This is to certify that the

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EFFECT OF VIBRATION AND PACKAGE TYPE ON BRUISING IN APPLES

presented by

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Masters degree in Packaging

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# EFFECT OF VIBRATION AND PACKAGE TYPE ON BRUISING IN APPLES

By

Ming Xu

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ABSTRACT

EFFECT OF VIBRATION AND PACKAGE TYPE ON BRUISING IN APPLES

By

Ming Xu

This thesis presents the effects of vibration and packaging systems on the bruising of apples. The study investigated four different types of interior packaging: the foam tray, the paper pulp tray, and two different paperboard partition/box combinations. Testing was done on a vibration table using a random controller driven by a power density spectrum simulating truck systems with leaf spring and air cushion suspensions traveling on expressways. The results showed that the foam tray was the best type of interior packaging followed by the paperboard partitions. The paper pulp tray produced the highest damage levels. The air cushion truck suspension showed lower damage levels than the leaf spring suspension for all package types.

I would like to dedicate this thesis to

my parents: Qiying Xu and Xianglan Ma,
for their love and hard work that helped me pursue higher education...

and my wife: Guangli Zhu
for her support through this period.

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# 1.0 INTRODUCTION

Apples packaged commercially undergo a series of shocks as a result of handling and transportation. Every process from picking the fruit to distribution to the consumer offers an opportunity for bruises, cuts, or punctures. Various studies have been done to determine the effects of picking, handling, and transportation on damage (Bartram et-al, 1983, Peleg et-al, 1986, Burton et-al, 1989, Schulte et-al, 1990, and Armstrong et-al, 1991). Some of the significant findings of these studies are presented in the next chapter on literature review.

This study investigated the effect of packaging, and vibration test methods used to simulate the truck shipping environment. Four types of packaging methods were investigated that had different kinds of internal separators and dunnage to protect apples from bruising. In addition vibration test methods used to simulate real life shipments were compared. The use of random vibration for package performance testing has become increasingly important since the damaging effects can be significantly different than for purely sinusoidal vibration which up to now has been the norm for lab simulation of the transportation environment (ASTM D999). With the introduction of ASTM Standard D4728, packaging engineers can now use recommended Power Density Spectrums to simulate changing vibration levels that occur in various transportation systems. The vibration tests used in

this study included the ASTM D999 recommended sinusoidal vibration, and the ASTM D4728 random vibration tests using two of the reference spectra. In addition two additional random vibration spectra were used that were developed from real time vibration measurements on trailers with leaf spring and air cushion suspensions traveling on interstate expressways (Singh, 1991). The literature review reveals no prior study that shows the difference in total damage in packaged products when tested using the different vibration test methods.

Specifically the objectives of this study were:

1. To compare the severity of different sine and random vibration test methods recommended by ASTM.

2. To compare the effect of vibration as a function of package type on bruising levels and USDA grade in apples.

3. To compare the effect of truck suspension (air ride v/s leaf spring) on the damage levels in packaged apples.

## 2.0 LITERATURE REVIEW

Most of the previous studies that investigated apple bruising have focused on impact damage resulting from orchard picking, loading and unloading, handling, packing, etc. Some researchers have also done field transportation testing using different packages and road conditions. The literature review presents studies in chronological order that have observed apple damage due to orchard picking, packing house handling, and transportation.

Schomer (1957) reported that the total bruising in apples was a result of all forms of handling and shipping from harvest to sale at retail stores. He found that the amount of bruising is directly proportional to the number of times the fruit is handled. The study recommended that the following critical steps were necessary to reduce apple bruising:

a. Strict supervision during picking, handling and packing operations.

b. Selection of best type of pack with pads, liners, and trays or cells.

c. Training of careful operation of equipment to truck and machine operators.

d. Adjusting and timing warehouse equipment for minimum injury to fruit.

Another study done by O'Brien et-al (1963) concluded that the resonant frequency of bins used to ship fruit is severely influenced by the design of bin depth and fruit elasticity. Results showed that the peak accelerations of the fruit at the

top layer of the bins is larger than that at the bottom, and if this exceeds 1.0 G, the intermediate layers can get significant movement and rotation to cause damage.

Sargent et-al (1987) observed the mechanical damage on hand harvested 'McIntosh' apples after harvest and transport to packing houses from six commercial orchards. The majority of the damaged apples during harvesting were bruised (81%), followed by punctures (3%) and cuts (1%). At the packing houses the majority of the bruises (91%) were small (0.25 to 0.50 inch in diameter). The study recommended maintaining proper supervision of workers, employing appropriate equipment and reducing unnecessary handling to achieve high quality apples.

Brown et-al (1989) studied the damage in 'Golden Delicious' apples on eight different packing lines to identify the cause of damage and ways to reduce it. The study identified different equipment and locations on the packing line that were monitored with damage free apples as: input at the washer, output from the dryer, on the sizer, on the packing table, and after bagging on the conveyor. The study concluded that starting with bruise-free apples in the flotation tank, 98% to 99% of the apples arriving at the pack table were bruised (86% to 91% of the bruises were between 0.25 to 0.50 inch diameter). In addition the bagging operation, on the average caused more bruises than any other single operation. He also estimated that the typical kinetic

energy when impacting a hard surface on the packing line was between 0.2 J to 0.3 J. The study recommended that in order to prevent damage, the kinetic energy should not exceed 0.05 J, which can be achieved by minimizing transfer ramp slope and roll length, and by greater use of deceleration curtains or brushes. Also a 6.4 mm thick sheet of neoprene sponge should be used to cover all hard impact surfaces. In another study Burton et-al (1989) evaluated areas where apple damage occurs during orchard bin filling and handling, and transport to the packing houses. The study showed that when a combination of the least damaging practices were used (apples gently placed in bins, handled by a standard fork-lift with long tines and transported by a tri-axle fifth-wheel trailer pulled by a pick-up) there were 1.46 bruises/apple (B/A). If a stake-truck replaced the trailer, there were 1.88 B/A. The worst combination was a bin hauled on the rear of a bin carrier in the orchard and transported by truck causing 2.32 B/A. When bins with foam plastic liners were used in the above three methods, the number of B/A were found to be 0.95, 1.23, and 1.38, respectively.

Schulte et-al (1990) investigated the effect of intrastate shipments on damage to "Golden Delicious" apples. The study evaluated the damage to apples when shipped from packing house to the distribution centers and then onto retail stores for eight different shipments. She pointed out that bruising was mainly influenced by the quality of road surface,

the distance shipped, and the type of apple packaging system used. Results also showed that tray-master cartons incurred greatest damage followed by bag-master cartons. The foam cell-master cartons showed the least bruising.

In a later study Schulte (1991) reported bruising effects when picking aides are employed during hand harvest and placement of apples into bulk bins. They found that hand picking was the most significant factor to determine how many bruises can be produced during picking, placement into the picking bucket, and then into storage bulk bins. By using either a deluxe padded picking bucket or a cushioned bin bottom, bruise-free apples can be increased by six to seven percent. The use of gloves during picking led to another six percent less bruised apples.

Armstrong et-al (1991) investigated the damage incurred by apples during transportation in three different bulk bin types made from plywood and hardwood. The apples were found to resonate between 5 to 14 Hertz, and this was dependent on the stiffness of bin bottom. In addition the plywood bulk bin showed the least amount of damage.

## 3.0 EXPERIMENTAL DESIGN

In order to accomplish the objectives of the study four different package types were selected and five types of vibration tests performed on each package type. The apples and respective package types, and the vibration tests used are described in this chapter.

### 3.1 Apple Package Types:

The apples used in this test were hand picked 'McIntosh' apples, approximately 70 to 76 mm (2.76 to 3.00 in) in diameter, obtained from the MSU Clarksville Horticultural Experiment Station. In order to speed up the measurement of apple size, an electronic balance was used to weigh the apples instead of measuring the apple diameter with a ruler, since the apple diameter is related to apple weight.

The graded apples were randomized at the storage facility so as to remove any bias due to a specific tree condition and placed in cold storage at 40°F and 85% RH for at least four days after picking which is the recommended storage temperature (Agriculture Handbook No. 105, USDA, Nov. 1970). The apples were then packaged in four different types of packages A, B, C, and D.

Package A consisted of a FTHS (Full Telescopic Half Slotted) corrugated box with a telescopic top cover. The complete package is shown in Figure 1. This box is designed to hold 120 apples per box in four layers, 30 apples per

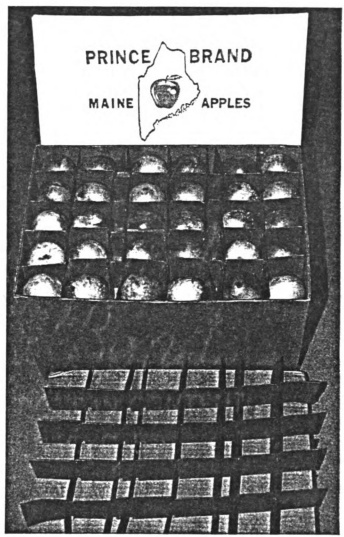


Figure 1: Package A

layer. Each layer is partitioned into individual cells using paperboard and separated from the next layer with corrugated sheets. The box and the cover are made from single wall C-flute corrugated board with a burst strength of 200 psi. This package is commonly used for export shipments in the New England states with apples placed on their cheeks or sides.

