contributing factors that cannot be controlled, such as, weather, pest and disease pressures, soil types, cultural practices, etc. The results of this experiment were disappointing. Although the MB dosages were 8 to 16 g/m³ less than those reported in earlier work (2), reduction in the amount of decay was not sufficient to eliminate it as a problem. It is questionable whether industry could tolerate so much loss in mid and late season grapefruit.

*Experiment 2.* Peel injury was observed in the January lot of fruit only (Table 3). We believe that 2 hard freezes which occurred ca. 2 weeks prior to harvest are the principal causes of this atypical injury. Aerating the fruit for 24 hr following fumigation significantly reduced peel injury as compared to 4 hr aeration.

Table 3. Effect of methyl bromide fumigation followed by 4 or 24 hr aeration, then storage at 60 F, on peel injury of grapefruit.

| Treatment | | Aeration after Fumigation (hr) | % Peel injury on indicated dates[z] | | |
|---|---|---|---|---|---|
| MB (g/m³) | Cold storage °F | | Oct '80 | Jan '81 | Apr '81 |
| 0 | 60°—4 wk (control) | — | 0 | 0 | 0 |
| 40 | 75°—4 wk (control) | — | 0 | 2.8 | 0 |
| 40 | 60°—3 wk | 4 | 0 | 14.8 | 0 |
| 40 | 60°—3 wk | 24 | 0 | 1.9 | 0 |
| 32 | 60°—4 wk | 4 | 0 | 13.0 | 0 |
| 32 | 60°—4 wk | 24 | 0 | 6.5 | 0 |

[z]Readings made over a period of 2 weeks after fruit was removed to ambient temperature (75°F). Each value is based on examination of 144 fruits (4 replicates) for Oct. and 108 fruits 3 (replicates) for Jan. and Apr.

It appears that overall decay was slightly higher in the January fruit as compared to the other lots, (Table 4), again, possibly due to the freezes that closely preceded harvest. None of the decay can be attributed to MB fumigation since the control (60°F for 4 weeks) had more decay than the fumigated lots. There were no consistent differences between the 4 hr and 24 hr aeration periods.

Table 4. Effect of methyl bromide fumigation followed by 4 or 24 hr aeration, then storage at 60°F, on decay of grapefruit.

| Treatment | | Aeration after Fumigation (hr) | % Decay on indicated dates[z] | | |
|---|---|---|---|---|---|
| MB (g/m³) | Cold storage °F | | Oct '80 | Jan '81 | Apr '81 |
| 0 | 60°—4 wk (control) | — | 5.6 | 16.7 | 3.7 |
| 40 | 75°—4 wk (control) | — | 6.5 | 5.6 | 2.8 |
| 40 | 60°—3 wk | 4 | 6.9 | 13.9 | 3.7 |
| 40 | 60°—3 wk | 24 | 6.3 | 10.2 | 0.9 |
| 32 | 60°—4 wk | 4 | 7.6 | 6.5 | 1.9 |
| 32 | 60°—4 wk | 24 | 9.7 | 10.2 | 2.8 |

[z]Readings made over a period of 2 weeks after fruit was removed to ambient temperature (75°F). Each value is based on examination of 144 fruits (4 replicates) for Oct. and 108 fruits (3 replicates) for Jan. and Apr.

Methyl bromide fumigation, when followed by storage temperatures of 50° or lower, produced peel injury in early grapefruit and increased decay in mid- and late-season fruit to levels that would not be commercially acceptable.

Combining MB fumigation with a storage temperature of 60°F would provide an alternative for minimizing peel injury and decay when treatments to destroy the Caribbean fruit fly are required.

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# EFFECTS OF STORAGE TEMPERATURE ON MARKET QUALITY OF FREEZE-DAMAGED MURCOTTS


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*Abstract.* **Murcotts from a freeze-damaged grove, picked within a few days following the January 1981 freeze, were tested to detrmine best holding conditions and whether fruit could be salvaged for the fresh fruit market or processed products. External and internal quality (such as blemishes, softness, °Brix, acid, alcohol content and appearance), as well as juice processing characteristics (such as % culls, juice yield and pulp content) were determined prior to storage. The freeze-damaged Murcotts were not acceptable for the fresh fruit market under any conditions studied, because of excess softness, discoloration and formation of mold. Fruit held at 10°C or above was also unsuitable for canned juice. However, fruit before storage, and after 2 wks at 4°C or 4 wks at 1°C yielded acceptable canned juice for use in processed products. Thus, 1°C is the recommended temperature for holding freeze-damaged Murcotts for salvage.**


