DEVELOPMENT OF A STANDARDIZED PEPPER CONTAINER

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Additional index words. Forced-air and room cooling, MUM, vent opening, Capsicum annuum, palletization.

Abstract. Florida green (bell) peppers are produced for fresh market and shipped in corrugated containers, but over 2 dozen different containers are used. A need was recognized for a standardized container to facilitate marketing, promote palletization, reduce handling cost and mechanical injury, and improve cooling efficiency. A 40 x 30 cm MUM container with 5% effective vent opening area was developed through the combined efforts of the Florida Bell Pepper Growers Exchange, IFAS, and two corrugated container manufacturers. The design considerations for this standardized container are presented. Comparative cooling tests for peppers packed in the MUM containers and current 1-1/9 bushel containers (2-4% vent opening area) were conducted with individual containers, simulated pallets, and commercial pallets using room cooling and with commercial pallets using forced-air cooling. The MUM containers allowed over 10% more airflow and cooled at least 20% faster than the 1-1/9 bushel containers.

Florida green (bell) peppers are produced for fresh market and shipped in corrugated containers. Over 2 dozen different containers were used by the pepper industry. A need was recognized for a standardized container to facilitate marketing, promote palletization, reduce handling cost and mechanical injury, and improve cooling efficiency. A 40 x 30 cm MUM (Modularization, Unitization, and Metrication) container with 5% effective vent opening area was developed through the combined efforts of the Florida Bell Pepper Growers Exchange, IFAS, and two corrugated container manufacturers. The new container has received considerable national publicity. Sargent and Talbot (1992) and Brown (1992) described this new standard container and announced its introduction by the Florida pepper industry effective October 1, 1992. This MUM container has been well received by receivers and produce organizations in other states. Sanders (1992) applauded the Florida Bell Pepper Growers Exchange for developing the new standard pepper container and indicated the change would be good for the industry although some adjustments would be necessary. Growers in other states, such as Texas and California, and Mexico are strongly considering adoption of the new container. The potential for wide spread adoption is possible as many companies are planning to use this container for other vegetables, such as cucumbers, eggplants, squash, and green beans.

The objective of this report is to present the design considerations and decision making background which led to the final recommendation for this standardized container by the growers exchange. The final design was an adaptation which resulted from the contribution and cooperation of the growers exchange, two corrugated container manufacturers, and the IFAS postharvest research group. Several factors were considered and evaluated prior to selection of a final “best” design which satisfied the criteria specified by each of the cooperating groups. Design considerations (the size, location, and alignment of vent holes) which enhance efficient precooling will be emphasized as well as the techniques used to evaluate the cooling performance of various prototype containers.

Materials and Methods

Table 1 summarizes the various containers evaluated and the cooling experiments conducted. In all cooling tests, 30 gauge thermocouples and Campbell Scientific data loggers were used to measure temperatures. Thermocouples were inserted approximately 2.5 cm (1 inch) into the stem end of the peppers similar to the technique described by Gaffney and Baird (1977). Depending on the cooling test, thermocouples were installed in 3 to 15 peppers and these peppers were uniformly distributed in the container being evaluated. The inlet (cooling) air and outlet air temperatures were also measured.

Initial Single Container Side-by-Side Tests

Sargent et al. (1990) conducted pepper filling tests to compare the performance of various prototype containers.

<table>
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<th>Table 1. Summary of cooling experiments.</th>
</tr>
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<td>Initial Single Container Side-by-Side Tests</td>
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The authors gratefully acknowledge the assistance and cooperation of Mr. Reginal L. Brown, Florida Fruit and Vegetable Association; ABC Farms, Inc., Immokalee; R. G. Thomas Farms, Inc., LaGrange; Green Cay Farms, Inc., Boynton Beach; Roger Harloff Packing, Inc., Bradenton; Hamilton County Produce Co., Jennings; Western Kraft Paper Group, Griffin, GA; Jefferson Smurfit Corp., Jacksonville; and the funding support and guidance of the Florida Bell Pepper Growers Exchange, Inc. Loren Miller, Engineer Technician, Agricultural Engineering Department, University of Florida, provided invaluable technical support and cooling system development and maintenance.
Fig. 1. Stacking configuration on 100 × 120 cm (40 × 48 inch) pallet for 40X30 MUM, 50X30 MUM, and 1-1/9 bushel containers.

