HANDLING TOMATOES in PALLET BOXES

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Handling Tomatoes in Pallet Boxes

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SUMMARY

Laboratory tests made on various materials used in making pallet boxes showed that wire mesh caused less injury to tomatoes than either plywood or plastic. Ripe (processing) and mature-green (fresh-market) tomatoes were tested.

Pallet boxes were then built of plastic, fiberboard, wood, plywood, and wire mesh for handling tests. Ripe tomatoes were machine-harvested into the pallet boxes, and the boxes were loaded by fork-lift onto trucks and hauled various distances before the tomatoes were dumped and checked for injury. There was no great difference in injury to tomatoes caused by the various boxes. The plastic boxes, however, should be rigid to prevent bulging and resultant injury to the tomatoes. Primary factors to consider in constructing pallet boxes for processing tomatoes are initial cost, life expectancy, and ease of cleaning.

In one test of fresh-market tomatoes, the fruits were hand-harvested into small baskets and then dumped into a quarter section of the pallet boxes. The pallet boxes were loaded onto a truck and hauled 20 miles. The tomatoes were then removed from the boxes and placed in a ripening room. When they were checked 6 days later, the tomatoes showed little difference in injury caused by the various pallet boxes. In a second test, fresh-market tomatoes were shipped in pallet boxes from Arkansas to Michigan, 975 miles, without excessive injury.

The depth of tomatoes in a pallet box, however, had an effect on the percentage of No. 1 tomatoes (tomatoes with little or no bruises or abrasions or two or three pressure marks) in a box. The percentage of No. 1's was higher in half loaded than fully loaded boxes.

INTRODUCTION

Most tomatoes for processing and for the fresh market are hand-picked into hampers or lugs holding less than 50 pounds of fruit. The practice of handling fruits and vegetables in pallet boxes [1] with capacities of 16 to 25 bushels is rapidly increasing in the United States. Mechanical tomato harvesters have been developed. But one of the foremost problems still confronting the users of these mechanical harvesters is to devise suitable systems of handling and transporting the tomatoes to the processing or packing plant without adversely affecting fruit quality (*7*).[2]

Ries and others (*8*) studied machine-harvesting of tomatoes into pallet boxes and dumping the tomatoes into water or onto a belt conveyor at the processing plant. They found that as the depth of the pallet boxes increased, fruit injury increased for both hand- and machine-harvested fruit. Pallet boxes 12 inches deep were found to be the most practical for handling the varieties Fireball and Libby C–52.

Ries and Stout (*7*) found that the number of cracked fruits in pallet boxes did not give a true picture of the injury from mechanical harvest and bulk handling. Results of their study showed that counts of the crushed fruits after fluming and washing provided a better basis for assessing damage, because injuries become more obvious when

[1] Sometimes called bulk boxes or bulk bins.

[2] Italic numbers in parentheses refer to Literature Cited, p. 12.

the fruits are placed in water. Injury, expressed in terms of the number of crushed fruit, was no greater for 12-inch-deep boxes than for 8-inch-deep boxes. Firm-fruited varieties were handled without excessive damage in boxes as deep as 16 inches.

Gould and others (*3*) studied bulk handling of processing tomatoes in hampers and in 12- and 18-inch-deep pallet boxes. Comparisons were made between dry- and water-handling methods. Detergent and chlorine were added to the water to help clean the fruit and control bacterial spore load. The minimum weight loss occurred when tomatoes were hand-harvested into standard hampers. Little difference occurred in drained weight between tomatoes machine-harvested into hampers and pallet boxes (4 by 3 by 1 or 1½ feet deep).

Mercer (*5*) found the following percentages of broken tomatoes in pallet boxes and lugs: Machine-harvested into pallet boxes (4 by 4 by 2 feet deep), 21–23 percent in the top half, 23–33 percent in the bottom half; machine-harvested into lug boxes, 14.7 percent; and hand-harvested into lug boxes, 10.2 percent.

Pearl (*6*) reported that about 16,000 tons of tomatoes were mechanically harvested in California in 1962. Pallet boxes 16 to 24 inches deep were evaluated. Under some conditions, tomatoes handled in 24-inch-deep boxes were damaged excessively and were unsuitable for whole pack. Canners found the 24-inch-deep pallet boxes satisfactory for handling tomatoes for uses other than whole pack.

This study was made at Michigan State University to evaluate several pallet box designs for use in handling tomatoes from the field to the packing or processing plant. Laboratory tests were made of the effects of box construction materials on tomato bruising. Pallet boxes were designed, and field tests were made of bruising of tomatoes handled in pallet boxes of different design and construction. Separate tests were made with processing (ripe) tomatoes and fresh-market (mature-green) tomatoes.

LABORATORY TESTS OF TOMATO DAMAGE CAUSED BY BOX CONSTRUCTION MATERIALS

Procedure

Two tests of tomato damage caused by materials used in boxes were made to obtain data on mature-green and ripe tomatoes that could be useful in designing pallet boxes for handling, shipping, and storing tomatoes. In the first, several carefully selected tomatoes were dropped 12, 24, and 36 inches onto various impact panels to determine the effect of the panels on tomato bruising. In the second, the bruising of fruit in contact with the panel was determined when another fruit was dropped on it.

The varieties of tomatoes used in the laboratory tests were Campbell 1327, Libby C–52, and Heinz 1370. The test panels were made of (1) 6-, 11-, and 13-gage wire mesh, (2) ½-inch plywood, and (3) ¼-inch linear polyethylene. Sizes of the wire mesh were 1 by 1, 1¼ by 1¼, 1½ by 1½, and 2 by 2 inches. Two runs were made for each test; each run consisted of 10 fruits of each variety.

The percentage of bruising of ripe tomatoes was determined from the number of tomatoes with cracks 1-inch long or longer. Damage to the mature-green fruits was evaluated after ripening by cutting and observing the locules (seed-containing cavities) as described by McColloch (*4*).

Results and Discussion

The difference in injury of tomatoes caused by dropping the fruit on various types of panels was more pronounced for ripe than for mature-green tomatoes for all varieties tested. Detailed results are given in the appendix. In general, the plywood and plastic panels caused more injury to both types of tomatoes than the steel wire panels. Large-sized wire (11-gage) resulted in more injury than small-sized wire (13-gage), and large-sized mesh (2 by 2 inch) in less injury than small-sized mesh (1 by 1 inch). The differences, however, were not significant in some tests.

The results of the dropping tests of mature-green and ripe tomatoes on different panel materials indicate that the best material for pallet boxes, from the standpoint of injury, is small-sized wire mesh. However, strength and cost of the material, among other things, should also be considered.

