Evaluation of Sugar Beet Storage Practices by Using the Percentage Purity of the "Thin Juice"[1]

S. T. DEXTER[2] AND M. G. FRAKES[2]

Received for publication July 16, 1964

In 1954 Brown and Serro (2)[3] described a rapid laboratory method for simulating the purity determination of the "thin juice" of the sugar factory. The results of this method were, for every practical purpose identical with those of the factory after liming and carbonation. Carruthers (3) corroborated their results and added a modification of his own. He states "if the ratio of sugar to total solids is known in the clarified (thin) juice, then the proportion of sugars which the factory can expect to obtain in crystal form is predictable." The Great Western Sugar Company has provided a formula for this prediction, together with a full explanation, on page 136 of "Sugarbeet Research" compiled by CRD, ARS and USDA. The sugar factories in Michigan seem in agreement with the formula, with slight modifications.

The authors of this paper make no claim to expert knowledge of factory practice or the complications of the application of this formula. However, since the thin juice methods and the formula are presented by the eminent authorities cited above, they may carry considerable authority to agronomists.

The particular purpose of this paper is to call attention to the tool that has been furnished the agronomist. By this method and formula, agronomists in a reasonably well equipped and mechanized laboratory can determine how much sugar will be bagged per ton of beets that have been grown under various practices. Most past and current papers report tons of beets per acre, and perhaps percentage sucrose, from which gross sugar per acre may be computed. However, with beets of various sucrose percentages and various thin juice purities, the percentage recovery as bagged sugar may readily range from less than 70 to more than 90% in beets of any one variety, harvested in any one season (See Table 1). Results based on total gross sugar are likely to lead to recommendation of uneconomic practices.

For example, a new beet variety was reported to yield 34 tons per acre in contrast to 21 tons for a commercial one. Gross sugar per acre was 20% higher for the new variety. Although

[1] Contribution from the Michigan State University Experiment Station, Journal paper No. 3414.

[2] Professor of Crop Science, MSU, and Research Director, Michigan Sugar Company.

[3] Numbers in parentheses refer to literature cited.

Table 1.—Percentage recovery as bagged sugar from beets of various qualities, according to The Great Wesetern formula.

Clear juice purity %	Percent sucrose in beets						
	12	13	14	15	16	17	18
85	68.7	68.9	67.0	69.1	69.2	69.2	69.3
86	71.1	71.2	71.3	71.4	71.5	71.6	71.7
87	73.2	73.4	73.5	73.6	73.7	73.8	73.9
88	75.3	75.5	75.6	75.7	75.8	75.9	76.0
89	77.4	77.6	77.7	77.8	77.9	78.0	78.1
90	79.4	79.6	79.7	79.8	79.9	80.0	80.1
91	81.4	81.6	81.7	81.8	81.9	82.0	82.1
92	83.4	83.5	83.7	83.8	83.9	84.0	84.1
93	85.3	85.4	85.6	85.7	85.8	85.9	86.0
94	87.1	87.3	87.4	87.6	87.7	87.8	87.9
95	89.0	89.1	89.3	89.4	89.5	89.6	89.7
96	90.8	90.9	91.1	91.2	91.3	91.4	91.5
97	92.5	92.6	92.9	93.0	93.1	93.2	93.3

no figures were given for bagged sugar per acre, it was possible to estimate from purities given that about 5,100 pounds would be bagged per acre in each case, although it required processing 34 vs. 21 tons for the two lots. Similar examples could be given of the effects of other agronomic variables.

The difficulties that would be involved in attempting to determine bagged sugar per ton by actual factory processing of small samples seem evident. By the use of this new technique, we have been able to evaluate a wide range of agronomic practices in terms of bagged sugar per ton and per acre.

In this paper, sucrose loss, in terms of bagged sugar per ton of original beets, will be reported as affected by storage conditions and original quality of beets. In the remainder of this paper, the juice clarified in the laboratory by Carruthers' modification will be designated "clear juice", to distinguish it from the factory "thin juice" with which we occasionally work.

