Effect of Cultivar and Mechanical Damage on Respiration and Storability of Sugarbeet Roots[1]

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Introduction

Sucrose loss during post-harvest storage of sugarbeet (*Beta vulgaris* L.) roots is a major concern of the sugarbeet industry. During post-harvest storage, sucrose losses can amount to 0.25 kg ton^{-1} day^{-1} (0.5 lb/ton/day). Sucrose is lost during storage through respiration, raffinose synthesis, storage pathogens, and inversion to glucose and fructose. Further sucrose loss during processing increases with storage due to an increase in raffinose and invert sugars which causes an increase in the melassigenic factor.

Respiration by the sugarbeet root accounts for 50 to 60% of the sucrose loss during post-harvest storage (8).[3] Storage pathogens account for 10% of the loss in sucrose during storage in the Red River Valley of North Dakota and Minnesota (3). The objectives of this study were to compare sugarbeet cultivars and to determine the effects of mechanical damage during harvest on respiration and storability of sugarbeet roots.

Materials and Methods

Seed of commercial cultivars was planted at Fargo, ND, in 1973 and 1974 on a silty clay soil. Plots were maintained weed-free manually. Soil nitrogen levels in the upper 60 cm were 168 and 258 kg/ha in 1973 and 1974, respectively. Sugarbeet roots were harvested manually in 1973, and with the aid of a modified mechanical lifter in 1974. Crowns were not removed from the sugarbeets either year. The roots were washed and samples of 10 roots were stored at 5°C and near 100% relative humidity in perforated plastic bags.

After storage periods of 75 and 53 days in 1973 and 1974, respectively, respiration measurements were made on 6 samples of each cultivar in order to compare respiration rates of different cultivars. Respiration rates were monitored up to 150 days after harvest. Respiration measurements were made by placing the samples into respiration chambers and circulating air through the chambers at a flow rate of 300 ml/min. Flow rates were regulated with capillary flow boards. Air samples were removed with a syringe from the exit flow and injected into a gas chromatograph with a silica gel column for determination of CO_2 levels both years.

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[3]Numbers in parentheses refer to literature cited.

At harvest, and at 50-day intervals after harvest for 150 days, various quality components were determined on 10 samples of each cultivar. Sucrose was determined with a polarimeter by the cold digestion method (5), invert sugar by 3,5-dinitrosalicylic acid (2), amino acids by ninhydrin (7), sodium and potassium by flame photometry, and impurity index values by a formula of Carruthers, Oldfield, and Teague (4).

Respiration rates were determined for sugarbeet roots which were subjected to various mechanical operations during harvesting and piling in 1973 and 1974. For testing, sugarbeet roots were selected from commercial sugarbeet growers each year and divided into the following groups by harvesting method: (a) control plants that were lifted manually, leaf petioles trimmed at the base, and the terminal bud removed; (b) plants that were mechanically topped and lifted manually; (c) plants that were topped and lifted mechanically (in 1973 the roots were obtained after they dropped onto a truck and in 1974 the roots were dropped onto the ground); and (d) plants that were topped, lifted, and piled for storage mechanically. Samples were stored and analyzed as described above.

Results and Discussion

Respiration rates of sugarbeet roots increased significantly with time in storage both years (Table 1). Significant differences among cultivars were detected each year (Table 2), but no significant storage by cultivar interaction was observed either year. This indicates that it is not necessary to monitor respiration rates over the entire storage period to detect significant differences among cultivars. Cultivars remained in relatively the same ranking both years except for 'American 4 Hybrid A.' The relative stability in rankings over years indicates that environmental influences during growth of the sugarbeet roots

Table 1. — Effect of time in storage on respiration rates of sugarbeet roots averaged over 6 cultivars during 2 storage periods.

Storage Periods			
1973-74		1974-75	
Days after harvest	Respiration rate	Days after harvest	Respiration rate†
	ml CO_2 kg^{-1} hr^{-1}		ml CO_2 kg^{-1} hr^{-1}
75	1.31	53	2.09
98	1.43	67	1.91
116	1.73	80	2.16
126	2.32	94	1.99
146	2.39	108	2.08
		122	2.11
		137	2.43
		150	2.60
LSD 0.05	0.14		0.11

†Averaged over all cultivars.

Table 2. — Respiration rates of sugarbeet cultivars during two storage periods.

*Cultivar	Storage period †1973-74	‡1974-75
	ml CO_2 kg^{-1} hr^{-1}	
American 4 Hybrid A	1.69	2.65
American 2 Hybrid B	2.06	2.44
American 4 Hybrid T	2.16	—
Holly HH 21	—	2.11
Beta 93	1.74	1.96
Beta 1224	—	1.81
Bush-Mono	1.68	—
Mono-Hy D2	1.68	1.70
LSD 0.05	0.16	0.14

*Average of 6 samples of each cultivars.
†Averaged over 5 sampling times from 75 to 146 days after harvest.
‡Averaged over 8 sampling times from 53 to 150 days after harvest.

Table 3. — Effect of cultivar and time in storage on apparent sucrose, invert sugar, and impurity index values of sugarbeet roots during two storage periods.

