Storage of Sugarbeets

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INTRODUCTION

Losses in sugar are caused by respiration, freezing and thawing, molding and dehydration during the storage of sugarbeets. The objective of a good storage program is to diminish drastically the effects of these destructive processes. A judicious choice of beet variety and field practices, prevention of excessive mechanical damage, a sound pile cooling system and possibly pile covering, will do much to fulfill this objective.

A large number of individual experiments have been conducted all over the world on the effect of many parameters on the loss of recoverable sugar during the storage of sugarbeets. The authors are attempting to evaluate these results and to employ them along with their own experimental data into a number of simulation models which will explain and calculate sugar losses during storage of sugarbeets.

EXPERIMENTAL

Over the past three years we have stored more than one thousand individual beets. A number of varieties have been tested, but most of the data have been collected on the hybrid monogerm variety US H20. The beets were stored for varying lengths of time (up to 120 days) at temperatures of 35 F, 40 F, 45 F and 50 F. The relative humidities tested were between 65 and 100 percent (obtained by the use of dehydrators and storage in plastic bags with wetted sawdust). The air flows in the storage varied from 0 to about 100 feet per minute.

Prior to being put in storage, the beets were washed in cold water and their weights taken in air and in water for calculation of specific gravity. Each year the relationship between the specific gravity and the sugar percentage was determined from a representative sample of one hundred beets.

The surface area of each beet was determined. The weight losses due to respiration and desiccation were taken periodically. Samples were removed from storage at regular intervals for analysis.

Sugar analyses were performed at the Michigan Sugar Company Agricultural Research Laboratory in Carrollton, Michigan. The recoverable white sugar per ton calculations were performed according to the relationships developed by Frakes (1970, 1971, 1972) [1/]

[1/] Frakes, M. G. (1970, 1971, 1972). Personal communication, Michigan Sugar Company, Carrollton, Michigan.

RESULTS AND DISCUSSION

Only some representative results will be given here. Later this year (1973) a full report will be published under USDA auspices.

The relationship between the specific gravity and the sugar percentage was slightly different each year. For the 1970 October harvested US H20 beets the following relationship was found:

$$\% \text{ sugar} = 53.2032 \text{ (specific gravity)}^2 - 43.6906$$

For all years, the correlation coefficients for the equations of sugar percentage as a function of specific gravity were between 0.8 and 0.9.

The surface area of sugarbeets directly affects their dehydration rate. The equation describing the surface area in terms of beet weight is:

$$\text{surface area, cm}^2 = C \text{ (weight, grams)}^{0.66}$$

The constant C depends on the height/diameter ratio of the beet. A value of 4.75 for C was found to be acceptable for engineering calculations of Michigan beets.

The weight loss of sugarbeets is affected by the respiration and the desiccation rate. The latter is responsible for the main losses. The effect of the surface area, wind velocity and water vapor pressure difference between the beet surface and the surrounding air on the desiccation rate of sugarbeets can be expressed by the following equation:

$$\text{Moisture loss} = \begin{array}{l}\text{(transfer coefficient) (surface area)} \\ \text{(water vapor pressure difference)}\end{array}$$

The transfer coefficient (hr^{-1}) can be calculated from the equation:

$$\text{transfer coefficient} = 0.00053 \left(\frac{\text{air velocity, ft/min}}{197}\right)$$

The moisture loss is given in pounds per hour if the surface area is in square feet and the water vapor pressure difference in pounds per square foot.

Linear regression was applied in order to evaluate the effect of storage conditions on the loss of sugar in stored beets. One of the relationships found was:

$$\begin{aligned}\text{sugar fraction} = {} & 43.1015 - 20.1717 \text{ (mass fraction)} \\ & - 0.0007 \text{ (time)} - 0.1529 \text{ (temperature)}\end{aligned}$$

The recoverable white sugar per ton of beets decreases due to high temperature and low humidity effects, to rotting and to respiration. The interior of a pile constitutes over 80 percent of the total volume. The main losses in this area are caused by respiration and are expressed by the following equation developed from data by Dilley, et al (1970)[2]:

Sugar loss, lbs/ton hr = [10.0649 + 0.01622 (temp. F)^2
- 2.150 (time, days) + 0.1940 (time, days)^2
+ 0.0060 (time, days)^3] 0.0090

