An Analysis of Root Damage During Piling *

Charles L. Peterson, Eldon R. Muller
Mark C. Hall and Joseph C. Thompson

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INTRODUCTION

Few pieces of regularly used equipment have an average age as old as the unloading and piling equipment used to handle sugarbeets at the company owned piling grounds. Not that age alone should imply anything derogatory, because updating, rebuilding and modernization are part of a continuing process within the agricultural maintenance divisions responsible for piler operation. What age does imply is that major changes occur very slowly and that new piling concepts for purposes of reducing damage to the sugarbeets must be modifications to existing equipment if there is any hope to have the equipment on-line in a reasonable amount of time.

PREVIOUS WORK

The loss of recoverable sugar due to injury is well documented in the literature.

Akeson and Stout (1) damaged sugarbeet roots with impacts of three and six feet upon a steel surface. They found that these impacts increased the respiration rate up to 23%, invert sugar accumulation up to 41%, sucrose loss up to 73%, and recoverable sugar loss up to 65%.

Cole (3) found that respiration rates were increased by as much as 26% by the level of mechanical damage during harvest and storage of the roots. He found that apparent sucrose was

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*Approved as Paper No. 8131 of the Idaho Agricultural Experiment Station. The authors are Professor, Graduate Student, Scientific Aide and Scientific Aide, respectively, Department of Agricultural Engineering, University of Idaho, Moscow, Idaho 83843.

reduced by up to one percent and invert sugars were increased by up to 22% as the number of mechanical operations to which the roots were subjected increased.

Wyse and Peterson (9) reported that hand harvested roots with minimal injury had the lowest respiration rate and severely injured, machine washed beets off the pile had the highest (69% higher) respiration rate. After ten days the injured roots were respiring at a rate 43% higher than that of the hand harvested controls.

Parks and Peterson (5) reported that respiration analysis showed the amount of damage caused by harvesting and piling the roots was comparable to dropping the roots two meters onto a solid surface. They reported in one study that damage reduced the percent of sucrose at 151 days' storage from 17.2% for beets with a bruise index of 10 compared to 15.6% for beets with a bruise index of 30.

Precht et al. (6) reported that in storage studies, machine harvested samples always had sugar loss and dehydration levels above those of artificially injured samples and considerably higher than the non-injured samples.

Backer et al. (2) reported that with the present estimate of loss of sugar due to respiration and microbial activity of 0.05 pounds per ton per day, a plant processing 5000 tons per day would lose 187,500 pounds of sugar per day.

Precht (7) found in 150 days' storage that current machine harvesting techniques resulted in a sugar loss equivalent to 0.333 pounds per ton per day while beets that were not damaged lost 0.20 pounds per ton per day.

Devletter and Von Gils (4) reported that changing "average" handling practices into "good" practices would save 3.6 kg sugar per metric ton of beets. They estimated an annual loss of sugar worth about $3.3 million in the Netherlands alone.

Wyse (8) found that machine harvesting increased sucrose losses 135% above their hand harvested controls.

MATERIALS AND METHODS

This paper reports on studies conducted between 1975 and

1979 in both Idaho and Washington. Data collected include bruise damage, respiration, sucrose loss, tare, and time and motion analyses.

Bruise analysis has included comparing the bruise level of beets after they have gone across the piler with the level in the trucks delivering beets to the piler; by passing hand harvested beets through the piler; and washing, weighing and marking individual beets, passing them through the piler, recovering them, and then evaluating the damage level.

The criterion for bruise index based on bruise depth was described by Parks and Peterson (5). They defined a slight damage as up to 10 mm, a moderate damage from 10 to 20 mm, and severe damage deeper than 20 mm. In all classifications, a damaged area was considered a single damage if it was less than one-quarter the face area of the root. If the damaged area was larger, the number of damages was the number of one-quarter face aras affected. A root was said to have a broken root tip if the diameter of the root at the point of breakage was 25 mm or more.

A total damage score for each root, called a bruise index is given by the following equation:

Bruise Index = Number of slights + (3 x number of moderates) + (8 x number of severes) + (2 x number of broken root tips).

