Effect of Pile Covering on Weight and Sugar Shrink in Pile Rims

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Deterioration of sugarbeets from dehydration and from alternate freezing and thawing occurs in the rims (outer two to three feet) of storage piles in the western United States. Early work by Pack (7)[2] and a number of European workers (8) showed that increased sugar losses are associated with dehydration. Dexter, et al. (4) investigated the loss of extractable sugar per ton of harvested beets when wilted at various temperatures in the laboratory without freezing and compared this with losses occurring in the outer portions of commercial piles. Wilting of beets resulted in a substantial increase in loss of extractable sugar, especially at high temperatures. Extractable sugar losses were higher in beets stored near the surface of the pile than in beets in refrigerated storage. Loss of sugar was nearly three times higher in the outer foot and nearly two times higher in the second foot than in the interior of the pile. These data gave evidence that total sugar loss could be substantially reduced if the rims were protected to reduce dehydration and alternate freezing and thawing in the rim. The purposes of the studies described in those papers were first to determine loss of sugar and extractable sugar in the rim of the piles for various lengths of time relative to loss in protected beets; and second, to determine the effectiveness of various types of covers in reducing loss.

Materials and Methods

The studies were carried out in 1970-71 and 1971-72 on an east-west oriented pile east of Ft. Collins, Colorado and a north-south oriented pile south of Greeley, Colorado. Fifteen beet samples were prepared from three loads of beets which were commercially topped and harvested from a single field. Abnormally large or small beets were excluded to reduce variability. Approximately one-half of the beets were rejected in this selection process. The beets had less than 0.5 percent dirt tare and so were not washed. Any remaining leaf or petiole material was cut from the beets. One of each four samples assembled was placed in a rubberized beet bag for immediate analysis and the remaining three samples which were to be placed in the pile were put into nylon net bags and closed with a numbered steel pin.

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[2]Numbers in parentheses refer to literature cited.

Analyses of percent sugar by a modified Sachs-le Docte (1) and clarified juice purity by a modification of Carruthers (2) were made without top taring before storage and on each date of removal. Analyses of invert sugars determined with the tetrazolium method (3) and of raffinose with the galactose oxidase method (6) were made on the clarified juice. Raffinose and invert determinations were used to correct apparent sucrose and apparent clear juice purity with the Great Western formula (9).

In 1970 each pile was divided into 75-foot sections which were to be covered in the following manner:

I. No cover on top and sides.
II. Woven polypropylene on sides and no cover on top.
III. Six inches of straw on sides and two inches of straw on top.
IV. Six inches of straw plus woven polypropylene on sides and no cover on top.
V. 18 inches of straw on sides and six inches of straw on top.

Tests were set up in the same manner in 1971 except that a loosely woven polypropylene cover was put on top of Section II and no cover was put on top of Section V.

Samples to be placed in the side rims were attached together in series of three with one-fourth inch nylon cord which was tied to an iron stake at the top of the pile. Each sample was buried an average of one foot below the surface. The three samples on a cord were spaced equidistant on the side. Series of three samples were equally spaced across the top of the pile and buried just below the surface. Thirty-six samples were placed on each side or top of each section with exception of Section IV which had 12 samples in each side. A total of 420 samples were buried in each of the two piles.

The samples were weighed to the nearest 0.1 pound before placement and after removal. One-third of the samples in Sections I, II, III and V were removed at each of three dates which were approximately 26, 49 and 71 days after placement. Samples were removed from Section IV at the final removal date.

In order to determine the loss in beets protected from freezing and thawing, 108 samples were enclosed in polyethylene bags to prevent dehydration and were stored under controlled temperature conditions to simulate conditions inside a pile. Temperatures were set at 55 degrees F. initially and gradually reduced to 40 degrees F. in 30 days and were left at 40 degrees F. after that. Thirty-six samples were taken for analysis on each date that samples were removed from the pile rims.