The effect of the initial cooling-down period on the dehydration and sugar losses in a pile of sugarbeets was studied using the above presented equations along with a model predicting the temperatures and humidities in the pile during this time. Figures 1, 2, and 3 are plots of the beet bed temperatures, the mass fractions, and the sugar losses at three positions within the beet pile during the cooling-down period of a typical test. The initial conditions of the beets in the ten-foot deep pile and the inlet cooling air conditions were:

beet temperature	52 F
pile depth	10 ft.
pile porosity	0.43
air temperature	32.0 F
airflow rate	18.0 lb/hr ft^2
air humidity	0.003 lb/lb

Figures 4, 5 and 6 are graphs of the pile temperatures, mass fraction, and sugar loss of the same pile of beets subjected to a sinusoidally changing temperature with an average of 40 F and an amplitude of 10 F. The airflow rate and humidity are the same as in Figure 1, 2, and 3.

In evaluating Figures 1-6, several interesting points stand out. Evaporative cooling causes the beet temperatures to fall below that of the cooling air temperature (see curves 1 and 4 in Figure 1). Also, respiration may cause a temperature rise during the initial storage period notwithstanding the fact that the pile is artifically cooled (see curve 3 in Figures 1 and 4).

The moisture losses due to respiration and moisture evaporation can be significant during the cooling-down period (see curve 1, Figure 5). How large the sugar losses per ton can be during the initial storage period is illustrated in Figures 3 and 6.

Only the outer 1 - 1 1/2 feet of an uncovered sugarbeet pile is seriously affected by outside weather conditions. The temperatures in over 80 percent (by volume) of the pile change only slowly. Data from European and American researchers are being assembled to investigate which factors were most responsible for the average inner pile temperatures during the storage season. The independent variables investigated are:

1. Maximum daily air temperature

2. Minimum daily air temperature

3. Average daily air temperature

2/ Dilley, D. R., R. R. Wood and P. Brimhall (1970). Respiration of sugarbeets. Journal of ASSBT, 15(8):671.

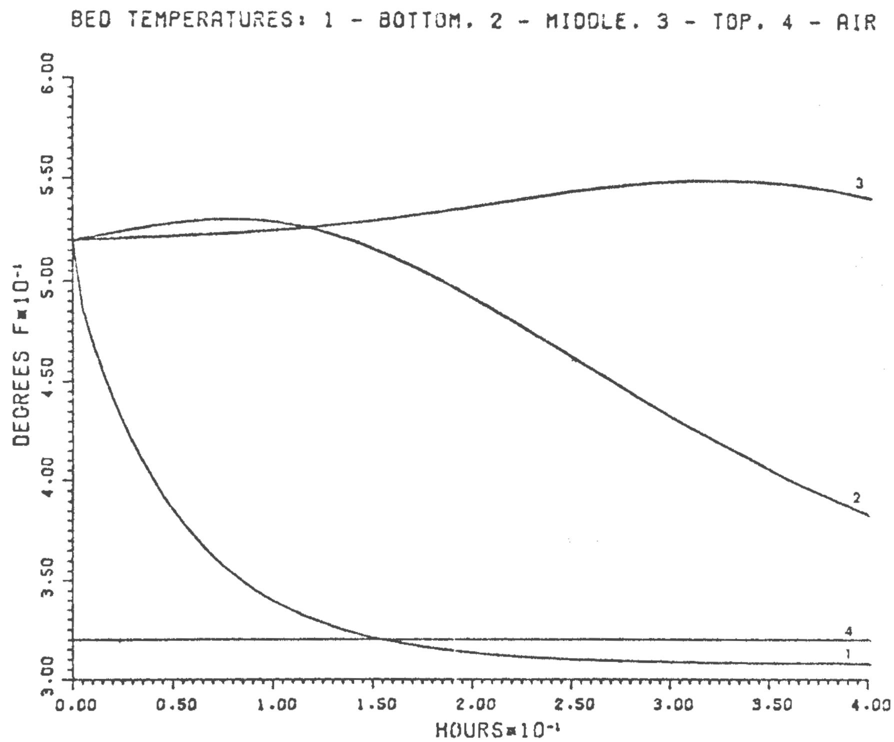

Figure 1. Simulated sugar beet and air temperatures at the bottom (0 ft), middle (5 ft), and top (10 ft), of a pile during forced air cooling.

