Evaluating Postharvest Injury to Fresh Market Tomatoes

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Abstract

Components of a single postharvest handling system (from harvest through the packinghouse) for fresh tomatoes are evaluated in terms of injuries which lead to losses of tomatoes. Immediate evidence, as well as delayed evidence of injury is included in the evaluation. A flow diagram and description of the system are provided with suspect components labeled. Suggestions for improving these components are given based on the findings of the study.

Introduction

Recent research indicates that there is still a significant amount of fresh market produce injured in postharvest handling systems. This is in spite of recent technological advances in such areas as refrigeration, controlled environment, and improved handling equipment. Halloran et al. (1982), for example, estimated the total loss of fresh produce to be between 9.04 and 16.61 percent. Other researchers (Hanna and Mohsenin, 1971, for example) have found that such percentages could be significantly higher when specific fruits or vegetables are studied and injury is considered in addition to loss.

The fresh market tomato is a leading produce commodity in the United States, with an average annual production of over two billion pounds valued at 517 million dollars (Mongelli, 1984). Considering both the quantity of fresh market tomatoes handled annually and the perishable nature of tomatoes, it is not surprising to find that a significant amount of tomatoes are injured and lost from postharvest handling systems each year. In 1965, for example, losses in tomatoes were estimated at approximately 13.68 million dollars--higher than any other fresh fruit or vegetable studied at that time (USDA, 1965). MacLeod et al. (1976) found that 55 percent of the tomatoes sampled at a shipping point in California were injured to some extent. This number was found to increase to 78 percent after a simulated transit, and was thought to be due primarily to symptoms developed from injuries that were initially present in

the tomatoes. Losses of 6.3 percent and 6.7 percent in tomatoes at the retail level alone were reported by Ceponis and Butterfield (1979) for prepackaged and loose fruits, respectively. A principal conclusion of these studies was that disease was the major cause of losses on the market, but in most cases tomatoes must be physically injured to be invaded by many of the organisms that cause disease.

The figures presented above clearly indicate that injury and loss problems continue to exist in fresh market tomatoes, despite the technological advances that have been made. Researchers (MacLeod et al., 1976; Ceponis and Butterfield, 1979) have pointed out, however, that much of the injury that leads to loss and adversely affects retail quality occurs before tomatoes are shipped from packinghouses. Thus, the true origins of injury in fresh market tomatoes are extremely difficult to determine. Further, since many of the tomatoes sold on the fresh market are harvested "mature-green," injury is not always immediately apparent in the fruit when it occurs. Delayed evidence of injury is common, and in some cases a tomato that is injured at or before harvest may make it to the retail or consumer level unnoticed (Campbell et al., 1985).

Clearly, injury in fresh market produce such as tomatoes must be investigated on the basis of specific postharvest handling systems. Only then may the practices and components that cause injury be properly identified and corrected. Every component of the postharvest handling system should be evaluated individually in terms of injury, and a method of investigating delayed evidence of injury caused by each of these components should be included. Controlled environment storage techniques such as those used by Halsey (1963) or MacLeod et al. (1976) should be adequate for this purpose.

A systems approach, similar to that used by Shewfelt et al. (1985) for evaluating injury in southern peas, is a good method for identifying components of a system that cause injury which can be detected immediately. The data collected by using such an approach can also be used in combination with systems analysis techniques to formulate and evaluate potential solutions to injury problems (Campbell et al., 1985). A complete systems analysis, however, will also require data pertaining to delayed evidence of injury. This will enable the researcher to account for *all* of the injury that occurs in any given system.

Objectives

Since past research has indicated that much of the injury that leads to loss of fresh market tomatoes occurs prior to shipping at the packinghouse, it was sought in this study to select one specific, yet typical postharvest handling system of fresh market tomatoes, and evaluate the components of that system from harvest through the packinghouse in terms of both immediate and delayed evidence of injury. Although the term "postharvest handling system" commonly refers to the processes that a fruit or vegetable undergoes from the farm to the consumer, for the purposes of this report, this term will be used to refer only to the processes that the fruits undergo from the farm through the packinghouse.