Results and Discussion

The loss as pounds per ton per day of weight, sugar, and recoverable sugar in the rim under the various treatments for the three dates

of removal is summarized in Table 1 for the 1970-71 tests. Weight, sugar, and recoverable sugar losses were significantly less in all side cover treatments at all dates than for their respective non-covered comparisons. The top cover (both 2" and 6" of straw) significantly reduced weight loss at all three dates and sugar and recoverable sugar losses at 49 and 70 days. At 27 days, losses under the top cover appeared to be less than in the non-covered comparison but the difference was not statistically significant. No differences were observed between the 2" and 6" top covers. Beets in the interior of the pile under the 6" top cover were several degrees warmer than the interior beets under the 2" top cover and no cover and so the 6" top cover may have an adverse effect upon storage. With exception of recoverable

Table 1.—Summary of weight, sugar and recoverable sugar losses in rim (outer 2') of piles, 1970-71.

Storage Period	Treatment	Loss as Lb/T/Day		
		Weight Loss	Sugar Loss	Rec. Sugar Loss
(Days)				
27	No cover-sides	21.57 a*	0.871 a	0.986 a
	6" straw-sides	10.41 b	0.229 b	0.447 b
	18" straw-sides	9.21 b	0.226 b	0.416 b
	plastic-sides	11.26 b	0.159 b	0.324 b
	No cover-top	15.01 a	0.306 a	0.543 a
	2" straw-top	7.20 b	0.114 a	0.289 a
	6" straw-top	6.02 b	0.113 a	0.303 a
	Interior*	2.72	0.290	0.405
49	No cover-sides	14.52 a	0.790 a	1.230 a
	6" straw-sides	7.68 b	0.407 b	0.699 b
	18" straw-sides	6.20 c	0.390 b,c	0.559 c
	plastic-sides	5.56 c	0.187 c	0.460 c
	No cover-top	9.65 a	0.438 a	0.994 a
	2" straw-top	3.29 b	0.116 b	0.399 b
	6" straw-top	3.99 b	0.138 b	0.373 b
	Interior*	2.31	0.230	0.318
70	No cover-sides	12.38 a	0.918 a	1.037 a
	6" straw-sides	6.64 b	0.417 b	0.565 b
	18" straw-sides	4.93 c	0.392 b	0.506 b,c
	plastic-sides	1.41 c	0.296 c	0.469 c
	6" straw + plastic-sides	3.36 d	0.277 c	0.409 c
	No cover-top	8.30 a	0.708 a	0.860 a
	2" straw-top	2.66 b	0.160 b	0.283 b
	6" straw-top	2.41 b	0.262 b	0.343 b
	Interior†	1.90	0.215	0.300

*Statistical significance (Duncan's Multiple Range) at the 5% level of treatments within a comparison (example: sugar loss-sides-27 days) is indicated by the small letter following the mean. If two means are followed by the same letter, they *are not* significantly different. If they are followed by different letters, they *are* significantly different.

†Determined from beets maintained under simulated storage conditions at Research Center.

sugar at 49 days, no difference was observed between the 6" and 18" side covers with respect to sugar and recoverable sugar losses. The woven polypropylene plastic was better than 6" of straw in reducing sugar and recoverable sugar losses at 49 and 70 days. Plastic on top of straw gave no better protection than plastic alone. Results of the 1971-72 tests (Table 2) followed a similar pattern to the tests in the previous year. As in the previous year, all side cover treatments had statistically less weight, sugar, and recoverable sugar losses than the non-covered comparisons. However, no significant difference existed in the side cover treatment between 49 and 71 days although losses appeared to be less under woven polypropylene. For an unknown reason the 2" straw top cover did not perform as well as in the previous year. Results under the loosely woven polypropylene on top of the pile are misleading. It gave good protection where the samples were located but several moldy, hot areas were found under the woven polypropylene which extended one to two feet into the pile. The moldy areas were caused by condensation of moisture under the plastic.

Table 2.—Summary of weight, sugar and recoverable sugar losses in rim of piles, 1971-72.

