Effect of Injury on Respiration Rates of Sugarbeet Roots*

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Introduction

When sugarbeets are first placed into storage, pile temperatures are the warmest and respiration rates are the highest (4, 6). Therefore, losses during the first weeks of storage may be an important part of the total losses incurred. Previous workers have shown the effects of mechanical damage and topping on respiration rates and on sucrose losses during extended storage (1, 2, 3, 4, 7), but little information is available on the relationship between injury and respiration immediately after harvest. The objective of this investigation was to determine the effect of harvest injury on respiration rates immediately after harvest and to determine the feasibility of using respiration as an injury index.

Materials and Methods

To determine the effects of normal harvest procedures on respiration, sugarbeet roots were randomly selected from various points in the harvest, handling, and piling process at the Fremont factory of the Northern Ohio Sugar Company. Sugarbeet roots from a single farmer were sampled 1) from

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the top of a load of beets (harvester with grab-roll screen); 2) after unloading over a grab-roll screen; 3) and after washing with a mechanical washer-piler. The mechanical washer was a modified grab-roll screen having small, rough protrusions on the surface of the rolls. These rolls inflicted severe abrasion wounds on the surface of the roots. As controls, roots from the same field were hand dug and washed with a hose and spray nozzle. A second control sample was taken from the grab-roll screen on the piler before the beets entered the washer. These roots were also hand washed. The roots were transported to East Lansing, Michigan, for respiration analysis. Respiration measurements were begun two days after harvest.

In a second experiment, the effect of temperature on the respiration rate of injured roots immediately after harvest was determined. Roots were hand harvested between 8 and 10 a.m. Root temperature was 15° C at the time of harvest. Injury was inflicted by dropping each root individually 150 cm onto an asphalt surface. Types of injury were surface abrasions and some cracking. The roots were placed in respiration chambers at 2 and 10° C and the first respiration measurements were made less than 6 hours after harvest. Temperatures were monitored with thermocouples inserted 3 cm into a root of representative size. Root temperatures stabilized at 10° C after 10 hours but required 16 hours to stabilize at 2° C.

In a third experiment, hand-dug roots were topped with a standard tare topper. Impact injury was inflicted by dropping a 2 kg weight from 61 cm onto the surface of the roots. Each root was impacted twice--once on each side. The respiration rate was then monitored at 10° C for 11 days.

In a fourth experiment, the effect of injury occurring in the harvesting and handling operation on respiration rates was determined by comparing 8 treatments. 1) Hand dug-untopped; hand harvested with only petioles removed;

2) Hand dug-topped; hand harvested with crowns removed; 3) Hand dug-machine topped; flailed and scalped with roto beater; 4) Hand dug-gouged; topped with standard tare machines and gouged 3 times (gouges were conic in shape, 25 to 40 mm deep and 40 mm in diameter); 5) Hand dug-through piler; roots passed across a standard piler after removal of the crowns with a standard tare machine; 6) Flat plate impact; beets were dropped 2 M onto a flat metal plate; 7) Mechanically harvested-off truck; lifter-load type harvester with samples collected from the top of the truck in the field; 8) Mechanically harvested-off pile; as in 7), beets passed across a standard piler and the roots collected from the storage pile.

Beets were obtained from the Beatrice station of U and I Sugar Company in Washington and transported to the Moses Lake research lab for analysis. Seven replications of each treatment with 7 to 10 kg per treatment were placed in plastic pails. Respiration rates were measured daily for 95 days. Temperature in the chamber was maintained at 2° C except for twice when mechanical difficulties caused the chamber temperature to increase.

Respiration rates were measured with an automated flow-through system. Samples of three to six beets with a total weight of 2.5 to 8 kg were placed in 24-liter, plastic pails. Air was introduced into each pail at a calibrated rate of 500 ml/min. The increase in carbon dioxide level of the air was determined with an infrared gas analyzer. All data were corrected to standard temperature and pressure and respiration rates were expressed as carbon dioxide produced per kilogram fresh weight.

