soft rot, bacterial soft rot (*Erwinia*) and gray mold rot (*Botrytis*) were the next most common causes of decay (26% and 22%, respectively). A minor cause of decay was green mold rot (*Cladosporium*). There was no evidence of significant differences in types of decay among different treatments, storage conditions, or growers.

Table 5. Major causes of decay in bell peppers held for 3 wk at 50°F and then for 3 days at 75°F.

Types of decay	Causal organism	Number decayed	% total
Black rot	*Alternaria sp.*	29	48.3
Gray mold rot[z]	*Botrytis cinerea*	14	22.4
Bacterial soft rot	*Erwinia* spp.	15	25.8
Green mold rot	*Cladosporium herbarum*	2	3.5

[z]Distinguished from bacterial soft rot by presence of gray, fungal sporulation on central portion of lesion after 24 h in a humidity chamber at 75°F.

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CELL-PACK BOXES FOR EXPORTING LARGE GRAPEFRUIT

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Abstract. **In 8 test shipments, fresh grapefruit packed in experimental cell-pack boxes and in standard 4/5 bu place-pack boxes were shipped under commercial packing and handling conditions from Florida to Tokyo, Japan to compare arrival condition and costs. Each cell-pack box contained 3 layers of 11 grapefruit each, for a total of 33 fruit—one more than the standard box. Vertical chipboard partitions placed in the cell-pack boxes and separated by fiberboard layer dividers formed individual cells for each grapefruit and reduced overhead pressure on each fruit. In all tests, serious deformation of fruit in the cell-pack boxes was 75% less than that of comparable size and quality fruit in the standard box. Additional packaging, direct labor, and transportation costs for the cell-pack box were $0.96 more/standard box equivalent than for the standard export box from Florida to Tokyo, Japan.**

Since 1972, the packaging and transportation staff of the U.S. Department of Agriculture at Orlando, Florida, has cooperated with Florida packers and the Florida Citrus Commission, Department of Citrus, State of Florida, in projects designed to develop and evaluate improved shipping containers for exporting grapefruit (*Citrus paradisi* Macf.). Results of controlled laboratory tests conducted by Hale (1) and of followup commercial export tests to Japan by Smoot and Hale (5) led to the adoption, by the citrus industry, of shipping boxes that were 0.5-inch deeper than standard export boxes and packed flat without bulge. In the deeper boxes, the amount of seriously deformed fruit, which ranged from 33% to 60% in the standard export boxes (2), was reduced to 12.1%. (Seriously deformed fruit is fruit on which the aggregate flattened or indented surface area equals 2 inches (5.1 cm) or more in diameter).

However, despite improvements made in reducing serious deformation by discontinuing the use of bulge-pack boxes, demands of foreign importers for near-perfect large fruit, sizes 32 and 27, that bring premium prices have grown steadily. Importers, especially those in Japan where fruit appearance is given top priority, have been reluctant in recent years to accept shipments of large grapefruit, because they are generally more susceptible to serious deformation than the smaller fruit. Seriously deformed fruit are discounted in price, are unattractive, and may have internal damage that would cause loss of juice and other desirable eating qualities. This study was undertaken to evaluate a new, cell-pack box proposed for the export of large grapefruit. The project was begun during the 1979 season, when 3 preliminary test shipments of fruit in handmade samples of the cell-pack boxes were made from Florida to Tokyo, Japan. On shipment arrival, the serious deformation averaged only 2.0% for fruit in the cell-pack box compared to 11.4% for fruit in the standard boxes (3). Plans were then made to test ship grapefruit in commercial-size lots of the cell-pack boxes during the 1980 season to confirm the arrival condition of the fruit, and to evaluate the performance of the cell-pack boxes and the cost of packing them with automatic equipment.

This research is part of an ongoing effort by Agricultural Research to evaluate new packages, shipping containers, and packing methods to reduce costs and improve arrival condition of agricultural products at overseas markets.

