Effect of potato harvesting injury on post-storage marketability

G. C. MISENER[1], C. D. McLEOD[1], J. R. WALSH[2], and C. F. EVERETT[3]

[1]*Research Station, Agriculture Canada, P.O. Box 20280, Fredericton, NB, Canada E3B 4Z7;* [2]*McCains Foods, Florenceville, NB, Canada E0J 1K0; and* [3]*New Brunswick Department of Agriculture, Fredericton, NB, Canada E3B 5H1.* *Received 27 January 1988, accepted 2 August 1988.*

Misener, G. C., McLeod, C. D. Walsh, J. R. and Everett, C. F. 1989. **Effect of potato harvesting injury on post-storage marketability.** Can. Agric. Eng. **31**: 7–10. The effect of mechanical injury of potatoes was evaluated based on the postharvest market quality of the potatoes at 10 commercial facilities. The damage index, which is a measure of the extent of mechanical injury, was identified as the most significant parameter affecting the grade of the potatoes entering storage. The magnitude of mechanical injury also had a significant effect on the percentage of marketable potatoes leaving storage. However, mechanical injury did not significantly influence weight loss of samples stored in the bulk storages.

INTRODUCTION

Research findings have shown that many factors influence the level of injury sustained by the potato crop during harvest. These factors include soil type and temperature, maturity of crop, variety, harvester design, and harvesting conditions. McRae (198–) presented a detailed overview of the causes of mechanical damage to potatoes and examined many technologies that could be employed to reduce injury levels. Under field conditions, Hyde et al. (1979) found that 18% of the tubers were mechanically damaged by the time they reached the boom conveyor on the harvester while another 27% were damaged when moving from the harvester boom to the potato storage.

The influence of the incidence of mechanical injury on potatoes in storage has been investigated by several researchers. Sparks (1954) measured the moisture lost from Russet Burbank potatoes with various types of injury. Tubers with digger cuts and serious bruises had significantly more moisture loss than those with little or no injury. Akonoby and Norris (1972) concluded that the weight loss of the tuber was highly influenced by the impact force applied to the tuber and the temperature at which the tuber was stored. Hudson and Orr (1977) found that decay caused by fusarium dry rot in samples of potatoes taken from bins at the end of the storage period averaged 19.9%. Since injury to the tubers during any phase of handling opens avenues of entry for decay organisms, Leach (1975) suggested methods of handling to reduce damage need to be developed and technologies to reduce decay during storage need to be applied. Buelow (1985) further measured the effect of maturity, bruise damage, wound healing, temperature, and dry tuber surfaces on controlling soft rot. Bruised potatoes were shown by Cargill et al. (1984) to have a higher weight loss than equivalently chemically treated and stored nonbruised potatoes. The poststorage market quality of bruised potatoes was found to be lower than the market quality of nonbruised potatoes stored under equivalent conditions and treatments.

The objective of this study was to determine the effect mechanical injury levels have on postharvest marketability of potatoes under commercial farming conditions with different storage types.

MATERIALS AND METHODS

Ten commercial potato farms were selected in New Brunswick to include a cross section of cultural management techniques and storage types. The farm storage types varied from older storages equipped with simple exhaust fans to more modern ones with fully automated forced-air ventilation and humidification capabilities. The potato variety tested in this experiment, Russet Burbank, was grown on each of the farms.

