# Improvement of Processing Quality of Sugar Beets By Breeding Methods

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## Introduction

It will be fairly obvious that, from a processing viewpoint, the production of varieties of sugar beets having in their makeup a minimum of melassogenic substances would be a highly desirable and very profitable research undertaking. While the title under which this is written is very general, the writers will discuss only such data as is accumulated by their investigations on the subject, employing new techniques and instruments recently developed.

The earliest application of chemical tests, other than sugar and purity by the Great Western Sugar Company to the selection of individual beets for development of improved varieties was made in 1932. From a group of roots of good size, shape and sugar content, individuals were selected which in chemical test by the slow classical methods showed low ash and chloride content, and high percentage calcium and magnesium on ash. In 1934, roots of various varieties including progeny from the 1932 selections were tested for ash content by an electrical conductivity method, and for harmful nitrogen by a colorimetric method, and selections of individuals were made. From these selections developed what were called "Chemical Varieties." These varieties were of high sugar content and very high purity, but yield per acre fell off disappointingly, probably because of too close inbreeding resulting from the vary narrow base for selection.

With the development of new tools, suitable for mass operations in chemical analyses, chemical tests have come to the front as a basis for selections. To date chemical tests adaptable to volume operations have been developed for the determination of sodium, potassium, calcium, magnesium and raffinose.

## Sodium

The method used for sodium determination utilizes the same lead clarified filtrate which is prepared for sugar test. A small volume of the filtrate is treated with a standard quantity of lithium nitrate solution and the solution is tested for sodium in a Perkin-Elmer flame photometer. Operations have been coordinated, and mechanical measuring devices, for solutions, developed to a degree permitting the testing of more than 600 individual roots per eight-hour day.

Prior to recent selection work, tests were made on a number of varieties grown in replicated plots in 1948 on a single test field. Wide variations in sodium content between varieties were demonstrated. Table 1 shows some representative results.

While within a given variety excellent negative correlations ($r = -.7$ to $-.9$) between sugar and sodium contents have been observed, when the foreign and domestic varieties are compared, higher sodium contents at given sugar contents are observed.

Large scale analyses for sodium content were first made in 1948; selections were made on the basis of sugar and sodium contents and the

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**Table 1.—Sugar, Apparent Purity and Sodium Content of Six Varieties of Sugar Beets, Fort Morgan, Colorado, 1948.**

| Accession Number | Sugar Percent | Apparent Purity | Sodium Percent |
|---|---|---|---|
| R & G "N" | 16.70 | 90.4 | 0.051 |
| Maribo | 15.79 | 90.2 | 0.072 |
| Hilleshog | 15.60 | 90.2 | 0.065 |
| GW 201 | 17.12 | 91.7 | 0.023 |
| C 305 | 16.28 | 91.2 | 0.028 |
| B 359 | 17.18 | 90.7 | 0.029 |

roots grouped as given in Table 2, due consideration having first been given such characters as weight, shape, etc. One thousand roots of Variety GW304 were analyzed for sugar; low sugar roots were screened from sodium determination as an economy of time.

**Table 2.—Averages of Roots in Breeding Groups of Sodium Selection.**

| Accession Number | No. Roots | Weight Pounds | Sugar Percent | Sodium Percent | Sugar/sodium Ratio |
|---|---|---|---|---|---|
| B474 | **82** | 2.87 | 13.67 | 0.049 | 279 |
| B475 | **93** | 2.94 | 13.82 | **0.145** | 126 |
| B476 | **54** | 2.50 | 15.97 | 0.045 | 355 |
| B477 | **61** | 3.10 | 10.92 | **0.216** | **51** |

Tests of progeny of these selections were made in three different locations during the 1950 and 1951 growing seasons. For brevity these are given in Table 3 as the average of results obtained at the three locations.

**Table 3.—Tests of Progency of Selection on Basis of Sodium Content, 1950-51.**

| | Sugar in Roots Percent | | Sodium in Roots Percent | | Pounds Sugar per Acre | |
|---|---|---|---|---|---|---|
| | 1950 | 1951 | 1950 | 1951 | 1950 | 1951 |
| C304 | 17.68 | 17.40 | 0.033 | 0.055 | 8,652 | 8,073 |
| B474 | 18.22 | 17.65 | 0.015 | 0.024 | 8,854 | 7,987 |
| B475 | 16.70 | 18.01 | 0.023 | 0.031 | 8,233 | 8,015 |
| B476 | 18.68 | 18.21 | 0.018 | 0.021 | 8,679 | 7,920 |
| B477 | 17.82 | 17.48 | 0.030 | 0.034 | 8,857 | 8,097 |
| LSD 5% pt. | 0.32 | 0.24 | 0.002 | —[1] | 402 | 415 |

[1] Earlier tests had shown the LSD for sodium was very low, consequently not calculated here.