**40X30 MUM PEPPER CONTAINERS**

**PROTOTYPE-1**

- Vents - 1
  2.86 cm dia. semicircle (1-1/8 in)

- Hand Hole - 2
  2.5 X 8.9 cm semicircular ended slot (1 x 3-1/2 in)

**PROTOTYPE-2**

- Vents - 3
  4.6 cm dia. semicircle (1-13/16 in)

- Extra Vents - 4
  3.5 cm dia. circle (3/8 in)

- Vents - 5
  2.54 cm wide, 3.81 cm long semicircular ended slot (1 in. wide, 1-1/2 in. long)

**PROTOTYPE-3**

- Vents - 7
  3.5 cm wide, 3.2 cm long semicircular ended slot (1-3/8 in wide, 1-1/4 in. long)

**PROTOTYPE-4**

- Vents - 1
  3.81 cm dia. semicircle (1-1/2 in)

- Hand Hole - 2
  2.5 X 8.9 cm semicircular ended slot (1 x 3-1/2 in)

- Vents - 3
  3.5 cm dia. semicircle (1-3/8 in)

- Vents - 4
  1.6 cm dia. semicircle (5/8 in)

- Hand Hole - 5
  2.5 X 9.5 cm semicircular ended slot (1 x 3-3/4 in)

**PROTOTYPE-5**

- Side Vents - 6
  1.1 X 6.0 cm vert. slot (7/16 x 2-3/8 in)

- Extra Vents - 7
  3.5 cm dia. circle (1-3/8 in)

**PROTOTYPE-6**

- End Vents - 8
  2.5 X 8.6 cm vert. slot (1 x 3-3/8 in)

**PROTOTYPE-7**

- End Vent - 9
  1.6 X 5.7 cm vert. slot (5/8 x 2-1/4 in)

**PROTOTYPE-8**

- End Vent - 10
  1.9 X 3.5 cm vert. slot (7/16 x 1-1/2 in)

**PROTOTYPE-9**

- Hand Hole - 11
  2.5 X 9.5 cm semicircular ended slot (1 x 3-3/4 in)

- Side Vents - 12
  1.1 X 6.0 cm vert. slot (7/16 x 2-3/8 in)

- Extra Vents - 13
  3.5 cm dia. circle (1-3/8 in)

- End Vents - 14
  2.5 X 8.6 cm vert. slot (1 x 3-3/8 in)

**PROTOTYPE-10**

- End Vent - 15
  1.6 X 5.7 cm vert. slot (5/8 x 2-1/4 in)

**PROTOTYPE-11**

- Hand Hole - 16
  2.5 X 9.5 cm semicircular ended slot (1 x 3-3/4 in)

- Side Vents - 17
  1.1 X 6.0 cm vert. slot (7/16 x 2-3/8 in)

- Extra Vents - 18
  3.5 cm dia. circle (1-3/8 in)

- End Vents - 19
  2.5 X 8.6 cm vert. slot (1 x 3-3/8 in)

**PROTOTYPE-12**

- End Vent - 20
  1.6 X 5.7 cm vert. slot (5/8 x 2-1/4 in)

Fig. 2. Front and side view of 40X30 MUM containers showing vent size, location, and percent area.

weight and count of prototype 40X30 and 50X30 MUM containers with currently used 1-1/9 bushel containers. Soon after that study, Prototype-1 40X30 (Fig. 1 and 2) and Prototype (PT) 50X30 (Fig. 1 and 3) containers were provided by a corrugated container manufacturer with vent openings to allow forced-air cooling. The 1-1/9 bushel (WK) container provided by a shipper filled with the pepper and shown in Fig. 3 was used for the initial side-by-side cooling comparison tests.

A forced-air cooler designed specifically for research by Baird et al. (1975) was used for this study. Air velocity, air temperature, relative humidity, container venting, and product stacking arrangement were important variables related to cooling biological materials that could be controlled. Temperature distribution within the individual product and within the product container, static pressure loss (drop) across the product container, air flow through the product container, and product moisture loss were among the parameters that could be measured during a test.