Materials and Methods

The prototype automatic machine used in these tests for filling the cell-pack boxes was designed for packing only size 32 fruit, which has an average diameter of 4.25 inches (10.8 cm). However, full production machines and chipboard cell partitions will be available for packing all fruit sizes and counts required. For measurement of the effect of cell-packing fruit on their physical protection during handling and shipment, 3 commercial lots, each containing a minimum of 208 cell-pack boxes, were shipped from Florida to Tokyo, Japan, during January and February 1980 (Series I shipments). Arrival observations revealed a slack space between the top of each cell and the grapefruit in each layer, which resulted in slight compression of the cell-pack boxes. Thus, the height of the cell-pack boxes and their respective chipboard cell partitions was reduced a total of 1 inch (2.5 cm), and a second series of 5 shipments (Series II shipments) of grapefruit packed in cell-pack boxes was originated during April and May 1980. The second series of shipments contained a minimum of 8 handmade samples of cell-pack boxes, packed manually by researchers at the U.S. Horticultural Research Laboratory, Orlando, Florida, and then taken to ports where they were loaded with commercial grapefruit for shipment to Japan. As required by the Japanese Government, the grapefruit in all test shipments were fumigated with ethylene dibromide after they were packed in the cell-pack boxes. Following is a description of the experimental cell-packs, where the automatic packing machine was located, and a description of the methods and operations used for packing the cell-pack boxes.

The cell-pack box is a full-telescope, single-wall fiberboard box with inside dimensions of 17 x 11.5 x 11.5 inches (43.2 x 29.2 x 29.2 cm) (Fig. 1). Each side panel of the box has two ventilation slots measuring 0.625 x 3.0 inches (1.59 x 7.62 cm). The gap in the outer flaps of the cover measures 0.5 x 5.75 inches (1.27 x 14.7 cm), and the gap in the bottom flaps of the body measures 0.75 x 5.75 inches (1.9 x 14.7 cm). The body of the shipping container was fabricated from 350-lb-test fiberboard, and the cover was fabricated from 200-lb-test fiberboard. The machine for packing the cell-pack boxes was placed in a regular commercial packinghouse located at Vero Beach, Florida. Because these experiments involved a minimum of only 208 cell-pack boxes in any one commercial shipment, the automatic packing machine was not installed in line with the regular packinghouse equipment. Hence, the fruit and preassembled cell-pack shipping containers were manually delivered to the packing area. The fruit were fed via guide chutes into a spotting tray where they were picked up by a regenerative airflow system. Simultaneously, a single-wall partition of chipboard material 0.017 inch (0.43 mm) thick was automatically expanded, collated with a fiberboard layer divider containing ten 15/16-inch (2.38-cm) ventilation holes, and placed in position to accept the waiting grapefruit. The expanded partition formed individual cells 3.75 inches (9.2 cm) high for each fruit. The fruit were then lowered into individual cells and the complete layer was then packed automatically into the cell-pack box shipping container. The process was repeated until the box was packed with 3 layers of grapefruit, 11 fruit per layer, for a total of 33 fruit—one more than in the standard 4/5-bu (28.2 L) place-pack box. The support provided by the chipboard partitions, in combination with the fiberboard layer dividers, prevented overhead pressure on each fruit in each layer. The standard boxes were packed manually on regular packinghouse lines.

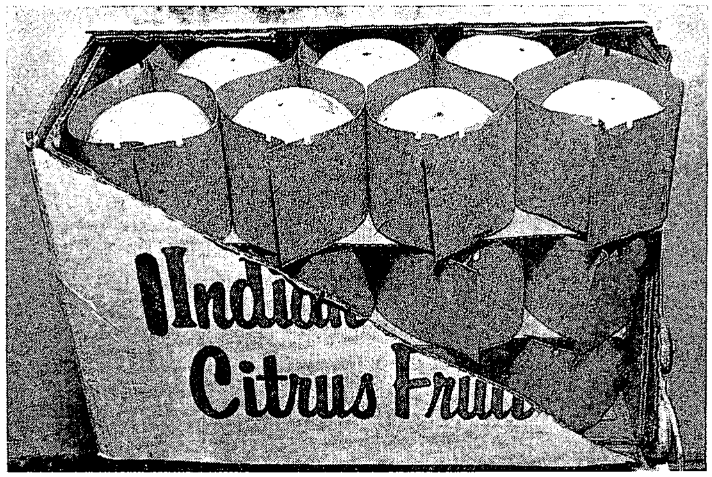

Fig. 1. Cell-pack box with three layers of size 32 Florida grapefruit, 11 fruit per layer.