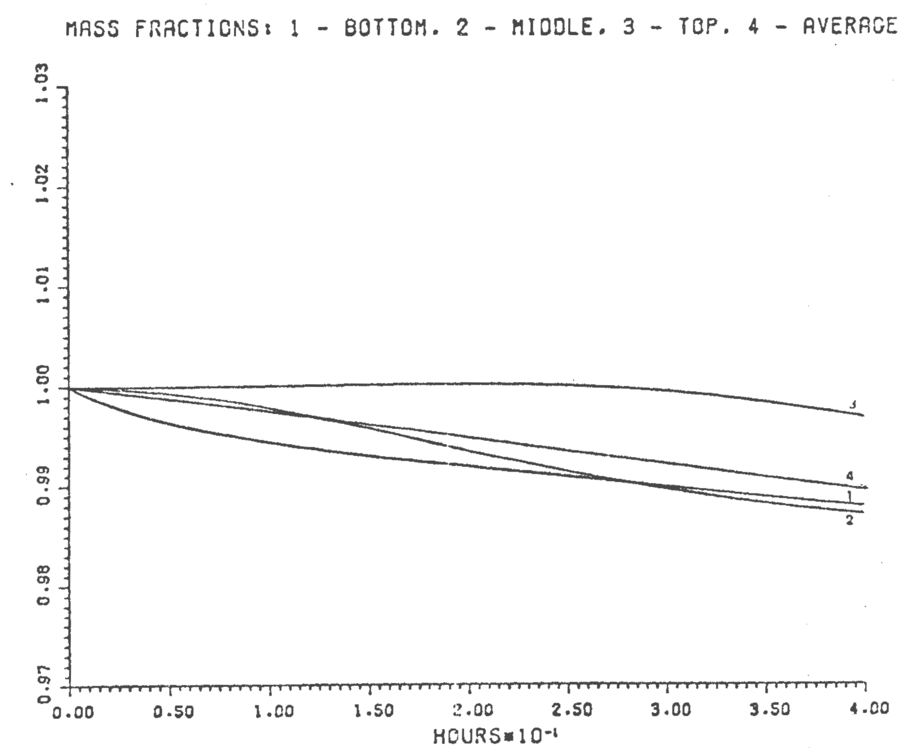

Figure 2. Simulated mass fractions of sugar beets at the bottom (0 ft), middle (5 ft), and top (10 ft) of a pile during forced air cooling. The average mass fraction of the pile is also drawn.

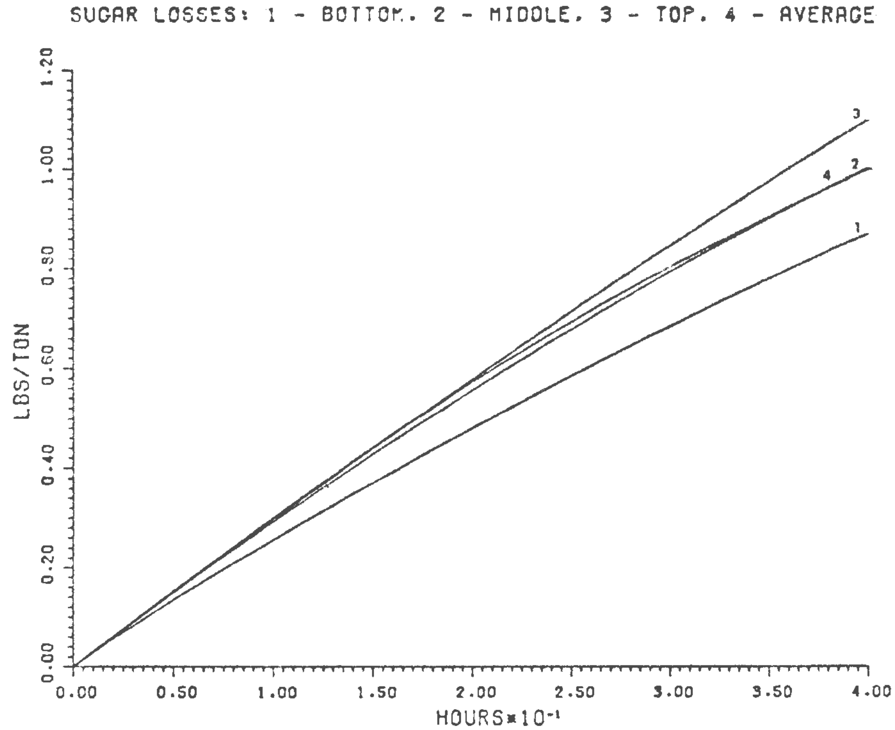

Figure 3. Simulated sugar losses of sugar beets at the bottom (0 ft), middle (5 ft), and top (10 ft) of a pile during forced air cooling. The average sugar loss of the pile is also drawn.