In order to study side-by-side container and simulated pallets, the product chamber of the research forced-air cooler was modified as shown in Fig. 4 to accept two small experimental forced-air units. These units incorporate a fan (10-5/8 inch Dayton Blower model 4C108) driven by a 1 hp motor (General Electric model 5KC48PR156U), a
pressure differential flow element (annubar) to measure the flow rate leaving the fan, a gate valve to control the flow rate, a plywood plenum, transition, and base (platform). The upper and lower fans operated at 3450 and 1750 rpm, respectively.

During the experiments, cold air is pulled through the containers of pepper, the transition, the plenum, the fan, and exits through the annubar and gate valve. The annubar is installed in a 6.4 cm (2-1/2 inch) diameter PVC pipe and the flow rate was determined as a function of the difference between the velocity and static pressure, measured with an electronic differential pressure manometer. A simple wood gate valve was installed on the exit of the PVC pipe to adjust the flow rate and corresponding pressure drop across the containers of pepper. The wider the gate valve was opened the more flow and the higher the pressure drop across the containers. The pressure drop was set by adjusting the gate valve until the desired pressure drop reading was indicated by the digital manometer. The pressure drop selected for the side-by-side tests were 50 and 150 pa (0.2 and 0.6 inches of water), which were within the range of pressure drops reported by Talbot and Baird (1991) in commercial forced-air cooling systems. The temperature of the cooling air entering the forced-air units was controlled at a constant temperature of 5°C (41°F).

After the thermocouples were installed and the peppers were placed in the containers, the containers of pepper were heated in a electric resistance heating chamber. The thermocouples were connected to the data logger and the pepper in the containers were heated to an average temperature 24°C (76°F).

The heated containers of pepper were quickly placed on the forced-air platforms and all gaps between adjacent containers, between the containers and the platform, and on the top and sides of the containers were sealed with duct tape and plastic. This provided one-dimensional flow. Two tests were conducted. In the first test the PT-1 40×30 (Fig. 2) and 1-1/9 bushel (WK) container (Fig. 3) were placed side by side on the upper and lower forced-air units as indicated in Fig. 4, with air flow through the sides (Fig. 1). In the second test, the PT-1 40×30 containers were replaced with the PT 50×30 containers (Fig. 3). The PT 50×30 containers were arranged so the air flowed through the ends (Fig. 1).

The forced-air units were rolled into the experimental cooler where the thermocouples were connected to the data logger and the pressure drop was adjusted to 50 pa and 150 pa (0.2 and 0.6 inches of water) for lower and upper units, respectively. To determine the flow rate through each of the side-by-side containers, the vents in one container were sealed and the pressure drop was readjusted (by adjusting the gate valve) to the initial value and the annubar reading was recorded. The procedure was reversed to determine the flow through the second container.

Single Container Side-by-Side Tests. After the initial tests, the 50×30 container was dropped from consideration and the PT-2 40×30 (Fig. 2), with larger vent openings, was provided by a corrugated container manufacturer. The PT-3 40×30 (Fig. 2) was constructed by utilizing on hand PT-1 40×30 and cutting larger vent openings with a razor knife. The PT-4 40×30 (Fig. 1 and 2) with a different vent number and position was provided by a second corrugated container manufacturer as a potential improvement to the PT-2 40×30 container from a structural strength perspective. The 1-1/9 bushel (CCA) container (Fig. 3) was provided by a shipper filled with the pepper and used for the side-by-side cooling comparison tests. Additional vent openings (Fig. 2 and 3) were added to the four containers using a razor knife.

The pressure drop selected for the side-by-side tests was 50 pa (0.2 inches of water) for both the upper and lower forced-air units. The thermocouples were installed and the containers were placed on the platforms. The four containers were placed as shown in Fig. 5 (with air flow through the sides) and all gaps between adjacent containers, between the containers and the platform, and on the top and sides of the containers were sealed with duct tape and plastic. Two tests were conducted. During the first test the extra vent openings were sealed with plastic and duct tape. For the second test, the forced-air units were rolled out of the experimental cooler, the extra vents were opened and the containers of pepper were reheated prior to the second cooling test.

