Effect of Topping Procedure on Beet Quality and Storage Losses

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Numerous papers have been published regarding the effect of topping on yield, sugar content, purity, and impurity components of beets grown in various parts of the world (1, 4, 7, 12, 10, 15)[2]. These studies showed that sucrose is lower while mineral, invert sugar, and organic nitrogen compounds are higher in the crown than in the root; and so untopped beets have lower sugar percentage and purity than topped beets.

Stout (13) reported that beets severed into top and bottom halves before storage respired and spoiled more rapidly than beets stored intact. Dexter, et al. (7, 8) likewise found that spoilage and storage losses were greater in topped than in untopped beets. The same team also reported that more extractable sugar was harvested per acre from untopped beets than topped beets. Zielke (15) showed in Michigan studies that crowns when separated from the roots at the lowest leaf scar account for 20 percent of the total weight of the whole beets and about 16 percent of the recoverable sugar produced per acre.

The reported studies show that untopped beets produce more sugar per acre and have lower storage losses than topped beets even though the quality of the untopped beets is lower. The purposes of the studies reported herein were first to determine whether topping procedures would have the same effect on beets from throughout Great Western growing areas; and second, to determine whether the same differences in storage loss between topped and non-topped beets occur when they are machine harvested and stored in commercial piles as was reported from hand dug beets stored in laboratory tests.

Methods and Materials

Beets used in laboratory storage studies in 1970 and pile studies in 1971, 1972, and 1973 were machine harvested from commercial fields after having been flailed to remove petiole and leaf material. The machines used to defoliate the beets had one set of steel flails followed by two sets of rubber flails rotating in opposite directions. Scalper knives were set to remove the crown bud and leave a cut about

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[2]Numbers in parentheses refer to literature cited.

one inch in diameter. All beets for a given test were harvested from the same field. The beets for the 1970 laboratory study were harvested from a field near Greeley, Colorado. Beets for the remainder of the tests, except for the Lovell, Wyoming test, were taken from commercial fields near Longmont, Colorado. A 1971 laboratory test used beets of five varieties (Mono-Hy A-1, Mono-Hy D-2, Mono-Hy E-2, and two experimental varieties) which were grown near Longmont, Colorado. These beets were hand harvested and the leaves, petioles, and apical buds were removed by hand leaving a cut area about one inch in diameter.

Beets were sorted so that large, small, damaged or abnormal individuals were eliminated, then they were divided into two or three lots. One lot was crowned by hand at the lowest leaf scar and a second lot was left non-crowned. In one series of tests, a third lot of beets was topped so that only half the crown was removed. Topped beets for the 1973 tests were machine topped before harvest.

Samples for test storage in commercial piles weighed 25 to 30 pounds each and were made up from one lot of beets. They were put into nylon net bags, closed with a numbered, four inch safety pin for identification, and weighed to the nearest 0.1 pound. A group of four samples was put on a nylon cord and placed into a section of a pile as it was being filled. The end of the cord was tied to an iron stake driven into the top of the pile. All samples for a given pile were put in during a single day. Fifty samples of each topping treatment were placed on each pile. Duplicate samples of each lot of beets were analyzed immediately for sugar (2) and clear juice purity (3). Juice samples were frozen for later raffinose (11) and invert sugar analysis (5). The captive samples were recovered when the pile was reloaded and then weighed and analyzed in the same manner as the duplicate samples analyzed earlier. Raffinose and invert sugar determinations were used to correct the apparent sucrose and clear juice purity (6). Recoverable sugar was calculated from corrected sucrose and clear juice purity using the Great Western formula (14).

Samples for laboratory studies were prepared in a manner similar to that described for the pile studies except that they were washed before storage. Three samples of the same treatment were placed in respiration chambers in a controlled temperature room. The room temperature was programmed to simulate internal pile temperatures as shown in Figure 1. In the initial study (1970-71), twenty-seven samples of each treatment were put into the respiration chambers. Nine samples per treatment were removed after 35, 92 and 181 days for analysis. In 1971-72 nine samples of each variety and treatment were placed in respiration chambers for 41 days after which they were stored in a humidified root cellar for an additional 65 days.