All of the test cell-pack boxes were loaded in refrigerated holds of the ships in a tight stack, 8 and 9 high. As "controls" in each shipment, a minimum of 8 cell-pack boxes and 8 standard, place-pack 4/5-bu boxes currently used by the industry for exporting grapefruit were specially identified and placed in the bottom layer of the box stacks. The bottom layer location was selected for these control test boxes because fruit and boxes in that location undergo the greatest physical damage.

On arrival in Tokyo, Japan, the grapefruit were examined for deformation and decay by USDA researchers. The boxes were also measured to determine changes in size or configuration, such as side bulge, end bulge, bottom sag, and compression. The lapsed time from packing the fruit in the cell-pack boxes at shipping point until recovery of the fruit in Tokyo and examination of their arrival condition averaged 38 days for the 8 test shipments (Table 1). Observations of cell-packed grapefruit from the first commercial shipment were also made at the Kanda and Tsukiji wholesale markets in Tokyo, Japan, during March 1980.

Table 1. Log of two series (8 tests) of shipments of Florida grapefruit to Japan, 1980.

Test no.	Date fruit packed	Date fruit fumigated and delivered to port terminal	Date loaded on ship	Date ship sailed	Date ship arrived at Tokyo, Japan	Date fruit recovered and examined	Elapsed days
Series I:							
1	February 1	February 6	February 7	February 10	March 8	March 12	40
2	February 13	February 15	February 15	February 17	March 14	March 19	35
3	February 23	February 25	February 25	February 29	April 8	April 14	51
Series II:							
4	April 7	April 10	April 10	April 12	May 6	May 12	35
5	April 16	April 18	April 18	April 19	May 16	May 22	36
6	April 23	April 25	April 25	April 26	May 23	June 2	40
7	April 29	April 30	April 30	May 2	May 27	June 4	36
8	May 13	May 15	May 15	May 17	June 9	June 13	31

The t test for paired differences was used to analyze deformation data between treatments.

Results

Deformation. In all 8 test shipments (series I and II), all degrees of deformation were less for the grapefruit packed in the cell-pack boxes on arrival than for those shipped in the standard 4/5-bu boxes (Table 2). In test series I, the serious deformation of fruit shipped in standard boxes averaged 10.2%, whereas that of fruit shipped in cell-pack boxes was only 2.7%. Similar results were obtained from the second series of shipments; the amount of serious deformation was 6.8% for fruit shipped in standard boxes and only 2.0% for fruit shipped in cell-pack boxes. The better arrival condition of the fruit in the cell-pack boxes was attributed to the additional vertical strength provided by the chipboard partitions in combination with layer dividers, which provided protection from overhead weight for each fruit. These differences of slight and serious deformation between treatments for both series of shipments were significant at the 1% level.

Table 2. Percentage of Florida grapefruit deformed in experimental cell-pack boxes and in standard 4/5-bu boxes on arrival at Tokyo, Japan, in two series (8 tests) of shipments, 1980.

Type of container	Degrees of deformation[z] Slight[y]	Serious[y] (Percent)	Total deformation[x]
Series I (3 tests):			
Cell-pack box[w]	5.4a	2.7a	8.1
Standard 4/5-bu box	21.5b	10.2b	31.7
Series II (5 tests):			
Cell-pack box[v]	10.8c	2.0c	12.8
Standard 4/5-bu box	19.5d	6.8d	26.3

[z]Slight deformation = total aggregate flattened or indented surface area 1 to 2 inches in diameter; serious deformation = total aggregate flattened or indented surface area more than 2 inches in diameter. Fruit with deformed areas totaling less than 1 inch in diameter were classified as sound.
[y]Values with different letters in columns are significantly different at the 1% level according to the "t" test for paired differences.
[x]Percentage of 792 fruit examined from cell-pack boxes and of 768 from standard 475-bu boxes in series I; and percentage of 1320 fruit examined from cell-pack boxes and of 1088 from standard boxes in series II.
[w]Original design with inside dimensions of 17 x 11.5 x 12.5 inches.
[v]Final design with inside dimensions of 17 x 11.5 x 11.5 inches.

