Comparative Composition of Different Parts of the Sugar Beet Root[1]

C. A. FORT[2] AND MYRON STOUT[3]

A FEW STUDIES of the composition of different parts of the sugar beet root have been reported in European literature, but there have been none on beets grown in this country. Doubtless many experiments have been made with the object of determining the optimum topping level, but there is no evidence of more comprehensive studies. The work to be presented in this report was carried out in 1943-44 and developed out of the difficulties being experienced in obtaining truly representative pulp samples from stored beets. It was observed that when rasping sugar beet roots that were even slightly withered, the composition of the pulp collected on the shield differed from that of the pulp which accumulated on the beets along the edge of the rasped segments.

The published analyses of Von Floderer and Herke (1) in 1911 and of Von Urban (2) in 1907 primarily show the composition of cross sections of the sugar beet root beginning with the crown and ending with the tail section. It is evident from their data that the sugar concentrations tend to follow the contour of the beet. That is, the sugar concentration is lowest at the crown and at the end of the root. Beginning at the crown, it increases quickly to the maximum value about where the beet reaches its maximum diameter. From there on the sugar concentration decreases very slowly as the beet tapers down to the small tap root. Von Floderer and Herke also made some longitudinal sections as subdivisions of the cross sections, but the sectioning used indicated only small differences in composition between the central and outer portions.

In the present sectioning experiments longitudinal segments were taken of sugar beet roots topped as for commercial utilization with the object of learning the composition of the different layers proceeding from the outside to the center of the beet. The work also included sectioning of the crown portions so these data are also presented.

When a trimmed but untopped beet is split in half it is observed that the separation between crown tissue and the body tissue of the beet is quite definitely accomplished by a cut just slightly below the bottom leaf scar. The crowns were removed at this point and the outside 1/8 inch pared off. The crown tissue was divided into two parts, a top part and a bottom part. The point of division roughly corresponded to the bottom green leaf. In the case of the body of the beet it too was pared by removing the outside 1/8 inch. The tail portion was then removed roughly where the diameter was 1 inch.

[1]Agricultural Chemical Research Division Contribution No. 225.

[2]Chemist, Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

[3]Physiologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Agricultural Research Administration, United States Department of Agriculture.

The main body of the beet was then sectioned lengthwise. The core or heart was removed by using a curved knife. It was about 1 inch in diameter at the top and tapered to a very thin piece at the bottom. Still using the curved knife, an additional sample was cut about $1/2$ inch thick at the top, but tapered toward the bottom, and represented the material next to the core. The remainder of the body of the beet, which still amounted to half the total beet weight, was taken as the final sample. In two of the experiments eight beets each were used and the corresponding samples composited. In the third experiment only one beet was used. All beets weighed about $2\frac{1}{2}$ pounds each and were thoroughly washed and the surfaces dried before sampling. Figure 1 shows the scheme of sectioning used and table 1 gives the composite results on the composition of the segments and the calculated compositions of the commercial beet, of the crown, and of the whole beet. All analytical results are given as percentages on beet tissue unless otherwise indicated.

Although it is recognized that similar sectioning of other beets from different fields, areas, and seasons may yield greater or smaller differences between segments, it is felt that these data indicate two general situations that are probably characteristic. First, there is the relatively low sucrose of the core portion of the beet with the sucrose increasing to its highest value in the outside 2/3 of the beet but dropping to a low value in the outer $1/8$ inch. It is certain that in sampling beets for analysis the segment cut or rasped must remove the proper proportion of all layers in the depth of the beet toward the center as well as of the entire length of the beet. Even on fresh beets careless rasping, which does not cut to the true center or cuts deeper than the center, will lead to analyses which do not correctly represent the beet composition.