Respiration measurements were made daily in the following manner: Air which had been humidified and scrubbed clean of carbon

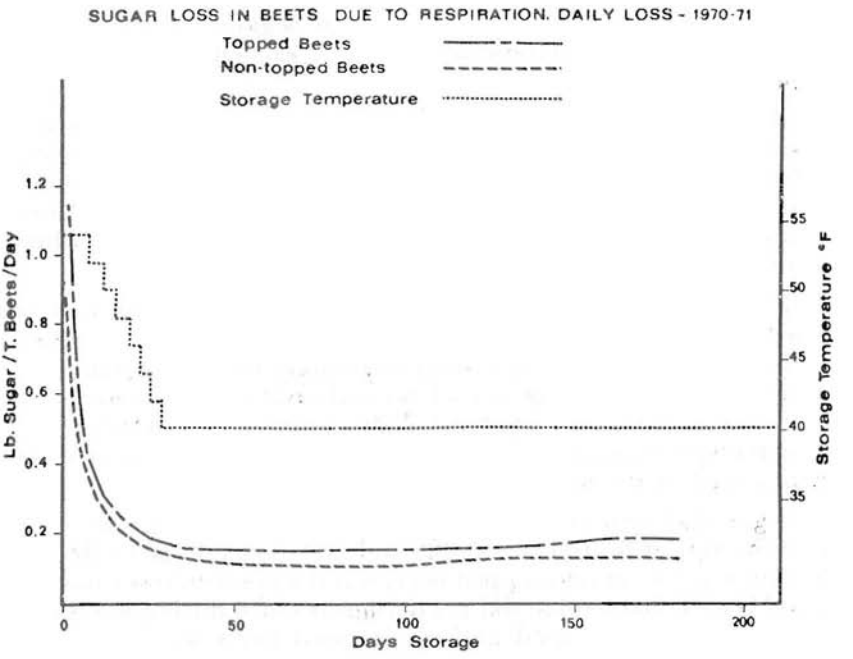

Figure 1.—Daily loss of sugar due to respiration in topped and non-topped beets stored under controlled laboratory conditions.

dioxide flowed through chambers containing beets, flushing out the carbon dioxide given off by respiration of the beets. The carbon dioxide was captured in a 1 N sodium hydroxide solution and then determined by back titration with 0.5 N hydrochloric acid to phenolphthalin and methyl orange endpoints.

A survey was conducted in 1971 to determine the proportion of weight, sugar, and recoverable sugar in the root and crown in beets grown in the various areas of the company. Twenty beet samples were dug from each of ten fields in each factory district. The crowns were removed at the lowest leaf scar and weight and sugar percent of root and crown portions of each sample were measured. Juice from the brie remaining after the sugar determination was mixed with calcium hydroxide (one gram per 50 ml juice) and stored at 3°C for later determination of clear juice purity.

Results and Conclusions

Continuous daily respiration rates of topped and non-topped beets are shown in Figure 1. Data were originally measured as mg CO_2 released per hour per kg of beets but were converted to the equivalent pounds of sugar per ton of beets per day so that results could be compared with actual rate of sugar loss. The respiration rates of both

topped and non-topped beets were high at the beginning of the storage period but declined until constant rates were reached after thirty days of storage.

Dilley, et al. (9) also reported that a high respiration rate occurs immediately after harvest followed by a rapid decline until a constant rate is reached. The steady respiration rates were only 10 to 15 percent of the rates observed immediately after harvest. Respiration rates remained constant until the latter part of the storage period when slight increases were recorded.

The respiration rate of non-topped beets was less than that in topped beets for the entire storage period. Initially, the difference in respiration was caused by wound respiration from the freshly cut surface. Later in the storage period, rot and mold was observed on the cut surface and around exposed hollow crowns which likely caused the high respiration rate later in the storage period. Little rot or mold was observed on the non-topped beets.

Sugar and recoverable sugar losses, like respiration rate, were higher in topped beets after 35, 92, and 180 days storage (Table 1). Clear juice purity in non-topped beets was 0.9 percent lower than in topped beets at harvest but did not decline as much during storage so that the purity of topped and non-topped beets was essentially identical after 181 days.

