A Rapid Method of Sorting Sugar Beets for Storage[1]

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Attempts to harvest and store beets in a manner and at a time to get optimum sugar recovery per acre or per ton are commonplace in the sugar beet industry. It has frequently been claimed without specific experimental evidence, and rarely been shown, that beets of higher sugar contents and higher purity store with less deterioration than beets of inferior quality. The purpose of this paper is to explore the practicability of quickly identifying truck loads of beets in the delivery line that are high or low in sugar content so that they may be directed to an appropriate point of unloading. The general relationship between the specific gravity of individual beets or lots of beets and the sugar content has frequently been pointed out. This paper shows the mathematical possibilities of such a sorting method, together with experimental figures for over 100 commercial samples of one variety and 40 samples with wide genetic diversity. The effects of mud and hollow beets are shown.

Literature Cited

No comprehensive review of papers concerning the general relationship between specific gravity and sugar content of beets seems necessary. However, in a study with about 3,000 individual mother beets, Down (M.Agr. thesis Michigan State University, 1922) showed a correlation of about 0.7 between sucrose content and specific gravity even with these beets of numerous genetic backgrounds. He found that by using one salt solution he could divide his mother beets, almost without error, into two groups: one containing all superior beets and the other almost all inferior in sucrose content. Dexter and Frakes (1)[3] separated a pile of beets of one variety into three groups on a specific gravity basis, with sugar contents of about 18, 16, and 14% respectively. In storage experiments, the higher quality beets were found to lose a smaller percentage of recoverable sugar. Similarly in an experiment with beets grown with different amounts of nitrogen, the beets with higher sugar content stored better (2). Silin (3) repeatedly emphasized the fact that damaged, immature or late planted beets should not be stored.

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Mathematics of the Method

Sugar beet roots have a specific gravity ranging mainly between 1.03 and 1.07. For purposes of calculation, a sample of 40 pounds of reasonably dirt-free beets will be assumed in the equations below, and a specific gravity of 1.02. By converting the 40 pounds to grams, the calculations may be more evident. The purpose of the calculations is to show the weight of a 40-pound sample of beets when it is submerged in water, as related to the specific gravity of the roots. Weight in air minus weight of water displaced = weight in water.

$$\frac{453.59 \times 40}{1} \text{ minus } \frac{453.59 \times 40}{\text{Sp. Gr. of Roots}} = \text{weight in water (grams).}$$

Assuming a specific gravity of 1.02 and clearing, we have

$$\frac{0.02\,(453.59 \times 40)}{1.02}$$

$$= 356\text{g} = \text{weight in water of 40 pounds of roots with sp. gr. of 1.02.}$$

Table 1.—Weight of beet sample submerged in water, in grams and pounds.

	Weight of sample in pounds, in air									
Specific	38.0		39.0		40.0		41.0		42.0	
gravity	g	lb	g	lb	g	lb	g	lb	g	lb
1.02	338	.745	347	.765	356	.785	365	.805	374	.829
1.03	503	1.108	515	1.14	529	1.17	542	1.19	555	1.22
1.04	663	1.46	680	1.50	698	1.54	715	1.58	733	1.63
1.05	821	1.81	842	1.86	864	1.91	886	1.95	907	2.00
1.06	975	2.15	1001	2.21	1027	2.27	1053	2.32	1078	2.38
1.07	1128	2.49	1157	2.55	1187	2.62	1217	2.68	1246	2.75

Table 1 is intended to bring out the point that with specific gravities close to 1.00, a slight difference in specific gravity results in a large relative difference in the "submerged" weights. Thus, between 1.02 and 1.03 specific gravity, the submerged weights change 50%; between 1.03 and 1.04, 33% and so forth. The accuracy of taking the original sample weights becomes almost insignificant in the separation of samples into their proper groups. The submerged weight of a sample weighing 42 pounds is $\frac{42}{38}$ of that of a 38 pound sample in every case with a given specific gravity, a difference of about 10%. The accuracy of the determination of the "submerged" weights is far more important than that of the weight of the sample. From examination of Table 1 it appears that for most practical purposes, the submerged weight of a standard container filled with about 40 pounds of beets (unweighed) might be adequate.

