates of applied nitrogen. Environment from location to location and year to year altered the betaine content of the juice by two-fold.

Potassium in the clarified juice did not correlate very highly with total impurities, therefore it would not be suitable as a possible index of quality. The percentage of sucrose in the beet did not correlate well with any of the major quality indices of clarified juice and the association for any particular location or experiment was unpredictable. Betaine did not correlate well with total impurities or any other chemical constituent analyzed.

Acknowledgments

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