The results of the two seasons are not identical, but they demonstrate that definite reduction in sodium content was accomplished. Most variable are the results on B475. This variety is abnormal since it was selected to contain beets of both high sugar and high sodium content, reversing the normal relationship found in sugar beets.

In both seasons B474 and B476, selected for low sodium content, produced beets of significantly higher sugar content than the parent with no significant change in yield of sugar per acre. In view of all results, it appears that one can select beets on the basis of sodium content, for sugar content and associated improvement in working qualities, without significant loss in yield or total sugar per acre.

Beets of a given variety of the normal heterozygous type may show wide variations in absolute sodium content, but will show a high negative correlation between sugar and sodium content. Tests on a few inbred lines, which appear to be comparatively homozygous, show much less variation

in sodium content. Table 4 compares results obtained by analyses of three U.S.D.A. (Deming) inbred lines and one commercial G.W. variety.

**Table 4.—Variability of Sodium Content in Individual Beet Roots.**

| Accession Number | Type | No. roots tested | Sodium Content Mean | Maximum | Minimum |
|---|---|---|---|---|---|
| 1036 | Inbred | **10** | 0.044 | **0.051** | 0.038 |
| 1058 | Inbred | **10** | 0.088 | **0.100** | 0.070 |
| 1079 | Inbred | **10** | 0.038 | **0.060** | 0.028 |
| GW201 | Com'l. | **25** | 0.035 | **0.106** | 0.015 |

As one might expect, after several generations of inbreeding the varieties show a much reduced variability in sodium content; it would also seem a reasonable assumption that inbreeding would tend to reduce variability in other chemical characteristics as well.

## Potassium

Potassium is determined on the same sample employed for the sodium test.

Many investigators, notably those in Europe, have claimed they observe a positive correlation between potassium and the sugar content of roots. Van Ginneken (1)[2] showed an excellent correlation between the potassium content of beet leaves and the sugar content of the roots. Previous to 1950 our own investigations have shown no such correlation. Recent and somewhat extensive analysis (unpublished) indicate there may indeed be a relationship between sugar and potash but that the r value is negative. Possibly our beet growing areas are sufficiently well supplied with available potash in soils to permit luxury consumption by the beet at all times; it is known that in most areas of Europe potash must be applied.

## Raffinose

The method used for raffinose determination was presented by the senior writer at the 1951 Boston meeting of the American Chemical Society. (2) Briefly, the method consists of obtaining a small sample of press juice from the mother beet, preparation of the juice sample for test, and test of the sample by paper chromatography. The method has been developed to a point where 50 to 100 individual roots can be tested per eight-hour day.

The method provides a degree of accuracy highly satisfactory for purpose of selection. All beets in a group of 204 were tested individually, in duplicate, for raffinose content. The comparison of results of duplicate tests is given in Table 5.

**Table 5.—Comparison of Duplicate Tests of Raffinose Percent on Sugar on 204 Single Beet Roots.**

| Number of roots in group | Spread in observed percent raffinose on sugar between duplicates |
|---|---|
| **102** | zero |
| **68** | 0.1 |
| **29** | 0.2 |
| **4** | 0.3 |
| **1** | 0.4 |

These beets were very high in raffinose content, ranging from 0.65 to 1,5+ percent raffinose on sugar, with a mean of 1.33 percent. Beets con-

[2] Numbers in parentheses refer **to** literature cited.

taining less raffinose show lower absolute variations in results of duplicate tests.