Package B is similar to package A except that the box is a RSC (Regular Slotted Container). The corrugated board used to make the box was also single wall C-flute with a burst strength of 200 psi. The box is made to hold 120 apples in the same configuration as Package A but with a slightly different partition. The apples are also placed on their sides. The complete package is shown in Figure 2.

Package C is a FTHS telescopic corrugated box made from a single wall C-Flute corrugated board with a burst strength of 275 psi. The inside of the box contains five molded paper pulp trays designed to hold 20 apples per tray for a total of 100 apples per box. The apples are placed on their bottom in the cavity formed in the tray as in Figure 3. This package system is used commonly in the Mid West states.

Package D is also a FTHS telescopic box similar in construction and materials used in Package C. The inside of each box uses four pre-molded polystyrene foam trays designed to hold 24 apples per layer for a total of 96 apples per box. This package is shown in Figure 4.

The apples were removed from cold storage and inspected

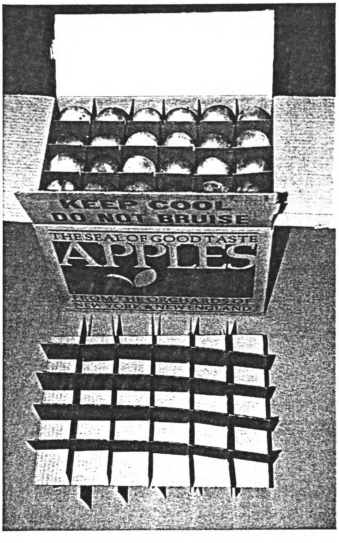


Figure 2: Package B

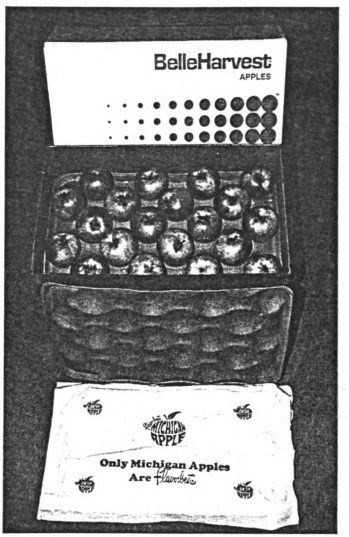


Figure 3: Package C

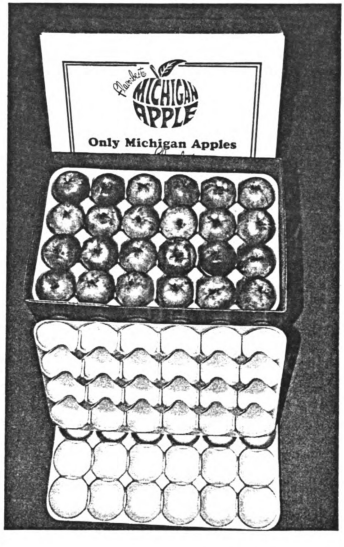


Figure 4: Package D

for any visible fruit damage in the form of a bruise, cut, or puncture. Pre-test damage was marked so as to not be included in the test results. This procedure was used for all apples that were packaged and then immediately subjected to a specific vibration tests that are described in the next section.

3.2 Vibration Tests:

The vibration tests were performed on a electrohydraulic vibration table. A MTS sine sweep and a Solatron random controller were used to perform the necessary tests. The apple packages were column stacked five high and the top two boxes were stretch wrapped. Guide rods were placed on the side to protect the column from falling sideways. The test setup is shown in Figure 5. The stacked packages were then subjected to five different types of vibration tests V1, V2, V3, V4, and V5.

Vibration test V1 is the sinusoidal vibration test in accordance with ASTM D999-86, Method C. The column was subjected to a frequency scan from 2 to 100 Hertz at a rate of 1 octave per minute, and an acceleration level of 0.5 g's. The resonance conditions were determined in accordance with the test procedure. The stacked column was then subjected to a vibration dwell at 0.5 g's for fifteen minutes at each resonant frequency. The resonant frequencies determined for Package A were 7.0 and 21.1 Hertz, for Package B were 6.0 and 12.1 Hertz, for Package C were 6.6 and 9.4 Hertz, and for

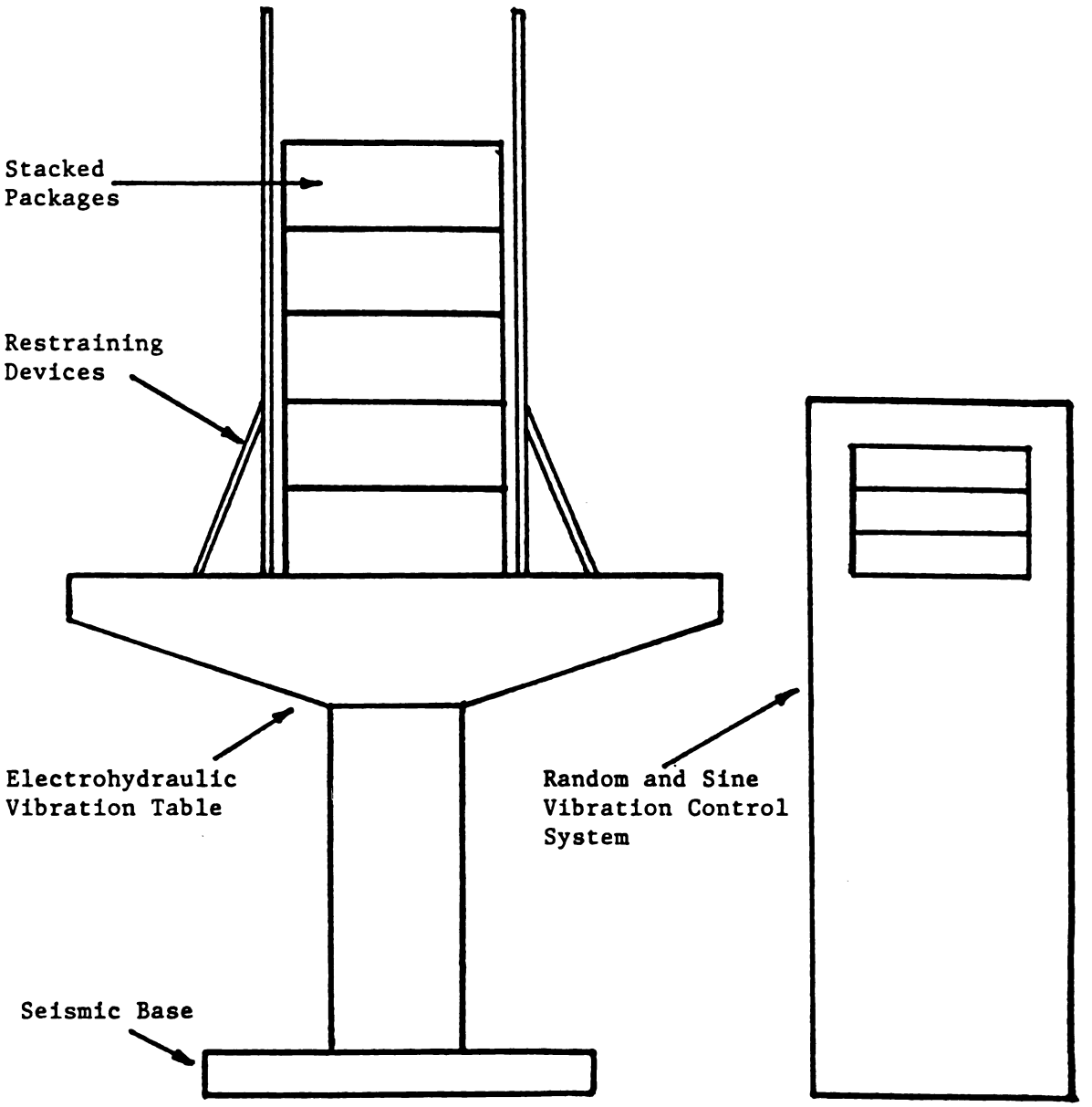


Figure 5: Experimental Test Setup

Package D were 4.6 and 16.7 Hertz respectively.

Vibration test V2 is the random vibration test in accordance with ASTM D4728-87, Method A. The Power Density spectrum used was the 'Commercial Truck Transport Random Vibration Spectra' described in the standard (Figure 6). The test was performed for 180 minutes.

Vibration test V3 is the random vibration test in accordance with ASTM D4728-87, Method A. The Power Density spectrum used was the 'Route Comparison Leaf Spring Truck Vertical Vibration, C-Expressway' described in the standard (Figure 7). The test was performed for 180 minutes.

Vibration test V4 is the random vibration test in accordance with ASTM D4728-87, Method A. The Power Density spectrum used for this test represents the composite spectrum at the rear of a 40 foot long trailer with a leaf spring suspension (Figure 8). Data reflects a trailer with a payload of 20,000 lbs. and travelling at 55 mph on interstate expressways (Singh, 1991). The test duration was 180 minutes.

Vibration test V5 is the random vibration test in accordance with ASTM D4728-87, Method A. The Power Density spectrum used for this test represents the composite spectrum at the rear of a 40 foot long trailer with an air ride suspension (Figure 9). Data reflects a trailer with a payload of 18,000 lbs. and travelling at 55 mph on interstate expressways (Singh, 1991). The test duration was 180 minutes.

