Methods of Measuring Quality Losses in Laboratory Storage Experiments

Roger E. Wyse, USDA-ARS

During storage, sucrose is lost directly as carbon dioxide via respiration and by conversion to other compounds such as invert sugar and raffinose. Physical deterioration and the accumulation of impurities also affect processing. I will limit this discussion to factors that affect decreases in recoverable sugar per ton, as measured by percent sucrose and clear-juice purity (CJP). In my storage studies, percent sucrose by pol, CJP, recoverable white sugar per ton (RWST), respiration, raffinose, and reducing sugars are routinely measured.

Variety evaluation It is now commonly accepted that some varieties or breeding lines do not maintain quality during storage as well as others. In the future it will be necessary to screen all released varieties for quality losses during storage.

First, let us consider the characteristics of a superior storing variety. It would be a variety that has a low respiration rate, because respiration accounts for about 70% of the decrease in RWST under good storage conditions. A superior variety would have minimal impurity accumulation when stored below 45 F. It must have some resistance to mold invasion, because molds are probably the major cause of the decline in processing quality in commercial storage. Other preferred characteristics would be a stable marc and resistance to injury. Low respiration rate and resistance to mold invasion are the two most important characteristics.

The plant breeder has enough problems with sugar, purity, tonnage, and disease resistance and cannot be expected to select for 4 or 5 more storage characteristics. The conservation of RWST during storage is a good composite test for general storing ability and probably is a satisfactory test for varietal screening, but it may be too gross for genetic studies. At the very minimum, all new releases should be screened for this storage characteristic.

Following are some of the characteristics that I feel go into making up a good variety test. Use only beets from plots having a very uniform stand. This will greatly reduce sample variability and thus allow use of fewer replications. Injury should be minimized, because it increases respiration rates and mold susceptibility, and these effects can easily override genetic characteristics. Use beets of uniform size or an equal representation of sizes within a variety. All appropriate determinations (those based on percent fresh weight) must be corrected for weight loss during storage. All polarimeter readings for percent sucrose must be corrected for the optical activity of raffinose and invert sugars.

I use the following experimental method in variety-evaluation studies. Normally at least ten replications of 8 to 10 beets are needed for an accurate estimate of storage characteristics. However, fewer

replications (3 or 4 reps of 5 beets) are needed for determining varietal susceptibility to raffinose and reducing sugar accumulation. My normal procedure is to store the varieties at 5 C in 3-mil plastic bags containing 10 holes made with a paper punch. Using this system, water loss is less than 2 to 3% in 160 days.

You will note that my philosophy is to eliminate all variables except variety. Another valid approach would be to place the varieties under stress by mold inoculation, warm temperature, desiccation, injury, or other less-than-ideal storage conditions. The problem in this approach is to control the degree of stress to avoid completely overshadowing all genetic influence.

Respiration Respiration rates are measured by monitoring carbon dioxide evolution with a flow-through system. A flow rate of 300 ± 5 ml/min of air is metered to the samples by means of a flowboard. The air from one channel flows through 3 plastic containers attached in a series.

The increase in carbon dioxide content of the airstream going through a single 10-beet sample is determined by use of a Perkin-Elmer gas chromatograph . Gas samples are taken with a syringe at regular intervals and injected directly into the gas chromatograph. Precision is normally ± 0.05 lb/T.D for a single determination. Time for a single assay is 1.5 minutes.

Measurements of respiration are much more precise than the determination of chemical sucrose, but they do require considerable attention to detail and are not easily adapted to screening large numbers of samples.

Chemical determinations Percent sucrose is determined by polarimetric methods and corrected for the optical errors caused by raffinose and invert sugars. The correction formula used is:

$$\text{Corr. \% S in C.J.*} = \text{App \% S} - \frac{1.59\ (\text{mg/ml Raff}) - 0.302\ (\text{mg/ml Invert})}{10}$$

* % by volume in clear juice

$$\text{Corr. \% S on beets} = \frac{\text{Corr. \% S in C.J.}}{\text{App. \% S in C.J.}} \times \text{\% S on beets}$$

This correction equation assumes that glucose and fructose exist in equal quantities in the beet. All determinations based on percent fresh weight are multiplied by the following factor to correct for weight loss during storage:

$$\frac{\text{sample weight into storage}}{\text{sample weight after storage}}$$

Reducing sugars are rapidly determined by using a dinitrosalicylic acid reagent. Raffinose is determined with galactose oxidase; however,

care must be taken when this reagent is used in long-term storage experiments. Clear-juice samples sometimes contain an inhibitor of galactose oxidase, which causes false low readings. Therefore, the readings should be spot-checked by paper chromatography.