Determination of Sugar Recovery as a Function of Beet Storage Time

S. E. Bichsel
General Chemist & Director of Research
Holly Sugar Corporation

To determine the percent recovery of sugar produced during long term low temperature beet storage or relatively high temperature, short term transport and storage it is necessary to arrive at values describing:

A. Percent reduction of total weight of sucrose introduced into the factory (beets sliced) as compared with total weight of sugar in beets purchased (percent sugar shrink).

B. Percent reduction in total extractable sugar in beets purchased vs beets sliced.

Basic calculations involved in determining percent recovery (the percent of sugar extracted on a straight house basis as a percent on total sugar in beets purchased) is demonstrated by example in the paper included in the proceedings, "Quality Losses in Commercial Piles, An Approximate Cost Analysis" pg 7.

Historically the methodology involved in determining weight sugar lost due to respiration and microorganism utilization has involved the captive sample technique which is described in the proceedings. In an effort to develop a measurement method involving less labor and greater accuracy, Holly Sugar Research has evaluated the K-Ratio Method of measuring sugar loss in beets during long term storage in northern growing areas and short term transport and storage in California growing areas. It should be noted at the onset that this method is still under evaluation. As such, the method is classified as experimental and cannot be recommended at this time, without reservation, as a replacement for the time proven captive sample method.

The K-Ratio Method is best explained by considering an actual example. Assume an average northern factory slice of 4,000 tons per day. During the northern harvest period from approximately October 1 to October 27 all beets purchased for slice will be received at the receiving stations and tare samples will be taken representing loads received. Assume that the investigator wishes to evaluate the extent of sugar loss over a 120-day storage period during 30-day increments in a 50,000 ton factory yard pile. Beets received in the tare lab representing 4,000 ton staked volume increments in Figure 1 are received in the tare lab, washed and the percent sugar determined on the <u>uncrowned beets</u>. If the average beet load is 8 tons and 50% of the loads are sampled for tare at the receiving station, the 4,000 ton one day slice pile volume increment will be represented by a zero storage time control sampling of 250 samples. It is, of course, necessary to make sure the 250 samples representing the approximate 4,000 tons of beets received are piled within stakes 1 and 2 in the factory pile. Percent sugar content determined by pol is recorded and a sample of the leaded filtrate is saved from each sample for determination of GLC true sucrose and potassium as determined by flame photometer of atomic absorption. Potassium values are expressed as percent potassium on true sucrose in leaded filtrate. In addition, brei composites are taken from the Spreckels' saw for preparation of press juice (hot Waring Blender extraction method) for determination of synthetic thin juice purity. The storage time-0 synthetic thin juice purity value will be compared with storage time +30 day volume increment-A press juice synthetic thin juice purity when the beet in volume increment-A is introduced into the factory for slice. At a predetermined time from storage time-0, time of piling +30 days, the A section of the pile having a volume increment of 4,000 tons is introduced into the factory. During the period the beets are being sliced (approximately 24 hours) continuous grab sample composites are taken from the cossette belt (3 composite samples per hour). Over a 24 hour slice period a total of 72 samples are analyzed for pol percent sugar. Leaded filtrates are saved for GLC true sucrose analysis and determination of percent potassium in leaded filtrate on true GLC sugar. In addition press juice is prepared from composite ground cossette samples using the hot Waring Blender extraction method. Press juice representing the 24 hour slice period is used to determine synthetic thin juice purity which is compared with storage time-0 synthetic thin juice purity to determine extraction decrease as related to storage time.

Table 1 gives a numerical example of determination of percent sugar shrink and as a matter of interest, percent weight shrink at +60 days storage time. Each approximate 1-day slice pile volume storage increment must be compared on a separate basis with the storage time-0 volume increment as received and tared in the tare lab which coincides with the pile volume increment. The basis of the K-Ratio Method lies in the fact that potassium remains constant in the face of dehydration and metabolite shifts within the respiring beets. Also potassium may be rapidly and accurately determined in leaded filtrate. Wet lead prepared from lead acetate contains only traces of potassium, therefore, wet lead blank values deducted from total ppm potassium in leaded filtrate are small. Since potassium is a constant any significant increase of percent potassium on true GLC percent sucrose represents a decrease in sugar due to respiration and microorganism utilization.