When dealing with beets that have lost moisture, as in storage or even during transportation or in the windrow, there is a tendency for some segregation of material from the different layers of the beet even if the rasping is done properly. It appears that the central portion of the beet which is lower in sucrose and higher in moisture is rasped by the outer edge of the rasp and rather completely thrown against the sample shield. The outer portions of the beet are to a considerable extent rasped by the sides of the rasp. Since this part of the beet is lower in moisture and relatively higher in sugar (in spite of the outer rind portion), and is also higher in marc (due to this rind portion), it is not completely thrown to the shield but is partly rolled over onto the beet along the edges of the cut. The more withered the beet, the more pronounced is this trend. This leads to a low sucrose result if the test is made on the pulp caught by the shield. This situation is of especial importance in beet-storage studies, and it has been necessary to adopt a procedure in which the proper segment is cut out of the beet by a special knife and the combined segments of a sample disintegrated in a mill to prepare a pulp for analysis.

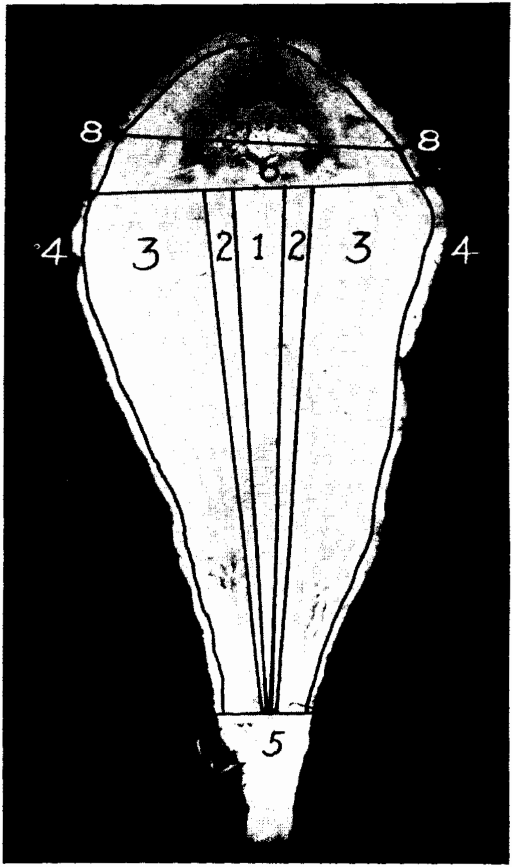

Figure 1.—Diagram of sectioning used.

Table 1. Comparative composition of different parts of a sugar beet root.

	Commercially topped beet						Crown section				Whole trimmed beet
	Core	Next core	Main body	Paring	Tail	Whole	Paring	Top tissue	Bottom tissue	Whole	
Section number	1	2	3	4	5	1-5	8	7	6	6-8	1-8
Weight, percentage part of beet	14.6	16.1	52.7	13.0	3.6	100	33.0	38.5	28.5	100	--
Weight, percentage whole root	12.7	14.0	45.9	11.3	3.1	87.0	4.3	5.0	3.7	13.0	100
Direct polarization	14.4	14.8	15.5	13.5	13.8	14.9	11.7	14.0	15.0	13.5	14.7
True sucrose,* percentage	13.7	14.2	14.9	13.0	13.4	14.3	11.1	13.3	14.4	12.9	14.1
Reducing sugars, percentage	0.12	0.12	0.13	0.28	0.13	0.15	0.24	0.16	0.14	0.18	0.15
Raffinose,* percentage	0.36	0.21	0.24	0.15	0.06	0.23	0.13	0.23	0.13	0.17	0.22
Total sugars, percentage	14.18	14.53	15.27	13.43	13.59	14.68	11.47	13.69	14.67	13.25	14.47
Total dry solids, percentage	21.3	21.7	22.2	23.5	22.0	22.1	23.8	22.4	22.6	22.9	22.2
Marc (non-diffusables), percentage	3.9	4.2	4.5	6.4	5.2	4.6	7.7	5.4	5.1	6.0	4.8
Juice dry solids, percentage	17.4	17.5	17.7	17.1	16.8	17.5	16.1	17.0	17.5	16.9	17.4
Cold diffusion juice											
Sulphated ash, percentage	1.35	1.25	0.95	1.40	1.25	1.13	1.58	1.13	1.03	1.25	1.15
Organic non-sugars	1.87	1.72	1.48	2.27	1.96	1.69	3.05	2.18	1.80	2.40	1.78
Total nitrogen X 6.25, percentage	1.20	1.15	1.04	1.78	1.44	1.19	1.73	2.03	1.28	1.72	1.26
Non-protein N X 6.25, percentage	0.36	0.34	0.39	0.91	0.59	0.45	0.81	0.87	0.49	0.74	0.49
On juice dry solids basis											
Polarization purity	82.7	84.6	87.6	78.9	82.1	85.1	72.7	82.3	85.7	79.9	84.5
True sucrose purity	78.7	81.1	84.2	76.0	79.8	81.7	68.9	78.2	82.3	76.3	81.0
Reducing sugars, percentage	0.69	0.68	0.73	1.64	0.77	0.86	1.49	0.94	0.80	1.07	0.86
Sulphated ash, percentage	7.8	7.1	5.4	8.2	7.4	6.5	9.8	6.6	5.9	7.4	6.6
Organic non-sugars, percentage	10.7	9.8	8.4	13.3	11.7	9.7	18.9	12.8	10.3	14.2	10.2