PALLET BOX DESIGN

Most commercial pallet boxes used today are wood. They are built either from dimension lumber or plywood or a combination of these materials. Some are equipped with special fasteners such as metal corners or wire straps.

The design of pallet boxes is influenced primarily by the material, cost, required life expectancy, and way in which the boxes will be handled. The size, weight, sanitation requirements, the type of pallet, and susceptibility to injury of the fruit to be handled should also be considered. Although results of the dropping tests showed that both plastic and plywood caused greater injury to the tomatoes than the small-sized wire mesh, the difference was small enough that other factors, such as cost, may be the predominant factor in the choice of pallet box design. Therefore, plywood and plastic were studied along with the small-sized wire mesh as materials for pallet boxes.

Four materials were selected for construction of the pallet boxes in this study.

1. *Plastic.*—Plastic has many advantages over other materials, such as durability, ease of repair, lightweight, and ease of cleaning. Disadvantages are its high initial cost and difficulty of construction.

2. *Wire mesh.*—Wire-mesh pallet boxes are strong, durable, and easy to clean. The boxes can be collapsible. Disadvantages are the high initial cost and the susceptibility to corrosion.

3. *Wood.*—Wooden boxes are low cost and easily repaired. A disadvantage is that they are difficult to clean.

4. *Fiberboard.*—Fiberboard is low cost, the principal reason it was included in the box designs. It is also lightweight, but lacks durability and strength and is difficult to clean. Fiberboard can be used for bulk boxes only if the pallet is made of a stronger material.

Five pallet boxes were fabricated for preliminary tests. All boxes were 43- by 47-inches wide (outside) and 16-inches deep (inside) with a capacity of about 670 pounds of tomatoes. The pallet boxes were as follows:

1. Plastic pallet box (fig. 1).

This pallet box was welded from sheets of polyethylene. The wooden pallet was bolted to the container.

2. Fiberboard pallet box (fig. 2).

This box was collapsible. The sides were constructed from ½-inch-thick triwall fiberboard and stapled to the horizontal and vertical wood members. The corner posts were 4- by 4-inch members split on both diagonals so that one-quarter of each 4 by 4 was stapled to each end of a side. The horizontal wood members were held together with spring clips. The pallet was constructed from nominal 1- by 6-inch and 4- by 4-inch lumber. The deck boards had beveled upper edges and the stringers were notched for stacking and four-way entry.

3. Wood box I (fig. 3).

This box had plywood sides and metal corners and was collapsible. Interlocking metal corners were riveted to the plywood sides. The sides were held to the pallet with heavy gage steel clips that were bolted to the sides. The 1- by 6-inch-deck boards had the upper edges beveled and the 4- by 4-inch stringers notched for stacking and four-way entry.

4. Wood box II (fig. 4).

The sidewalls consisted of mixed hardwoods that were stapled to the horizontal members. The

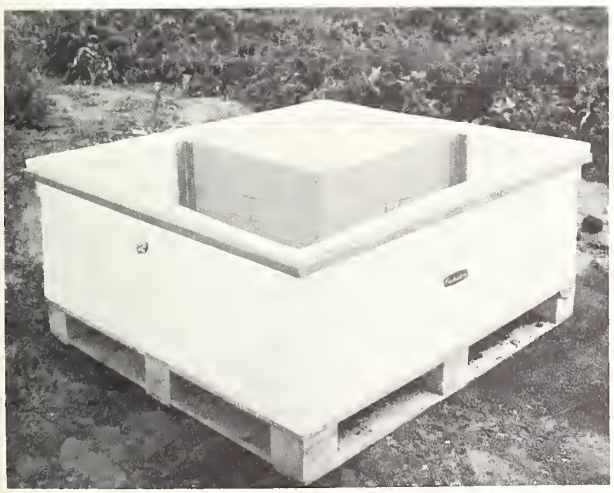

FIGURE 1.—Welded polyethylene pallet box with one-quarter partition.

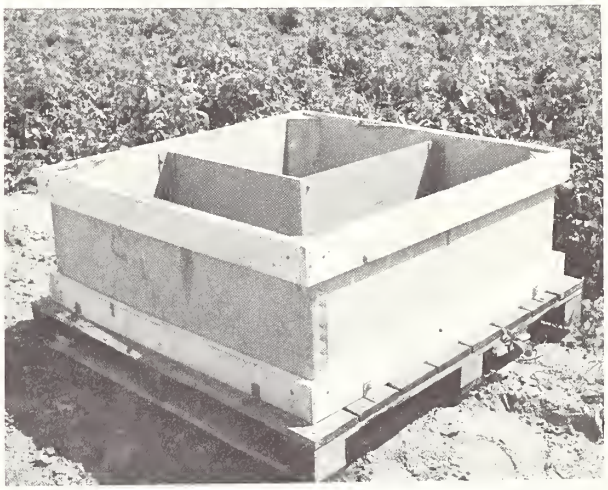

FIGURE 2.—Fiberboard pallet box with one-quarter partition.

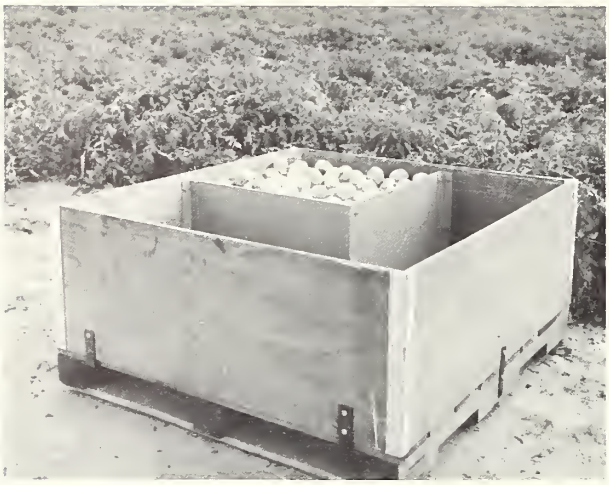

FIGURE 3.—Wood box No. I with one-quarter partition.