In addition to determining the synthetic thin juice purity on storage time zero press juice and volume increment at time of slice, a routine non-sugar analysis is also performed on the press juice samples. Non-sugars are classified using the system developed by the Amalgamated Sugar Company. All soluble non-sugars are classified as carbonation non-removable non-sugars (NRN) and carbonation removable non-sugars (RNS) impurities. The major classification of carbonation non-removable non-sugars is further divided into sub classifications of non-removable non-sugars (NRN) and storage sensitive non-removable non-sugars (SSNN). The NRN group of non-sugars composed of the amino acids, betaine, sodium, potassium, chlorides and nitrates approximates 30% to 50% of the total soluble non-sugars in press juice. The SSNN group of non-sugars composed of invert, raffinose, kestose, dextran and levan make up approximately 10% of the total non-sugars in fresh beet press juice but may approach 35% of the total soluble non-sugars at the end of a 130 day storage period. The carbonation removable non-sugars (RNS) group composed of organic acids which are partially eliminated as insoluble calcium salts-citrates, oxalates, malates and inorganic anions which form insoluble calcium salts, sulfates and phosphates make up

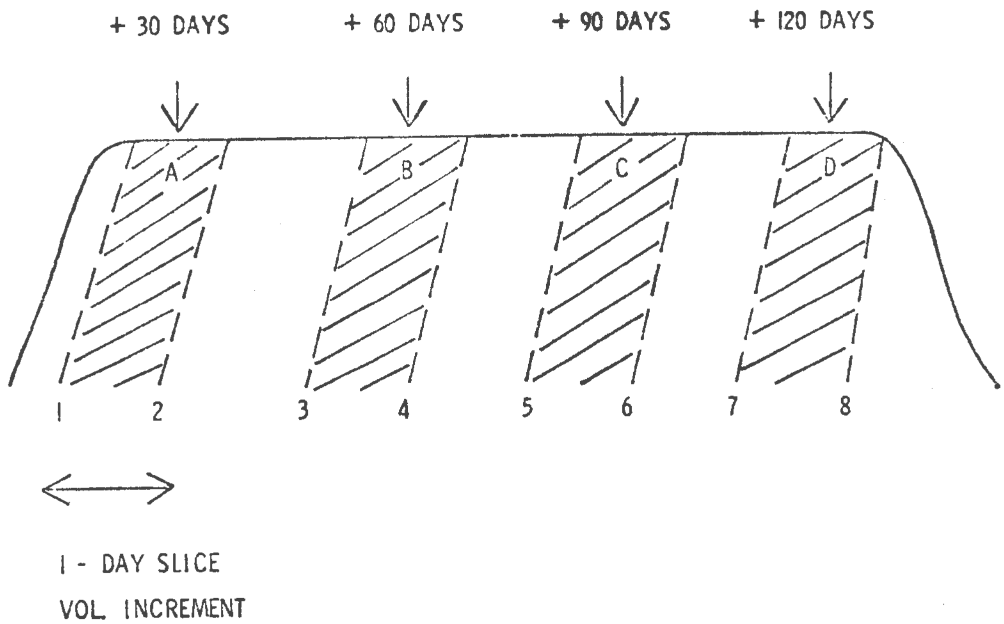

Figure 1.

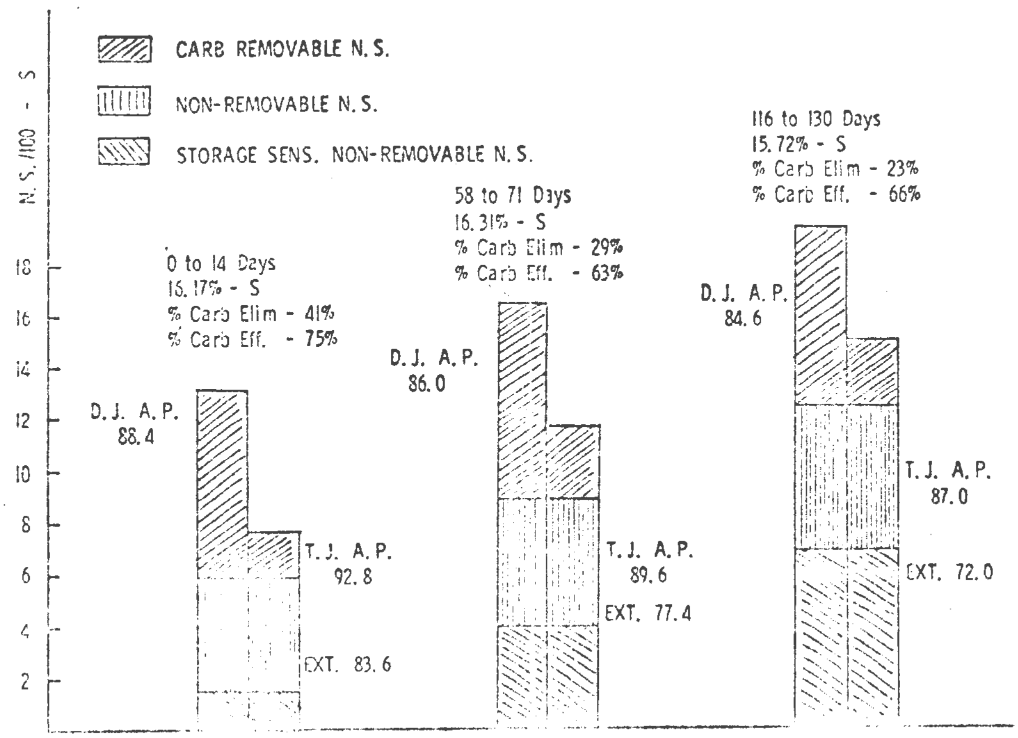

Figure 2.