Results

The respiration rates of roots sampled during the harvesting and handling process reflected the amount of injury inflicted (Figure 1). The hand-harvested roots with minimal injury (topped with a tare topper) had the lowest

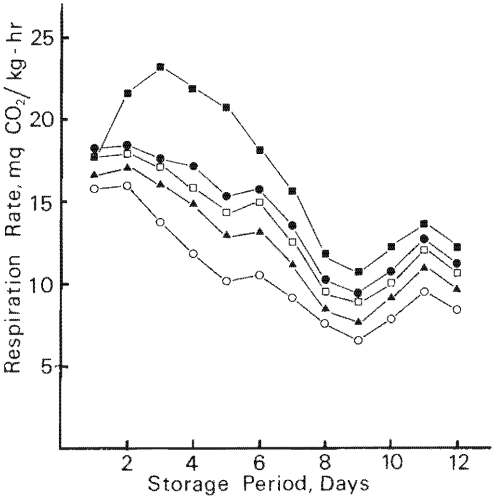

Figure 1. Respiration rate of sugarbeet roots subjected to various degrees of harvest and handling injury. Temperature, 10° C.

- ○ - hand harvested control
- ▲ - machine harvested (off top of truck)
- □ - roots collected after piler grab-roll screen
- ● - over piler grab-roll screen and hand washed
- ■ - roots collected in pile after machine washing

respiration rate, and the severely injured machine-washed beets had the highest. Each step in the handling process caused an incremental increase in respiration that was sustained throughout the 12 days at 10° C. These data indicated that the effect of injury existed well beyond the initial high respiration period. These data also indicated the sensitivity of respiration as an indicator of relative injury in sugarbeets.

When roots were placed in storage at 10° C, respiration rates increased rapidly to a maximum during the first 24 hours and then decreased to a stable rate after 11 days (Figure 2). The injured roots reached a peak 10 hours

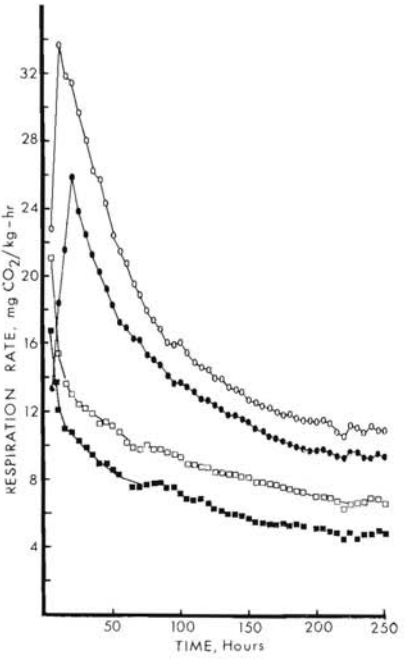

Figure 2. Effect of temperature and injury on the respiration rate of sugarbeet roots during the initial 250 hours after harvest. -○- 10° C, injured; -●- 10° C, uninjured; -□- 2° C, injured; -■- 2° C, uninjured.

before the uninjured controls and then their rate paralleled that of the controls. The injured roots were still respiring at a rate 25 percent higher than that of the hand-dug controls after 11 days.

At 2° C there was no apparent increase in respiration during the initial 24 hours, but approximately 10 days were required for the respiration rate to stabilize. After 10 days the injured roots were respiring at a rate 43 percent higher than that of the hand-harvested controls.

The effect of topping and impact damage on sugarbeet root respiration at 10° C is shown in Figure 3. Crown removal

greatly increased respiration rates during the first 96 hours of storage. However, after this time the topped roots respired at a lower rate than the untopped roots. Impact injury increased the respiration rate of topped and untopped roots by 5.6 and 8 percent, respectively.