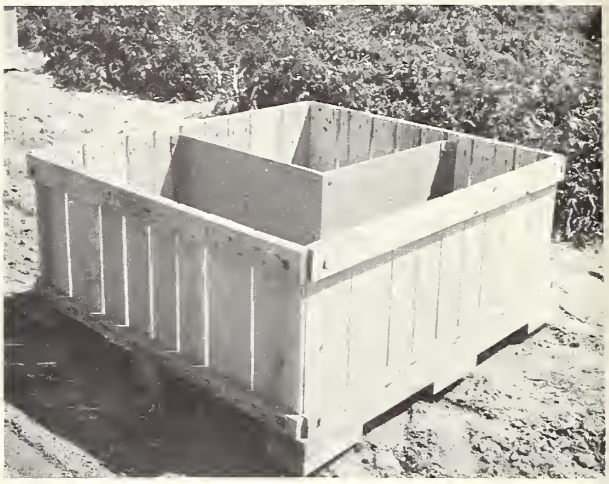

FIGURE 4.—Wood box No. II with one-quarter partition.

horizontal members were fastened together with interlocking wire-loop hinges, allowing the walls to collapse flat. All four sidewalls were completely locked in position with a steel strap. The pallet had built-up stringers and a dimension lumber deck. The sides and pallet base of this box were held together with a steel strap. All inside edges of the boards were rounded to prevent damage to fruit.

5. Wire-mesh box (fig. 5).

Wire mesh of 7-gage wires on 1¼-inch centers was used for the vertical side members. The horizontal sides were 3-gage wires on 3-inch centers. The bottom wires were 7-gage spaced 1¼ inches on center supported by 3/16- by 1-inch-steel members. The corner posts were 1½- by 1½- by ⅛-inch angle iron. The legs were supported by corner brackets when the pallet boxes were stacked. All metal was galvanized or plastic-coated.

Larger and deeper boxes were used in some of the tests.

FIGURE 5.—Wire-mesh pallet box with one-quarter partition.

HANDLING PROCESSING (RIPE) TOMATOES IN PALLET BOXES

1962 Tests

During 1962, ripe tomatoes (Heinz 1370 and 1350, Libby C–52, and Campbell 1327) harvested on 7 days were used in handling tests. The tomatoes were mechanically harvested with the 1960 model Michigan State University (M.S.U.) harvester (*8*) into the fiberboard pallet box, wood pallet box I, and plastic-coated and galvanized wire-mesh pallet boxes. Two boxes each of the four types of boxes were used. The depth of the tomatoes in the pallet boxes was 16 inches.

Immediately after harvest the pallet boxes of tomatoes were loaded by a forklift onto a truck and hauled approximately 10 miles and taken to the M.S.U. experimental dumper-washer. The day following harvest, the tomatoes were dumped from the pallet boxes, washed, and sorted with the M.S.U. experimental dumper-washer.

Just before dumping, samples of 100 fruit were taken from the bottom 4 inches of each pallet box, and the number of fruit with cracks over 1 inch long was recorded. The tomatoes of each pallet box were sampled again after they had been washed by

taking 100 fruits at random from the sorting table, and the number of crushed fruits was recorded.

Table 1 shows there was little difference among the injury figures for the four pallet boxes. The average of cracked fruit before dumping was the lowest for the wire-mesh pallet boxes. This finding agreed with the results obtained during the laboratory tests of a similar material.

In a second test, three varieties of tomatoes, C–52, 1327, 1350, were machine-harvested into the boxes to depths of 12, 16, and 24 inches. The tomatoes were examined for cracks before dumping and for crushing injury after washing.

There were more cracked fruits in the bottom 4 inches of all boxes containing variety C–52 than in those containing either variety 1327 or variety 1350. Cracking was greater as the depth of box increased for the varieties C–52 and 1350, but not for variety 1327 (fig. 6). After the fruit was washed, there was no difference in the number of crushed fruit from the three depths of boxes studied for the varieties 1327 and 1350 (fig. 7). As the depth was increased from 12 to 24 inches, the number of crushed fruit increased for the variety C–52. The variety 1350 had fewer crushed fruit than variety 1327, and variety 1327 fewer than variety C–52.

1963 Tests

In the 1963 tests, tomatoes (Campbell 1327) were mechanically harvested in wood pallet boxes I and II and into the wire-mesh and plastic pallet boxes. Three boxes of each type were used. A self-propelled tomato harvester was used to fill each box to a depth of about 16 inches with about 670 pounds of tomatoes.

Both green and ripe fruits were used to fill the pallet boxes because sufficient ripe fruits had not matured at the time of harvest. The control treatments consisted of fruit hand-harvested into a quarter of a wire-mesh pallet box (fig. 5).

After harvest, the pallet boxes were transferred by forklift onto a truck (fig. 8) and hauled 20 miles to the dumping and washing apparatus.

Within 24 hours after harvest, the tomatoes were dumped with the M.S.U. experimental pallet box dumper and washed (fig. 9). Before dumping, samples of 50 ripe fruit each were taken from the top 4 inches and bottom 4 inches of each box and the number of fruit having cracks over 1 inch long was recorded. These samples were not returned to the boxes. After dumping and washing, the number of crushed fruit was determined by taking 100-fruit samples of each box from the sorting table.

Table 2 gives the result of three harvests of variety 1327. The figures are averages of the three replicates for the three tests. More cracked fruit was found in the bottom than in the top of the pallet boxes. Hand-harvested tomatoes were injured less than machine-harvested tomatoes. There were

TABLE 1.—*Injury found in specified varieties of ripe tomatoes machine-harvested into pallet boxes, hauled 10 miles before being dumped into water and washed with an experimental dumper-washer, by type of pallet box*

Type of pallet box	Fruit cracked before dumping [1]							
	Variety 1370		Variety C–52	Variety 1327		Variety 1350		Average
	Lot 1	Lot 2		Lot 1	Lot 2	Lot 1	Lot 2	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Wood box I	41.5	27.3	19.0	39.5	35.5	31.0	30.7	32.1
Galvanized wire-mesh	37.0	29.3	30.0	43.0	-----	20.0	26.0	30.9
Plastic-coated wire-mesh	-----	28.7	-----	-----	28.0	-----	24.7	27.1
Fiberboard	39.2	27.8	27.2	41.2	32.8	25.5	27.1	31.5
	Fruit crushed after washing [2]							
Wood box I	5.0	5.3	10.0	12.0	9.0	4.5	11.7	8.2
Galvanized wire-mesh	7.0	7.0	11.5	11.5	-----	10.5	8.3	9.3
Plastic-coated wire-mesh	-----	8.0	-----	-----	11.0	-----	8.3	9.1
Fiberboard	7.0	6.6	10.8	11.8	9.5	7.5	9.4	8.9

[1] A sample of 100 tomatoes taken from the bottom 4 inches of each box before the boxes were dumped.

[2] A sample of 100 tomatoes from each pallet box taken at random from the sorting table. (Tomatoes removed for examination before dumping were not returned to the boxes.)