In 1971-72, a laboratory study was carried out in which the respiration rate, sugar loss, and invert sugar accumulation were measured in topped and non-topped beets of five commercial and semi-commercial varieties (Table 2). The respiration rate was an average for the first 41 days of storage while the sugar loss and invert sugar accumulations were measured after 106 days of storage. Mechanical problems in the laboratory prevented the purity determination. As in the previous year, respiration and sugar loss averaged higher in the topped than in non-topped beets. Analysis of variance of both respiration rate and sugar loss showed that differences between topping procedures were significant at the five percent level while variety differences were significant at one percent. The invert sugar accumulations were numerically higher in topped beets of all varieties but the difference was not significant at five percent. On the other hand, highly significant differences existed between varieties in level of invert sugar formation. Numerically, differences between varieties in respiration, sugar loss, and invert sugar formation were greater than differences in topping procedure.

Laboratory studies confirmed the findings of other investigators (7, 8, 13) that sugar losses during storage are less in non-topped beets than in topped beets. All of these studies were carried out under laboratory storage conditions which may or may not simulate actual pile conditions. Results of five tests in which beets with various degrees

Table 1.—Effect of topping procedure on respiration, sugar loss and accumulation of impurities in beets stored under laboratory conditions for various lengths of time, 1970-1971.

Treatment	Storage Period Days	Average Respiration Rate Lb/T/D	Sugar Loss Lb/T/D	Recoverable Sugar Loss Lb/T/D	C J Purity %	Invert Sugar g/100 RDS
		Mean ± S.E.	Mean	Mean	Mean	Mean
Non-topped	0	--	--	--	92.1	0.52
Topped	0	--	--	--	93.0	0.55
Non-topped	35	0.265 ± 0.029	0.289 ± 0.080	0.429 ± 0.070	90.9	1.62
Topped	35	0.335 ± 0.040	0.357 ± 0.070	0.500 ± 0.060	91.6	2.60
Non-topped	92	0.173 ± 0.013	0.201 ± 0.070	0.270 ± 0.050	90.3	1.33
Topped	92	0.228 ± 0.018	0.272 ± 0.030	0.312 ± 0.030	90.7	1.29
Non-topped	181	0.152 ± 0.007	0.213 ± 0.030	0.260 ± 0.030	88.4	1.87
Topped	181	0.200 ± 0.009	0.301 ± 0.030	0.393 ± 0.030	88.2	4.37

Table 2.—Effect of topping procedure on storage loss and factors affecting storage loss in five commercial and semi-commercial varieties during 106 days storage, 1971-1972.

Variety	Treatment	Respiration Rate Lb/T/D	Sugar Loss Lb/T/D	Invert Sugar Accumulation g/100 RDS
Mono-Hy A-1	Non-topped	0.256 ± 0.016	0.190 ± 0.052	0.33
	Topped	0.286 ± 0.017	0.237 ± 0.050	1.32
Semi-commercial A	Non-topped	0.263 ± 0.016	0.170 ± 0.018	0.79
	Topped	0.263 ± 0.016	0.179 ± 0.045	1.09
Mono-Hy D-2	Non-topped	0.251 ± 0.017	0.195 ± 0.020	0.17
	Topped	0.262 ± 0.018	0.249 ± 0.027	0.51
Mono-HY E-2	Non-topped	0.295 ± 0.015	0.303 ± 0.046	2.20
	Topped	0.324 ± 0.016	0.428 ± 0.068	2.30
Semi-commercial B	Non-topped	--	0.505 ± 0.092	3.17
	Topped	--	0.578 ± 0.090	3.37
Avg. All Varieties	Non-topped	0.284	0.334	1.72
	Topped	0.266	0.273	1.33

of topping were stored as captive samples in commercial piles are given in Table 3. Sugar and recoverable sugar losses averaged 12.6 and 11.3 percent less respectively in non-topped beets than in beets topped to the lowest leaf scar. In each test losses were numerically, but not always statistically, less in the non-topped beets. In three tests, a third group was included in which beets with half the crown removed were compared with non-topped beets and topped beets. Sugar and recoverable sugar losses in the half-topped beets were as high as or higher than in the topped beets. The hollow crown was normally exposed in the half-topped beets but often completely removed with the topped beets. Since the hollow crown area is most susceptible to rots and molds, higher storage loss could occur when this area is exposed.