Background

The postharvest handling system of fresh market tomatoes chosen for this study is located in western North Carolina. For continuity in collecting data as the tomatoes traveled through the system, only one farm was chosen for evaluation. The tomatoes grown in this area are trellis grown and harvested in the "breaker" stage of maturity. It is in this stage that the tomato will just begin to turn from green to yellow in color at the blossom end.

Harvesting at the farm and processing through the packinghouse takes place in the following manner. Migrant workers pick breaker tomatoes from the vine by hand and place them into plastic buckets. When a plastic bucket is full, it is handed across several rows to a worker stationed on a small trailer. This worker then empties the bucket

into a wooden apple crate on the trailer. A small tractor is used to pull the trailer through the field so that it is kept even with the workers in the rows. Typically, one and one-third buckets fill one wooden apple crate. When a section (five rows) of the tomatoes has been picked, the full wooden apple crates are unloaded from the trailer and stacked five to six crates high at the ends of the rows to await completion of the harvesting. Empty crates are stacked onto the trailer, and picking continues in the next section of tomatoes. This process is repeated until harvesting on that day is complete. Typically, harvesting of an entire field takes from five to seven hours, so the first tomatoes harvested remain in crates at the ends of rows for nearly this length of time. Since migrant workers are usually paid by the harvested bucketful, nearly every tomato from mature-green to very ripe and decayed is harvested. However, severely injured tomatoes are typically discarded in the field.

When the harvesting process is complete for the day, a flatbed truck is driven along the ends of the rows and the crated tomatoes are stacked onto the truck, three to four crates high, for delivery to the packinghouse. Normally, 60 to 80 crates of tomatoes are harvested on any harvesting day. When the truck is loaded, tomatoes are transported approximately 35 miles to the packinghouse. This trip usually takes about an hour.

Upon arrival at the packinghouse, the truck sits in a queue waiting to be unloaded for approximately one hour. Unloading typically requires 10 to 15 minutes. During the unloading process, crates are taken off of the truck individually and are manually dumped onto a belt conveyor that carries the tomatoes to a washer. Upon entry to the washer (a series of cold water sprays and soft bristled brushes), tomatoes fall onto a roller conveyor that carries them past the graders. The graders discard severely injured and decayed tomatoes, sort out the very ripe and "number three" (irregular or slightly injured) tomatoes and place them on separate conveyors for boxing. The remainder of the tomatoes continue through the system on belt conveyors where they are size-sorted, color-sorted, and placed in 25-pound boxes. It typically takes a tomato about five minutes to traverse the entire packinghouse operation from unloading to boxing. Tomatoes at the packinghouse studied are sorted and sold in eight categories:

1) Very Ripes
2) Number Threes
3) 5x6 Pink (P)
4) 5x6 Light Pink (LP)
5) 6x6 Pink (P)
6) 6x6 Light Pink (LP)
7) 6x7 Pink (P)
8) 6x7 Light Pink (LP)

Categories 3 through 8 are sold by the packinghouse as USDA "Combination" tomatoes which, by specification, consist of at least 60 percent USDA Number One tomatoes (uninjured) and the remaining percentage USDA Number Two tomatoes (only slightly injured). These will be referred to as "shipping" tomatoes for the remainder of this paper. The figures above, such as "5x6" indicate size groupings of tomatoes.

After boxing, the tomatoes are palletized and set aside for approximately five to ten hours to await shipment via transport truck to a wholesale distribution center in the northeast.

Many postharvest handling systems operate in this manner, and typically, other farms in the area function in a manner very similar to the farm chosen for this study.

Procedures

Tomato samples were taken at the locations and in the manner indicated below. Each sampling consisted of three replications of 20 randomly selected tomatoes for a total of 60 tomatoes at each location. Grading at each location was done by a trained grader, and the amount (percent) of tomatoes with any visible injury at each location was recorded. "Injury" included growth defects, damage, and decay that was apparent at that location.

Sampling Locations

1) Off the Plant: The first 60 tomatoes that would have been picked by the workers were selected.

2) Out of Crate: When harvesting was complete in a section of tomatoes samples were taken from full crates at the ends of rows.