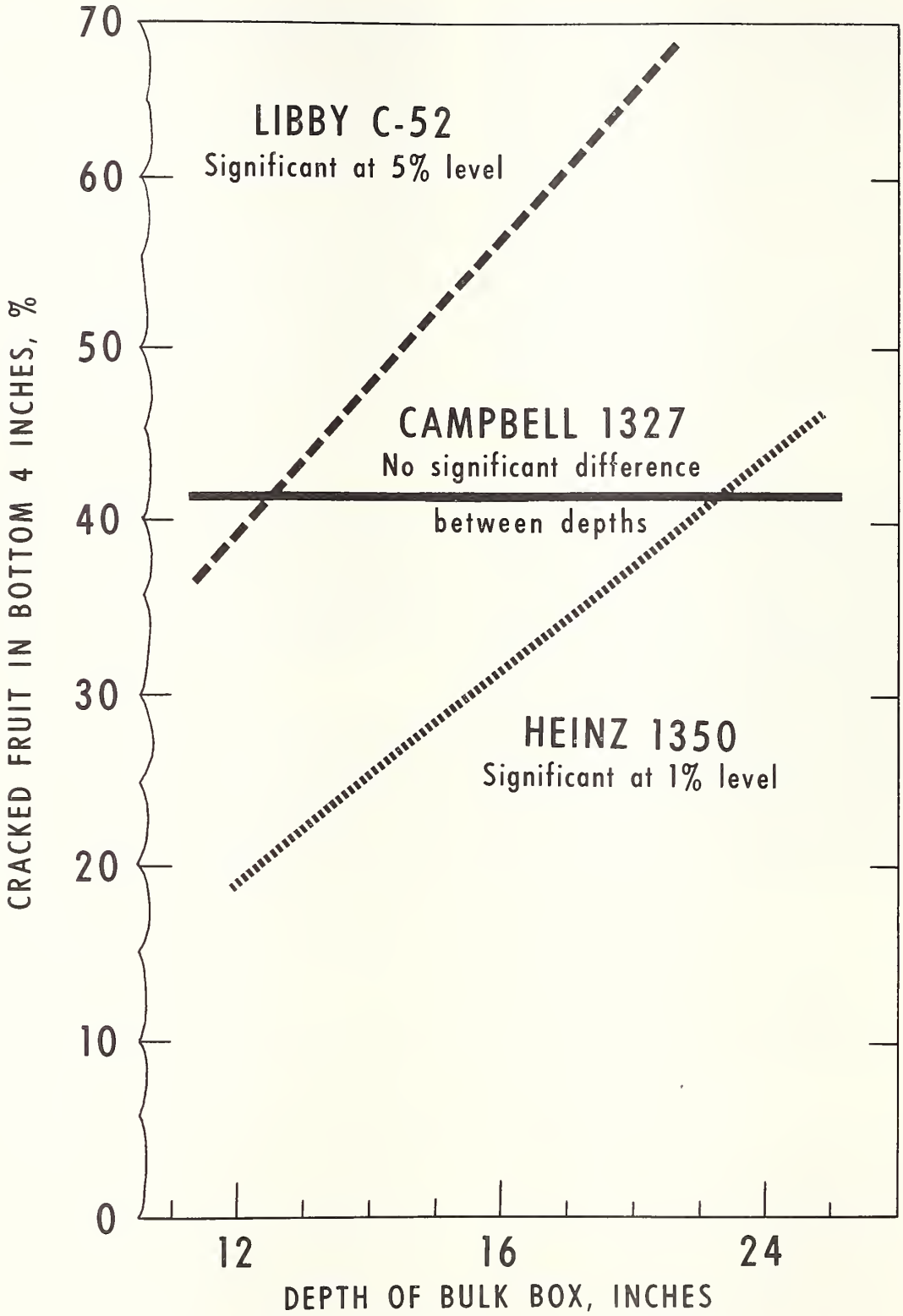

FIGURE 6.—The relationship between depth of bulk box and cracked ripe tomatoes.