The test procedure was similar to initial tests except for the heating prior to the cooling tests. Heating was accomplished by ducting hot air through a duct formed with
canvas wrapped around the upper and lower forced air units and connected to the outside of the plenums. The forced-air unit fans were used to pull the hot air, provided through an insulated duct from the reheat section of the experimental cooler, through the containers of pepper. The thermocouple readings were recorded using the data logger and heating was continued until the average pepper temperature reached 32°C (90°F).

The forced-air units were rolled into the experimental cooler with the thermocouples already connected to the data logger and the pressure drop was adjusted to 50 pa (0.2 inches of water) for both lower and upper units. To determine the flow rate through each of the side-by-side containers, the vents in one container were sealed and the pressure drop was readjusted (by adjusting the gate valve) to the initial value and the annubar reading was recorded. The procedure was reversed to determine the flow through the second container.

**Simulated Pallet Cooling Tests.** PT-2 (Fig. 2) and PT-4 (Fig. 2) 40×30 containers and 1-1/9 bushel (RFC) (Fig. 3) containers provided by a shipper filled with pepper were used for the simulated pallet cooling tests. In order to simulate cooling of pepper in containers on a pallet, a portion of one pallet layer of containers, as indicated in Figs. 1 and 5, was placed on the forced-air units. The top view shown in these figures illustrate that the cooling air first passed through container 3, then passed through container 2, and finally passed through container 1. The cooling air is warmed as it passes through each subsequent container, therefore peppers in container 3 cool the fastest while peppers in container 1 cool the slowest. This is frequently called “bed effect”. The pressure drop selected for the simulated pallet tests was 150 pa (0.6 inches of water) for both the upper and lower forced-air units. The containers were placed on the forced-air units as shown in Fig. 5. Thermocouples were installed in 10 peppers in each of the numbered containers and the containers were placed on the forced-air platforms.

The other containers shown were also filled with peppers but not instrumented. Again the gaps between adjacent containers, between the containers and the platform, and the top and sides of the containers were sealed with duct tape and plastic. Two tests were conducted. In the first test, PT-4 40×30 containers were installed on the upper forced-air unit and 1-1/9 bushel (RFC) containers were installed on the lower forced-air unit. For the second test, the PT-4 40×30 containers were replaced with PT-2 40×30 containers. The same 1-1/9 bushel (RFC) container setup was used for the second test.

The test procedures were the same as for the side-by-side tests except for the higher pressure drop and the requirement to determine only a single flow rate value through the simulated pallet layer.

**Commercial Forced-air Cooling Tests at Two Packinghouses.** Cooling tests were conducted at two commercial pepper packinghouses. Both facilities stacked containers of peppers 5 layers high on each pallet and used 1-1/9 bushel containers similar to the (CCA) container shown in Fig. 3. Thermocouples were placed in three peppers, which were uniformly distributed, in each of 8 containers on the third layer (of 5) of a pallet of 1-1/9 bushel containers filled with peppers and in each of 10 containers on the third layer (of 5) of a pallet of PT-4 40×30 containers filled with peppers.

The two pallets were moved into the packinghouse cold storage room and placed adjacent to each other. The thermocouples were connected to the data logger and temperature readings were recorded over night. The air temperature surrounding the pallets was also monitored.

**Commercial Forced-air Cooling Tests at Two Packinghouses.** Forced-air cooling tests were conducted at the same two commercial packinghouses used for room cooling. The third layer of containers on a pallet of 1-1/9 bushel containers and a pallet of PT-4 40×30 containers were instrumented as described in the room cooling tests.

The two pallets were moved into the forced-air cooler and placed at the last pallet position and on opposite sides of the cooling tunnel. Refer to Talbot et al. (1992) for a description of forced-air cooling tunnels. The thermocouples were connected to the data logger and the temperature readings were recorded for several hours. The temperature of the air around the forced-air cooling tunnel was also measured.