3) Off the Truck: Samples were obtained from crated tomatoes immediately after they were loaded onto the flatbed truck from the ends of rows.

4) Upon Unloading: Samples were taken as the crates were being unloaded from the truck at the packinghouse.

5) After Grading: Samples were taken from tomatoes that had passed inspection by the graders. Note that the tomatoes at this point included neither culls, "Number Threes," or "Very Ripes."

6) After Boxing: Samples from each of the eight categories of tomatoes sold by the packinghouse were obtained. These tomatoes were taken from boxes that had been palletized and prepared for shipment in a manner that normally occurs at the packinghouse.

It should be noted here that tomatoes sampled in the system were chosen completely at random without interfering with the normal operation of the system in any way. All tomatoes chosen for study were pulled from the system on the same day to assure continuity, and every tomato sampled originated at the same farm. Finally, tomatoes were pulled from the system in a manner such that every operation suspected of causing injury could be evaluated, and in a manner such that the components of the system could be evaluated when the study was complete.

When all the tomato samples had been pulled from the system on the day of harvest, labelled, graded, and carefully packed in boxes for storage, they were transported to a controlled environment storage facility. Here tomatoes were stored in their original boxes in precisely the same manner as they would be stored in wholesale or retail storage. Tomatoes were stored for seven days at 21 degrees C and a relative humidity (RH) of 65 percent. On the fourth and seventh days after the samples were collected, the tomatoes were taken out of storage and regraded by the same grader who evaluated them initially to investigate delayed evidence of injury. After regrading, labels on the boxes in which the tomatoes were stored enabled the grader to identify the points in the system from which the tomatoes were taken. *Utmost* care was taken to assure that the tomato samples received no further injury either in being transported to the controlled environment or during grading.

Results and Discussion

The results of the injury evaluation done for the postharvest handling system of this study are shown in Table 1 (immediate evidence of injury) and Table 2 (delayed evidence of injury). Table 1 shows the changes in the percentage of injured tomatoes as the fruit traveled through the system. The results of three separate Duncan's Multiple Range Tests (one for each day) are given along with the percentage of injured tomatoes found at each sampling location. Differences in these percentages were considered significant at the 0.05 level. The results of the re-evaluation of the samples done on days four and seven are presented to indicate any changes in these differences as the fruit ripens. It can be seen from Table 1 that 58 percent of the tomatoes of normal harvest ripeness (breaker) and sampled directly from the plants were visibly injured to some extent (had preharvest defects). This figure indicates a need for better crop management to increase the yield of undefective fruit. When tomatoes were sampled out of the crates, immediately after placement at the ends of rows, it was found that one-third were injured to some extent. The significant reduction in the amount of injured tomatoes (by about 25 percent) that took place between the plants and the crates indicates that the pickers did more

Table 1

Percentages of Injured Tomatoes at Each Component of
A Fresh Market Tomato Postharvest Handling System

Percentages with the same letter are not significantly different. Percentages may be compared for significance only in the *vertical* direction.

	Percent of Tomatoes Injured		
Location	Day 1	Day 4	**Day 7
Off the Plant	58 BC	95 A	98 A
Out of Crate	33 D	62 BC	83 BC
Off the Truck	62 B	80 AB	95 AB
Upon Unloading	65 B	73 B	82 BC
After Grading	40 CD	60 BC	72 CDE
*Number Threes	96 A	96 A	94 AB
*Very Ripes	54 BC	64 BC	77 BCD
*5x6 LP	32 D	48 C	63 CDEF
*5x6 P	63 B	72 B	63 CDEF
*6x6 LP	33 D	65 BC	42 G
*6x6 P	47 BCD	60 BC	53 EFG
*6x7 LP	28 D	43 C	60 DEFG
*6x7 P	32 D	43 C	50 FG

* The samples from each of these categories were obtained from packed boxes that were prepared for distribution.

** In some cases injury at day 7 was difficult to determine, as it was often obscured by overripening.

Table 2

Percentages of Injured Tomatoes at Each Component of
A Postharvest Handling System as a Function of Days from Harvest

Percentages with the same letter are not significantly different. Comparisons between percentages can only be made in the vertical direction.