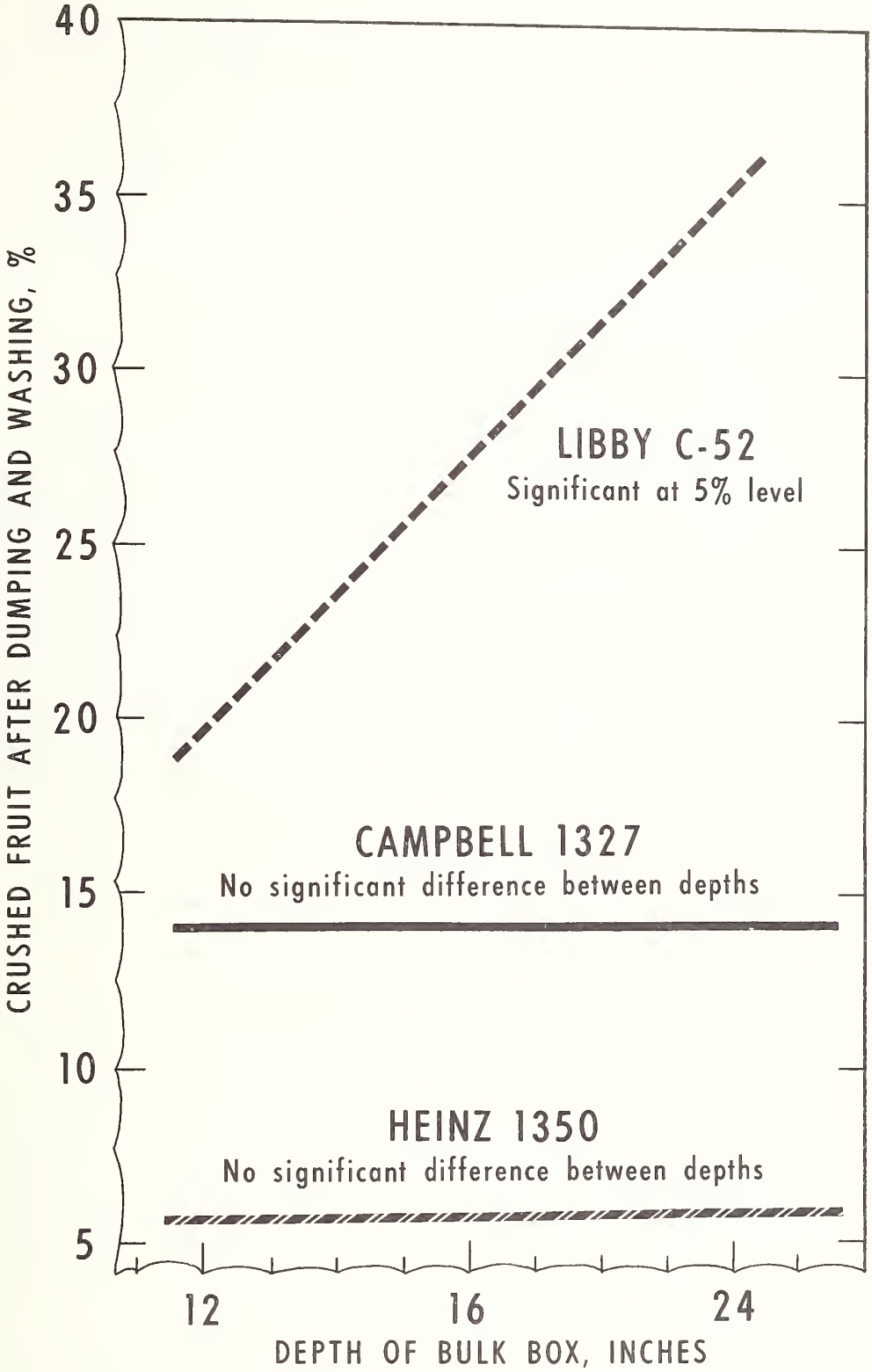

FIGURE 7.—The relationship between depth of bulk box and crushed ripe tomatoes after dumping and washing.

TABLE 2.—*Injury found in variety 1327 ripe tomatoes, machine-harvested into pallet boxes, hauled 20 miles by truck before being dumped into water and washed with an experimental dumper-washer* [1]

Type of pallet box	Fruit cracked before dumping [2]		Fruit crushed after washing [3]
	Top 4 inches of the box	Bottom 4 inches of the box	
	Percent	*Percent*	*Percent*
Wood box I	18.0 a	27.6 a	5.3 a
Wood box II	19.6 a	30.8 a	5.0 a
Plastic	29.8 b	41.8 b	5.0 a
Wire-mesh	23.4 a	30.4 a	7.5 b
Control—hand-harvested into quarter of a wire-mesh box	7.4 c	16.4 c	1.6 c
Average [4]	19.6	29.4	----------

[1] Means in each column followed by the same letter or letters are not significantly different from each other at the 1-percent level.
[2] 50 ripe fruit from the top and 50 from the bottom of the boxes were examined.
[3] A sample of 100 tomatoes from each pallet box taken at random from the sorting table. (Tomatoes removed for examination before dumping were not returned to the boxes for washing.)
[4] "F" value for interaction of top times bottom significant at 1-percent level.

TABLE 3.—*Injury found in variety 1350 ripe tomatoes, machine-harvested into pallet boxes, hauled 20 miles by truck before being dumped into water and washed with an experimental dumper-washer, by type of pallet box* [1]

Type of pallet box	Cracked fruit—					Crushed fruit after washing [1]
	Before hauling		After hauling		Average [1]	
	Top 4 inches of box	Bottom 4 inches of box	Top 4 inches of box	Bottom 4 inches of box		
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Wood box II	10.6	20.0	[2] 7.4	23.4	15.4 a	9.7 a
Wood box I	9.4	22.0	10.0	29.4	17.7 a	6.3 ab
Plastic	18.0	18.0	[2] 11.4	28.6	19.0 a	7.7 a
Wire-mesh	11.4	16.6	22.0	18.6	17.2 a	11.3 a
Control—hand-harvested into quarter of a wire-mesh box	5.4	11.4	7.4	[2] 9.4	8.4 b	2.3 b
Average [3]	14.3		16.8		--------	---------
Average top versus bottom [4]	11.3	19.8	--------	--------	--------	---------

[1] Means in a column followed by the same letter or letters are not significantly different from each other at the 1-percent level.
[2] Sample error.
[3] "F" value for interaction of before hauling times after hauling significant at 1-percent level.
[4] "F" value for interaction of top times bottom significant at 1-percent level.

FIGURE 8.—Pallet boxes filled with tomatoes ready for hauling.

FIGURE 9.—Michigan State University (M.S.U.) pallet box dumper, flume, washing system as used in 1963.

more cracked machine-harvested fruit in the plastic pallet boxes than in the other types of pallet boxes. The wire-mesh pallet box, however, resulted in the largest percentage of crushed fruit after washing.

Table 3 shows the effect of hauling on the number of cracked and crushed fruit. Hauling usually increased the number of cracked fruit, especially in the bottom of the pallet boxes.

Table 4 compares injury of two tomato varieties harvested on the same day. The data show differences in the injury figures between varieties given the same treatment. However, the plastic pallet boxes caused the largest percentage of cracked fruit (similar to results in table 2).

Conclusions and Recommendations

The material of which a pallet box is constructed has little or no effect on the amount of injury to ripe tomatoes. A plastic box may cause more fruit injury, but this is the result of bulging of the box, not of the material. Rigid plastic pallet boxes will most likely show the same results as the wire-mesh, plywood, and wood bulk boxes. Regardless of the construction material, there is more cracked fruit in the bottom 4 inches of a pallet box than in the top 4 inches.

The box design or material used for pallet boxes does not affect the percentage injury of ripe tomatoes as long as the pallet boxes are rigid and do not rack during handling. Therefore, the initial cost, life expectancy, and ease of cleaning are the primary factors that should be considered in the construction of pallet boxes for ripe tomatoes.

TABLE 4.—*Injury found in ripe tomatoes machine-harvested into pallet boxes, dumped into water and washed with an experimental dumper-washer, by tomato variety and type of box*

Type of pallet box	Fruit cracked before dumping			Fruit crushed after washing		
	Variety 1350	Variety 1370	Average [1]	Variety 1350	Variety 1370	Average [1]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Wood box I	17. 5	21. 0	19. 2 a	6. 5	7. 0	6. 8 a
Wood box II	17. 0	17. 0	17. 0 a	5. 5	3. 0	4. 2 a
Plastic	30. 5	17. 0	28. 8 b	8. 0	3. 0	5. 5 a
Wire-mesh	24. 0	12. 0	18. 0 a	6. 5	3. 0	4. 8 a
Control—hand-harvested into quarter of a wire-mesh box	13. 5	14. 0	13. 8 a	1. 5	0	. 8 b
Average	20. 5	16. 2	--------	[2] 5. 6	[2] 3. 2	--------

[1] Means in a column followed by the same letter or letters are not significantly different from each other at the 1-percent level.
[2] "F" value for interaction of varieties crushed significant at 1-percent level.