**Results and Discussion**

**Initial Single Container Side-by-Side Tests.** Baird et al. (1988), Talbot and Baird (1991), Talbot et al. (1992), and others recommend a vent opening of 5% for containers used for forced-air cooling. The side vent 0.9% opening
For the 1-1/9 bushel (WK) container (Fig. 3) is lower than most 1-1/9 bushel containers. The vent size for the PT-1 40×30 MUM (Fig. 2) and PT 50×30 (Fig. 3) containers were much less than 5% area desired. For a pressure drop of 50 pa (0.2 inches of water), the PT-1 40×30 and PT 50×30 MUM containers cooled (3/4-Cool) peppers 0.33 and 0.52 hours (20 and 35%) faster, respectively, compared to the 1-1/9 bushel (WK) container (Fig. 6). The 3/4-cooling time is the time required to remove 3/4 of the temperature difference between the initial product temperature and the cooling air temperature. For these tests it would be the time to cool to a temperature of 9.4°C (49°F). The two MUM containers also provided 20% and 22% more air flow, respectively, than the 1-1/9 bushel (WK) container.

For the 150 pa (0.6 inches of water) pressure drop cooling tests (not illustrated), The PT-1 40×30 and PT 50×30 containers cooled peppers 0.52 and 0.68 hours (48% and 58%) faster, respectively, and provided 20% and 34% more air flow, respectively, than the 1-1/9 bushel (WK) container.

Single Container Side-By-Side Tests. The PT 50×30 container was dropped from consideration by the growers exchange, in part due to the register or column stacking (Fig. 1), which does not allow cross stacking of the containers to stabilize the pallet load. The PT-1 40×30 MUM design was modified by specifying larger vents, and the new design became PT-2 40×30 MUM container (Fig. 2) which was provided by a corrugated container manufacturer. The PT-3 40×30 MUM container was constructed from PT-1 40×30 MUM by elongating the vent hole openings using a razor knife. The rational behind these longer vent openings was to keep the same vent center lines and increase the opening area but with a narrow vent width in an attempt to maintain the distance between the vent openings and the corners of the container. The PT-4 40×30 MUM container was provided by a second corrugated container manufacturer as an alternative for PT-2 40×30 MUM. This corrugated manufacturer stated that the vents located near the corners would reduce the structural strength of the container. The vent number and location were modified. Initially, the vents were the same size as used for PT-2. Since fewer vents were used (Fig. 2) to maintain the desired percent vent opening area, the vent size was redesigned and made larger. However, the corrugated container manufacturer did not construct the vent area in accordance with the recommended size (Fig. 9). As noted in Fig. 2, the PT-4 40×30 MUM container provides less than 5% vent opening area and when stacked on a pallet, the effective vent opening area is reduced due to misalignment where 10 vent locations line up with the gap between two adjacent containers (Fig. 1) rather than with vent holes of the adjacent container.

Table 2 summarizes the results of the single container side-by-side cooling tests. All three prototype 40×30 MUM containers allowed higher flow rates and faster cooling when compared to the 1-1/9 bushel container. The PT-2 40×30 MUM container performed the best (100% more flow and 59% faster cooling than the 1-1/9 bushel container) but only slightly better than the PT-4 40×30 MUM container (100% more flow and 54% faster cooling than the 1-1/9 bushel container). Even though the PT-3 40×30 MUM container had the greatest percent vent opening area, it provided a lower flow rate (41% more flow than the 1-1/9 bushel container) and slower cooling (52% faster cooling than the 1-1/9 bushel container) when compared to the other two prototype containers. This can be attributed to the narrower vent openings which would produce more resistance, allowing less flow, and subsequently slower cooling.

For all four containers, increasing the percent vent opening area by using the extra vents in the second cooling test, produced increased flow rate through the container and a faster cooling. For the 1-1/9 bushel (CCA) container, a 2% increase in vent area reduced the cooling time by 0.6 hours (52%) and increased the air flow by 58%. The importance of adequate vent opening area is very obvious. Structural strength reductions which the extra vents could cause were not considered.