The sampling procedure involved taking samples during October 1986, approximately in the middle of the harvest season. Three handling treatments were used in the sampling procedure in order to obtain varying levels of mechanical injury — hand dug from the field, randomly picked from the bulk truck as it unloaded at storage (normal) and selected damaged tubers from the base of the pile (harsh). For each treatment, three 10-kg samples and two 5-kg samples were taken, placed into meshed bags and weighed. Two 10-kg samples were randomly distributed in the bulk storage while the two 5-kg samples were placed into a control storage. Smaller samples were placed in the control storage because they were stored in pallet boxes and could be easily identified. The third 10-kg sample was stored at room temperature for 15–20 d and then analyzed for marketability and mechanical injury. This procedure was repeated five times on each farm, at different dates, for a total of 10 samples per handling treatment in each storage. The samples placed in the bulk storages remained there until the grower emptied the storage at which time the sample was assessed for marketability and weighed. All samples at the control storage were weighed and graded for marketability in mid-March. For the mechanical injury assessment, the method described by Thornton (1969) was employed. Tuber damage was determined using a potato peeler to remove a slice approximately 3 mm thick with each stroke. Damage was classified as follows (a) undamaged, (b) scuffed or skinned — skin only broken, (c) slightly or peeler — flesh damage removed by a 3-mm deep stroke of the peeler, (d) severely damaged — damage to flesh which was not removed with one peeler stroke, and (e) black spot. A damage index was then calculated based on the percentage of tubers in each category multiplied by 0, 1, 3, 7, and 5, respectively, and then added to give a total index (Robertson 1970; McGechan 1980). Market quality evaluation was determined by examining each tuber and classifying it as marketable or nonmarketable.

For the purpose of this study, marketable tubers were determined to be those tubers whose size, shape, and condition

defects would meet those of Canada Number 1 as outlined in the Potato Inspection Manual compiled by Dairy, Fruit, and Vegetable Division, Agriculture Canada. The maximum mechanical damage limit was set at the severe level where tubers below this level were acceptable. Although this limit of mechanical injury is more rigid than that for Canada Number 1, the level is similar to the limit that processors desire and is equivalent to the British standards (McRae 198–). The contribution of the effect of black spot to the damage index was determined only with the potatoes entering storage. The identification of black spot in tubers would be impractical in a packing line because of the destructive tests associated with identifying the problem. However, black spot is graded carefully in processing potatoes. The actual marketability is a specific shipper-buyer negotiated standard, and any definition would be subject to considerable variability.

Total potato loss after the poststorage grading to marketable levels was determined by expressing net loss as a percentage of initial weight of the sample according to the following equation:

$$TPL = \frac{Iw - FMw}{Iw} \times 100 \quad (1)$$

where:

TPL = total potato loss (%),
Iw = initial weight of sample of harvest, and
FMw = final marketable weight of sample after postharvest grading.

Differences in the magnitude of storage loss as measured by weight loss and marketable loss due to tuber injury were analyzed statistically using the analysis of variance, Duncan's multiple range and regression analysis techniques available with the SAS Statistics Version 5 software program.

RESULTS AND DISCUSSION

Average damage indices without black spot of the hand-dug, normal, and harsh treatments were 100.3, 297.7, and 397.8, respectively. With the addition of black spot, the indices increased to 111.2, 368.6, and 452.2 for an average increase of 17%. The maximum value that the damage index can reach is 700. The distribution of the damage index over the five sampling intervals is depicted in Fig. 1 for farm number 1. Similar patterns were evident for the remaining farms. Temperatures were unusually low during this harvest period which may have influenced the level of mechanical injury. Peterson et al. (1975) have shown that lower soil temperatures resulted in more tuber damage.

Average total storage losses as determined by Eq. 1 were significantly affected by the extent of injury to the tubers as defined by the three treatments. Five of the ten farms and the control storage had significantly higher storage losses for the normally harvested potatoes than for the hand-dug samples. With the harsh treatments, storage losses were all significantly greater than the hand-dug samples on all farms and the control storage (Table I). The average total loss from storage of the hand, normal, and harsh treatments were 22.6%, 36.4%, and 51.8%, respectively. Losses due to black spot were not included in the above analysis. Storage type also had a significant effect on total storage loss as indicated in Table II. Storages equipped with a forced-air and humidification system tended to have less storage loss.