Respiration measurements were made by the USDA respiration lab as reported by Wyse (8) and the research laboratory of U & I, Inc. Both of these methods monitor CO_2 respired by the beets. Samples used were collected at each step of the harvesting and handling operation. Tare studies compared tare samples taken from the current position following the cleaning screen and a location as the truck was unloaded. Current practice requires emptying the piler and leaving a gap following each truck. Consequently, each truck empties into an empty hopper resulting in considerable damage to the beets. For these studies a grab sample technique was used to obtain the samples at the truck and the existing tare bucket system for the samples following the cleaning screen. Pilers were selected for evaluation where dump trucks were being used to collect the tare dirt so that a weight of tare dirt removed between the two sample collecting points was available. All of the tare samples were evaluated by the respective sugar company tare laboratories.

To determine the time lost as a result of the typical start-stop procedure of piler operation time and motion studies were conducted. The studies recorded all idle time of the piler. No attempt was made to estimate the portion of the time the piler was carrying less than a full load of sugar beets such as would happen at the beginning or end of each load.

RESULTS AND DISCUSSION

Evaluation of sugarbeet piling equipment has included a number of different aspects over several years. Data discussed here includes sugarbeet damage measured by both respiration analysis and bruise index, and analysis of the potential for moving the tare sampling location, and time and motion studies of the lost time at the piler.

Sugarbeet Damage

Various sampling techniques have been used to determine the damage levels inflicted by the piler. Generally beets that have been lifted with conventional equipment already have high damage levels when delivered to the piler. The increase in damage caused by the piler is then difficult to measure. Therefore in several studies, hand-harvested sugarbeets were introduced into the piler hopper with the regular flow of beets. In these instances damage levels about two-thirds of those occurring in harvesting were observed.

The first evaluations of piler damage, made in connection with harvester studies, included both point-to-point studies which monitored the damage from field to pile and comparison studies which monitored differences between harvesters and the piler. Fig. 1 gives an example of typical point-to-point data for one cooperator. Figs. 2 and 3 are examples of the injury levels typical of the comparison experiments. Six different point-to-point studies each with a different grower and four different piling ground studies were included in the original experiment. The data shown are typical of the other experiments.

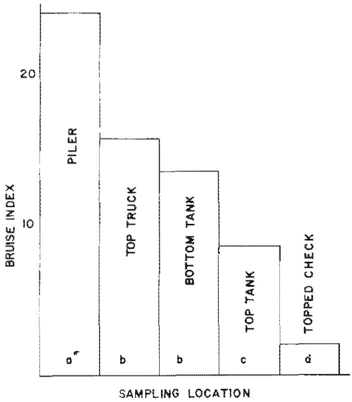


Figure 1. - Bruise index treatment means for an operation using a tank type harvester, Harvesting and Piling Point-to-Point Study 1975. The asterisk indicates Duncan's New Multi-Range Test, lsd (.05) = 3.6.

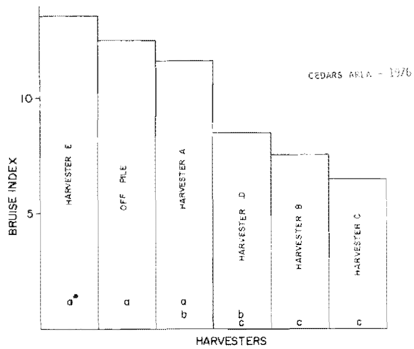


Figure 2. - Cedars area, bruise index treatment means, Harvester Study 1976. The asterisk indicates Duncan's New Multi-Range Test lsd(.05)= 3.1.

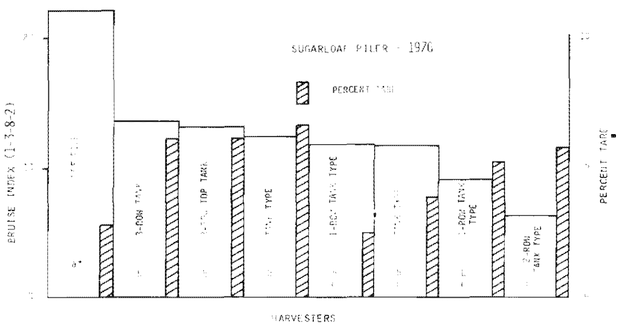


Figure 3. - Bruise Index and percent tare for six harvesters and the sugarloaf piler, 1976 Harvester injury study. The asterisk indicates Duncan's New Multi-Range Test, lsd (.05) = 5.16.

During the latter part of the 1975 harvesting season, an experiment was performed to evaluate the effect of the piler on uninjured roots. Hand-dug roots of average size and quality were selected. They were washed and their tops were removed with a tare machine. They were then painted fluorescent red so they could be easily seen in the pile and numbered with an indelible pencil so a record of weight and damage for each root could be made.