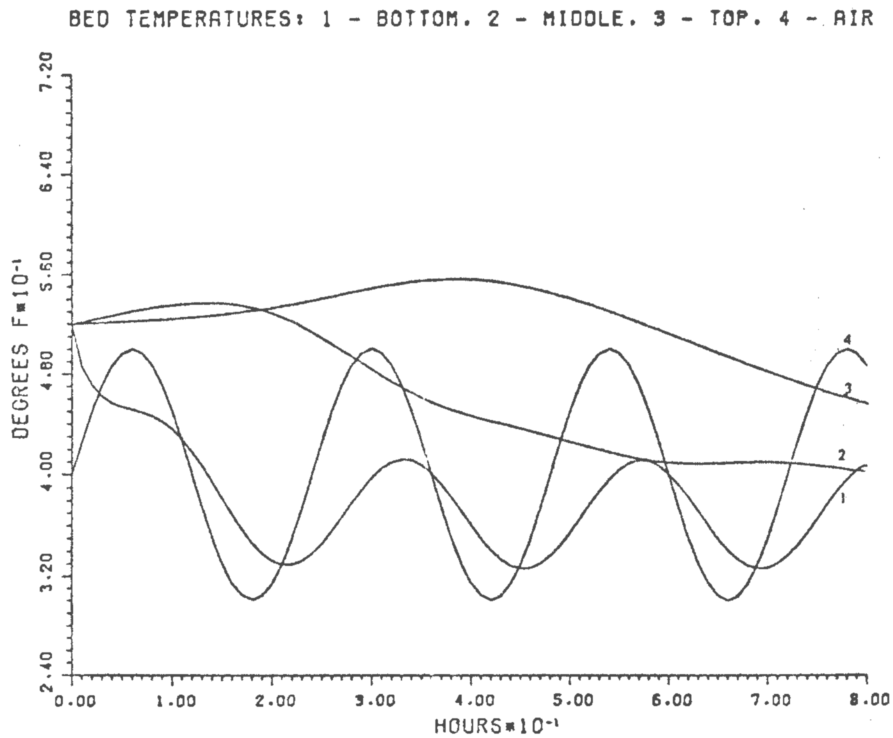

Figure 4. Simulated sugar beet and air temperatures at the bottom (0 ft), middle (5 ft), and top (10 ft) of a pile during forced air cooling.