The prestorage treatments had no significant effect on the weight loss of the samples during storage; these results were similar to those published by the Potato Marketing Board (1983). Weight loss is mainly attributed to moisture loss from the samples. The average weight loss of the hand-dug, normal, and harsh treatments was 6.3%, 6.7%, and 7.0%, respectively. This result suggests that the expected effects of mechanical injury of the tubers on moisture loss were masked by the relatively smaller percentage of tubers with injury as compared to the higher percentage of tubers without. Tubers that had been affected by frost injury may have masked the effect as well.

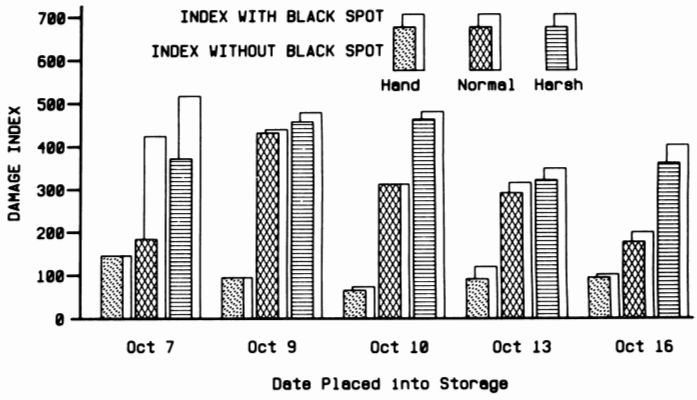

Fig. 1. Damage index determined at five time intervals for farm no. 1. Prestorage harvesting treatments include hand, normal and harsh.

Table I. Accumulated potato losses as a percent of the harvested weight after the stored product was graded to marketable levels

Farm number	Days in storage	Storage type†	Prestorage treatment		
			Hand	Normal	Harsh
1	135.0	3	25.4*a*	36.1*a*	50.0*b*
2	118.8	2	22.1*a*	40.0*b*	50.8*b*
3	66.8	1	17.9*a*	25.6*a*	36.2*b*
4	248.8	1	19.7*a*	53.5*b*	56.3*b*
5	126.1	3	24.9*a*	38.7*b*	66.5*c*
6	225.2	2	30.3*a*	51.6*b*	60.1*b*
7	71.8	1	21.5*a*	26.8*ab*	34.1*b*
8	143.6	2	25.7*a*	30.4*a*	65.1*b*
9	83.6	2	21.4*a*	29.7*a*	49.0*b*
10	147.0	3	18.7*a*	36.0*b*	50.5c
Control	134.3	–	24.2*a*	37.1*b*	51.8*c*

†Storage type: 1, equipped with forced air plus humidification; 2, equipped with forced air; 3, equipped with exhaust fan.
a-c Means followed by the same letter in any row are not significantly different at the 95% confidence level.

Table II. Effect of ventilation system on storage loss and moisture loss

Storage type	Marketable storage loss (%)	Percent moisture loss/day
Forced air with humidification	31.8*a*	0.052*a*
Forced air	39.1*b*	0.056*ab*
Exhaust fan	38.4*b*	0.061*b*
Control	37.6*b*	0.054*ab*

a,b Means followed by the same letter are not significantly different at the 95% confidence level.

However, storages that were not well equipped with ventilation systems tended to have a higher weight loss per day than better-equipped storages (Table II).

The percent of marketable tubers delivered to storage was analyzed as a function of the damage index, the percent of tubers not within size tolerances, the percent of tubers with condition defects such as frosted or diseased, and the percent of tubers misshapened. The stepwise regression procedure yielded Eq. 2 with $R^2 = 0.91$:

$$Mw = 109.4 - 0.12 \text{ index} - 1.12 \text{ size} - 0.42 \text{ shape} - 0.68 \text{ defect} \quad (2)$$

where:

Mw	=	percent marketable tubers,
index	=	damage index,
size	=	percent of tubers not within size tolerances,
shape	=	percent of tubers misshapened, and
defect	=	percent of tubers with condition defects.