PALLET BOX TESTING WITH FRESH-MARKET (MATURE-GREEN) TOMATOES

1963 Tests

Tomato variety 1327 was used for tests of fresh-market tomatoes. Some of the tomatoes were mature-green at time of picking and some were breakers.[3] The tomatoes were hand-harvested into small wire-mesh baskets and then dumped into a quarter of each of the five types of pallet boxes—wood boxes I and II, fiberboard, wire-mesh, and plastic—to a depth of 16 inches. Three replications of each type of pallet box were used. After the harvest, the pallet boxes were loaded onto a truck and hauled a distance of 20 miles over gravel and asphalt roads. Immediately following the trip, the boxes were unloaded and placed in the shade. Forty-eight hours after harvest, three samples of 150 tomatoes each were taken from the top, middle, and bottom of each of the pallet boxes and placed on racks in a ripening room at 68° F. After 6 days, 50 tomatoes were taken at random from each sample and rated for damage.

The rating system used ranged from 1 to 5 as follows: (1) Sound fruit, no apparent damage; (2) indented external bruise due to fixed pressure (either flat surface or wire marks); (3) pericarp or septa or placenta water-soaked; (4) pericarp or septa or placenta water-soaked and one locule injured; and (5) two locules injured with or without water-soaked area.

The average ratings on the extent of injury to the mature-green tomatoes as a result of handling in five types of pallet boxes are given in table 5. There is little difference in injury among fruit positions in the box or among pallet boxes. The mature-green tomatoes withstood the pallet box handling very well.

TABLE 5.—*Injury found in variety 1327 mature-green tomatoes, hand-harvested into pallet boxes, hauled 20 miles by truck, and ripened on racks for 6 days, by type of pallet box and position in box* [1]

Type of pallet box	Injury rating by position in box			Average [2]
	Top	Center	Bottom	
Wire-mesh	2.1	2.2	2.2	2.2 a
Fiberboard	2.1	2.1	2.2	2.1 ab
Plastic	2.1	2.0	1.9	2.0 ab
Wood box I	2.0	2.0	2.0	2.0 ab
Wood box II	2.0	1.7	2.0	1.9 b
Average [2]	2.1 a	2.0 b	2.1 a	--------

[1] Hand-harvested into small wire-mesh baskets and then dumped into a quarter of each pallet box; injury ratings, averages for 3 boxes of each type, were as follows:
(1) Sound fruit, no apparent damage.
(2) Indented internal bruise due to fixed pressure (either flat surface or wire marks).
(3) Pericarp or septa or placenta water-soaked.
(4) Pericarp or septa or placenta water-soaked and 1 locule injured.
(5) 2 locules injured with or without water-soaked area.

[2] Means followed by the same letter or letters are not significantly different from each other at the 1-percent level.

1964 Tests

Tomatoes of the variety Bradley were hand-picked in Monticello, Ark., and hauled by truck directly to East Lansing, Mich., a distance of 975 miles. Because of the limited space on the truck, only four types of pallet boxes—wood boxes I and II, wire-mesh, and plastic—were tested. Two replicates of each pallet box were used. The 25-pound crate which is normally used in Arkansas for shipping tomatoes was used as a control (fig. 10). The pallet boxes were filled with 670 pounds of tomatoes except for two wooden boxes which were only half-filled (335 pounds). Approximately 3 tons of tomatoes were involved in the experiment.

The weather during the picking was cloudy with a temperature of 84° F. When the truck was loaded and ready to leave, the temperature had risen to 95°, and it was still cloudy. By the time the truck reached East Lansing, the temperature had dropped to 62°. No rain was encountered during any part of the experiment.

During the trip, the temperature of the tomatoes was recorded on a thermograph imbedded in the center of each type of pallet box.

FIGURE 10.—Bulk boxes and 25-pound crates used in study of handling mature-green tomatoes.

[3] Breakers are tomatoes which show a break in color up to 25 percent red or yellow.

TABLE 6.—*Variety Bradley mature-green tomatoes hand-harvested, hauled in pallet boxes and crates 975 miles by truck: Percent without bruising and percent No. 1 tomatoes, by type of box and method of packing*

Type of box, pounds of tomatoes, and method of packing [2]	No bruising			No. 1 tomatoes [1]		
	Top layer of box	Bottom layer of box	Average	Top layer of box	Bottom layer of box	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Wood pallet box I, 670 lb., dumped into box	18	8	13	72	42	57
Wood pallet boxes I and II, 335 lb., dumped into box	30	4	17	92	72	82
Wire-mesh pallet box, 670 lb., dumped into box	10	2	6	56	48	52
Plastic pallet box, 670 lb., dumped into box	14	6	10	52	40	46
Wood pallet box II, 670 lb., individually wrapped and packed	92	42	67	98	100	99
Crate, 25 lb., dumped into crate	18	8	13	74	66	70
Crate, 25 lb., packed	24	18	21	100	100	100
Crate, 25 lb., individually wrapped and packed	72	56	64	100	94	97

[1] Includes those without bruising or abrasions, with slight bruising or some abrasions, or with 2 or 3 pressure marks. (Tomatoes with greater injuries than these were considered No. 2 tomatoes.)

[2] Tomatoes were either dumped from field crates into the shipping container or individually packed in the containers. Some tomatoes were also individually wrapped.

In East Lansing, the boxes were unloaded and stored in a shed overnight. At 8 a.m. the next day, the boxes were taken out of the shed and samples of 25 tomatoes each were taken from the top and bottom layers of each box and rated for bruising. Tomatoes with no bruising or abrasions, very slight bruising or some abrasions, or two or three pressure marks were considered U.S. No. 1 tomatoes. Tomatoes with greater injuries than these were considered No. 2 tomatoes.

The percentage of nonbruised tomatoes was consistently higher in the wooden than in the wire-mesh and plastic pallet boxes (table 6). The wooden boxes also had a higher percentage of No. 1 tomatoes.

There was almost no difference in the percentages of nonbruised tomatoes wrapped and packed in a 25-pound crate and wrapped and packed in a slatted wooden pallet box (wood box II). Also, the slatted wooden pallet box gave as high a percentage of No. 1 tomatoes as the 25-pound crate.

The depth of the tomatoes in a pallet box has an effect on the percentage of No. 1 tomatoes. The percentage of No. 1 tomatoes was higher in the half-loaded than in the fully loaded wooden pallet boxes.