A variety of factors appear to affect the raffinose content of beets. Among these are:

1. Heredity, 2. Environment during growth, and 3. Conditions of storage after harvest.

1. Ten varieties of foreign and domestic seed were grown in six replicated plots each. Raffinose was determined on all replicates. The mean percentage raffinose on sugar found in the ten different varieties at harvest time ranged from 0.29 to 0.49, and standard errors of the means ranged from 0.013 to 0.041. Another group of data gives results indicative of heredity differences in raffinose content. Fifty inbred varieties were grown at Longmont in plots of three replicates of each variety. The beets from all replicates of one variety were composited and tested for raffinose content at harvest time. The results range from a minimum of 0.15 percent (or less) to 0.68 percent raffinose on sugar.

2. It has long been observed that the raffinose content of beet factory liquors varies with conditions under which the beets are grown.

Indicative of these effects are results obtained on 12 varieties grown in replicated field trials in 1951 at three locations. The beets of each variety from all six replicates were composited for the raffinose tests. The results are given in Table 6. All results show the raffinose content at harvest time.

**Table 6.—Raffinose Content of Beets Grown in Different Locations.**

| | Percent Raffinose on sugar at harvest time | | |
|---|---|---|---|
| **ety No.** | **Longmont, Colo.** | **Fort Morgan, Colo.** | **Gering, Nebr.** |
| **1** | 0.33 | 0.28 | 0.54 |
| **2** | 0.30 | 0.33 | 0.43 |
| **3** | 0.30 | 0.40 | 0.63 |
| **4** | 0.30 | 0.28 | **0.61** |
| **5** | 0.38 | 0.28 | **0.48** |
| **6** | 0.38 | 0.33 | 0.50 |
| **7** | 0.30 | 0.33 | 0.58 |
| **8** | 0.38 | 0.28 | **0.45** |
| **9** | 0.33 | 0.35 | **0.49** |
| **10** | 0.38 | 0.30 | **0.60** |
| **11** | 0.30 | 0.33 | **0.50** |
| **12** | **0.60** | 0.45 | 0.65 |

The higher raffinose content of beets grown at Gering is shown in Table 7. Whether or not the higher raffinose content at Gering is associated with the lower sugar content is not as yet clearly defined.

**Table 7.—Mean Composition of 12 Varieties Grown at Three Locations.**

| **Location** | **Sugar Percent** | **Apparent Purity** | **Raffinose on sugar percent** |
|---|---|---|---|
| **Longmont** | **17.74** | **90.63** | 0.357 |
| **Fort Morgan** | **18.11** | **91.34** | 0.328 |
| **Gering** | **16.22** | **89.06** | **0.538** |

3. The raffinose content of beets increases during storage, and the quality of roots entering storage probably affects the rate of increase. Table 8 gives data on the rate of increase of raffinose during storage.

Table 8.—Increase in Percent Raffinose on Sugar in Beets During Storage.

| Type of Beets | Type of Storage | Number Weeks storage | Increase in percent raffinose on sugar per week |
|---|---|---|---|
| Experimental (Low purity) | Cellar at 8° C. | 7 | 0.076 |
| Experimental (High purity) | Cellar at 8° C. | 13.5 | 0.027 |
| Commercial | Commercial pile | 8 | 0.021 |

Because of the effect of storage of beets on raffinose content, all tests on beets of the 1951 season were made on beets as harvested. This was accomplishd by sampling the beets immediately after harvest and storing the rasped pulp at temperatures below 0° F. until tests could be made.

It remains to be demonstrated whether the beet which shows the minimum raffinose content at harvest time will also show minimum raffinose content after normal storage in piles, as practiced in the Rocky Mountain area.

Improvement in quality of beets following selection of individual roots for lower raffinose content awaits demonstration in the future; results of progeny tests should be available following the 1952 harvest.

## Calcium and Magnesium

Methods have been developed whereby selection of individual roots on basis of calcium and magnesium content can be made when and if the geneticist decides to take these factors into consideration. The methods employ acid extraction of beet pulp to obtain essentially all of the calcium and magnesium, determination of Ca by flame photometer and Mg by difference after determination of Ca plus Mg by versene titration.

## Summary

The application of the flame photometer to the mass determination of sodium in mother beets is discussed, data are presented showing variations in sodium content between varieties and results of progeny tests of selections on basis of sodium content.

The possible relationship of potassium to sugar content, in areas where soils are relatively rich in potash, is discussed briefly.

The method of determination of raffinose by paper chromatography is outlined and results are presented showing some effects of heredity, growth environment and storage on the raffinose content of beets. Progeny tests are not yet available.

Determination of Ca and Mg have been noted.

## Literature Cited

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