Table 1. K- Ratio Calculation Example

Storage Time - 0 Days

GLC Sucrose = 15.05% Average

Potassium in Leaded Filtrate = 1.50% on Sugar (Tare Lab)

Storage Time - + 60 Days

GLC True Sucrose = 14.90% Average

Potassium in Leaded Filtrate = 1.55% on Sugar (Beet Test)

$$\% \text{ Sugar Shrink} = 100 - \left(\frac{1.50}{1.55} \times 100\right)$$

$$\% \text{ Sugar Shrink} = -3.23\%$$

$$\% \text{ Weight Shrink} = 100 - \left[\frac{(100 - 3.23\%) \times (15.05\%)}{14.90\%}\right]$$

$$\% \text{ Weight Shrink} = -2.28\%$$

approximately 55% of the total soluble non-sugars in fresh beet press juice. Figure 2 shows a graphic representation of a typical diffusion juice, thin juice pairing at the beginning, middle and end of a 130 day campaign. Decreases in diffusion juice and thin juice purities from the beginning of the run to the end are reflected in extraction decreases from 83.6 to 72.0. Although it appears that carbonation elimination is decreasing through campaign from 41% to 23%, when calculated on total soluble non-sugars, actually percent carbonation elimination expressed as % elimination (efficiency) on removable non-sugars remains approximately the same throughout campaign. Extraction decreases throughout campaign when compared with a base time-0 storage fresh beet value of 83.6% may be totally attributed to the increase in carbonation non-removable storage sensitive non-sugars (SSNN). Increases in this important group of carbonation non-removable non-sugars is a function of sugar losses during storage due to respiration and rot. In interpreting the base extraction level of fresh beets at time-0 the non-removable non-sugar classification total NRN expressed as percent on sugar or non-sugar/100 sugar is indicative of the intensity of nitrogen fertilization. High nitrogen fertilization is reflected in high amino acid levels expressed as percent on sugar in conjunction with elevated sodium and potassium levels to maintain cation anion balance within the beets. The use of the non-sugar classification concept as described is a valuable tool for interpretation of beet quality with respect to extractable sugar per ton of beets fresh harvested or after long term pile storage.

DISCUSSION

Question: Is a fungicide used to treat roots prior to placing them in respiration chambers?

Wyse: I do not. Mold is not a problem in these studies. Normally the beets stay in excellent condition, free of mold.

Fox: A question for Jay Law. On these canopy versus non-canopy tests, your losses were 0.2 lbs/T/day. Is that loss recoverable sugar loss or is it based on pol only and is it corrected?

Law: That was raw loss based on sugar content only and is not corrected

Ellis: In our experience we are getting very rapid drops in sugar and purity during the first 24-48 hours after harvest. I was wondering whether anyone here has done any effective work on the advange or disadvantage of rapid cooling during this period.

Wyse: In my laboratory experiments, the beets receive minimal injury and the temperature of the root rarely gets above 10 C and the roots are placed in storage at 5 C within 5-6 hours of harvest. Under these conditions and using 10 replications of 10 beets I cannot detect this reported rapid loss immediately after harvest.

Oldemeyer: A point to remember here is that these beets hold a lot of heat. We put beets into a cold room and found it took several days for the interior of the beet to reach room temperature.

Bichsel: The thought occurs that since we need to wash the beets anyway that jet spray washing would combine washing and evaporative cooling at the same time.

Ellis: Since we've started to keep much closer records on pile temperatures, our program at the present time is to start reading temperatures just as soon as possible and read them on a 24-hour a day basis until such time as they stabilize and then we generally read them on a 3-day interval. We're finding a definite correlation between loss of sugar and the speed with which we're bringing the beets to a desirable temperature and then our ability to hold on to that temperature during the storage period. I can't be that specific on weight loss because we haven't been that precise. By just previewing the pile temperature data on an aggregate basis we quite accurately now determine which one of our piles we're going to have high sugar loss on and which one we're going to have low sugar loss in, quite a while before we start processing them. We can eventually bring a pile to standard temperature, but if it has taken us very long to get there, we never seem to regain the quality lost. It seems like that early loss is something that if we once lose it, we never can regain it even though a month or 6 weeks later we bring the pile to a standard temperature.

Fox: If beets are held for 30 days at 60 F, there is a very high loss during that period. You can easily lose 30 pounds of sugar per ton right in those early days.

Ellis: Our experience is that it does not take 30 days - the time is much less.