Although the wrapped tomatoes bruised less than the unwrapped tomatoes in the wooden pallet box, the wrapped tomatoes may have ripened faster because of undesirable higher temperatures in the box. Figure 11 shows the temperature readings of the tomatoes from the time of loading until the time the tomatoes were taken from the boxes. While the temperature of the wrapped tomatoes remain at 80° F., the temperature of the unwrapped tomatoes decreased to approximately 64°. The temperature of the tomatoes in the wire-mesh pallet box dropped faster than in the other two types of pallet boxes, although the difference was small.

Conclusions and Recommendations

The results of the handling studies in 1963 and 1964 indicate that mature-green tomatoes can be handled in pallet boxes without excessive injury. Additional research is recommended, however, to establish design criteria for a bulk-handling system and to evaluate the economics of such a system.

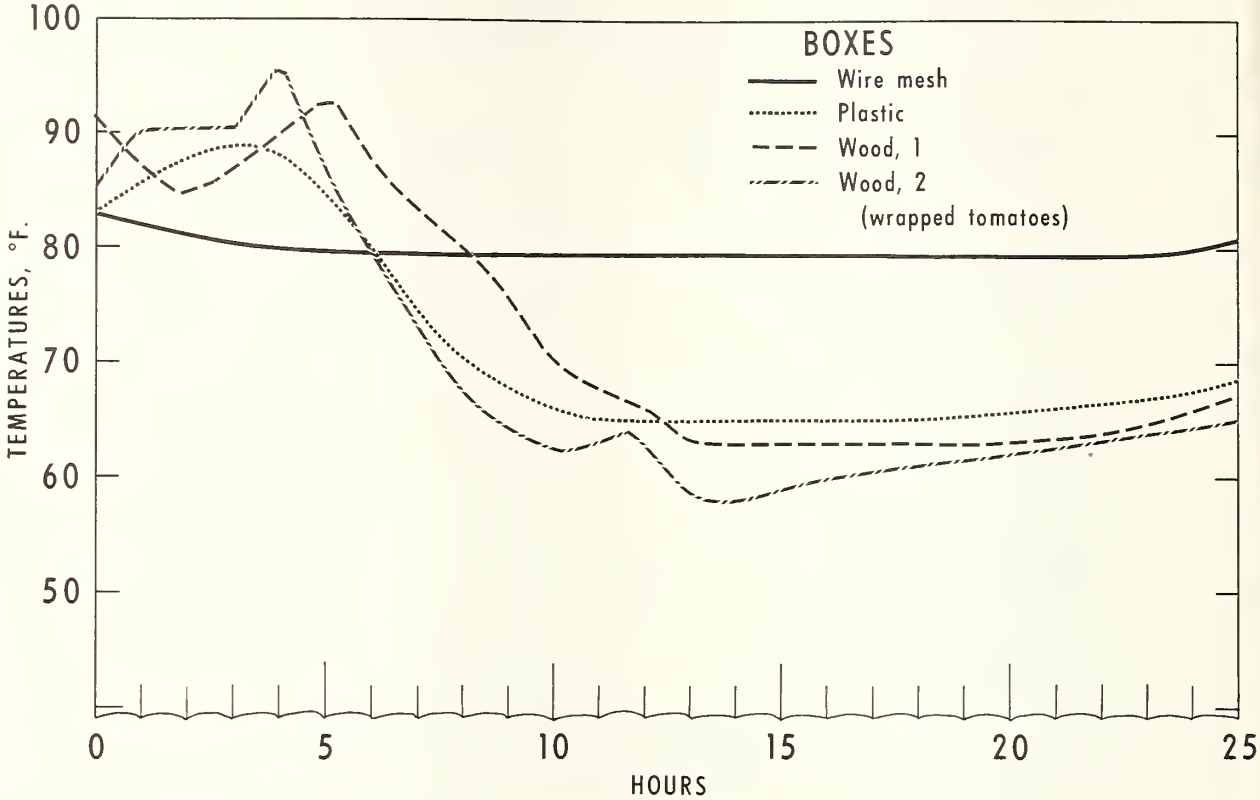

FIGURE 11.—Tomato temperature in wood, wire-mesh, and plastic pallet boxes from the time of loading until unloading.

The 1963 and 1964 harvest data are somewhat contradictory. In 1963, there were no great differences in injury to mature-green tomatoes handled in different types of boxes. In 1964, the percentage of nonbruised tomatoes was consistently higher in the wooden pallet boxes than in the steel-mesh or plastic boxes. In 1963, one-quarter of each pallet box was filled, while in 1964 the boxes were completely filled. The 1964 results were obtained under more realistic conditions. Continued studies are recommended with emphasis on wooden pallet boxes to confirm these results.

There was no great difference in injury to the tomatoes between the top and bottom of the pallet boxes (see table 5). Therefore, a depth of at least 16 inches, and possibly deeper, is recommended for further study.

LITERATURE CITED

(1) DENNY, C. B., and BOHRER, C. W.
1964. BACTERIOLOGICAL DETERMINATIONS ON HANDLING OF MECHANICALLY HARVESTED TOMATOES, 1963 DATA FROM MICHIGAN. Natl. Canners Assoc. Res. 2-64, 22 pp., illus. April.

(2) ——— and DECAMP, R. A.
1962. BACTERIOLOGICAL DETERMINATIONS ON MECHANICALLY PICKED VS. HAND PICKED TOMATOES, 1962 DATA FROM MICHIGAN. Natl. Canners Assoc. Res. 1-62, 24 pp., illus. October.

(3) GOULD, W. A., BASCH, W. D., YINGST, D. E., and others.
1963. HANDLING AND HOLDING STUDIES OF MECHANICALLY HARVESTED TOMATOES. Natl. Canners Assoc. Inform. Letter 1909: 80-81. Jan. 31.

(4) MCCOLLOCH, L. P.
1962. BRUISING INJURY OF TOMATOES. U.S. Dept. Agr. Mktg. Res. Rpt. 513, 31 pp., illus.

(5) MERCER, W. A.
1963. NCA RESEARCH ON MECHANICAL HARVESTING OF TOMATOES. Natl. Canners Assoc. Inform. Letter 1909: 85-87. Jan. 31.

(6) PEARL, R. D.
1963. TOMATO MECHANICAL HARVEST RESEARCH IN CALIFORNIA. Natl. Canners Assoc. Inform. Letter 1909: 88-89. Jan. 31.

(7) RIES, S. K., and STOUT, B. A.
1962. BULK HANDLING STUDIES WITH MECHANICALLY HARVESTED TOMATOES. Amer. Soc. Hort. Sci. Proc. 81: 479-487.