Storage Period	Treatment		Loss Lb/T/Day		
			Weight	Gross Sugar	Recoverable Sugar
(Days)					
25	No cover	Sides	17.39 a*	1.823 a	1.823 a
	Woven polypropylene	Sides	7.57 b,c	.352 c	.414 c
	6" Straw	Sides	12.03 b	.581 b,c	.777 b,c
	18" Straw	Sides	10.85 b,c	1.050 b	1.111 b
	No cover	Top	15.12 a	1.697 a	1.893 a
	Woven polypropylene	Top	9.25 b	.534 a	.631 b
	2" Straw	Top	8.24 b	.506 a	.548 b
49	No cover	Sides	16.19 a	1.226 a	1.142 a
	Woven polypropylene	Sides	6.87 c	.551 b	.564 b
	6" Straw	Sides	8.75 b	.596 b	.614 b
	18" Straw	Sides	8.34 b	.666 b	.677 b
	No cover	Top	10.94 a	.753 a	.740 a
	Woven polypropylene	Top	6.53 b	.498 b	.594 a,b
	2" Straw	Top	5.68 b	.418 b	.466 b
71	No cover	Sides	11.28 a	1.210 a	1.225 a
	Woven polypropylene	Sides	4.44 c	.282 b	.433 b
	6" Straw	Sides	5.42 b	.396 b	.541 b
	18" Straw	Sides	5.21 b	.431 b	.561 b
	6" Straw + woven polypropylene	Sides	3.29 d	.261 b	.411 b
	No cover	Top	7.82 a	.611 a	.707 a
	Woven polypropylene	Top	3.09 c	.208 b	.312 b
	2" Straw	Top	5.71 b	.637 a	.661 a

*Statistical significance at the 5% level of treatments within a comparison is indicated by the small letter following the mean.

A summary of recoverable sugar losses by location on the rim for the two years' data is given in Table 3. A large loss of recoverable sugar occurs in the rim on all non-covered sides of the pile. All covers reduced recoverable sugar losses on each side of the pile. Woven polypropylene often gives numerically but not statistically better protection than straw cover.

Table 3.—Loss of recoverable sugar by locations on rim.

Storage Dates	Treatment	Location on Pile Loss of Recoverable Sugar — lb/T/D Southside	Westside	Northside	Eastside	Top
26	No cover	1.522 a*	1.417 a	1.582 a	1.098 a	1.211 a
	Straw — 2"					0.418 b
	Straw — 6"	0.499 b	0.655 b	0.691 b	0.602 ab	
	Straw — 18"	0.969 ab	0.362 b	0.980 ab	0.745 ab	
	Plastic	0.498 b	0.386 b	0.643 b	0.343 b	
49	No cover	1.202 a	1.154 a	1.215 a	1.110 a	0.797 a
	Straw — 2"					0.433 b
	Straw — 6"	0.691 b	0.616 b	0.697 b	0.622 b	
	Straw — 18"	0.561 b	0.747 b	0.617 b	0.547 b	
	Plastic	0.532 b	0.415 c	0.627 b	0.522 b	
71	No cover	1.174 a	0.988 a	1.273 a	1.088 a	0.784 a
	Straw — 2"					0.472 b
	Straw — 6"	0.516 b	0.473 b	0.645 b	0.578 b	
	Straw — 18"	0.470 b	0.498 b	0.623 b	0.536 b	
	Plastic	0.369 bc	0.558 b	0.408 c	0.438 b	
	Straw + Plastic	0.282 c	0.414 b	0.504 bc	0.469 b	

*Statistical significance at 5% level of treatments within a comparison is indicated by the small letter following the mean.

Accumulative loss of recoverable sugar in beets stored in side and top rims under various covers and in beets protected from freezing and thawing is given in Figure 1. Data from both years' studies are represented. Average recoverable sugar loss in non-covered side rims was over 3.5 times greater than loss which occurred in beets which were protected from freezing and thawing. Loss in the top rim was 2.5 times greater than in the simulated interior. Straw covering reduced rim loss to about half of that in the non-covered section. Protection from straw is not perfect, however, and side rim losses under straw are 70 percent higher than would occur if beets were completely protected from freezing and thawing. An 18 inch layer of straw gave no better protection than the six inch layer. Overall rim losses under woven polypropylene were about 20 percent less than under straw. The combination of straw and plastic was no better than plastic alone.