Decay. On arrival, decay averaged less than 2% in both types of shipping containers. Most of the decay was stem-end rot (*Phomopsis citri* (Fawc.)).

Container damage. In all 8 test shipments (series I and II), the cell-pack boxes had less side and end bulge and less compression than the standard 4/5-bu boxes (Table 3), likely because of the chipboard dividers that increased the vertical strength of the cell-pack boxes. However, the cell-pack boxes had slightly more bottom sag than the standard boxes. The cell-pack box was 1.1 inch (2.8 cm) wider than the standard 4/5-bu box, and that extra width may have been a factor in the additional bottom sag in the cell-pack box.

Costs. The costs of packaging materials, direct labor, and transport for packing and shipping size 32 Florida grapefruit in cell-pack boxes and in standard 4/5-bu boxes from Florida to Tokyo, Japan, are listed in Table 4. The costs of packaging materials are based on quotations received from cooperating container manufacturers. Time studies of one commercial trial of packing 208 cell-pack boxes indicated

Table 3. Amount of physical damage to experimental cell-pack boxes and standard 4/5-bu boxes during two series (8 tests) of shipments from Florida to Tokyo, Japan, 1980.

Type of container	Type of container damage Bottom sag	Side bulge[z] (inches)	End bulge[z]	Compression
Series I (3 tests):				
Cell-pack box	0.8	0.3	0.0	0.3
Standard 4/5-bu box	0.6	0.6	0.6	0.5
Series II (5 tests):				
Cell-pack box	1.2	0.4	0.1	0.2
Standard 4/5-bu box	0.8	0.9	0.4	0.5

[z]Total bulge of both sides or both ends.

that the machine averaged one cell-pack box every 0.86 production-min., whereas labor for manually packing the standard box on the regular packinghouse line averaged one standard box every 0.52 production-min. The automatic cell-pack box packing machine performed satisfactorily, and discussions with the design engineer indicated that in full production, cell-pack machines would have a production rate of 4 cell-pack boxes/minute. The direct labor costs listed in Table 4 include costs of assembling, packing, and closing both types of shipping containers. The standard box costs are based on the weighted average of costs at 16 export packinghouses in Florida (4). Direct labor costs for assembling and closing cell-pack boxes were assumed to be the same as for the standard boxes. The cost of direct labor for packing the cell-pack boxes was supplied by the cooperating package-machine manufacturer and was based on a machine lease rate of $0.08/cell-pack box. The direct labor costs did not include labor for receiving, trucking, dumping, grading, checking, loading, or supervision, because these costs were the same, regardless of the type of container being packed.

The transport cost was based on a charter ship stowage rate of $2.4367/ft^3 displacement to Japan, and stowage factors of 1.539 ft^3 for the standard box and 1.875 ft^3 for

Table 4. Costs of packaging materials, direct labor, and transport for packing and shipping size 32 Florida grapefruit in experimental cell-pack boxes and in standard 4/5-bu boxes from Florida to Tokyo, Japan, 1980.

Cost item	Cost Cell-pack box (dollars)	Standard box
Packaging materials[z]	0.98	0.63
Direct labor	.12	.13
Transport	4.89	4.04
Total per box	5.99	4.80
Cost per fruit[y]	.18	.15
Added cost:		
Per fruit[x]	.03	
Per standard box equivalent	.96	

[z]Based on price/thousand delivered in truckload lots to Florida east coast areas, March 1980, on using 200-lb-test fiberboard cover and 350-lb-test fiberboard body for the cell-pack box and for the standard box, and on a blue liner cover for the standard box and an oyster-white liner cover for the cell-pack box; both containers printed in one or two colors.
[y]Based on a fruit count of 33 for experimental cell-pack box and of 32 for standard box, and rounded to the nearest cent.
[x]Calculation is for additional cost/fruit over that of standard box.

the cell-pack box. The stowage factor for both containers included an additional 20% stowage allowance. The transport cost also included the truck transport charge from Vero Beach, Florida, to the port of Tampa, and the fumigation charge per trailerload of fruit.