Quality of the non-topped beets was lower than that of the topped beets at harvest but the difference was not as great after storage. Topped beets initially were 0.25 and 0.46 percent higher in sugar and purity respectively than non-topped beets; but after storage the respective differences were 0.15 and 0.25 percent. Quality of the half-topped beets was nearly equal to that of the topped beets at harvest. Degree of topping had little effect on invert sugars at harvest or raffinose at harvest or after storage. However, as in the laboratory tests, more invert sugars accumulated in the topped than in non-topped beets (0.62 g/100 RDS vs 0.43 g/100 RDS).

The relative effect of degree of topping on tonnage and sugar production per acre at harvest and after storage for beets in the Longmont, Sterling and Mitchell tests is summarized in Table 4. Non-topped beets had 8.2 percent more tonnage than topped beets but, because of lower quality, the former produced only 5.3 percent more recoverable sugar per acre at harvest. Half-topped beets yielded 4.5

Table 3.—Effect of topping procedure on weight, sugar and recoverable sugar losses in beets stored as captive samples in commercial piles.

Location	Treatment	Storage Period Days	LOSS — Lb/T/D		
			Weight Loss Mean ± S.E.	Sugar Loss Mean ± S.E.	Recoverable Sugar Loss Mean ± S.E.
Longmont	Non-topped	98	1.500 ± 0.099	0.310 ± 0.020	0.276 ± 0.022
1971-72	Topped	98	1.940 ± 0.160	0.403 ± 0.030	0.357 ± 0.027
Longmont	Non-topped	124	0.564 ± 0.067	0.268 ± 0.014	0.352 ± 0.012
1972-73	Half topped	124	0.716 ± 0.084	0.281 ± 0.016	0.370 ± 0.014
	Topped	124	0.724 ± 0.108	0.332 ± 0.019	0.438 ± 0.017
Sterling	Non-topped	96	0.295 ± 0.098	0.204 ± 0.027	0.367 ± 0.022
1972-73	Half topped	96	0.501 ± 0.055	0.290 ± 0.024	0.452 ± 0.020
	Topped	96	0.550 ± 0.095	0.249 ± 0.025	0.400 ± 0.020
Mitchell	Non-topped	117	0.918 ± 0.115	0.243 ± 0.030	0.375 ± 0.025
1972-73	Half topped	117	0.940 ± 0.088	0.316 ± 0.024	0.451 ± 0.020
	Topped	117	0.896 ± 0.084	0.257 ± 0.018	0.383 ± 0.016
Lovell	Non-topped	130	0.866 ± 0.053	0.287 ± 0.013	0.370 ± 0.010
1972-73	Topped	130	0.850 ± 0.040	0.313 ± 0.011	0.392 ± 0.008
Eaton	Non-topped	89	2.148 ± 0.134	0.367 ± 0.021	0.458 ± 0.014
1973-74	Topped	89	1.987 ± 0.062	0.369 ± 0.016	0.518 ± 0.010
Longmont	Non-topped	99	1.336 ± 0.123	0.231 ± 0.023	0.387 ± 0.018
1973-74	Topped	99	1.544 ± 0.175	0.269 ± 0.032	0.392 ± 0.026
Goodland	Non-topped	108	1.399 ± 0.107	0.257 ± 0.022	0.231 ± 0.019
1973-74	Topped	108	1.658 ± 0.116	0.284 ± 0.019	0.292 ± 0.016
Average	Non-topped	107.6	1.128	0.271	0.352
all tests	Topped	107.6	1.268	0.310	0.397
Average	Non-topped	112.3	0.592	0.238	0.364
Longmont,	Half topped	112.3	0.719	0.296	0.424
Sterling,	Topped	112.3	0.723	0.279	0.407
& Mitchell 1972-73					

Table 4.—Effect of topping on beet quality before and after storage as captive samples in commercial piles.