Note: All values on beet tissue basis except in bottom section of table.
*True sucrose and raffinose determined by double enzyme method.

The second characteristic to which attention will be called is the relatively high sucrose percentage of the crown portion of the beet once the crown is pared thus removing the petiole stubs, scar tissue, and rind. In the beets used in this study the petioles had been previously trimmed close to the skin, hence the very low test of the crown parings still is not low as it would be if longer petiole stubs had been present. In both the crown and the body of the beet the highest concentrations of reducing sugars and of organic non-sugars and minerals occur in the parings.

The variation that may occur between experiments on sectioning beets (including comparisons of crowns and commercial beets) is well demonstrated in the case of two of the experiments of this study which compared beets from high- and low-fertility levels in the same test field and using the same variety. The difference in fertility level was due to the fact that the one plot was not manured while the other received an especially heavy application of chicken manure. The comparison of results is given in table 2. Eight beets of similar size (about $2\frac{1}{2}$ pounds each) were used in each experiment.

This comparison of high- and low-fertility beets indicates that the contrasts between different segments are much greater in the low-fertility, high-sucrose beet. In the first place the proportional amount of crown tissue was smaller for the low-fertility beet even as the leaf growth probably was less. It should be recalled that the beets were topped, after they were split, near the line separating the crown tissue from the remainder of the root. This seemed to correspond to low field topping. The sucrose in the commercial beet from the high-fertility plot was numerically higher than that of the total crown by only 0.9 percent and the purity difference was 4.1. In the low-fertility beet the differences were 3.5 percent for sucrose and 10.5 in purity. This was true in spite of the fact that the crown of the low-fertility beet was of fair quality. Thus, from the viewpoint of untopped whole beets, the inclusion of the crown is not too serious in the low-sucrose, high-fertility beets, although it dropped the sucrose reading 0.2 percent and the juice purity 0.9 percent below the readings for the commercial beet. For the low-fertility beet the respective differences were 0.4 percent sucrose and 1.1 percent in purity. The low-fertility beet represents the usual field condition and the high-fertility level used here is an unusual situation.

The comparative values for non-sugars are not as was expected because the low-fertility beets show approximately as high mineral and organic non-sugar concentrations as the high-fertility beets. On the solids basis, due to the greater storage of sugars in the low-fertility beets, the non-sugar percentages are lowest in the low-fertility beets. The total nitrogen concentration is the same at both fertility levels in the commercial or the whole beets, but the crowns of the low-fertility beets were higher in nitrogen than the crowns of the high-fertility beet. The reverse was true for the body of the beets.

Table 2.—Comparative composition of sectioned beets from high- and low-fertility plots.