The January 1981 freeze produced problems for Florida Murcott growers. Murcotts (a mandarin hybrid) are usually sold to the fresh fruit packer, and packinghouse rejects (due to surface blemishes, color, etc.) or excess fruit are processed

[1]Southern Region, Agricultural Research Service, U. S. Department of Agriculture. Mention of a trademark or propirietary product is for identification only and does not recommend its approval over other products that may also be suitable by the U. S. Department of Agriculture.

for juice. Both these market outlets were restricted following the freeze. A fresh fruit embargo was imposed in January 1981 for several weeks. During several weeks immediately following the freeze, processors operated at full capacity with the glut of oranges that had been harvested under emergency conditions in order to try and salvage as much freeze-damaged fruit as possible. Following previous freezes, growers as well as juice processors have considered the possibility of storing Murcotts for later processing. The best temperature for holding such freeze damaged fruit for later processing has never been determined.

Deszyck and Ting (5) discussed the availability and characteristics of Murcotts in 1960. In a normal season Murcotts are available for the fresh fruit market after most other mandarin hybrids have been harvested, sometimes as late as February or March. Fruit unacceptable for this market has usually been processed for juice. Processors found, as reported by Barron and Metcalf (2) that judicious blending of Murcott juice into FCOJ can improve the color without affecting the flavor. During the 1979-1980 season nearly 50% (6) of the Murcott crop was processed and blended into FCOJ. Thus, the blending of Murcott juice appears to offer an opportunity for salvaging damaged fruit following a freeze. To help determine best conditions for storing until they can be processed, Murcotts picked within a few days after the 1981 freeze were kept at several different temperatures. These studies will help determine conditions under which fruit could best be salvaged for the fresh fruit or processed juice markets.

## Materials and Methods

Internal and external quality of all fruit were examined prior to storage. These preliminary tests included fresh fruit evaluation (°Brix, acid, ratio, softness and cell damage) and processed juice evaluation (% culls, juice yield, °Brix, acid, ratio, ascorbic acid, color, pulp content and alcohol content). Murcott samples were stored at 1°, 4° and 10°C, as well as room temperature (21° to 24°C), as indicated below. These samples were evaluated after 2 and 4 wks at each temperature.

### *Fruit*

Murcotts for fresh fruit evaluations were randomly picked from random trees in a commercial grove that had experienced very low temperatures (−9°C for 7 hrs). The 2100 fruit were divided into samples of 100 fruit each. Initially 3 samples were evaluated and the remaining samples (6 each) were held at 1°, 4° and 10°C for evaluations after 2 and 4 wks.

Commercially picked fruit (approximately 2,000 kg) from the same grove was randomly divided into 46, 40.8 kg orange field boxes for juice processing evaluations. Six boxes were evaluated initially and the remainder stored (10 boxes each) at 1°, 4°, 10° and 21-24°C (ambient, in our pilot plant) to be evaluated after 2 and 4 wks.

### *Juice Processing*

Juice was extracted on an FMC Corporation (Citrus Division, Lakeland, FL) extractor with the following settings: 1. Standard orifice tube with a 1.1 cm long restrictor, 2. a 0.10 cm strainer and 3. the beam down 1.9 cm. Juice from the extractor was finished in a screw-type finisher (Chisholm-Ryder Co., Niagara Falls, NY) with a 0.08 cm screen. Finished juice was pasteurized at 85°C and filled while hot into 1.4 l cans, sealed and stored for later analyzes.

### *Fresh Fruit Evaluations*

*°Brix (total soluble solids).* Values on juice samples were measured using a Zeiss refractometer with a sucrose scale and corrections for temperature and acid were made.

*Acid.* Citric acid levels in juice were determined on 10 g samples titrated with standardized sodium hydroxide solution to pH 8.2 (11).

*°Brix/acid.* Ratios were calculated by dividing corrected total soluble solids by the titratable acid content, calculated as citric acid.

*% Softness.* Samples were manually and visually checked using the fruit inspection procedures for determining quality grade of Florida citrus (9).

*% Cell damage.* Samples were sliced and the internal juice cells visually examined for ruptures as described in fruit inspection procedures (9).

*Flavor.* Five to 10 panelists experienced in tasting fresh Murcotts were presented samples of the whole fruit as well as the juice from whole fruit. These samples were evaluated independently and individually as being acceptable, or unacceptable.