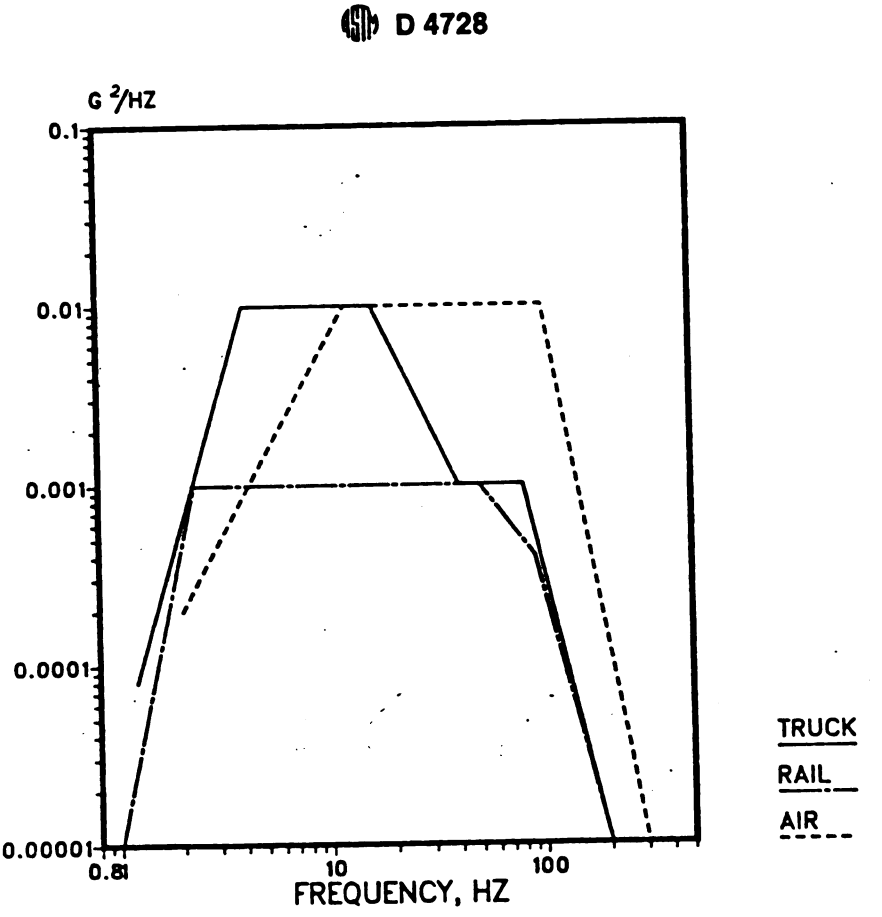


Figure 6: ASTM D4728 X1.1 Power Density Spectrum (Truck)

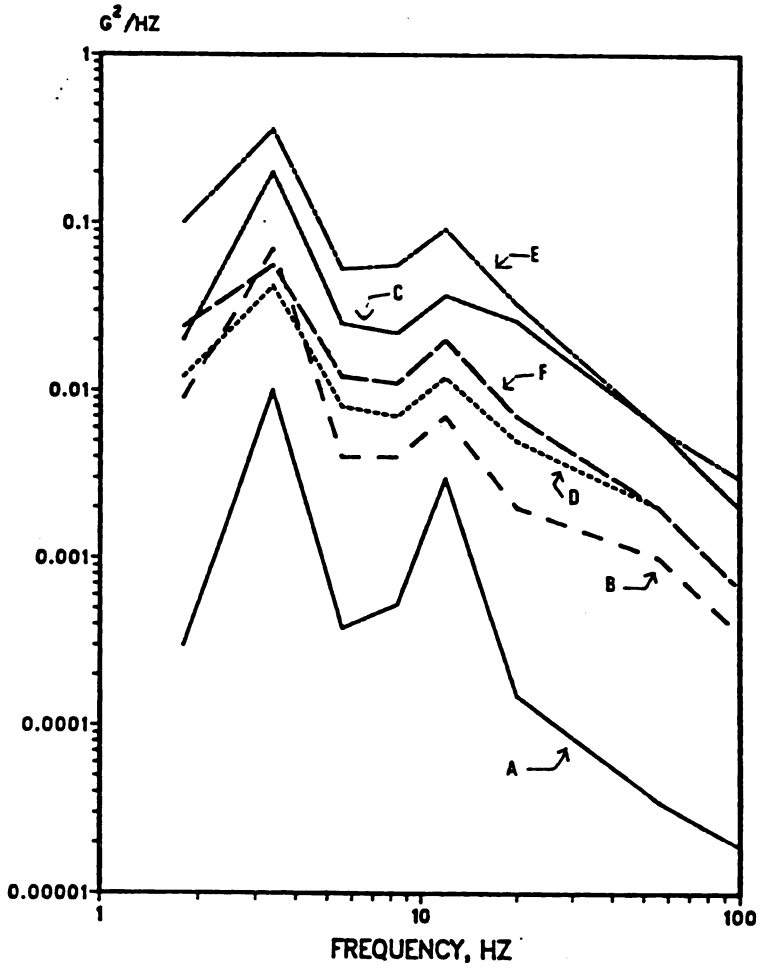


Figure 7: ASTM D4728 X1.2 Power Density Spectrum (Expressway)

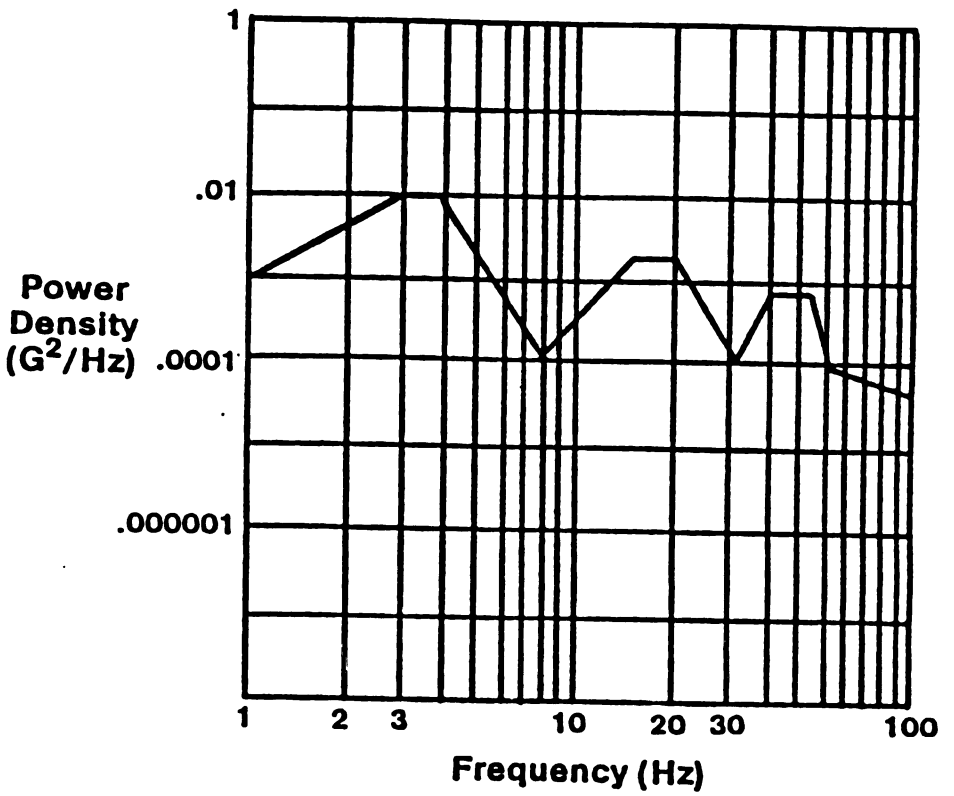


Figure 8: Power Density Spectrum of Leaf Spring Truck

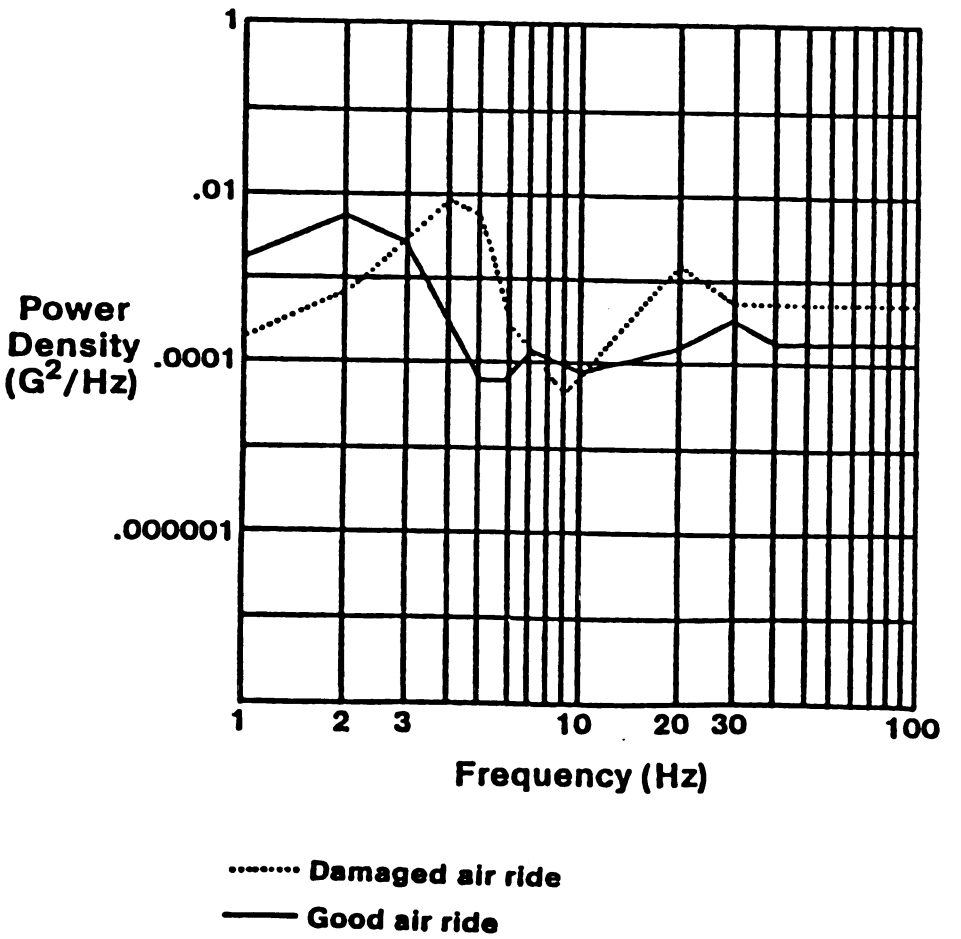


Figure 9: Power Density Spectrum of Air Ride Truck

3.3 Quantifying Damage to Apples:

At the end of each vibration test of a column stack of packages, the top and bottom packages were removed and stored in cold storage [40°F, 85% RH] for 72 hours. The packages were then removed and each apple was inspected.