	Beets from high-fertility plots					Beets from low-fertility plots				
	(W) Whole trimmed beet	(C) Crown section	(T) Topped beet	Numerical differences		(W) Whole trimmed beet	(C) Crown section	(T) Topped beet	Numerical differences	
				T-W	T-C				T-W	T-C
Weight, percentage of whole root	100	15.2	84.8	--	--	100	11.2	88.8	--	--
Pulp analysis										
Total dry solids, percentage	18.6	19.3	18.4	—0.2	—0.9	25.3	25.7	25.1	—0.2	—0.6
Water, percentage	82.4	80.7	81.6	+0.2	+0.9	74.7	74.3	74.9	+0.2	+0.6
Marc (non-diffusable), percentage	4.0	5.0	3.7	—0.3	—1.3	4.7	6.6	4.3	—0.4	—2.3
Diffusion juice (cold)										
Dry solids, percentage beet	14.6	14.3	14.7	+0.1	+0.4	20.6	19.1	20.8	+0.2	+1.7
Direct polarization	12.3	11.4	12.5	+0.1	+1.1	18.1	15.1	18.5	+0.4	+3.4
True sucrose, percentage beet	11.6	10.9	11.8	+0.2	+0.9	17.8	14.7	18.2	+0.4	+3.5
Reducing sugars, percentage beet	0.09	0.12	0.08	—0.01	—0.04	0.17	0.21	0.16	—0.01	—0.05
Sulphated ash, percentage beet	1.20	1.29	1.18	—0.02	—0.11	1.01	1.30	0.97	—0.04	—0.33
Organic non-sugars, percentage beet	1.43	1.76	1.35	—0.08	—0.41	1.48	2.75	1.32	—0.16	—1.43
Total nitrogen X 6.25 percentage beet	0.88	1.25	0.81	—0.07	—0.44	0.88	1.51	0.80	—0.08	—0.71
Non-protein N X 6.25, percentage beet	0.52	0.74	0.48	—0.04	—0.26	0.59	0.99	0.54	—0.05	—0.45
On dry solids basis										
Purity (true sucrose)	79.4	76.2	80.3	+0.9	+4.1	86.4	77.0	87.5	+1.1	+10.5
Reducing sugars, percentage solids	0.62	0.84	0.54	—0.08	—0.30	0.78	1.10	0.77	—0.01	— 0.33
Sulphated ash, percentage solids	8.22	9.0	8.0	—0.2	—1.0	4.90	6.8	4.7	—0.2	— 2.1
Organic non-sugars, percentage solids	9.8	12.3	9.2	—0.6	—3.1	7.2	14.4	6.3	—0.9	— 8.1

Note: The difference in fertility level consisted of an extra heavy application of chicken manure as contrasted with no manure. The tonnage of topped beets compared as 22 tons to 16 tons per acre, respectively. By calculation the untopped beet tonnages would have been 26 tons and 18 tons, respectively.

In the experiments discussed above analyses of the ash constituents were not made, but in an earlier experiment they were. These supplemental tests are given in table 3.

Table 3.—Distribution of non-sugars in a sugar beet root.

			Commercially topped beet		
	Crown	Core	Next core	Main body	Paring
Weight distribution, percentage	11.4	22.7	31.8	22.7	11.4
Total dry solids, percentage	23.41	20.63	21.12	22.83	23.20
Diffusion juice dry solids, percentage	17.14	16.33	16.90	17.05	15.81
Marc (non-diffusable dry solids) percentage	6.27	4.30	4.22	5.78	7.39
True sucrose, percentage	12.8	12.2	13.9	14.6	11.7
True juice purity, percentage	74.9	74.9	82.2	85.4	74.1
Carbonate ash, total in pulp, percentage	1.17	1.23	1.12	0.90	1.48
Carbonate ash, diffusable, percentage	0.90	1.06	0.97	0.65	1.06
Carbonate ash, non-diffusable, percentage	0.27	0.17	0.15	0.25	0.42
Sulphated ash, total in pulp, percentage	1.51	1.57	1.49	1.19	1.97
Sulphated ash, diffusable, percentage	1.12	1.48	1.33	0.85	1.44
Sulphated ash, non-diffusable, percentage	0.39	0.09	0.16	0.34	0.53
Silica (SiO_2) in pulp, percentage	0.009	0.003	0.005	0.022	0.081
Silica, diffusable, percentage	0.006	0.000	0.000	0.008	0.007
Silica, non-diffusable, percentage	0.003	0.003	0.005	0.014	0.074
Chloride, diffusable, (Cl), percentage	0.161	0.205	0.171	0.100	0.019
Sulphate, diffusable, (SO_3), percentage	0.032	0.029	0.042	0.020	0.037
Phosphate, diffusable, (P_2O_5), percentage	0.061	0.076	0.067	0.045	0.100
Organic acid radical,* percentage	0.434	0.626	0.486	0.384	0.748
Organic non-sugars, diffusable, percentage	2.64	2.18	2.20	2.12	2.96
Total nitrogen X 6.25, pulp, percentage	2.81	2.12	2.51	2.28	3.24
Nonprotein N X 6.25, diffusable, percentage	1.01	1.33	1.38	1.04	1.26
Amino nitrogen X 10.5,** percentage	0.34	0.75	0.77	0.51	0.56
pH of normal diffusate	6.8	6.4	6.6	6.8	6.8