Literature Review

The literature on storage of beets is so voluminous that only a few papers particularly pertinent to this study will be mentioned. In general, respiration of beets increases rapidly with the temperature of storage, Barr et al. (1). Although there is considerable variation in the results of the experiments in which carbon dioxide production per pound of beets was determined, there is remarkably good agreement in some cases between the sugar loss by computation and that lost by actual analysis. In some cases loss of sugar from undetermined causes is very considerable, but in many cases this loss is related to growth or to the quality of the beets. Larmer (5) studied the keeping quality

as influenced by nutritional factors and found that adequate phosphate was particularly helpful. In Michigan, it has commonly been thought that beets high in sugar and/or purity store better than do beets inferior in these regards. Desiccation during storage has been shown by Pack (6) to lead to accelerated loss of sugar. Freezing and thawing has been shown to be detrimental, but storage in the frozen condition has repeatedly been found to essentially stop sugar loss. Storage of beets submerged in water at about 35°F has been shown by Dexter (4), to lead to small losses in total sugar up to about 4 weeks of storage, with appreciable losses thereafter. Pack (6) found sugar losses of about 50% when beets were submerged over 100 days in cold water.

Method

In the first four experiments, beets from one variety were used. Except as indicated, they were machine topped from a field with an excellent stand of beets. They were washed thoroughly and surface dried. From a pile of such beets, samples were selected, in turn, as follows:

1. Six half-bushel mesh bags of the largest beets and six of the smallest beets were taken and weighed. On two lots of each, analyses were made at once. Two of the six bags were buried in a company pile for storage, and two were stored in the frozen condition for ten weeks. After reweighing, analyses were made to compare the storage characteristics of large and small beets.
2. From the remaining middle-sized beets, beets high in specific gravity (over 17 Brix) and those of medium specific gravity (15-17 Brix) were selected. By harvesting an outside row, a few beets of low specific gravity (below 14 Brix) were obtained. These were weighed, stored, reweighed and analyzed as in the first experiment. It has been suggested that beets high in sugar store with very little difficulty or loss in sugar. Since small beets or those high in specific gravity are likely to be high in sugar, and since it should be a simple matter to separate such beets, on a large scale, their storage characteristics would be of interest.
3. Similarly, from the same variety of beets, samples were prepared without removal of the crown, and some even had traces of leaf petioles left; others were topped near the first leaf scar; while other samples consisted of the removed crown tissue. These were similarly weighed, stored in the pile or frozen condition, reweighed and analyzed.

4. From the remaining machine-topped beets, samples were prepared for storage at about 32°F in air, in ice water, in 2% salt brine, in the company pile, and in the frozen condition. In all cases, weights before and after storage were taken to correct bagged sugar recovery in terms of the original weight of the samples.

Results and Discussion

Table 1 gives an idea of the percentage of recovery of gross sugar in sugar beets of varying percentages of sucrose and clear juice purity. It may be noted that the *percentage recovery as bagged sugar* is relatively uniform for any thin juice purity, increasing less than 1% in the sucrose range from 12 to 18% in the beets.

Table 2 compares the bagged sugar per ton of original beets and the clear juice purity of the samples after storage for 10 weeks under two conditions. In general, the beets of the highest quality, over 17 Brix and small beets, appeared to store as well in the company pile as in the frozen condition.

Table 2.—The bagged sugar per ton and clear juice purity are compared for beets stored 10 weeks in the company pile or in the frozen condition.

	Bagged sugar per ton of original beets		Clear juice purity	
Sample	In Pile lbs.	Frozen lbs.	In Pile %	Frozen %
Large beets	258	276	91.1	90.2
Small beets	301	293	92.9	92.4
Over 17 Brix	293	284	92.1	91.1
15-17 Brix	267	281	91.1	91.3
Below 14 Brix	202	237	86.1	88.6
Whole beets	240	285	88.2	90.6
Topped beets	265	307	89.7	92.6
Crowns	122	158	80.2	84.7

With beets of originally poorer quality, storage in the frozen condition appeared to preserve the sugar considerably better than did storage in the company piles. In beets below 14 Brix, in untopped beets, and in crowns only, recoverable sugar was notably higher in samples that were stored in the frozen condition. It would appear that in the pile these beets lost about 0.5 pound of sugar per ton per day more than when frozen.

Table 3 compares loss in percent sugar in the company pile versus storage in the frozen condition. In the "Ratio calculated from shrinkage", the weights after shrinkage were compared for storage in the pile or frozen. The beets stored in the pile

Table 3.—Effect of 10 weeks storage in the pile or in the frozen condition on the loss in percentage sugar in beets, corrected to the original weight of each sample. The ratio of $\frac{\%\text{ sugar in beets stored in pile}}{\%\text{ sugar in beets stored in frozen condition}}$ is given in the table.