Tests	Treatment	Sugar — %		Purity — %		Invert Sugars g/100 RDS		Raffinose g/100 RDS		Proportion of Whole Root Removed—%
		In	Out	In	Out	In	Out	In	Out	
Average — Eight	Non-topped	16.92	16.45	91.84	89.75	0.47	0.90	0.59	1.13	--
Pile Tests	Topped	17.17	16.60	92.30	90.00	0.48	1.10	0.58	1.12	--
Average — Longmont,	Non-topped	18.37	17.71	94.46	91.91	0.56	0.68	0.34	0.88	0
Sterling & Mitchell	Half-topped	18.63	17.84	94.94	92.23	0.59	0.82	0.33	0.96	4.46
1972-1973	Topped	18.67	17.92	95.01	92.26	0.56	0.86	0.33	1.01	8.19

and 4.2 percent respectively more tonnage and sugar per acre than topped beets at harvest. Recoverable sugar yield per acre in non-topped beets after storage was 3.5 and 7.2 percent higher respectively than in the half-topped or topped beets (Table 5). These data suggest that most efficient production of sugar would be obtained from half-topped beets at harvest and for short storage periods and from non-topped beets for the longer storage periods.

Table 5.—Relative recoverable sugar per acre in non-topped, half topped, and topped beets at harvest and after storage of 112 days.

Treatment	(*) Yield Per Acre Harvest	(†) Recoverable Sugar Per Acre	
		Harvest Time	After Storage 112 Days
Non-topped	108.2	105.3	94.1
Half topped	104.5	104.2	90.9
Topped	100.0	100.0	87.8

*Yield (beet weight) per acre relative to topped beets.
†Recoverable sugar per acre relative to topped beets at harvest.

Differences in beet quality between topped and non-topped beets used in the storage study may have been less than normally occurs. A survey of beets sampled from ten fields in each of the Great Western factory districts in 1971 showed that the non-topped beets were 0.38 (vs 0.25) percent lower in sugar and 0.68 (vs 0.46) percent lower in purity than in beets topped to the lowest leaf scar (Table 6). In that survey the crown accounted for about 15.7 percent of total root weight but only 13.7 percent of the sugar and 12.4 percent of the recoverable sugar present in the whole beet.

The studies reported in this paper show that storage losses would be 10 to 15 percent less and recoverable sugar production per acre would be 5 to 10 percent more if beets were harvested without crown removal than if conventionally topped. The lower quality of non-topped beets would decrease the operating efficiency of the factories, and so we must conduct further studies to determine whether additional income resulting from reduced storage loss and higher total yield of sugar will be greater than additional factory costs.

Summary

Three years' tests in which captive samples of flailed, non-topped beets and beets topped to the lowest leaf scar were stored in commercial beet piles showed that non-topped beets lost 12.6 and 11.3 percent less sugar and recoverable sugar respectively than did topped beets. These results were in general agreement with two years of tests under laboratory storage conditions. Beets which had half the crown removed had storage losses equal to or greater than fully topped beets.

Non-topped beets had lower sugar (0.25 to 0.38%) and lower purity (0.46 to 0.68%) than topped beets at harvest. Half-topped beets were nearly equal in sugar and purity to topped beets.

Table 6.—Summary of crown — root study — freshly harvested beets, 1971.

	Average Great Western	Average Northern Ohio
No. Samples (20 Beets per Sample)	**172**	**20**
Percent Sugar		
A. Root	15.74	15.86
B. Crown	13.21	13.90
C. Whole Beet	15.36	15.58
D. Root — Whole Beet	0.38	0.28
Percent Purity		
A. Root	90.21	90.88
B. Crown	85.89	90.20
C. Whole Beet	89.53	86.22
D. Root — Whole Beet	0.68	0.68
Pounds of Sugar per Ton of Beets		
A. Root	314.6	317.2
B. Whole Beet	307.2	311.6
C. Root — Whole Beet	7.4	5.6
Pounds of Recoverable Sugar per Ton		
A. Root	253.3	259.2
B. Whole Beet	242.8	250.2
C. Root — Whole Beet	10.5	9.2
Distribution of Weight		
A. Root (percent of whole beet)	84.3	85.5
B. Crown (percent of whole beet)	15.7	14.5
Distribution of Sugar		
A. Root (percent of whole beet)	86.3	87.0
B. Crown (percent of whole beet)	13.7	13.0
Distribution of Recoverable Sugar		
A. Root (percent of whole beet)	87.6	88.4
B. Crown (percent of whole beet)	12.4	11.6

Five to 10 percent more recoverable sugar would be harvested per acre if beets were flailed and not topped than if they were topped to the lowest leaf scar.

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