Note: All data given as percentage on beet tissue unless otherwise indicated. The diffusions were made at room temperature.

*Organic acids calculated from true ash alkalinity and an assumed combining weight of 80 for the acid.

**Amino nitrogen determined by colorimetric copper nitrate method and expressed as glutamic acid.

In the main, the ash constituents follow the trends shown by the total ash. The chloride content was determined direct on juice but sulphate and phosphate were determined on the carbonate ashes. The organic acid radical is a calculated value based on true ash alkalinities. In general, it is highest where the mineral acid radicals are lowest in concentration. The differences between the total ash in pulp and the diffusable ash shows that a fair proportion of total ash is not diffusable. This material is not primarily silica, as might be supposed, because the silica determined is a very small part of the total non-diffusable ash with the exception of the paring where the silica does account for 19 percent of the insoluble ash. This value possibly indicates the slight contamination with soil that still remained after washing the beets.

Total nitrogen was greatest in the crown and paring but non-protein nitrogen (the part not coagulable by acetic acid and boiling) was highest in the central portions of the body of the beet. In other words, a much larger proportion of the nitrogen in the crown and paring was protein. The amino acid content, as indicated by the colorimetric copper nitrate method, was in agreement with the trends shown by concentrations of non-protein nitrogen.

A final observation can be made concerning the reducing sugar content in beets, namely that there is a possibility that storage, where spoilage is not a factor, increases the content of these sugars in the crown more rapidly than in the beet proper. As these sectioning tests were incidental to the regular program of work they were in part made after storage in a moist root cellar at about 40 to 45 degrees Fahrenheit. The one experiment made on fresh beets showed 0.12 percent reducing sugars in the crown against 0.09 percent in the commercial beet. Another experiment made after 30 days in storage showed corresponding values of 0.21 percent and 0.15 percent reducing sugars. In the case of an experiment made after 80 days' storage, 0.35 percent and 0.15 percent of reducing sugars were found in the crown and commercial beets, respectively. These results are tentative as the experiments were not planned for study of this kind. Under some storage conditions, topped beets show more susceptibility to spoilage by micro-organisms and are higher in reducing sugars than corresponding untopped beets.

Summary

1. The core of the sugar beet root analyses much lower in sugars and higher in minerals than the main body of the root. From the core outward sucrose percentage increases to a maximum and then sharply drops at the outside ⅛-inch rind layer.

2. It is pointed out that this variation in composition may have a decided effect on analytical results unless care is taken that the rasping of pulp is correctly performed.

3. Analyses made of crowns and topped-root portions of the beets from plots of low- and high-fertility levels indicate that beets low in sucrose because of over-fertilization have sucrose and purity values for the crowns and for the corresponding commercial beets that are not very different, but in high-sucrose beets from fields of normal values for fertility there are large differences in sucrose and purity between these portions of the root.

4. The mineral and nitrogen concentrations in beets from high-fertility plots were lower than in the beets from low-fertility plots, but the reverse is true on the solids basis.

5. Mineral constituents such as chlorides, sulphates, and phosphates follow the general trends indicated by total ash.

6. It is possible that in the storage of trimmed but untopped beets there is a more rapid increase in reducing sugars in the crown tissue than in the body of the sound beet.

Literature Cited

(1) VON FLODERER, ALEXANDER, AND HERKE, ALEXANDER.
1911. Zeitschrift für Zuckerindustrie und Landwirtschaft 40: 385-397.

(2) VON URBAN, J.
1907. Zeitschrift für Zuckerindustrie in Bölmen. 32: 17-24.