Methods and Results

In the first trial, 10-beet samples from fertilizer and management trials were used. While the beets were all of one variety, they had been grown under a wide range of cultural practices. The beets were washed. weighed to the nearest 0.1 lb in air, and submerged in water. For the weight in water, a scale that could be read to 0.01 was used, but (by mistake) only the reading to the nearest 0.1 lb was recorded. One-hundred ten samples were used, ranging from 15.6 to 35.1 lb, with five of these samples less than 20 and 10 more than 30 lb in weight. The sugar content and clear juice purities were determined in the routine manner. Since, in this particular year, purities were almost uniformly very high, no attention was paid to the effect of purity on the density of the juice.

Figure 1 is a graph of the 110 samples, when specific gravity was determined from weights taken to the nearest 0.1 lb. In this experiment, reasonably good separation on a sugar content basis could be made in spite of the rather small samples, and beets about 1.060 in sp. gr. might have been piled for long storage, those somewhat less for shorter storage, while the samples with specific gravity below 1.050 might have been routed for immediate processing. The three circled points show the com-

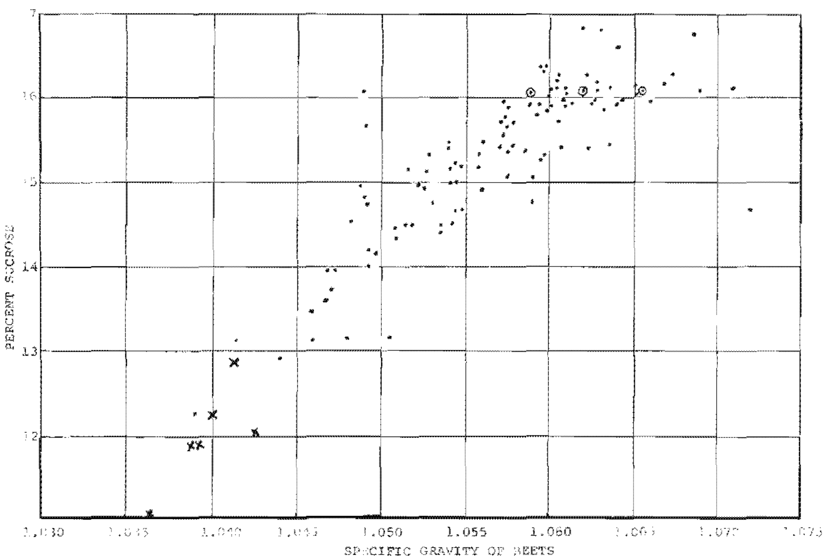

Figure 1.—Relation of specific gravity to sucrose content of sugar beets, X's are samples from the piles. Correlation Coefficient = 0.898.

puted specific gravity on a 34.2 lb sample, which weighed 2.0 lb submerged, (center point), while the other two points indicate the sp. gr. if the submerged weight had been recorded as 1.9 or 2.1 lbs. The error is considerable and on smaller samples would be more. In Figure 1, correlation coefficient between percent sucrose and specific gravity — 0.898.

Similarly about 40 samples of beets of different varieties were used. These samples ranged in weight from 12 to 24 pounds, with three samples over 20, and 12 less than 15 lb. With these samples, results were similar to those of Down when he worked with individual mother roots. Although the separation was reasonably good, the varietial characteristics were evident. These samples were too small to avoid considerable error in weighing in water.

A third experiment was run with beets from a commercial pile. Large, muddy beets were selected with their crowns completely intact, to give four samples of approximately 40 pounds each. The experiment was intended to determine: the specific gravity of beets before and after the removal of mud; of beets with air-filled hollow crowns versus the same beets with no air in the hollows versus the same beets with no crowns; and the specific gravity of crowns alone.