Simulated Pallet Cooling Tests. Cooling an individual container of peppers is much easier than cooling peppers in palletized containers. The cooling air must pass through more peppers and vent openings along the flow path than for an individual container. The amount of energy (pressure drop) to force the cooling air through the pallet of

![Fig. 6. Cooling curves for initial side-by-side pepper container test.](image)

![Fig. 7. Cooling curves for commercial room cooling of pepper container test.](image)

Forced-air Cooling of Palletized Peppers  
1-1/9 bu. vs. 40 X 30 cm Containers

Fig. 8. Cooling curves for commercial forced-air cooling of pepper container test.

Commercial Forced-Air Cooling Tests. Laboratory scale tests provide valuable information but the growers exchange was interested in performance evaluation of the 40 x 30 container.

Table 3 summarizes the results of the simulated pallet cooling tests. The 1-1/9 bushel (RFC) container has one of the highest percent vent openings areas available in this type container. However, the PT-2 and PT-4 40 x 30 MUM containers provided more cooling air flow (60% and 10%, respectively) and a faster cooling time, 1.75 and 2.2 hours (51% and 20%, respectively) when compared to the 1-1/9 bushel container. The PT-2 40 x 30 container allowed the greatest air flow and fastest cooling time. This is due to better vent alignment with adjacent containers and a larger percent vent opening area (larger effective percent vent area) when compared to the PT-4 40 x 30 container. Some vent misalignment was noted for the both 40 x 30 containers. But the wider vent openings prevented complete blockage of a vent.

Comparing the cooling times listed in Table 2 and Table 3 illustrates that cooling a pallet width of peppers in containers takes longer and generates a higher pressure drop than when cooling peppers in an individual container.

The PT-2 40 x 30 container provided a more uniform vent pattern, enhanced vent alignment, and performed better during both side-by-side and simulated pallet cooling tests. However, due to concerns over structural deterioration that might be caused by the vent openings near the corners of the container, this design was dropped from consideration. The structural integrity concerns were based on the experience of the corrugated container manufacturing personnel and no structural evaluations were conducted. Because of the merits of this design, structural evaluations should be conducted to determine scientifically whether the PT-2 40 x 30 container is structurally adequate.

Commercial Room Cooling Tests. For the commercial room cooling, the total length of time to achieve adequate cooling is much too long for proper maintenance of the pepper quality.

Commercial Forced-Air Cooling Tests. Fig. 8 illustrates the commercial forced-air cooling performances of the PT-4 40 x 30 and 1-1/9 bushel containers. Peppers in the PT-4

STANDARD 40 X 30 cm MUM CONTAINER

5% Effective Vent Openings

VENTS FOR STANDARD 40X30 MUM PEPPER CONTAINER

Fig. 9. Standard 40 x 30 cm MUM pepper container with 5% effective vent area and specification of the vent hole.
Table 2. Single container side-by-side cooling tests.$^{2}$

<table>
<thead>
<tr>
<th>Type Container</th>
<th>Vent Area %</th>
<th>Flow Rate</th>
<th>3/4 Cooling Time, hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/9 Bushel (CCA)</td>
<td>1.9</td>
<td>3.5</td>
<td>1.5 (30.9)</td>
</tr>
<tr>
<td>Prototype-2 MUM 40 $\times$ 30 cm</td>
<td>5.3</td>
<td>N/A</td>
<td>2.3 (48.9)</td>
</tr>
<tr>
<td>Prototype-3 MUM 40 $\times$ 30 cm</td>
<td>5.7</td>
<td>5.7</td>
<td>2.1 (43.7)</td>
</tr>
<tr>
<td>Prototype-4 MUM 40 $\times$ 30 cm</td>
<td>4.6</td>
<td>4.1</td>
<td>2.9 (61.8)</td>
</tr>
</tbody>
</table>

$^{2}$Pressure drop, 50 pa (0.2 in. water); initial pulp temperature 32°C (90°F); cooling air temperature 4.4°C (40°F).