All apples were graded according to the USDA (1964) grade standards for bruise, cut, and puncture damage. Apples showing a total roller bruise on its sides or a total bruise were also accounted for. Each bruise was given a rating of A, B, C, D, or E, corresponding to the average diameter as judged using a set of circular discs. Table 1 shows the classification of the bruise category and the diameter range. Bruises with diameter smaller than 0.25 inch were not counted. The number of bruises in each category were recorded for each box type and each vibration test performed. A computer program developed to analyze apple damage data (Brown et al., 1989) was used to summarize the data. Four types of apple damage data was determined;

- Percent bruised apple (PBA)
- Average number of bruises per apple (N)
- Average bruise area per fruit in sq.in. (A)
- Mean USDA Grade (GRD)

The percent bruised fruit gives the percent ratio of all apples in a carton that are bruised in any way. The average number of bruises per apple is the total number of bruises on all apples divided by total number of apples in the container. The average bruise area per fruit is the total bruise area on all apples that were bruised in any way divided by total

TABLE 1: BRUISE CATEGORY AND DIAMETER CLASSIFICATION

| BRUISE CATEGORY | DIAMETER RANGE (INCHES) |
|---|---|
| A | $0.25 < DIA \leq 0.50$ |
| B | $0.50 < DIA \leq 0.75$ |
| C | $0.75 < DIA \leq 0.87$ |
| D | $0.87 < DIA \leq 1.25$ |
| E | $DIA > 1.25$ |

number of apples in the container. The USDA grade is determined by using all the previous three values and is determined for the whole container.

## 4.0 DATA AND RESULTS

The apples were inspected and the damage levels measured according to the methodology described in 3.3 for each type of vibration test and package type. The damage levels were evaluated for the top and bottom package in the stack subjected to the vibration test. The Appendix lists the data for each carton evaluated using the computer program developed by Brown et-al (1989). Tables A1 to A40 list the data for each carton evaluated in this study.

Table 2 shows the percentage of all apples tested that were bruised in any way for each package type and vibration test performed. For example, in a stack of five package type C boxes, subjected to a random vibration test for a trailer with a leaf spring suspension (Test V4), 78 out of 100 apples in the top box were found to have some degree of bruising and only 40 out of 100 in the bottom box.

Table 3 shows the average number (N) of bruises per apple taken over all the apples in each container for each package type and vibration test done (calculated as total number of bruises on all apples in a given container divided by the number of apples in that container). In the same example used for Table 2 then, there were 188 bruises on 78 of the 100 apples in the top box in the stack.

Table 4 shows the average bruise area in square inches per apple taken over all the apples in the container, for each package type and vibration test used. The total bruise area

Table 2: Percent Bruised Apples in Package Vibration Tests

| Vibration Test | Stack Location | Package Type | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| V1 | Top | 41.6 | 44.1 | 99.0 | 42.7 |
| | Bottom | 14.2 | 16.7 | 37.0 | 5.2 |
| V2 | Top | 88.4 | 55.0 | 100.0 | 31.3 |
| | Bottom | 42.5 | 55.8 | 91.9 | 1.0 |
| V3 | Top | 100.0 | 100.0 | 100.0 | 100.0 |
| | Bottom | 100.0 | 100.0 | 100.0 | 66.7 |
| V4 | Top | 6.7 | 24.2 | 78.0 | 5.2 |
| | Bottom | 17.7 | 40.3 | 40.0 | 0.0 |
| V5 | Top | 13.3 | 5.0 | 33.0 | 1.0 |
| | Bottom | 0.8 | 0.8 | 24.0 | 0.0 |

Table 3: Average Number of Bruises per Apple in Package Vibration Tests

| Vibration Test | Stack Location | Package Type | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| V1 | Top | 0.66 | 0.72 | 4.04 | 0.74 |
| | Bottom | 0.15 | 0.17 | 0.44 | 0.05 |
| V2 | Top | 2.80 | 0.97 | 4.17 | 0.63 |
| | Bottom | 0.57 | 0.76 | 2.41 | 0.01 |
| V3 | Top | 4.22 | 2.88 | * | 2.73 |
| | Bottom | 3.58 | 3.75 | 5.60 | 1.34 |
| V4 | Top | 0.09 | 0.32 | 1.88 | 0.05 |
| | Bottom | 0.19 | 0.43 | 0.56 | 0.00 |
| V5 | Top | 0.17 | 0.06 | 0.52 | 0.01 |
| | Bottom | 0.01 | 0.01 | 0.24 | 0.00 |

* All apples and the package were damaged in the test.

Table 4: Average Bruise Area ($in^2$) per Apple in Package Vibration Tests

| Vibration Test | Stack Location | Package Type | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| V1 | Top | 0.22 | 0.28 | 1.45 | 0.30 |
| | Bottom | 0.02 | 0.03 | 0.06 | 0.01 |
| V2 | Top | 0.77 | 0.18 | 1.29 | 0.24 |
| | Bottom | 0.13 | 0.15 | 0.47 | 0.01 |
| V3 | Top | 1.93 | 1.17 | * | 1.20 |
| | Bottom | 1.85 | 2.26 | 3.01 | 0.87 |
| V4 | Top | 0.02 | 0.05 | 0.25 | 0.01 |
| | Bottom | 0.04 | 0.07 | 0.07 | 0.00 |
| V5 | Top | 0.02 | 0.01 | 0.08 | 0.09 |
| | Bottom | 0.00 | 0.00 | 0.03 | 0.00 |

* All apples and the package were damaged in the test.

for the entire box of 100 apples (same example) then was 25 $in^2$ distributed over 188 bruises on 78 apples. The averages reported in Tables 3 and 4 are taken over all of the apples in a particular container instead of only those that actually bruised because cartons are graded on this basis. The average bruise diameter may be deduced from the given data in a straight forward manner: in this example, 25 $in^2$/188 bruises = 0.133 $in^2$ per bruise = $\pi D^2/4$ from which D = 0.4 inches.

Table 5 shows the USDA grade based on the average apple size and bruise data per container determined for each package type and vibration test in accordance with USDA (1964) requirements. A USDA grade of 1.00 reflects apples with insignificant bruise level and are classified as 'Extra Fancy'. A grade of 2.00 reflects some bruising and is called 'Fancy'. Both these types are used as good quality eating apples. A USDA grade of 3.00 is called 'U.S. No. 1', and is a low grade eating apple. A grade of 4.00 is called 'Utility' and is generally used for processing into juices, purees, sauce, etc. A grade of 5.00 is 'Reject' and these apples are discarded.

Based on the values computed for the USDA grade (Table 5) determined from the data in Tables 2-4, it is clear that vibration test V3 is a significantly severe test and does not replicate a real life shipment. All the top containers and the apples were totally damaged for all package types (Table 5). Even the apples in bottom packages in the bottom layer

Table 5: USDA Grade Determined for Apple Package Vibration Tests

| Vibration Test | Stack Location | Package Type | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| V1 | Top | 1.63 | 2.04 | 4.53 | 1.88 |
| | Bottom | 1.03 | 1.05 | 1.08 | 1.00 |
| V2 | Top | 3.17 | 1.53 | 4.06 | 1.58 |
| | Bottom | 1.33 | 1.57 | 2.17 | 1.00 |
| V3 | Top | 5.00 | 5.00 | 5.00 | 4.99 |
| | Bottom | 4.64 | 4.96 | 4.99 | 2.60 |
| V4 | Top | 1.02 | 1.09 | 1.88 | 1.00 |
| | Bottom | 1.12 | 1.11 | 1.13 | 1.00 |
| V5 | Top | 1.04 | 1.01 | 1.16 | 1.00 |
| | Bottom | 1.00 | 1.00 | 1.00 | 1.00 |

showed excessive damage. Figures 10 and 11 show pictures of package types B and C after completion of the test. The boxes were damaged, the internal partitions and trays had been severely crushed and the apples were totally bruised. If this test replicated a true shipping scenario, none of the apple packages would protect apples from total bruising based on the results. However this is contradictory to Schulte et-al (1990) findings for real on-the-road shipments.