Weights in air and in water were determined on unwashed beets. The beets then were washed and reweighed both in air and submerged in water. To open the hollows in the crowns, the beets were sawed in two lengthwise and reweighed in air and water. The brei was used for a sugar determination (in each of the samples, 8 out of 11 beets had hollow crowns). The halved beets were now topped to remove the crowns, and reweighed in air and water. Finally, the combined crowns from the 4 samples were weighed in air and water and a sugar analysis was made of the crowns alone. Table 2 shows the results of this experiment. The specific gravities of muddy beets were, in all cases, higher than when washed. Similarly, when the beets were sawed to avoid the buoyancy of the air pockets in the crown, the specific gravity invariably increased. And when the crowns were removed, the specific gravity was again increased, so that the topped, washed beets had almost the same specific gravity as the muddy untopped ones. All of these samples would have fallen in the group for immediate processing.

Occasional samples were taken from the piles, after delivery. Each of the samples fell within the specific gravity group that was indicated by its sugar content.

Table 2.—The effect of mud, hollow intact crowns, sawing lengthwise and topping on the specific gravity of sugar beets.

	Muddy			After washing, only					After sawing			After topping		
	Weight in			Weight in					Weight in			Weight in		
Sample	Air	Water	Sp. Gr.	Air	Water	Sp. Gr.	% Mud	% Sucrose	Air	Water	Sp. Gr.	Air	Water	Sp. Gr.
1.	40.05	1.75	1.0457	39.80	1.62	1.0404	3.1	12.25	38.15	1.60	1.0438	28.42	1.35	1.0464
2.	43.05	1.97	1.0458	42.45	1.68	1.0412	1.4	12.85	41.65	1.69	1.0423	31.72	1.39	1.0458
3.	42.15	1.71	1.0423	42.05	1.55	1.0383	0.25	11.80	40.35	1.62	1.0418	31.78	1.35	1.0444
4.	40.60	1.75	1.0457	40.35	1.50	1.0386	0.6	11.80	38.90	1.53	1.0409	27.45	1.20	1.0457
Crowns								10.30				26.02	0.85	1.0388

Discussion

Further calculations of the ratio of weight in air to weight lost by submersion will enable one to calculate the degree of accuracy in weighing required for his purposes. In general, with samples about 40 pounds in weight in air, an error of 0.5 pound in the sample weight introduces about the same error in the calculated specific gravity as does an error of 0.02 pounds in the "submerged" weight. Rounding off the submerged weight to the nearest 0.1 pound as for example 2.05 ± 0.05, introduces the same error as an air weight of 40 ± 1.0 pounds. If it should appear desirable to sort loads for immediate processing, long storage, etc., the specific gravity method is worth considering. With a little practice, loads might be classified with nothing more than a weight in water. With a small scale, on which a tare for the weight of the container in water could be adjusted and assuming a 40 pound sample, some such figures as those shown in Table 1 might be used. For example:

Weight in water
Below 1.7 lbs. process immediately (perhaps the lowest $1/3$)
Above 1.7 but below 2.2, store to (perhaps the middle $1/3$)
process before mid-campaign.,
Above 2.2 store for late processing. (perhaps the top $1/3$)

The equipment required is inexpensive and fool-proof, and if suitably mechanized. the determination need take no more than one minute per load.

If considerable accuracy were desired, it would be desirable to record the air-weight to the nearest 0.1 pound, and the "submerged" weight to the nearest 0.01 pound, and read the specific gravity from a table. In any case, for high accuracy, with one sample (both in sampling and mathematically) it is suggested that a sample consisting of about 20 beets, and weighing about 40 pounds should be used, rather than a smaller one, and that the scale used for determining the submerged weight should be capable of reading to 0.01 pounds (or 5 grams). Suitable balances with these characteristics are available in the low range needed for "submerged" weights.

Beets are now cleaned and accurately weighed in the tare house to obtain tare on farmer's loads of beets. With the addition of one accurate scale, the finished tare samples could be weighed in water and the weight printed on the present tare ticket. Both percent tare and specific gravity could then be calculated for each sample. After a standard regression equation has been established for specific gravity vs. sucrose content the specific gravities obtained from each sample could easily be used to obtain an estimate of percent sucrose. Such an estimate of the average sucrose contents for a farmer's beets factored to the average estimate for all growers may agree so closely with laboratory analyses that the expense of a sugar laboratory could be eliminated. For companies not now making individual sugar analyses, information relating to the accuracy of such an estimate would be of considerable interest.

Literature Cited

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