Data obtained from the rim studies can be used to estimate the effectiveness of each material in reducing loss in the entire pile. The benefit from covering comes primarily from reduction of rim losses. Therefore, a material which does not reduce loss on the rim will not reduce loss in the entire pile. On the other hand, the covering may have an adverse effect, such as higher temperatures, upon storage

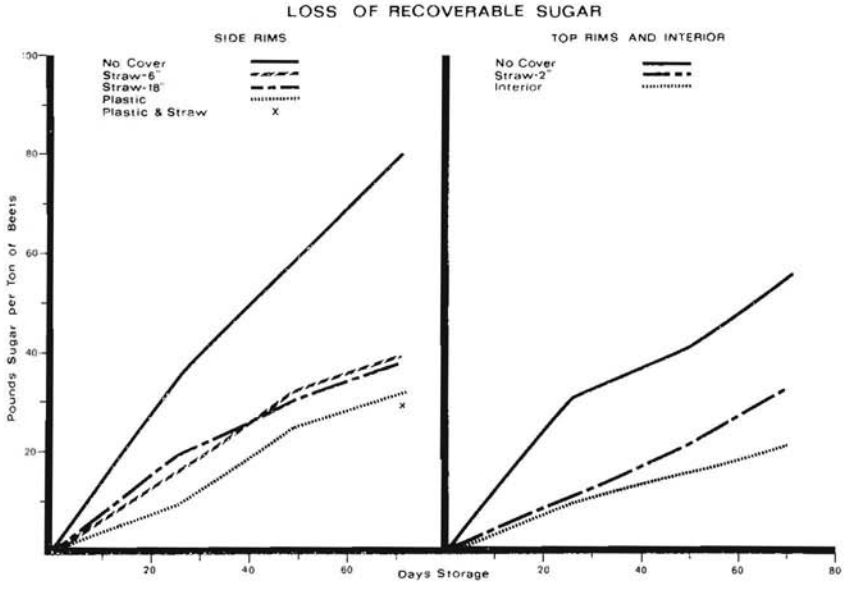

Figure 1.—Accumulative loss of recoverable sugar per ton of beets in rims (outer 2 feet) of pile.

losses in the interior of the pile which may offset rim savings. Therefore, rim tests are useful in screening potential covering materials but cannot be used as a substitute for tests involving the whole pile.

Rim test data can be used to measure potential savings from a given cover for the entire pile with the following formula:

$$\text{Total loss (Lb/T/D)} = 0.073T + 0.097S + \left(1 + \frac{F.I}{18}\right) 0.83$$

Where

T = top rim loss
S = side rim loss
I = interior loss
F = increase in internal temperature as a result of pile covering

The formula was developed from the following assumptions: 1) Captive samples represented the outer two feet of pile which was the only portion of pile that benefitted from pile cover; 2) The average company pile (single width) has 4.26 square feet of surface area per ton of beets of which 57 percent is side rims and 43 percent is top rim (5); 3) One ton of beets occupy 50 cubic feet; 4) Sugar loss doubles for every 18 degrees F. (10 degrees C.) increase in temperature above 40 degree F.

Examples of calculations from rim loss data are given in Table 4. Loss of recoverable sugar in the entire pile would be substantially de-

Table 4.—Estimation of loss of recoverable sugar in the total pile from rim loss data.

Treatment	Estimate Loss of Recoverable Sugar — Lb/T/D					
	Assumption: Interior of Covered Piles Same Temperature as Non-covered Pile.			Assumption: Interior of Covered Pile 5 Degrees F Warmer than Non-covered Pile.		
	26 days	49 days	71 days	26 days	49 days	71 days
No cover Top and Sides	0.561	0.439	0.416	--	--	--
Woven plastic Sides	0.461	0.374	0.350	0.554	0.447	0.419
Straw — 6" Sides 2" Top	0.426	0.359	0.337	0.519	0.433	0.406

creased by reducing rim loss with pile covering if the covering does not increase interior loss. On the other hand, increased sugar losses in the interior of the pile caused by a five degree F. higher temperature under cover would offset any rim savings. Any other condition caused by the covering which substantially increased loss on the interior of the pile would offset rim savings.

Finally, these data show that 40 to 45 percent of total recoverable sugar loss occurred in the rim (outer two feet) of the pile although the rim accounted for only 17 percent of pile volume.

Summary

A method is presented for measuring the effectiveness of various pile covering materials in reducing loss of weight, sugar, and recoverable sugar in the rim of the pile. Over 40 percent of the recoverable sugar loss in non-covered piles occurred in the outer two feet of the pile. Loss of recoverable sugar in the rim of non-covered piles is three to four times as great as in the interior of the pile. A straw cover substantially reduces but does not eliminate rim loss. A layer of 18 inches of straw gave no more protection than straw. A combination of straw and woven polypropylene was no better than woven polypropylene alone. When loss in the interior of the pile is increased by pile covering, benefits from rim savings will be offset.

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