A weight loss was calculated for each root run through the piler. Out of the 24 roots recovered, 18 lost weight. The data were analyzed statistically using a paired "t" test. These roots were also visually graded for bruise damage. A bruise index of 15.9 was measured. No correlation could be found between weight loss and damage level. There was, however, a correlation between weight loss and broken root tips. Of the 24 roots in this study, 10 (42%) had broken root tips. Broken root tips were the major contributor to weight loss in piling the undamaged roots.

In October 1976, studies were conducted at the Cedars and Sugarloaf piling grounds near Twin Falls, Idaho, to assess piler damage on sugarbeets. Hand-dug beets were washed, crowned with a tare machine, and painted for identification. Three treatments were identified: beets conveyed through an empty piler, beets introduced into the piler hopper during normal piling, and beets added to the top of the piler flow. All samples in this study were given a bruise index score.

Based on this study, once the roots were in the piler hopper, it appeared that visible damage was the same for a loaded or partially loaded piler. Damage was the same for roots on the bottom as well as on the top of the hopper (see Table 1).

Damage levels for the treatments in this study were low compared to similar treatments in the storage studies. This study was conducted on a warm fall day. Since the roots had been dug the day before, they were warm when run through the piler which probably caused the bruise index to be lower than normal.

In November of 1976, sugarbeet samples were taken from the Winchester piler near Quincy, Washington. Samples were taken

Table 1. Number of Roots Recovered, Bruise Index Score, and Standard Deviation Shown for Each Treatment and Location.

Treatment	Number of Roots	Bruise Index Mean	S
Location: Cedars			
#1	58	3.81	4.91
#2	38	4.50	3.90
#3	48	2.54	3.52
Location: Sugarloaf			
#1	64	4.98	6.79
#2	61	3.69	5.52
#3	59	5.29	6.83
Average Mean Score		4.13	

Location #1 - Beets conveyed through an empty piler
Location #2 - Beets introduced into a piler during normal piling
Location #3 - Beets added to the top of piler flow

from the top of a truck, from four locations within the piler, and off the piler for each of three truck loads. Bruise index and percent tare were computed for each sample.

In this study, the amount of increased damage through the piler was not statistically significant. Damage levels of samples from off the top of a truck were already high, so assessment of further damage was difficult.

The analysis of percent tare showed that with one harvester beets were significantly reduced in tare by running them through the piler. The beets from the other harvester, however, were cleaner than those off the pile. This suggests that cleaning is sometimes excessive in the harvesting-piling operation.

Two studies in 1976, one at the Minidoka piling ground in Idaho (Fig. 4) and the other at the Moses Lake, Washington piling ground (Fig. 5) demonstrated the damage levels which could be expected from the piler when injury free beets were delivered to the piling grounds. Both studies used hand-harvested beets which were then passed through the piler with no other handling as one of the treatments. In both cases the piler alone caused approximately two-thirds the damage levels measured in beets which had been both mechanically harvested and piled. Fig. 6 shows the sucrose content after 151 days versus bruise index obtained from a storage study using the Idaho treatments.

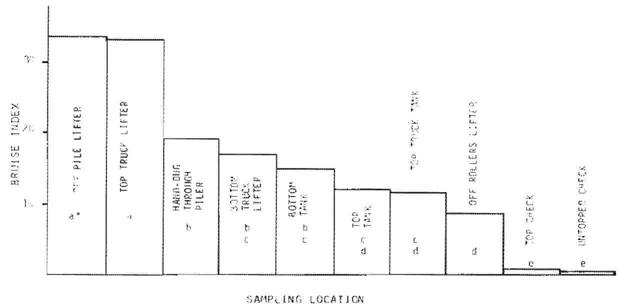
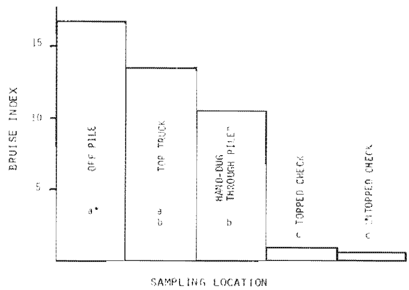


Figure 4. - Bruise index treatment means, South Idaho Storage Study 1976. The asterisk indicates Duncan's New Multi-Range Test, lsd (.05) = 5.6. The column for the top truck lifter was improperly harvested.

Figure 5. - Bruise index treat-means, Moses Lake Storage Study 1976. The asterisk indicates Duncan's New Multi-Range Test, lsd (.05) = 5.2.