Parameter	Apparent sucrose, % 1973-74	Apparent sucrose, % 1974-75	Invert sugars, mg g^{-1} 1973-74	Invert sugars, mg g^{-1} 1974-75	Impurity index 1974-75
Cultivar					
American 4 Hy T	12.7†	—	1.7	—	--
Mono-Hy D-2	12.1	12.7	1.6	2.6	789
Beta 93	12.1	12.9	1.8	2.9	949
American 2 Hy B	11.7	12.7	1.9	3.0	875
American 4 Hy A	11.6	13.7	3.0	4.1	793
Bush-Mono	11.0	—	2.3	—	—
Beta 1224	—	14.0	—	3.1	811
Holly HH 21	—	13.1	—	2.5	845
LSD 0.05	0.3	0.2	0.3	0.3	32
Days in storage					
0	12.4‡	13.5	1.3	2.6	847
50	12.1	13.4	1.6	2.5	831
100	11.9	13.4	2.4	3.6	822
150	11.1	12.4	3.0	3.5	874
	0.3	0.2	0.3	0.2	32

†Averaged over 150 days of storage.
‡Averaged over all cultivars.

have less influence in determining post-harvest respiration rates than genetic differences. The planting date in 1974 was 30 days later than in 1973, which may have influenced the change in the ranking of American 4 Hybrid A.

Significant differences in sucrose content were evident among cultivars, and sucrose levels decreased significantly during storage (Table 3). The cultivar by time in storage interaction for sucrose content was nonsignificant both years. Average apparent sucrose was 11.9 and 13.2 percent in the 1973-74 and 1974-75 storage periods, respectively. Environmental conditions during the 1974 growing season compared to conditions in 1973 must have been better suited to sucrose accumulation since the growing season was 30 days shorter in 1974.

Invert sugar contents in sugarbeet roots were the lowest at harvest and increased with time in storage (Table 3). Cultivars differed in invert sugars averaged over the storage period, but the interaction between cultivars and time in storage for invert sugar content was nonsignificant. Average invert sugar levels were 33% higher in the 1974-75 than in the 1973-74 storage period. The increase was probably from the 13% increase in respiration rates, averaged over all cultivars, and the late seeding in 1974 which delayed maturity of the plants.

Cultivars differed significantly in impurity index values in the 1974-75 storage period. Impurity index values give a general indication of processing quality of the roots. The lower impurity index values indicate the best cultivars for processing.

Respiration rates of sugarbeet roots were significantly increased by the level of mechanical damage during harvest and storage of the roots (Table 4). In general, respiration rates increased each time the beets were subjected to a mechanical operation. In the 1974-75 storage period, some difficulty in obtaining a uniform and representative sample after piling was encountered, which may have accounted for the respiration rate of damage level 4 being significantly lower than damage level 3 (Table 4). For example, the roots selected for damage level 4 in 1973-74 were from a small load (2 tons) compared to the larger load (16 tons) in 1974-75.

Apparent sucrose was significantly affected by damage level in 1973-74 (Table 5). The control (damage level 1) had the highest average sugar content in 1973-74 and no significant interaction for sucrose content between damage level and time in storage was evident either year.

Table 4. — Respiration rates of sugarbeet roots during two storage periods of 150 days duration subjected to various mechanical operations during harvest.

Treatment*	Storage period 1973-74	Storage period 1974-75
	ml CO_2 kg^{-1} hr^{-1}	
1	1.99†	1.57‡
2	2.06	1.79
3	2.32	2.04
4	2.47	1.88
LSD 0.05	0.22	0.13

*1) Control, non-topped, lifted manually; 2) mechanically topped, lifted manually; 3) topped and lifted mechanically, obtained off truck in 1973 and roots dropped to ground in 1974; 4) collected after piling.

†Averaged over 5 sampling times from 53 to 146 days after harvest.

‡Averaged over 10 sampling times from 40 to 150 days after harvest.

Table 5. — Effect of damage level on apparent sucrose, invert sugars, and impurity index values of sugarbeet roots during two storage periods of 150 days.

	Apparent sucrose, %		Invert sugars, mg g^{-1}		Impurity index
Parameter	1973-74	1974-75	1973-74	1974-75	1974-75
Damage level					
1	16.0	14.5	0.9	2.3	582
2	15.8	14.4	0.8	2.5	613
3	15.4	14.2	1.0	3.0	683
4	15.0	14.5	1.1	2.5	637
LSD 0.05	0.3	ns	0.1	0.2	51

Invert sugars were significantly increased as the number of mechanical operations the roots were subjected to increased (Table 5). Visual estimates indicated that the roots with damage level 1 had less decayed tissue than roots from the other damage level treatments. Other researchers (1, 6) have concluded that exposing the crown area by topping increases the root susceptibility to decay by storage pathogens. Thus, the observed increase in invert sugars may not be the result of mechanical damage *per se*, but the result of the metabolic action of pathogens invading the mechanically damaged root tissues. The respiration rates, also, were significantly higher in roots that were harvested mechanically in this investigation.

The results of this study indicate that cultivars and mechanical damage can significantly affect the storability of sugarbeet roots for a period of 150 days after harvest. Cultivars that exhibit desirable storage characteristics, low invert sugar accumulation, and low impurity index values can be selected for storage and processing. Selecting for these initial qualities may be offset by losses caused by rough handling during harvest and storage of the roots. Also, partial removal of the crown increases respiration and susceptibility to storage pathogens.

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