If the incidence of black spot is included in the damage index, then Eq. 2 is transformed to the following:

$$Mw = 107.4 - 0.15 \text{ index} - 0.86 \text{ size} - 0.53 \text{ defect} \quad (3)$$

The R^2 term was determined to be 0.92 and the term 'index' was identified as the term contributing to the largest reduction in the sums of squares for both equations. Table III reflects the profound effect that grading for black spot has on marketable yield. In the normal treatment, 29.8% of the marketable yield is lost when black spot is included as an undesirable parameter.

Equations 2 and 3 were developed for the data reflecting the three handling treatments. A second set of equations was derived based only on the normal treatment which represents standard farming practices. The analysis yielded the following:

$$Mw = 115.8 - 0.13 \text{ index} - 1.46 \text{ size} - 0.66 \text{ shape} - 0.93 \text{ defects} \quad (4)$$

With black spot included in the damage index, the analysis yielded:

$$Mw = 117.2 - 0.18 \text{ index} - 0.68 \text{ defects} \quad (5)$$

The variable, index, was again selected as the first term to be entered into the equations. The calculated R^2 of Eqs. 4 and 5 were found to be 0.90 and 0.87, respectively. A distribution of the factors affecting marketability averaged for the 10 farms studied is presented in Fig. 2. This graph demonstrates the average percentage of the harvested crop falling within a specified defective classification. Some form of mechanical damage was present in 80.5% of the harvested crop, whereas only 13.7% of the crop had no visible defects.

Table III. Influence of black spot on marketability of individual tuber

Type	Treatment		
	Hand	Normal	Harsh
Marketable yield entering storage (%) (without considering black spot)	85.0	72.4	53.0
Marketable yield entering storage (%) (grading out black spot)	83.0	50.8	35.9
Loss/marketable yield† (%)	2.4	29.8	32.3

†Additional marketable loss attributed to the inclusion of black spot.

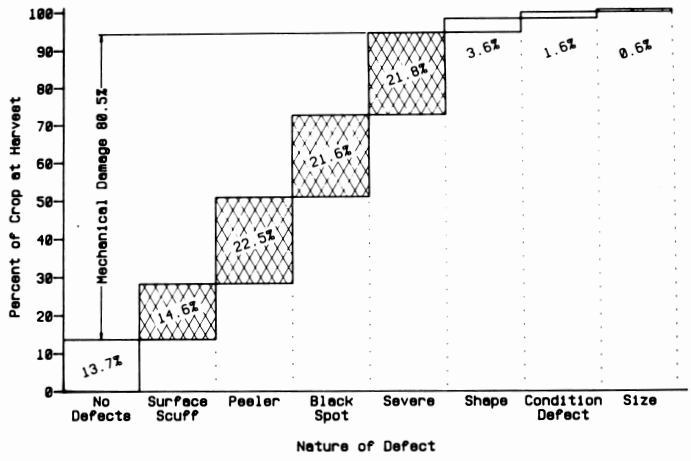

Figure 2. Graph of the average distribution of damage factors for 10 farms (normal treatment).

It should be noted that in the above analysis, marketable yield was determined based on individual tubers. No tolerances were assigned for establishing the overall grade of the samples as is done in the table stock industry. The processors also establish tolerances for specific grade defects.

CONCLUSIONS

The results of this investigation indicated that the amount of mechanical injury done to potatoes during harvesting and subsequent handling was the most significant factor affecting the percentage of marketable tubers. Normal harvesting, as conducted in New Brunswick, resulted in 60.1% more poststorage losses of marketable potatoes than hand harvesting. However, the proportion of the loss that was weight loss (moisture) from the potatoes was not significantly affected by the damage level. The extent of ventilation and humidification capabilities of the storages was reflected in both lower storage loss and weight loss of the product leaving storage.

The results suggested that the damage level of the potatoes entering storage had a very significant effect on the quality of the product leaving storage. Within the damage index, the inclusion of the black spot classification was found to significantly decrease the marketable yield. Efforts to minimize the injury imparted to potatoes during harvesting and handling need to be stressed in order to not incur loss of marketable product.

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