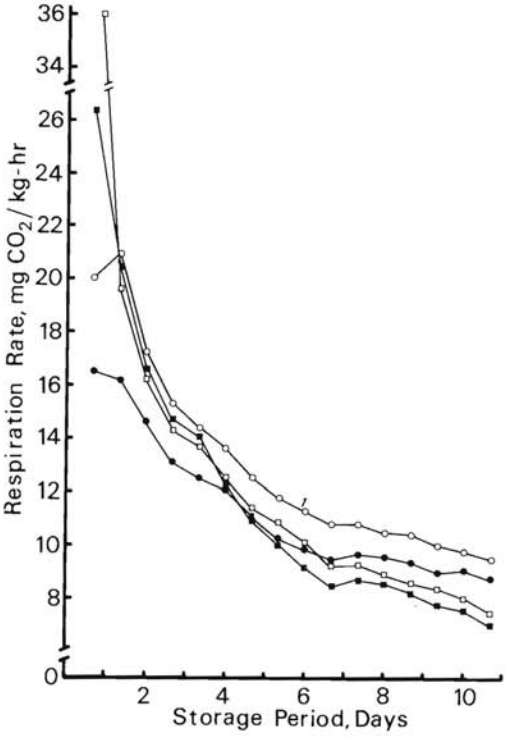

Figure 3. Effect of topping and impact injury on the respiration rate of sugar-beet roots at 10° C during the first 10 days of storage. -●- untopped, no impact; -○- untopped, impact injury; -■- topped, no impact; -□- topped, impact injury.

To determine why untopped roots respired at a higher rate than the topped roots, the respiration rate of topped and untopped roots and crowns was determined. Roots previously stored for 30 days at 5° C were used. Roots were topped by removing the crown at the lowest leaf scar. The crown

tissue removed represented 13.4 percent of the weight of the original root. Respiration rates were then determined at 5° C. The topped roots respired at a lower rate (4.49) than the untopped roots (5.09). The crown tissue respired at a rate approximately three-fold higher than that of the topped root (14.1 vs. 4.49). Therefore, the higher respiration rate of untopped roots can be explained by the high respiration rate of the crown tissue. The effect of topping injury can be estimated as follows:

(% weight of roots x resp. of roots) + (% weight of crown) x (resp. of crowns) = Total resp.

(4.49 x 0.866) + (14.1 x 0.134) = 5.78

5.78 - 5.09 = 0.69, or 14%

Therefore, topping increased respiration rates approximately 14 percent.

The increase in respiration due to the degree of damage and the effect of mechanical handling operations for the 95-day time period is shown in Figure 4. Figure 5 shows the average respiration rate for each treatment for the entire storage period. For the first 20 days the artificially damaged treatments had higher respiration rates than the rest of the samples. For the remainder of the storage period, samples taken from the storage pile and from the top of the truck had the highest respiration rates. Considering the severe damage inflicted to the beets in the artificial damage treatments, it is significant that the ordinary methods of handling beets resulted in even higher rates of respiration. Hand harvested samples either topped or untopped had consistently lower rates of respiration than the other treatments. The beets with crowns removed and otherwise undamaged generally had lower rates of respiration than those with the crowns intact, but the differences were not statistically significant.

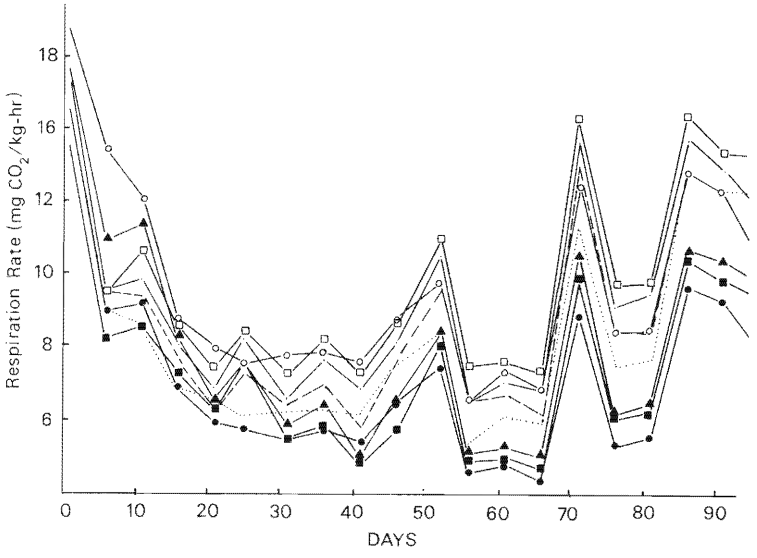

Figure 4. Effect of injury on respiration rate of sugarbeet roots during a 95-day storage period.