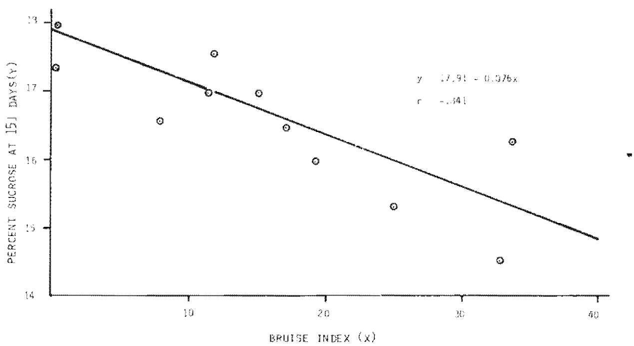


Figure 6. - Regression of the mean values of percentage of sucrose at 151 days corrected to initial weight and bruise index, South Idaho Storage Study 1976.

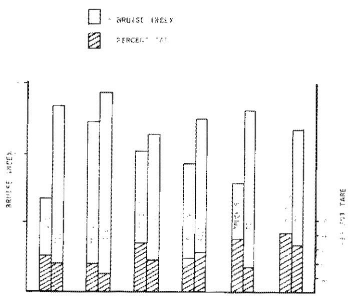
In the fall of 1977, sugarbeet samples were collected in south Idaho and the Columbia Basin to determine the bruise and tare differences existing between harvesters, points within harvesters, and pilers.

Six truckloads were sampled at the Mini-Cassia piling ground at Paul, Idaho. Harvester type was recorded for each load. Beets were taken from the top of each truck before unloading. The load was then dumped, run through the piler, and sampled again off the end of the boom. Additional samples were taken from the face of the pile.

Eight truck loads were sampled at the Utah-Idaho factory super piler in Moses lake, Washington. Harvester type was recorded for each load. beets were taken from the top of each load and from the face of the pile. Samples were also taken from adjacent piles. The pile and a truck were sampled at the Beatrice piling ground near Cunningham, Washington. Beets were taken from the top of trucks at the K_2H piling ground near Eureka, Washington. Samples were also taken from the pile face.

All samples were visually graded and bruises were categorized giving a bruise index score. Each sample was also weighed, washed and reweighed for tare determination. The data for bruise index and tare for the study at Mini-Cassia are shown as Fig. 7. In general, damage was increased and tare reduced in passing the beets through the piler. These data are typical for the other similar studies.

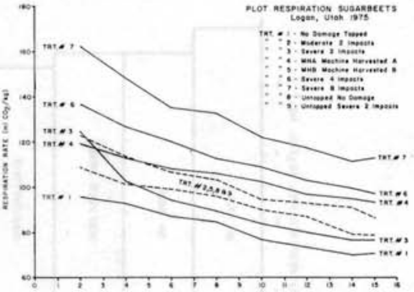
Figure 7. - Percent tare and bruise index showing comparisons between truck and pile at the Mini-Cassia piling ground in 1977.



Respiration Studies

In 1975, a respiration study was conducted cooperatively with the USDA Laboratory at Logan, Utah. Treatments included artificially damaged beets, mechanically harvested and handled beets and both topped and untopped checks. Severely damaged beets respired at a level 69% above the topped check (Fig. 8).

Figure 8. - Respiration rates of artificially damaged and machine harvest damaged sugarbeets.



In October 1976, a sugarbeet respiration study was conducted at U & I, Inc. in Moses Lake, Washington. two of the eight treatments used in this study were run through a piler, while others were given various levels of damage. All samples were placed in respiration chambers for 90 days, where CO_2 content was monitored.

Fig. 9 shows that CO_2 content varies through the storage period, but generally that increased levels of damage give higher

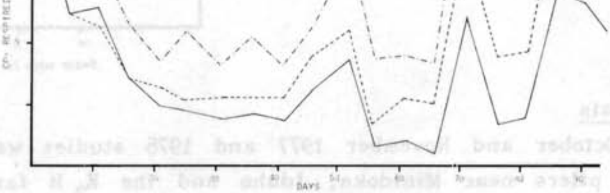


Figure 9. - 1976 respiration study comparing hand harvested, hand harvested and machine piled, and machine harvested and piled roots.

respiration rates. Fig. 10 shows the mean respiration rates for all treatments between day 54 and day 68. The respiration rate of hand-harvested beets passed through the piler was significantly higher than the undamaged check but not lower than the machine-harvested beets passed over the piler. Fig. 11 shows a linearly increasing relationship between CO_2 content and bruise index.