(8) ——— STOUT, B.A., BEDFORD, C. L., and AUSTIN, M. E.
1961. BULK HANDLING TESTS WITH PROCESSING TOMATOES. Mich. Agr. Expt. Sta. Quart. Bul. 44(2): 282-300.

APPENDIX

Results of the laboratory tests of ripe and mature-green tomatoes are given in tables 7 to 13.

Injury to ripe fruit dropped 24 inches was lower on the steel-mesh panels than on the plywood or plastic panels. The smaller the wire size, the greater the deformation of the panel and the less the damage to the tomato. The amount of injury fluctuated with the variety. Libby C–52 cracked more than Campbell 1327 and Heinz 1370.

An increase in the height of drop from 12 to 36 inches resulted in significantly more damaged tomatoes. The 13-gage wire again caused less injury than the 11-gage. Injury from the 2- by 2-inch-mesh wire was less than that from the 1- by 1-inch mesh.

Ripe tomatoes placed on a plywood panel and struck with another fruit dropped from a 24-inch height were damaged significantly more than tomatoes placed on a steel-wire panel.

Injury of mature-green tomatoes due to a 24-inch drop on different panels was the greatest for plywood and smallest for the 13-gage mesh wire. In contrast with ripe tomatoes, the difference in injury among the three varieties was not large for mature-green tomatoes.

As was true for ripe tomatoes, the greater the height of drop of the mature-green tomatoes (12 to 36 inches), the larger the damage to the tomatoes.

Bruising percentages of tomatoes dropped on four mesh sizes made of 11- and 13-gage wire were lower for the larger mesh sizes, but the differences were not significant.

The percentage of mature-green tomatoes injured after being struck with another tomato dropped from a height of 24 inches was significantly greater for the 11-gage steel-mesh panel than for the other panels.

TABLE 7.—*Ripe tomatoes with cracks 1 inch long or longer after being dropped 24 inches onto specified panel materials*

Panel material	Tomato variety			Mean [1]
	1327	C–52	1370	
	Percent	*Percent*	*Percent*	*Percent*
Plywood, ½-in. thick	26	32	30	29.6 a
Plastic, ½-in. thick	22	34	11	22.5 ab
Steel mesh, 1½- by 1½-in.:				
6-gage	12	15	21	16.2 abc
11-gage	8	10	9	8.8 bc
13-gage	4	4	5	4.2 c
Mean	14.5	19.0	15.2	

[1] Means followed by the same letter or letters are not significantly different from each other at the 1-percent level.

TABLE 8.—*Ripe tomatoes with cracks 1 inch long or longer after being dropped from 12, 24, or 36 inches onto specified panel materials*

Panel material	12-inch drop	24-inch drop	36-inch drop	Mean
	Percent	*Percent*	*Percent*	*Percent*
Plywood, ½-in. thick	10	39	62	37.0
Plastic, ½-in. thick	3	25	48	25.3
Steel mesh, 1- by 1-in.: [1]				
11-gage	6	19	36	20.3
13-gage	0	10	26	12.0
Steel mesh, 2- by 2-in.: [1]				
11-gage	4	15	30	16.3
13-gage	1	14	13	9.3
Mean [2]	4.0	20.3	35.8	

[1] "F" value for interaction of mesh times gage significant at 1-percent level.
[2] Means are significantly different from each other at the 1-percent level.

TABLE 9.—*Ripe tomatoes with cracks 1 inch long or longer after being struck by another fruit dropped 24 inches*

Panel material in contact with tomatoes	Tomato variety			Mean [1]
	1327	C–52	1370	
	Percent	*Percent*	*Percent*	*Percent*
Plywood, ½-in. thick	58	55	38	50.3 a
Plastic, ½-in. thick	42	55	26	41.0 ab
Steel mesh, 1½- by 1½-in.:				
11-gage	26	28	15	23.0 bc
13-gage	15	25	4	14.7 c
Mean	35.2	40.8	20.8	

[1] Means followed by the same letter or letters are not significantly different from each other at the 1-percent level.

TABLE 10.—*Mature-green tomatoes with injured locules after being dropped 24 inches onto specified panel material*

Panel material	Tomato variety			Mean [1]
	1327	C–52	1370	
	Percent	*Percent*	*Percent*	*Percent*
Plywood, ½-in. thick	12	19	13	14.7
Plastic, ½-in. thick	11	9	13	11.0
Steel mesh, 1½- by 1½-in.:				
6-gage	12	16	13	13.7
11-gage	8	6	15	9.7
13-gage	6	11	8	8.3
Mean [2]	9.8 a	12.2 b	12.4 b	-------

[1] "F" value for interaction of panel type significant at 1-percent level.
[2] Means followed by the same letter or letters are not significantly different from each other at the 5-percent level.

TABLE 11.—*Mature-green tomatoes with injured locules after being dropped 12, 24, or 36 inches onto specified panels*

Panel material	12-inch drop	24-inch drop	36-inch drop	Mean
	Percent	*Percent*	*Percent*	*Percent*
Plywood, ½-in. thick	11	17	21	16.3
Steel mesh, 1- by 1-in.: [1]				
11-gage	8	14	15	12.3
13-gage	10	12	16	12.7
Steel mesh, 2- by 2-in.: [1]				
11-gage	9	9	18	12.0
13-gage	5	9	14	9.3
Mean [2]	8.3	12.3	17.2	-------

[1] "F" value for interaction of mesh times gage significant at 5-percent level.
[2] Means are significantly different from each other at the 5-percent level.

TABLE 12.—*Mature-green tomatoes with injured locules after being dropped 24 inches onto steel-mesh panels* [1]

Mesh size (inches)	11-gage	13-gage	Mean
	Percent	*Percent*	*Percent*
1 by 1	11	10	10.5
1¼ by 1¼	8	9	8.5
1½ by 1½	10	8	9.0
2 by 2	8	8	8.0
Mean	9.2	8.8	---------

[1] No significant differences found.

TABLE 13.—*Mature-green tomatoes with injured locules after being struck by another fruit dropped 24 inches*

Panel material in contact with tomatoes	Tomato variety			Mean [1]
	1327	C–52	1370	
	Percent	*Percent*	*Percent*	*Percent*
Plywood, ½-in. thick	5	7	8	6.7 a
Plastic, ½-in. thick	5	8	11	8.0 a
Steel mesh, 1½- by 1½-in.:				
11-gage	7	12	18	12.3 b
13-gage	6	8	12	8.7 a
Mean	5.8	8.8	12.2	-------

[1] Means followed by the same letter or letters are not significantly different from each other at the 1-percent level.

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