Sample	Ratio calculated from weight shrinkage	Actual ratio from sugar analysis	Change in ratio of sugar %
Large beets	0.981	0.900	—0.081
Small beets	0.951	0.976	0.025
Over 17 Brix	0.956	0.976	0.020
15-17 Brix	0.990	0.940	—0.050
Below 14 Brix	0.961	0.884	—0.077
Whole beets	0.986	0.859	—0.127
Topped beets	0.998	0.914	—0.084
Crowns	1.002	0.819	—0.183

shrunk slightly less (except for crowns) than did the frozen samples. Thus, from consideration of shrinkage alone, one would expect the beets stored in the pile to contain a slightly lower concentration of sugar than those stored frozen. Since in most cases the shrinkages were slightly different in the pile and in the frozen condition, the ratios in the first column approximate 1.00. The ratio of sugar percentages, determined by actual analysis, however, (corrected to the original weight of each sample) shows that losses in percent sugar were appreciably greater in the samples stored in the pile than in those stored frozen, except in the case of the two samples, over 17 Brix and small beets. Thus, 0.081 (for example) more of the gross sugar in the large beets disappeared in the pile than in the frozen condition.

If there were no loss of sugar, the values in the two columns would be identical. If there were no loss of sugar in the frozen samples, one must conclude that samples slightly higher in sugar were accidentally used in the case of "over Brix 17" and "small

Table 4.—Bagged sugar per ton of original beets and clear juice purities of beets stored at near freezing temperatures under water, under 2% brine, or in air, frozen, and in the company pile.

Storage period	Storage Method: Under water 32°F.	Under 2% brine 32°F.	In air 32°F.	Frozen	Company pile
	Bagged sugar per ton, corrected to original weight				
4 weeks	260	244	277	269	258
7 weeks	231	215	276	272	265
	Clear juice purities				
4 weeks	90.5	89.1	91.8	91.6	89.6
7 weeks	87.0	86.7	90.1	90.3	89.8

beets," stored in the pile. In general, however, the conclusions agree with those from the previous tables, namely, that storage in the frozen condition was particularly helpful in the case of the beets of poorer quality. Since, in general, both percentage sugar and clear juice purity were maintained better in beets stored in the frozen condition, bagged sugar per ton of beets was inevitably improved.

Table 4 compares storage under water with other storage. For the first 4 weeks, storage losses in beets under cold water were almost identical to those in the company pile. After this period, losses were appreciable in submerged storage. Storage under 2% brine was not helpful in preserving sugar, but did almost eliminate uptake of water by the sample.

Summary

Beets of various qualities were obtained by selecting samples of large beets; small beets; beets high, medium or low in specific gravity, and beets with and without crowns. They were stored, for 10 weeks, until January 10, in the company pile or in the frozen condition. Loss of recoverable sucrose in the company pile was much less in the case of high quality beets than in lower quality beets, as judged by the difference between sugar losses in the pile and in the frozen condition.

Beets stored under near-freezing water or 2% brine for 4 weeks lost slightly more bagged sugar, in terms of the weight of the original sample, than did beets stored in air at 32° or frozen. After 7 weeks of storage, the loss was appreciable in beets stored under water.

Literature Cited

(1) BARR, C. GUINN, E. M. MERVINE and R. A. RICE. 1940. A preliminary report on the effect of temperature and beet conditions on respiration and loss of sugar from beets in storage. Proc. Am. Soc. Sugar Beet Technol. 2 (1): 52-65.

(2) BROWN, R. T. and R. F. SERRO. 1954. A method for determination of thin juice purity from individual mother beets. Proc. Am. Soc. Sugar Beet Technol. 8 (2): 274.

(3) CARRUTHERS, A. and J. F. T. OLDFIELD. 1960. Methods of assessment of beet quality. Proc XIth Session of the commission internationale technique de sucrerie. Frankfort, 1960. Elsevier Pub. Co. 1962.

(4) DEXTER, S. T. 1963. Storing sugarbeet roots under cold water. Proc. Eastern Regional Meeting Am. Soc. Sugar Beet Technol.

(5) LARMER, F. C. 1937. Keeping qualities of sugar beets as influenced by growth and nutritional factors. J. Agr. Res. 54: 185-198.

(6) PACK, DEAN A. 1926. The effect of moisture on the loss of sugar from beets in storage. J. Agr. Res. 32: 1143-1152.