Figure 12 shows the different types of apples inspected after the vibration tests. The top layer shows an apple that has been pre-marked with any damage that may have occurred between the picking operation and the vibration test and a good apple with no damage. The bottom layer shows the first apple totally bruised, followed by an apple with a roller bruise (common in package A and B), the third and fourth with bruises on the top (common in Packages C and D), the fifth with a bruise on the side.

Tests V1 and V2 compared the damage levels observed using ASTM recommended sine versus random vibration test. The damage levels were consistently lower (showing minimal damage, GRD values close to 1.0) in all the package types for the bottom layer when using the sinusoidal vibration test as compared to the recommended random vibration test. However the damage levels were higher for the top layer for all package types except package A, when using the sinusoidal test

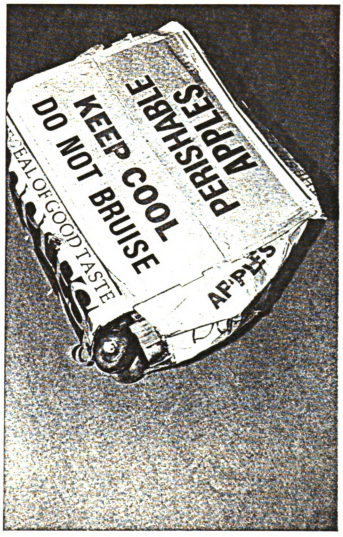


Figure 10: Damaged Apple Package B after Vibration Test 3

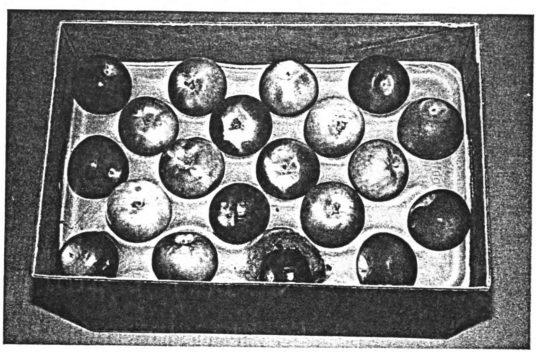

Figure 11: Damaged Apple Package C after Vibration Test 3

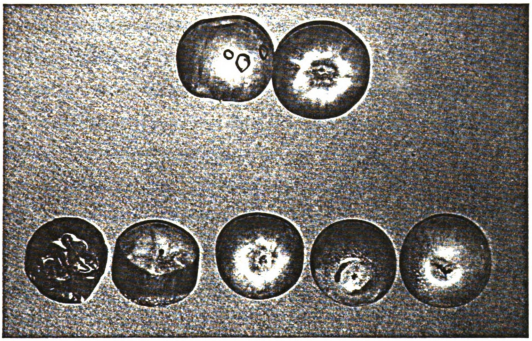

Figure 12: Samples of Apples Inspected for Damage

as compared to the random test. Results show that the recommended ASTM sinusoidal vibration test when compared to the random vibration test shows more damage on the top layer, and less damage on the bottom layer, for stacked apple packages.

The data from Table 5 shows that when comparing package types, the FTHS corrugated box with polystyrene foam partitions (Package D) showed the least damage (Test V1 and V2). The FTHS corrugated box with pulp partitions showed the maximum damage. The damage levels caused using Packages A and B (apples partitioned into individual cells using paperboard and separated from the next layer with corrugated sheets) showed intermediate damage levels.

In general all the packages were in good shape after the test. When evaluating the bruises in apples as a function of the interior partitions used, it is evident that the compression loading due to the weight of apples in the upper layers within a carton, is the main cause of bruising. This is evident by high bruising levels in Package C as compared to Packages A, B, and D, where the weight of the top layers is supported by the partitions. The second cause of damage is the actual movement of the apple in a cell or partition due to vibration. An ideal package should therefore cause no compression on the individual apples, and not allow any free movement within a cell. The use of paper-board partitions in Packages A, B, and C, generally will cause higher damage as

compared to expanded polystyrene because of the high coefficient of friction, resulting in more abrasion.

The damage levels to apples as a function of trailer suspension used was also compared in vibration tests V4 and V5. The results from Table 5 show trailers with leaf spring suspension (test V4) will generally produce similar or higher damage levels in apples in all package types evaluated as compared to trailers with air ride cushions. In addition the test results show that apple package D using a telescopic box and a EPS foam tray, showed no damage (GRD = 1.00) when using a trailer with air ride cushion.

## 5.0 CONCLUSIONS

The results of this study concluded the following:

1. The ASTM recommended sinusoidal tests (D999, Method C) show consistently lower damage levels in apples (showing minimal damage, GRD values close to 1.0) for the bottom layer as compared to the recommended random vibration test (D4728, Method A, Figure X1.1, Truck), for all types of apple packages evaluated. However the damage levels were higher for the top layer for all package types except package A, when using the sinusoidal test as compared to the random test. Also the recommended ASTM Truck Expressway spectrum (D4728, Figure X1.2) is a significantly severe test, and shows no correlation with real life shipments. This test should not be used to replicate shipment tests.

2. The results of the study show that the FTHS corrugated box with polystyrene foam trays (Package D) showed the least damage. The FTHS corrugated box with pulp partitions showed the maximum damage. The damage levels caused using FTHS and RSC corrugated boxes with individual cell partitions made of paperboard and separated from the next layer with corrugated sheets showed intermediate damage levels. In general an ideal package should cause no compression on individual apples in each partition. In addition they should be held in place in individual partitions to prevent movement during vibration. The material used to

make partitions should have a low coefficient of friction (plastics versus paper).

3. The results show that trailers with leaf spring suspension will generally produce similar or higher damage levels in apples in all package types evaluated as compared to trailers with air ride cushions. Results show that apples packaged using a FTHS box and a EPS foam tray, showed no damage (GRD = 1.00) when using a trailer with air ride cushion.

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# APPENDIX

**TABLE A1: Apple bruising and grading results,**
**Vibration Test V1; Package A; Top carton**

## BRUISING AND GRADING RESULTS

**Apples in test: 120**

## DAMAGE DISTRIBUTION

| | |
|---|---|
| **No Bruise Damage (OK):** | **58.3 %** |
| **Bruised Fruit (PBA):** | **41.6 %** |
| **Excess Bruise (EB):** | **0.0 %** |
| **Roller Bruise (RB):** | **0.0 %** |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | **39.1 %** |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | **39.4 %** |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | **11.8 %** |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | **7.3 %** |
| **(E) Bruise Damage > 1-1/4":** | **2.4 %** |

## Roller Bruise Distribution

| | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | **0.0 %** |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | **0.0 %** |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | **0.0 %** |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | **0.0 %** |
| **Roller Bruise Damage > 1-1/4" :** | **0.0 %** |

## Grade Distribution

| | |
|---|---|
| **Extra Fancy :** | **67.5 %** |
| **Fancy :** | **15.8 %** |
| **No. 1 :** | **5.8 %** |
| **Utility :** | **7.5 %** |
| **Reject :** | **3.3 %** |

## Means

| | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | **0.66** |
| **Mean Bruise Area/Apple ($in^2$) (A):** | **0.22** |
| **Mean USDA Apple Grade (GRD):** | **1.63** |

TABLE A2: Apple bruising and grading results,
Vibration Test V1; Package A; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

Apples in test: 120

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 85.8 % |
| Bruised Fruit (PBA): | 14.2 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 84.3 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 15.7 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 98.3 % |
| Fancy : | 0.8 % |
| No. 1 : | 0.0 % |
| Utility : | 0.8 % |
| Reject : | 0.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.15 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.02 |
| Mean USDA Apple Grade (GRD): | 1.03 |

TABLE A3: Apple bruising and grading results,
Vibration Test V1; Package B; Top carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test:** 120

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | 55.8 % |
| **Bruised Fruit (PBA):** | 44.1 % |
| **Excess Bruise (EB):** | 0.0 % |
| **Roller Bruise (RB):** | 6.6 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 27.0 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 39.5 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 13.5 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 17.3 % |
| **(E) Bruise Damage > 1-1/4":** | 2.7 % |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 62.5 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 37.5 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | 60.0 % |
| **Fancy :** | 13.3 % |
| **No. 1 :** | 4.2 % |
| **Utility :** | 7.5 % |
| **Reject :** | 15.0 % |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 0.72 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 0.28 |
| **Mean USDA Apple Grade (GRD):** | 2.04 |

TABLE A4: Apple bruising and grading results,
Vibration Test V1; Package B; Bottom carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| Apples in test: | 120 |

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 83.3 % |
| Bruised Fruit (PBA): | 16.7 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 81.7 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 13.9 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 4.4 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 95.8 % |
| Fancy : | 3.3 % |
| No. 1 : | 0.8 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.17 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.03 |
| Mean USDA Apple Grade (GRD): | 1.05 |

TABLE A5: Apple bruising and grading results,
Vibration Test V1; Package C; Top carton

| BRUISING AND GRADING RESULTS |
|---|

Apples in test: 100

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 1.0 % |
| Bruised Fruit (PBA): | 99.0 % |
| Excess Bruise (EB): | 20.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 30.4 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 37.9 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 20.3 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 11.4 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 1.0 % |
| Fancy : | 6.0 % |
| No. 1 : | 2.0 % |
| Utility : | 21.0 % |
| Reject : | 70.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 4.04 |
| Mean Bruise Area/Apple ($in^2$) (A): | 1.45 |
| Mean USDA Apple Grade (GRD): | 4.53 |