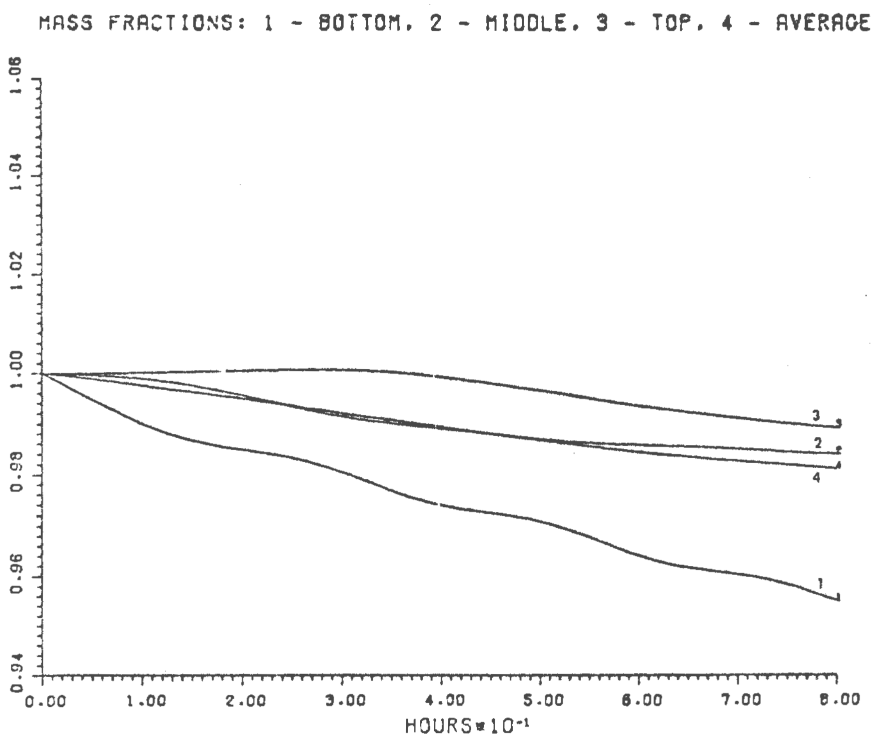

Figure 5. Simulated mass fractions of sugar beets at the bottom (0 ft), middle (5 ft), and top (10 ft) of a pile during forced air cooling. The average mass fraction of the pile is also drawn.

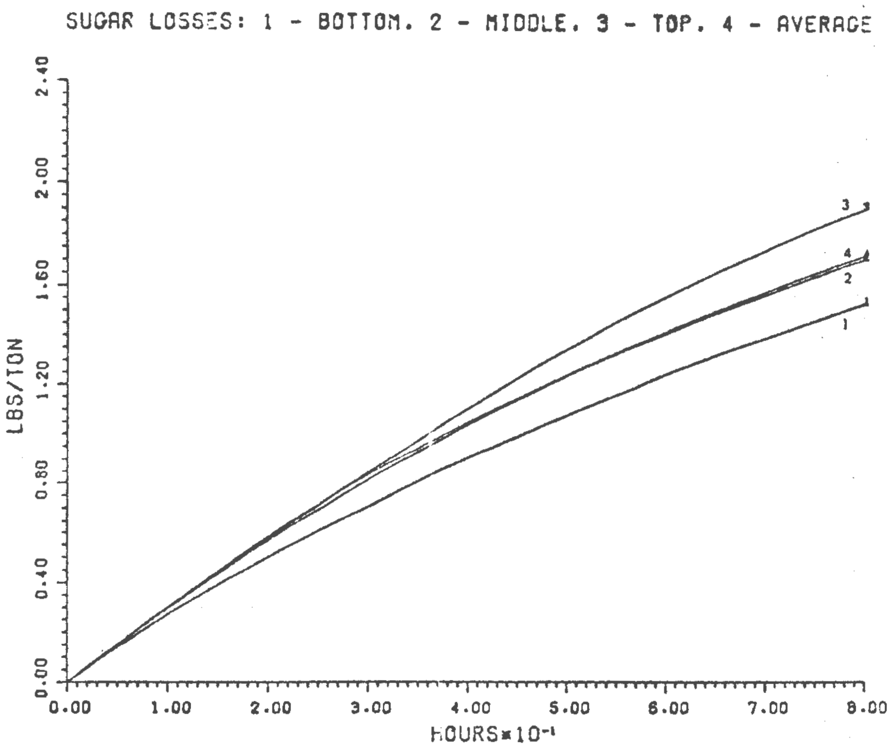

Figure 6. Simulated sugar losses of sugar beets at the bottom (0 ft), middle (5 ft), and top (10 ft) of a pile during forced air cooling. The average sugar loss of the pile is also drawn.

4. Time

5. Product - air temperature difference

6. Wind velocity

7. Rayleigh number

8. Discharge number

9. Pile air density

10. Atmospheric air temperature

11. Two and three factor interactions of the above

12. Second order powers of the above and two factor interactions.

The strongest relationship in the case of the average pile temperature proved to be one involving only the average daily air temperature:

$$TPROD = 11.90574235 + 2.82719594 * TAVE - .10297412 * TAVE^2 + .00128627 * TAVE^3$$

where

$$TAVE = \frac{TMAX + TMIN}{2}$$

and

TMAX = Maximum daily temperature, F

TMIN = Minimum daily temperature, F

Additional complete temperature histories which give temperature at various cross-sectional locations in the pile versus weather data are needed. Other data required are temperatures at 1/2-foot intervals for the first three feet of the rim and convective and forced (wind) air velocities on both side and the top of the pile. Some of these data will hopefully become available as a result of this conference.