The combined costs for packaging materials, direct labor, and transport for packing and shipping grapefruit to Tokyo, Japan, were $0.03 more/fruit for the cell-pack boxes than for the standard box (Table 4). For each standard box equivalent of 32 fruit, the additional packaging materials, direct labor, and transport costs to Tokyo amounted to $0.96 more (32 x $0.03) for fruit in the cell-pack box than for fruit in the standard box.

Trade reaction to commercial cell-pack boxes. The observations of grapefruit in cell-pack boxes from the first commercial shipment at the Kanda and Tsukiji wholesale fruit markets in Tokyo were made on March 27, 55 days after the fruit were packed at Vero Beach, Florida. Examinations of 17 cell-pack boxes selected at random at three wholesalers revealed that serious deformation averaged 1.4% and decay averaged about 3%. All of the Japanese wholesalers interviewed indicated that the cell-pack boxes delivered the fruit in near-perfect shape. The receivers agreed that a premium of about 270 yen ($1.08 when based on an exchange rate of 250 yen/U.S. dollar) would not be a problem for cell-pack boxes of fruit, provided that all fruit were of premium quality, in good shape, and without decay. Because the jobbers at the Kanda and Tsukiji markets examine and repack all of the grapefruit, thus guaranteeing their respective retailers 100% packout/box, they requested extra chipboard cell partitions and fiberboard layer dividers so that they could replace those soiled from decayed fruit. One jobber said that red or white chipboard cell partitions would complement the grapefruit more than the color of the kraft chipboard cell partitions used in these tests. Another jobber liked the vertical chipboard partitions because they permitted higher stacking of the boxes in the wholesale market stalls, where the cost of space is at a premium, than is possible with boxes not so equipped. A retailer stated that the chipboard cell partitions and fiberboard layer dividers should be kept in the cell-pack boxes, when repacking, to ensure quality at delivery into the retail stores from the wholesale markets.

Discussion

These tests demonstrated that Florida grapefruit packed in cell-pack boxes commercially with automatic equipment arrived in Tokyo, Japan in a better condition and with a better appearance than those shipped in standard 4/5-bu export boxes. The cell-pack boxes protected the grapefruit from deformation, and the reaction of the Japanese receivers to the use of the cell-packed boxes for large grapefruit was generally favorable. Although, at the time of our tests, it cost about $0.03 more/fruit to market Florida grapefruit in cell-pack boxes than in standard 4/5-bu export boxes in Tokyo, Japan, it appears that the cell-pack boxes are the best means currently available to ensure maintenance of quality, particularly avoidance of excessive deformation to grapefruit, during extended overseas shipments to Tokyo, Japan, which average 4 weeks or longer.

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EFFECT OF INDIVIDUAL FILM WRAPPING AND RELATIVE HUMIDITY ON QUALITY OF FLORIDA GRAPEFRUT AND CONDITION OF FIBERBOARD BOXES IN SIMULATED EXPORT TESTS[1]

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Abstract. **The effect of individual film wrapping with a low-density polyethylene bag and of in-transit relative humidity (RH) on the keeping quality of grapefruit and on the strength of fiberboard boxes were investigated. Florida 'Marsh' grapefruit harvested 3 times in 1979-80 were individually film wrapped or nonwrapped then stored to simulate a 4-week export period at 85% to 90% RH and 70°F (21°C) or 50% to 60% RH and 70°F, plus a 2-week marketing period at ambient conditions. Results indicated that if grapefruit were shipped in film wrapping, in-transit RH could be lowered below the currently recommended 85% to 90% RH without causing additional increase in weight loss, deformation, and decay. Reduced RH kept corrugated fiberboard drier than the 85% to 90% RH and thus, maintained its**

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