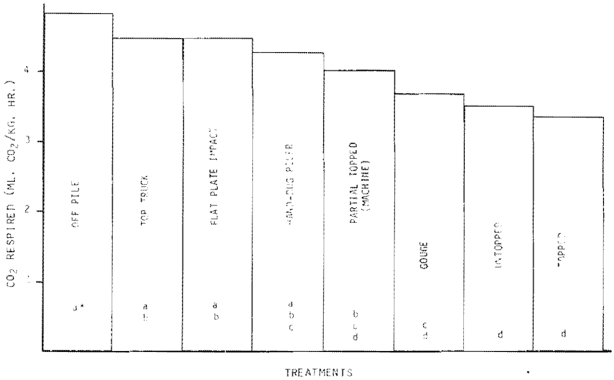
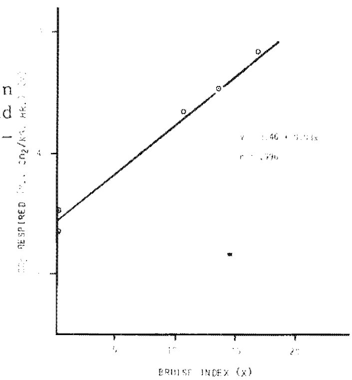


Figure 10. - Mean respiration rates for treatments. Days 54 to 68. Moses Lake Respiration Study 1976. The asterisk indicates Duncan's New Multi-Range Test, lsd (.05) = .71.

Figure 11. - Regression of mean respiration rates (day 54 to day 68) and bruise index, Moses Lake Respiration Study 1976.



Piler Analysis

In October and November 1977 and 1978 studies were conducted on pilers near Minidoka, Idaho and the K_2 H farm near Eureka, Washington. After each truck started to unload, sugarbeets were sampled from the cross conveyor at the base of the piler, while a conventional sample was taken at the tare bucket station. In the 1978 study, two and three samples were taken at each location to give an indication of tare sample variation. All grower truck weights and tare dirt truck weights were recorded. All samples were taken to their respective tare laboratories for conventional analysis.

The results show that the cross conveyor sampling technique underestimated conventional tare and therefore the estimate of tons paid for exceeded the actual paid tonnage by 1.75 to 4.5 percent. Cross conveyor sampling procedures could likely be improved from the simple catch frame used in these tests.

In 1977 and again in 1979, time and motion studies were run on eight different pilers in Idaho and Washington. Only busy piling stations were selected for this study. A special timing device containing two stopwatches and a memory was used. These data (Table 2) show that very large trucks unloading with similar gap times result in better piling efficiency, or less time loss. Piling stations that capture all tare dirt collectively also tend to minimize time loss between loads.

Table 2. Piler Analysis in 1977 and 1979.

Piler	Total Trucks	Total Time (min)	Avg. Gap (min)	Percent Time Loss
A	54	60.92	0.21	11.77
B	12	33.65	0.17	4.78
C	4	5.21	1.19	*
D	3	6.93	0.35	5.05
E	22	34.09	0.13	6.57
F	39	63.41	0.09	5.39
G	40	60.32	0.10	5.87
H	42	67.81	0.22	12.25

* Insufficient data

The data show that time losses varied between pilers, ranging from 5 to 12 percent. Operator discretion and truck driver ability were cause for variation.

CONCLUSIONS

These studies show a significant increase in root damage as sugarbeets are piled with conventional equipment. Contributing to that damage are long drops including the drop from the truck into the hopper and from the cleaning screen past the tare bucket onto the final elevator and the cleaning screen of either grab rolls or rubber kicker wheels. The procedure for taking tare currently in use requires that the pilers be operated in a stop-and-go manner completely emptying the machine following each truckload of beets. Intermittent operation of the piler can contribute to lost time of as much as 12 percent and often four to five percent.

Tare sampling procedures which obtain the sample prior to unloading the truck should be considered. Even an improvement of five percent in piler efficiency is comparable to one new piler for every 20 in operation or unloading one additional truck for every 20 presently unloaded. If this could accompany a reduction in damage levels even further savings could be realized.

Reducing damage at the piler and increasing piler operating efficiency could be of benefit to both the grower and the factory. Additional research will focus on specific remedies for reducing injury levels. Improved management practices can reduce injury with a minimum of capital expense and should be given first consideration at each piling ground.

ACKNOWLEDGMENTS

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