Day	Off the Plant	Out of Crate	Off the Truck	Upon Unloading	After Grading
1	58 A	33 A	62 A	65 A	40 A
4	95 B	62 B	80 AB	73 A	60 B
7	98 B	83 C	95 B	82 A	72 B

			After Boxing					
Day	Number Threes	Very Ripes	5x6 LP	5x6 P	6x6 LP	6x6 P	6x7 LP	6x7 P
1	96 A	55 A	32 A	63 A	33 A	47 A	28 A	32 A
4	96 A	64 AB	48 AB	72 A	65 B	60 A	43 AB	43 A
7	94 A	77 B	63 B	63 A	42 A	53 A	60 B	50 A

* In some cases injury at day 7 was difficult to determine, as it was often obscured by overripening.

culling in the field than was originally believed. Many of the defective tomatoes on the plants were simply left to decay. This was verified by inspection of the vines after harvesting of a section was complete.

By the time that the harvesting process was completed and the crates were collected and loaded onto the truck for shipment to the packinghouse, samples indicated that the percentage of injured tomatoes in the system had significantly increased (33 to 62 percent). This indicates that a significant percentage of the harvested tomatoes are injured by being stacked in crates at the ends of rows and allowed to sit in the sun from one to seven hours. The "awaiting shipment" component is identified as a major source of injury in tomatoes of this system. While such an increase in injury may seem unexpected, it can be accounted for by the following observations:

1) The wooden apple crates were often overfilled, resulting in the crushing of fruit when they are stacked, both in the field at the ends of rows and again on the truck.

2) Some tomatoes were exposed to direct sunlight and all were exposed to high temperatures as the crates were left sitting in the sun for between one and seven hours.

3) Disrepair of the insides of the crates caused some injury such as puncture and abrasive damage.

Upon unloading at the packinghouse, it was found that the amount of injury present in the tomatoes in the system had not significantly changed. Thus, in this case the vibration and shock encountered during the transport of tomatoes from the field to the packinghouse played little role in the injury of tomatoes that traveled through this system.

Forty percent of the tomatoes sampled after passing the graders showed some immediate evidence of injury. It was expected that the percentage injured would significantly decrease after grading, since during grading the culls were discarded and the "Number Threes" and "Very Ripes" were removed from the system and boxed. It was anticipated, however, that this percentage would be much lower if the grading was done effectively. It should be noted that most of the injury found after grading consisted of very small cracks, punctures and abrasions. These are, however, precisely the types of injury that are the causes of diseases, losses of quality, and ultimately losses of produce at points further along the marketing chain.

It was found that nearly all (96 percent) of the "Number Three" tomatoes sampled from the boxes after packing were injured. The samples of tomatoes from this group contained significantly higher amounts of injury than any other group studied. This is due to the fact that, by definition, "Number Three" tomatoes are slightly injured or irregular. For the "Very Ripe" tomatoes, it was found that 54 percent of the tomatoes sampled from packed boxes were injured. This is reasonable, since the amount of injury present in shipping tomatoes after they had ripened was found to be in this range. Ripe tomatoes are more susceptible to injury than others, and hence, are grouped together and sold along with the "Number Threes" to local markets.

Some unexpected results of this study are indicated by the percentages of injured tomatoes in samples taken from boxes of "shipping," supposedly less injured tomatoes. In five out of the six categories of shipping tomatoes, the percentage of injured tomatoes in these boxes would not have been significantly different had they been packed in the field from the crates. In two cases (5x6 P and 6x6 LP), injury was not significantly different from tomatoes sampled upon unloading of the trucks prior to grading. However, direct comparisons of injury before and after grading need to be carefully evaluated because records were not kept by marketing category before grading. Therefore, the distribution of injury could be different before and after grading.

To investigate delayed evidence of injury, samples collected at day 1 were stored in a controlled environment and regraded at the fourth and seventh days from harvest as dis-

cussed previously. Thirteen separate Duncan's Multiple Range Tests were run (one for each sampling location), and the results are shown in Table 2. Again differences were considered significant at the 0.05 level.