—— ○ ——	Flat plate impact
—— ● ——	Hand dug--topped
—— □ ——	Mechanically harvested--off pile
—— ■ ——	Hand dug--untopped
.....	Hand dug--through piler
- - - - - - - - - -	Hand dug--field machine topped
—— ▲ ——	Hand harvested--gouged
—— • ——	Mechanically harvested--off truck

Discussion

It was apparent that injury during harvest and handling had a significant effect on the respiration rate of sugarbeet roots during at least the first 10 days of storage. Injury as slight as dropping a 2 kg weight 60 cm onto the surface of roots was readily detectable, even on beets previously inflicted with topping injury. Therefore, respiration should be a useful technique for monitoring sources of injury in the handling of sugarbeets.

Injury to sugarbeet roots during harvesting, handling, and piling may have a significant effect on their ability for storage. Injury not only increases respiration rates

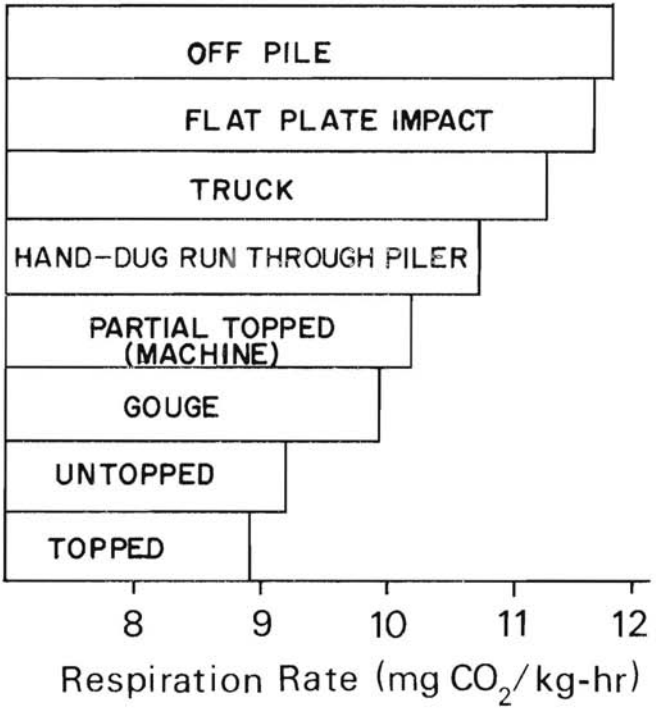

Figure 5. Average respiration rates for 8 injury treatments during 95-day storage period.

but also facilitates infection by fungal agents. Mumford and Wyse (5) found that the epidermal layer must be broken before infection by Penicillium or Botrytis can occur. Therefore, reducing surface injury to sugarbeet roots should significantly reduce sucrose losses resulting from respiration and mold growth during storage.

The respiration rate immediately after harvest is very important, not only as a factor in sucrose loss, but also as a producer of heat. This heat of respiration is a major source of heat that must be removed from a storage pile before it can be cooled significantly. The rate of cooling during this initial period can significantly contribute the total sucrose lost during the entire storage period (8).

The controversial question of whether it is better to remove the crown near the lowest leaf scar or to merely remove all green material was not clarified by this study. Crown removal by knife or tare machine increased respiration rates during the first 5-10 days of storage. However, after this time topped beets respired at a lower rate than did untopped beets. Apparently the higher respiration rate of the crown tissue had a greater effect after 5-10 days than did the increased respiration resulting from topping injury. When a field topper was used as in Experiment 4, even though hand harvested, the beets continued to respire at a high rate throughout the 95-day period. The reason for this conflict may be explained by the fact that the tare machine would inflict less damage and leave a smoother cut than the field topper. These results confirmed those of Akeson and colleagues (1) which indicated that mechanically topped roots respired faster than untopped roots during an entire 180-day period of storage.

Numerous studies have shown that, although the crown contains less sucrose and has a lower purity than the root, its contribution to recoverable sugar per acre can be considerable (3, 9). Stout and Smith (7) found that topped beets respired faster and spoiled quicker than untopped beets. The greatest spoilage was in beets topped near the center of the crown and resulted from exposure of the pith area to fungal organisms (1, 3).

Acknowledgements

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