TABLE A6: Apple bruising and grading results,
Vibration Test V1; Package C; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

Apples in test: 100

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 63.0 % |
| Bruised Fruit (PBA): | 37.0 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 93.2 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 6.8 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 92.0 % |
| Fancy : | 8.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.44 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.06 |
| Mean USDA Apple Grade (GRD): | 1.08 |

TABLE A7: Apple bruising and grading results,
Vibration Test V1; Package D; Top carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| Apples in test: | 96 |

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 57.3 % |
| Bruised Fruit (PBA): | 42.7 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 4.2 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 32.7 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 39.1 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 11.6 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 9.7 % |
| (E) Bruise Damage > 1-1/4": | 6.9 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 50.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 50.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 65.6 % |
| Fancy : | 12.5 % |
| No. 1 : | 2.1 % |
| Utility : | 8.3 % |
| Reject : | 11.4 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.74 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.30 |
| Mean USDA Apple Grade (GRD): | 1.88 |

TABLE A8: Apple bruising and grading results,
Vibration Test V1; Package D; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test: 96**

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 94.8 % |
| Bruised Fruit (PBA): | 5.2 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 100.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 0.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 100.0 % |
| Fancy : | 0.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.05 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.01 |
| Mean USDA Apple Grade (GRD): | 1.00 |

TABLE A9: Apple bruising and grading results,
Vibration Test V2; Package A; Top carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| Apples in test: | 120 |

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 11.6 % |
| Bruised Fruit (PBA): | 88.4 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 3.3 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 56.1 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 26.7 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 10.1 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 6.6 % |
| (E) Bruise Damage > 1-1/4": | 0.5 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 75.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 25.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 17.5 % |
| Fancy : | 21.7 % |
| No. 1 : | 10.8 % |
| Utility : | 26.7 % |
| Reject : | 23.3 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 2.80 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.77 |
| Mean USDA Apple Grade (GRD): | 3.17 |

**TABLE A10:** Apple bruising and grading results, Vibration Test V2; Package A; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test:** 120

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | **57.5 %** |
| **Bruised Fruit (PBA):** | **42.5 %** |
| **Excess Bruise (EB):** | **0.0 %** |
| **Roller Bruise (RB):** | **0.0 %** |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | **58.0 %** |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | **35.7 %** |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | **5.1 %** |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | **1.2 %** |
| **(E) Bruise Damage > 1-1/4":** | **0.0 %** |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | **0.0 %** |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | **0.0 %** |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | **0.0 %** |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | **0.0 %** |
| **Roller Bruise Damage > 1-1/4" :** | **0.0 %** |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | **76.6 %** |
| **Fancy :** | **17.5 %** |
| **No. 1 :** | **2.5 %** |
| **Utility :** | **3.3 %** |
| **Reject :** | **0.0 %** |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | **0.57** |
| **Mean Bruise Area/Apple ($in^2$) (A):** | **0.13** |
| **Mean USDA Apple Grade (GRD):** | **1.33** |

TABLE A11: Apple bruising and grading results, Vibration Test V2; Package B; Top carton

## BRUISING AND GRADING RESULTS

**Apples in test:** 120

## DAMAGE DISTRIBUTION

| | |
|---|---|
| No Bruise Damage (OK): | 45.8 % |
| Bruised Fruit (PBA): | 55.0 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.8 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 70.4 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 25.7 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 3.2 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.7 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

## Roller Bruise Distribution

| | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 100.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

## Grade Distribution

| | |
|---|---|
| Extra Fancy : | 64.2 % |
| Fancy : | 25.8 % |
| No. 1 : | 4.2 % |
| Utility : | 4.2 % |
| Reject : | 1.7 % |

## Means

| | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.97 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.18 |
| Mean USDA Apple Grade (GRD): | 1.53 |

**TABLE A12:** Apple bruising and grading results, Vibration Test V2; Package B; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test:** 120

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 44.1 % |
| Bruised Fruit (PBA): | 55.8 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 5.8 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 66.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 26.6 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 5.1 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 2.3 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 85.7 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 14.3 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 72.5 % |
| Fancy : | 13.4 % |
| No. 1 : | 5.0 % |
| Utility : | 3.3 % |
| Reject : | 5.8 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.76 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.15 |
| Mean USDA Apple Grade (GRD): | 1.57 |

TABLE A13: Apple bruising and grading results, Vibration Test V2; Package C; Top carton

## BRUISING AND GRADING RESULTS

**Apples in test:** 100

## DAMAGE DISTRIBUTION

| | |
|---|---|
| No Bruise Damage (OK): | 0.0 % |
| Bruised Fruit (PBA): | 100.0 % |
| Excess Bruise (EB): | 14.0 % |
| Roller Bruise (RB): | 3.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 47.1 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 31.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 11.1 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 7.4 % |
| (E) Bruise Damage > 1-1/4": | 3.4 % |

## Roller Bruise Distribution

| | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 33.3 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 66.7 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

## Grade Distribution

| | |
|---|---|
| Extra Fancy : | 1.0 % |
| Fancy : | 16.0 % |
| No. 1 : | 6.0 % |
| Utility : | 30.0 % |
| Reject : | 47.0 % |

## Means

| | |
|---|---|
| Mean Number of Bruises/Apple (N): | 4.17 |
| Mean Bruise Area/Apple ($in^2$) (A): | 1.29 |
| Mean USDA Apple Grade (GRD): | 4.06 |

TABLE A14: Apple bruising and grading results, Vibration Test V2; Package C; Bottom carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| **Apples in test:** | 100 |

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | 8.1 % |
| **Bruised Fruit (PBA):** | 91.9 % |
| **Excess Bruise (EB):** | 0.0 % |
| **Roller Bruise (RB):** | 0.0 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 86.2 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 6.4 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 4.2 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 2.9 % |
| **(E) Bruise Damage > 1-1/4":** | 0.3 % |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 0.0 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 0.0 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | 30.3 % |
| **Fancy :** | 43.4 % |
| **No. 1 :** | 13.1 % |
| **Utility :** | 5.1 % |
| **Reject :** | 8.1 % |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 2.41 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 0.47 |
| **Mean USDA Apple Grade (GRD):** | 2.17 |

TABLE A15: Apple bruising and grading results, Vibration Test V2; Package D; Top carton

## BRUISING AND GRADING RESULTS

**Apples in test: 96**

## DAMAGE DISTRIBUTION

| | |
|---|---|
| No Bruise Damage (OK): | 68.7 % |
| Bruised Fruit (PBA): | 31.3 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 1.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 56.7 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 14.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 16.7 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 5.6 % |
| (E) Bruise Damage > 1-1/4": | 7.0 % |

## Roller Bruise Distribution

| | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 100.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

## Grade Distribution

| | |
|---|---|
| Extra Fancy : | 76.0 % |
| Fancy : | 9.4% |
| No. 1 : | 3.1 % |
| Utility : | 4.2 % |
| Reject : | 7.3 % |

## Means

| | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.63 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.24 |
| Mean USDA Apple Grade (GRD): | 1.58 |

TABLE A16: Apple bruising and grading results, Vibration Test V2; Package D; Bottom carton

## BRUISING AND GRADING RESULTS

**Apples in test: 96**

## DAMAGE DISTRIBUTION

| | |
|---|---|
| No Bruise Damage (OK): | 98.9 % |
| Bruised Fruit (PBA): | 1.0 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 100.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 0.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

## Roller Bruise Distribution

| | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

## Grade Distribution

| | |
|---|---|
| Extra Fancy : | 100.0 % |
| Fancy : | 0.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

## Means

| | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.01 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.01 |
| Mean USDA Apple Grade (GRD): | 1.00 |

TABLE A17: Apple bruising and grading results, Vibration Test V3; Package A; Top carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| Apples in test: | 120 |

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 0.0 % |
| Bruised Fruit (PBA): | 100.0 % |
| Excess Bruise (EB): | 30.9 % |
| Roller Bruise (RB): | 23.3 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 37.3 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 33.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 6.2 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 11.2 % |
| (E) Bruise Damage > 1-1/4": | 12.2 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 7.1 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 75.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 17.8 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 0.0 % |
| Fancy : | 0.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 100.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 4.22 |
| Mean Bruise Area/Apple ($in^2$) (A): | 1.93 |
| Mean USDA Apple Grade (GRD): | 5.00 |

TABLE A18: Apple bruising and grading results, Vibration Test V3; Package A; Bottom carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| **Apples in test:** | **120** |

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | **0.0 %** |
| **Bruised Fruit (PBA):** | **100.0 %** |
| **Excess Bruise (EB):** | **0.0 %** |
| **Roller Bruise (RB):** | **3.3 %** |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | **28.2 %** |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | **21.1 %** |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | **21.9 %** |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | **23.0 %** |
| **(E) Bruise Damage > 1-1/4":** | **5.9 %** |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | **24.8 %** |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | **25.0 %** |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | **50.2 %** |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | **0.0 %** |
| **Roller Bruise Damage > 1-1/4" :** | **0.0 %** |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | **0.0 %** |
| **Fancy :** | **1.7 %** |
| **No. 1 :** | **5.8 %** |
| **Utility :** | **19.2 %** |
| **Reject :** | **73.3 %** |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | **3.58** |
| **Mean Bruise Area/Apple ($in^2$) (A):** | **1.85** |
| **Mean USDA Apple Grade (GRD):** | **4.64** |