The reason for this part of the study was twofold. First, it was expected that some of the injury in the fruit would not be apparent at the day of harvest, and thus, would be missed by the graders since grading is typically done on the day of harvest. The intent was to see if and when such injury becomes apparent, and by doing so, document possible effects of delayed evidence of injury in tomatoes as they travel through the marketing chain. The second reason for this part of the study was to be able to determine the amount of injury present in the tomatoes at a later date, as if they had been taken from the location indicated in Table 1 and sent directly to the parts of the marketing chain that they would normally be at in four and seven days after harvest.

The results in Table 2 indicate a significant increase in the percentage of injured tomatoes between days one and four for 4 of the 13 samples collected. Significant increases between days one and seven were detected for seven of the 13 samples. This indicates that there is indeed injury in some tomatoes at early stages of ripeness that does not become apparent until the fruit more fully ripens.

There are many ramifications to these findings. On the day of harvest for example, 40 percent of the tomatoes sampled after grading appeared to be injured to some extent. By day seven, a time that the tomatoes could feasibly be on display at a retail market, this figure was found to increase to 72 percent.

Of the tomatoes sold as shipping tomatoes, however, significant increases in injury were found in only two of the six categories. This suggests one or both of the following hypotheses:

1) Injuries inherent in some tomatoes that are not readily apparent on the day of harvest may often never become apparent until the fruit is cut open by a consumer.

2) Relatively few (about one-third in this case) of the tomatoes sustain injuries that cannot be detected immediately.

The evidence does suggest, however, that in some cases delayed evidence of injury is a problem that needs to be addressed in order to assure consistently high quality produce.

Finally, it is apparent that injury problems in those tomatoes sold for shipping and marketing in distant regions may be more a function of the initial amount of injury present in the boxes at the packinghouse than of delayed evidence of injury. Assuming that this postharvest handling system is typical of those located in this region of the United States, it is of little surprise that significant losses of tomatoes, such as those reported by MacLeod et al. (1976), are suffered in markets that handle those tomatoes.

Steps that could be taken to reduce the amount of injury suffered by tomatoes in this system include:

a) Better crop management;

b) Use of improved crates to transport tomatoes;

c) Filling of the crates to the proper levels;

d) Reduced exposure of the tomatoes to excessive temperatures;

e) More careful handling of the tomatoes;

f) Improved tomato grading techniques; and

g) A management scheme that would consolidate the interests of those involved with both production and postharvest handling and marketing.

Summary and Conclusions

By investigating both immediate and delayed evidence of injury in fresh market tomatoes that travel through a typical postharvest handling system in western North Carolina, the major source of injury in the tomatoes was identified. Further, the effect of delayed evidence of injury on the amount of injury present in tomato marketing chains was investigated. Finally, the amount of injury present in tomatoes sold by a packinghouse as USDA Combinations was determined and is discussed.

From a research study such as this a number of conclusions may be reached pertaining to the operation of the system, the magnitudes and origins of injury found in the system, and steps that can be taken to correct injury problems that are found. Although the conclusions reached in this study may apply to other postharvest-handling systems, *they are specific only to the system described in this report,* and are presented below:

1) A large percentage (58 percent) of the tomatoes in the field that were ready for harvest were injured to some extent. Significant levels of grading and culling were done by migrant pickers in the field as they harvested the tomatoes.

2) The major cause of injury in tomatoes of this system was the practice of stacking overfilled crates at the ends of rows.

3) Delayed evidence of injury exists in some cases. Therefore, detailed evaluations of complete postharvest systems should include studies of both immediately apparent and delayed injury.

For future studies, the authors suggest the following:

1) An entire postharvest system, from harvest through the retail consumer, should be evaluated so that the ultimate output of the system can be determined.

2) Injury should be separated into two groupings:

   a) injuries associated with production (preharvest defects), and
   b) mechanical injury (postharvest damage).

3) Records should be kept pertaining to the amount of loss suffered by a lot of produce as it travels through the system, and where those losses occur.

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