Table 3. Simulated pallet cooling test.$^{4}$

<table>
<thead>
<tr>
<th>Type Container</th>
<th>Vent Area %</th>
<th>Flow Rate</th>
<th>3/4 Cooling Time, hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/9 Bushel (RFC)</td>
<td>3.1</td>
<td>4.4</td>
<td>4.9 (103.6)</td>
</tr>
<tr>
<td>Prototype-2 MUM 40 $\times$ 30 cm</td>
<td>5.3</td>
<td>5.3</td>
<td>7.8 (165.7)</td>
</tr>
<tr>
<td>Prototype-4 MUM 40 $\times$ 30 cm</td>
<td>4.6</td>
<td>4.1</td>
<td>5.4 (113.6)</td>
</tr>
</tbody>
</table>

$^{4}$Pressure drop, 150 pa (0.6 in. water); initial pulp temperature 32°C (90°F); cooling air temperature 4.4°C (40°F).

40 $\times$ 30 container achieved 3/4-cooling in 1.6 hours at Packinghouse 2, 0.6 hours (37.5%) more rapidly than peppers in the 1-1/9 bushel containers. During the cooling test at Packinghouse 1 (not illustrated), the forced-air cooler operated at a higher air temperature and less efficiently than Packinghouse 2. Peppers in the PT-4 40 $\times$ 30 container achieved 3/4-cooling in 2.46 hours, 0.93 hours (37.8%) more rapidly than peppers in the 1-1/9 bushel containers.

It is evident that the PT-4 40 $\times$ 30 MUM container greatly improves the cooling efficiency. As a result of these data and other information related to marketing facilitation, palletization promotion, and handling cost and mechanical injury reduction, the growers exchanged recommended the 40 $\times$ 30 MUM container as the standard shipping container for the Florida pepper industry.

**Standard 40 $\times$ 30 MUM Pepper Container.** As noted above, the corrugated container manufacturer did not provide the recommended vent area for the PT-4 40 $\times$ 30 MUM container. In order to compensate for the vents not aligned with an adjoining vent, an assumption was made that these vents did not allow the flow of cooling air. For the crossstack plane shown in Fig. 1, it was further assumed that the vents that were aligned needed to provide a vent opening of 5% of the area of this plane or an “effective area” of 5%. The required vent area was calculated and then divided by the number of aligned vents on the plane. The dimensions of an individual vent to provide the required area were then calculated and is shown in Fig. 9. This vent size was recommended to the corrugated container manufacturer. However, due to a misunderstanding by the container layout crew, the shaded vent shown in Fig. 9 was the actual size of the vent provided with PT-4 40 $\times$ 30 container.

With the recommended vent size, the standard 40 $\times$ 30 cm MUM pepper container shown in Fig. 9 provides an effective vent opening area of 5% when the containers are palletized. The percent vent openings of the side and ends of an individual standard container (7.5% and 6.6%) are also shown in Fig. 9.

The outside dimensions for the standard 40 $\times$ 30 cm MUM container are 40 cm length $\times$ 30 cm width $\times$ 32 cm height (15-13/16 inch $\times$ 11-7/8 inch $\times$ 12-1/2 inch) with a wall thickness of 0.4 cm (5/32 inch). The interior volume is 3.56 decaliters, which was determined by setting the carton height as high as possible while maintaining carton stability during packing and handling. A decaliter equals 10 liters (610.2 cubic inches) and 3.56 decaliters equals 35.6 liters (2,172.4 cubic inches). In contrast, 1 bushel equals 35.2 liters (2,150.4 cubic inches) and 1-1/9 bushel equals 39.2 liters (2,389.3 cubic inches). Containers designed with thicker wall or which use lids (which will provide the 40 $\times$ 30 cm base dimension) will have reduced interior base dimensions. Consequently, the height must be increased to maintain the 3.56 decaliter volume.

The final design of the standard 40 $\times$ 30 cm MUM pepper container involved a number of design considerations and decisions which resulted in a "best" design which satisfied the criteria specified by the growers exchange, two corrugated container manufacturers, and the IFAS post-harvest research group. This final design will provide more efficient cooling than the PT-4 40 $\times$ 30 container, which was much more efficient than the 1-1/9 bushel pepper containers.

Growers are planning to use the new container dimensions for containers to pack other vegetables as well. The capability of delivering high quality vegetables to distant markets requires careful handling procedures from field to retail. The adoption of this standard shipping container will greatly benefit the Florida industry and, ultimately, the consumer.

**Literature Cited**