TABLE A19: Apple bruising and grading results, Vibration Test V3; Package B; Top carton

| BRUISING AND GRADING RESULTS |
|---|

Apples in test: 120

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 0.0 % |
| Bruised Fruit (PBA): | 100.0 % |
| Excess Bruise (EB): | 70.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 37.1 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 17.4 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 10.5 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 17.6 % |
| (E) Bruise Damage > 1-1/4": | 17.5 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 0.0 % |
| Fancy : | 0.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 100.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 2.88 |
| Mean Bruise Area/Apple ($in^2$) (A): | 1.17 |
| Mean USDA Apple Grade (GRD): | 5.00 |

TABLE A20: Apple bruising and grading results, Vibration Test V3; Package B; Bottom carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| **Apples in test:** | 120 |

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | 0.0 % |
| **Bruised Fruit (PBA):** | 100.0 % |
| **Excess Bruise (EB):** | 5.0 % |
| **Roller Bruise (RB):** | 22.5 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 28.1 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 17.7 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 9.9 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 25.8 % |
| **(E) Bruise Damage > 1-1/4":** | 18.5 % |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 3.7 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 14.8 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 77.7 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 3.7 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | 0.0 % |
| **Fancy :** | 0.8 % |
| **No. 1 :** | 0.0 % |
| **Utility :** | 1.6 % |
| **Reject :** | 97.5 % |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 3.75 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 2.26 |
| **Mean USDA Apple Grade (GRD):** | 4.96 |

**TABLE A21:** Apple bruising and grading results, Vibration Test V3; Package C; Top carton

## BRUISING AND GRADING RESULTS

**Apples in test:** 100

## DAMAGE DISTRIBUTION

| | |
|---|---|
| **No Bruise Damage (OK):** | **0.0 %** |
| **Bruised Fruit (PBA):** | **100.0 %** |
| **Excess Bruise (EB):** | **100.0 %** |
| **Roller Bruise (RB):** | **0.0 %** |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | **0.0 %** |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | **0.0 %** |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | **0.0 %** |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | **0.0 %** |
| **(E) Bruise Damage > 1-1/4":** | **0.0 %** |

## Roller Bruise Distribution

| | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | **0.0 %** |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | **0.0 %** |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | **0.0 %** |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | **0.0 %** |
| **Roller Bruise Damage > 1-1/4" :** | **0.0 %** |

## Grade Distribution

| | |
|---|---|
| **Extra Fancy :** | **0.0 %** |
| **Fancy :** | **0.0 %** |
| **No. 1 :** | **0.0 %** |
| **Utility :** | **0.0 %** |
| **Reject :** | **100.0 %** |

## Means

| | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | All Apples Damaged |
| **Mean Bruise Area/Apple ($in^2$) (A):** | Total Apple Area Bruised |
| **Mean USDA Apple Grade (GRD):** | 5.00 |

**TABLE A22:** Apple bruising and grading results, Vibration Test V3; Package C; Bottom carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| **Apples in test:** | 100 |

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | 0.0 % |
| **Bruised Fruit (PBA):** | 100.0 % |
| **Excess Bruise (EB):** | 9.0 % |
| **Roller Bruise (RB):** | 0.0 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 20.1 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 16.0 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 33.5 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 26.5 % |
| **(E) Bruise Damage > 1-1/4":** | 3.9 % |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 0.0 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 0.0 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | 0.0 % |
| **Fancy :** | 0.0 % |
| **No. 1 :** | 0.0 % |
| **Utility :** | 1.0 % |
| **Reject :** | 99.0 % |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 5.60 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 3.01 |
| **Mean USDA Apple Grade (GRD):** | 4.99 |

TABLE A23: Apple bruising and grading results, Vibration Test V3; Package D; Top carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| **Apples in test:** | 96 |

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | 0.0 % |
| **Bruised Fruit (PBA):** | 100.0 % |
| **Excess Bruise (EB):** | 62.5 % |
| **Roller Bruise (RB):** | 0.0 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 15.6 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 41.0 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 17.9 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 16.7 % |
| **(E) Bruise Damage > 1-1/4":** | 8.8 % |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 0.0 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 0.0 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | 0.0 % |
| **Fancy :** | 0.0 % |
| **No. 1 :** | 0.0 % |
| **Utility :** | 1.0 % |
| **Reject :** | 98.9 % |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 2.73 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 1.20 |
| **Mean USDA Apple Grade (GRD):** | 4.99 |

**TABLE A24:** Apple bruising and grading results, Vibration Test V3; Package D; Bottom carton

## BRUISING AND GRADING RESULTS

**Apples in test:** 96

## DAMAGE DISTRIBUTION

| | |
|---|---|
| **No Bruise Damage (OK):** | 33.3 % |
| **Bruised Fruit (PBA):** | 66.7 % |
| **Excess Bruise (EB):** | 1.0 % |
| **Roller Bruise (RB):** | 0.0 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 17.5 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 29.4 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 22.7 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 17.0 % |
| **(E) Bruise Damage > 1-1/4":** | 13.5 % |

## Roller Bruise Distribution

| | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 0.0 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 0.0 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

## Grade Distribution

| | |
|---|---|
| **Extra Fancy :** | 42.7 % |
| **Fancy :** | 14.6 % |
| **No. 1 :** | 7.3 % |
| **Utility :** | 10.4 % |
| **Reject :** | 25.0 % |

## Means

| | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 1.34 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 0.87 |
| **Mean USDA Apple Grade (GRD):** | 2.60 |

**TABLE A25:** Apple bruising and grading results, Vibration Test V4; Package A; Top carton

## BRUISING AND GRADING RESULTS

**Apples in test:** 120

## DAMAGE DISTRIBUTION

| | |
|---|---|
| **No Bruise Damage (OK):** | 93.3 % |
| **Bruised Fruit (PBA):** | 6.7 % |
| **Excess Bruise (EB):** | 0.0 % |
| **Roller Bruise (RB):** | 0.0 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 92.5 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 7.5 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 0.0 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 0.0 % |
| **(E) Bruise Damage > 1-1/4":** | 0.0 % |

## Roller Bruise Distribution

| | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 0.0 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 0.0 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

## Grade Distribution

| | |
|---|---|
| **Extra Fancy :** | 98.3 % |
| **Fancy :** | 0.8 % |
| **No. 1 :** | 0.8 % |
| **Utility :** | 0.0 % |
| **Reject :** | 0.0 % |

## Means

| | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 0.09 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 0.02 |
| **Mean USDA Apple Grade (GRD):** | 1.02 |

TABLE A26: Apple bruising and grading results, Vibration Test V4; Package A; Bottom carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| **Apples in test:** | 120 |

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | 82.3 % |
| **Bruised Fruit (PBA):** | 17.7 % |
| **Excess Bruise (EB):** | 0.0 % |
| **Roller Bruise (RB):** | 0.0 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 46.3 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 49.4 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 4.3 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 0.0 % |
| **(E) Bruise Damage > 1-1/4":** | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 0.0 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 0.0 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | 90.8 % |
| **Fancy :** | 7.5 % |
| **No. 1 :** | 0.8 % |
| **Utility :** | 0.8 % |
| **Reject :** | 0.0 % |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 0.19 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 0.04 |
| **Mean USDA Apple Grade (GRD):** | 1.12 |

**TABLE A27:** Apple bruising and grading results, Vibration Test V4; Package B; Top carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| **Apples in test:** | 120 |

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | 76.7 % |
| **Bruised Fruit (PBA):** | 24.2 % |
| **Excess Bruise (EB):** | 0.0 % |
| **Roller Bruise (RB):** | 0.0 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 78.7 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 21.3 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 0.0 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 0.0 % |
| **(E) Bruise Damage > 1-1/4":** | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 0.0 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 0.0 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | 90.8 % |
| **Fancy :** | 9.2 % |
| **No. 1 :** | 0.0 % |
| **Utility :** | 0.0 % |
| **Reject :** | 0.0 % |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 0.32 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 0.05 |
| **Mean USDA Apple Grade (GRD):** | 1.09 |

TABLE A28: Apple bruising and grading results, Vibration Test V4; Package B; Bottom carton

## BRUISING AND GRADING RESULTS

**Apples in test: 120**

## DAMAGE DISTRIBUTION

| | |
|---|---|
| No Bruise Damage (OK): | 59.7 % |
| Bruised Fruit (PBA): | 40.3 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 79.6 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 20.4 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

## Roller Bruise Distribution

| | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

## Grade Distribution

| | |
|---|---|
| Extra Fancy : | 89.1 % |
| Fancy : | 10.9 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

## Means

| | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.43 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.07 |
| Mean USDA Apple Grade (GRD): | 1.11 |

TABLE A29: Apple bruising and grading results, Vibration Test V4; Package C; Top carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test: 100**

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 22.0 % |
| Bruised Fruit (PBA): | 78.0 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 93.2 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 6.8 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 36.0 % |
| Fancy : | 45.0 % |
| No. 1 : | 14.0 % |
| Utility : | 5.0 % |
| Reject : | 0.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 1.88 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.25 |
| Mean USDA Apple Grade (GRD): | 1.88 |

TABLE A30: Apple bruising and grading results, Vibration Test V4; Package C; Bottom carton

## BRUISING AND GRADING RESULTS

**Apples in test: 100**

## DAMAGE DISTRIBUTION

| | |
|---|---|
| No Bruise Damage (OK): | 60.0 % |
| Bruised Fruit (PBA): | 40.0 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 100.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 0.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

## Roller Bruise Distribution

| | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

## Grade Distribution

| | |
|---|---|
| Extra Fancy : | 88.0 % |
| Fancy : | 11.0 % |
| No. 1 : | 1.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

## Means

| | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.56 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.07 |
| Mean USDA Apple Grade (GRD): | 1.13 |

TABLE A31: Apple bruising and grading results, Vibration Test V4; Package D; Top carton

## BRUISING AND GRADING RESULTS

**Apples in test: 96**

## DAMAGE DISTRIBUTION

| | |
|---|---|
| No Bruise Damage (OK): | 94.8 % |
| Bruised Fruit (PBA): | 5.2 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 100.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 0.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

## Roller Bruise Distribution

| | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

## Grade Distribution

| | |
|---|---|
| Extra Fancy : | 100.0 % |
| Fancy : | 0.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

## Means

| | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.05 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.01 |
| Mean USDA Apple Grade (GRD): | 1.00 |

**TABLE A32:** Apple bruising and grading results, Vibration Test V4; Package D; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test:** 96

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 100.0 % |
| Bruised Fruit (PBA): | 0.0 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 0.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 0.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 100.0 % |
| Fancy : | 0.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.00 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.00 |
| Mean USDA Apple Grade (GRD): | 1.00 |

TABLE A33: Apple bruising and grading results, Vibration Test V5; Package A; Top carton

## BRUISING AND GRADING RESULTS

**Apples in test:** 120

## DAMAGE DISTRIBUTION

| | |
|---|---|
| **No Bruise Damage (OK):** | 86.7 % |
| **Bruised Fruit (PBA):** | 13.3 % |
| **Excess Bruise (EB):** | 0.0 % |
| **Roller Bruise (RB):** | 0.0 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 95.2 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 4.8 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 0.0 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 0.0 % |
| **(E) Bruise Damage > 1-1/4":** | 0.0 % |

## Roller Bruise Distribution

| | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 0.0 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 0.0 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

## Grade Distribution

| | |
|---|---|
| **Extra Fancy :** | 95.8 % |
| **Fancy :** | 4.2 % |
| **No. 1 :** | 0.0 % |
| **Utility :** | 0.0 % |
| **Reject :** | 0.0 % |

## Means

| | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 0.17 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 0.02 |
| **Mean USDA Apple Grade (GRD):** | 1.04 |

**TABLE A34:** Apple bruising and grading results, Vibration Test V5; Package A; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test:** 120

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 99.2 % |
| Bruised Fruit (PBA): | 0.8 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 100.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 0.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 100.0 % |
| Fancy : | 0.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.01 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.00 |
| Mean USDA Apple Grade (GRD): | 1.00 |

TABLE A35: Apple bruising and grading results, Vibration Test V5; Package B; Top carton

| BRUISING AND GRADING RESULTS | |
|---|---|
| **Apples in test:** | 120 |

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | 95.0 % |
| **Bruised Fruit (PBA):** | 5.0 % |
| **Excess Bruise (EB):** | 0.0 % |
| **Roller Bruise (RB):** | 0.0 % |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | 100.0 % |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | 0.0 % |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | 0.0 % |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | 0.0 % |
| **(E) Bruise Damage > 1-1/4":** | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | 0.0 % |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | 0.0 % |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | 0.0 % |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | 0.0 % |
| **Roller Bruise Damage > 1-1/4" :** | 0.0 % |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | 99.2 % |
| **Fancy :** | 0.8 % |
| **No. 1 :** | 0.0 % |
| **Utility :** | 0.0 % |
| **Reject :** | 0.0 % |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | 0.06 |
| **Mean Bruise Area/Apple ($in^2$) (A):** | 0.01 |
| **Mean USDA Apple Grade (GRD):** | 1.01 |

TABLE A36: Apple bruising and grading results, Vibration Test V5; Package B; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test:** 120

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | **99.2 %** |
| **Bruised Fruit (PBA):** | **0.8 %** |
| **Excess Bruise (EB):** | **0.0 %** |
| **Roller Bruise (RB):** | **0.0 %** |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | **100.0 %** |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | **0.0 %** |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | **0.0 %** |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | **0.0 %** |
| **(E) Bruise Damage > 1-1/4":** | **0.0 %** |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | **0.0 %** |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | **0.0 %** |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | **0.0 %** |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | **0.0 %** |
| **Roller Bruise Damage > 1-1/4" :** | **0.0 %** |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | **100.0 %** |
| **Fancy :** | **0.0 %** |
| **No. 1 :** | **0.0 %** |
| **Utility :** | **0.0 %** |
| **Reject :** | **0.0 %** |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | **0.01** |
| **Mean Bruise Area/Apple ($in^2$) (A):** | **0.00** |
| **Mean USDA Apple Grade (GRD):** | **1.00** |

TABLE A37: Apple bruising and grading results, Vibration Test V5; Package C; Top carton

## BRUISING AND GRADING RESULTS

**Apples in test:** 100

## DAMAGE DISTRIBUTION

| | |
|---|---|
| No Bruise Damage (OK): | 67.0 % |
| Bruised Fruit (PBA): | 33.0 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 98.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 2.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

## Roller Bruise Distribution

| | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

## Grade Distribution

| | |
|---|---|
| Extra Fancy : | 84.0 % |
| Fancy : | 16.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

## Means

| | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.52 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.08 |
| Mean USDA Apple Grade (GRD): | 1.16 |

TABLE A38: Apple bruising and grading results, Vibration Test V5; Package C; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test:** 100

| DAMAGE DISTRIBUTION | |
|---|---|
| **No Bruise Damage (OK):** | **76.0 %** |
| **Bruised Fruit (PBA):** | **24.0 %** |
| **Excess Bruise (EB):** | **0.0 %** |
| **Roller Bruise (RB):** | **0.0 %** |
| **(A) 1/4" > Bruise Damage ≤ 1/2":** | **100.0 %** |
| **(B) 1/2" > Bruise Damage ≤ 3/4":** | **0.0 %** |
| **(C) 3/4" > Bruise Damage ≤ 7/8":** | **0.0 %** |
| **(D) 7/8" > Bruise Damage ≤ 1-1/4":** | **0.0 %** |
| **(E) Bruise Damage > 1-1/4":** | **0.0 %** |

| Roller Bruise Distribution | |
|---|---|
| **1/4" > Roller Bruise Damage ≤ 1/2" :** | **0.0 %** |
| **1/2" > Roller Bruise Damage ≤ 3/4" :** | **0.0 %** |
| **3/4" > Roller Bruise Damage ≤ 7/8" :** | **0.0 %** |
| **7/8" > Roller Bruise Damage ≤ 1-1/4" :** | **0.0 %** |
| **Roller Bruise Damage > 1-1/4" :** | **0.0 %** |

| Grade Distribution | |
|---|---|
| **Extra Fancy :** | **100.0 %** |
| **Fancy :** | **0.0 %** |
| **No. 1 :** | **0.0 %** |
| **Utility :** | **0.0 %** |
| **Reject :** | **0.0 %** |

| Means | |
|---|---|
| **Mean Number of Bruises/Apple (N):** | **0.24** |
| **Mean Bruise Area/Apple ($in^2$) (A):** | **0.03** |
| **Mean USDA Apple Grade (GRD):** | **1.00** |

TABLE A39: Apple bruising and grading results, Vibration Test V5; Package D; Top carton

| BRUISING AND GRADING RESULTS |
|---|

Apples in test: 96

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 98.9 % |
| Bruised Fruit (PBA): | 1.0 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 100.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 0.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 100.0 % |
| Fancy : | 0.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.01 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.09 |
| Mean USDA Apple Grade (GRD): | 1.00 |

TABLE A40: Apple bruising and grading results, Vibration Test V5; Package D; Bottom carton

| BRUISING AND GRADING RESULTS |
|---|

**Apples in test: 96**

| DAMAGE DISTRIBUTION | |
|---|---|
| No Bruise Damage (OK): | 100.0 % |
| Bruised Fruit (PBA): | 0.0 % |
| Excess Bruise (EB): | 0.0 % |
| Roller Bruise (RB): | 0.0 % |
| (A) 1/4" > Bruise Damage ≤ 1/2": | 0.0 % |
| (B) 1/2" > Bruise Damage ≤ 3/4": | 0.0 % |
| (C) 3/4" > Bruise Damage ≤ 7/8": | 0.0 % |
| (D) 7/8" > Bruise Damage ≤ 1-1/4": | 0.0 % |
| (E) Bruise Damage > 1-1/4": | 0.0 % |

| Roller Bruise Distribution | |
|---|---|
| 1/4" > Roller Bruise Damage ≤ 1/2" : | 0.0 % |
| 1/2" > Roller Bruise Damage ≤ 3/4" : | 0.0 % |
| 3/4" > Roller Bruise Damage ≤ 7/8" : | 0.0 % |
| 7/8" > Roller Bruise Damage ≤ 1-1/4" : | 0.0 % |
| Roller Bruise Damage > 1-1/4" : | 0.0 % |

| Grade Distribution | |
|---|---|
| Extra Fancy : | 100.0 % |
| Fancy : | 0.0 % |
| No. 1 : | 0.0 % |
| Utility : | 0.0 % |
| Reject : | 0.0 % |

| Means | |
|---|---|
| Mean Number of Bruises/Apple (N): | 0.00 |
| Mean Bruise Area/Apple ($in^2$) (A): | 0.00 |
| Mean USDA Apple Grade (GRD): | 1.00 |