### *Juice Processing Evaluations*

*% Culls.* Fruit determined by external appearance to be unwholesome, was removed, weighed and reported as a percentage of the total fruit weight.

*Juice yield.* The extracted juice weight divided by the total weight of the fruit minus weight of culls and losses was recorded at the % juice yield.

*Finisher yield.* The finisher juice weight divided by the total weight of the fruit minus weights of culls and losses was recorded as the finisher yield.

*% Oil.* Recoverable oil was measured by the bromate titration method (1).

*Ascorbic acid.* Juice samples were titrated with standard 2,6-dichloro benzenone-indophenol (1) to a potentiometric end point.

*% Pulp.* Juice samples (50 ml) were centrifuged 10 min at 1550 rpm and volume of settled pulp was measured (11).

*Color.* A Hunterlab D45D2 citrus colorimeter (Hunter Associates Laboratories, Fairfax, VA) was used to measure color of juice samples (8).

*Ethanol content.* Freshly extracted juice samples were placed in 1.4 l cans and frozen. After thawing, contents of ethanol and acetaldehyde were determined by GLC using the procedure of Davis (4).

*Flavor.* Six panelists experienced in tasting reconstituted orange concentrate were each presented three samples. These samples were an identified control of commercial orange concentrate reconstituted to 12°Brix and two samples each, of the same concentrate with 10% blended processed Murcott juice (2 weeks at 4°C and 4 weeks at 1°C). Panelists were asked to evaluate the three samples and rate them as acceptable or unacceptable noting any specific traits.

## Results and Discussion

Our studies indicated freeze damaged Murcotts, under some conditions could be processed to an acceptable juice product. However, juice yield decreased even after short times at low temperatures, and therefore, growers or processors would need to determine whether the cost of storage was justifiable. Freeze damaged Murcotts would not appear to be acceptable for the fresh fruit market under any of the conditions studied.

Fresh fruit characteristics (Table 1) such as soluble solids (12.5°Brix), acid (0.79%) and a ratio of 16 indicate the maturity of the Murcotts used in this study. These fruit would

Table 1. Fresh fruit characteristics of freeze-damaged Murcotts initially and after storage.

| | °Brix | Acid % | Ratio | Softness % | Ruptured cells % |
|---|---|---|---|---|---|
| Initial | 12.5 | 0.79 | 16 | 18 | 23 |
| After 2 wks @ | | | | | |
| 1°C | 12.5 | 0.68 | 18 | 11 | 37 |
| 4°C | 12.3 | 0.64 | 19 | 7 | 31 |
| 10°C | 12.3 | 0.53 | 23 | 4 | 33 |

have been acceptable considering maturity standards (10). However, the softness (18%) and ruptured cells (23%) indicate the extent of freeze damage the fruit had sustained. This damage rendered the fruit unsatisfactory for the fresh fruit market even before storage because of internal appearance and quality. The freeze damage to this fruit continued to affect juice characteristics while it was stored. After two weeks at 1°, 4° and 10°C the acid was further reduced as others (12) had reported with freeze-damaged oranges. Although the % softness decreased during storage, the % ruptured cells increased. These results are probably due to the loss of water from the fruit. This is an effect freeze damage has been previously reported to produce in the fruit. Although all members of an informal taste panel found the fresh fruit unacceptable, some members found the fresh juice acceptable.

Even though freeze-damaged Murcotts were excluded from the fresh market, they might still be suitable for canning and processing. Initially, 1.4% culls (externally damaged unsound fruit) were found in the Murcotts (Table 2).

Table 2. Processing characteristics of freeze-damaged Murcotts initially and after storage.

| | Culls % | Extractor yield % | Finisher yield % |
|---|---|---|---|
| Initial | 1.4 | 50.9 | 42.5 |
| After 2 wks @ | | | |
| 1°C | 3.2 | 46.0 | 32.7 |
| 4°C | 2.9 | 48.8 | 26.8 |
| 10°C | 29.4 | 48.1 | 33.5 |
| 21-24°C | 35.3 | — | — |
| After 4 wks @ | | | |
| 1°C | 7.5 | 42.8 | 35.8 |
| 4°C | 23.9 | 42.6 | 33.8 |
| 10°C | 68.5 | — | — |
| 21-24°C | — | — | — |

Percentage of culls increased with increased time and/or temperature and the major cause was green mold. Hatton reported similar results with undamaged mandarin cultivars (7).

After two weeks of storage at 1°, 4° and 10°C extractor juice yield (Table 2) had decreased from the initial yield (50.9%) to a range of 46.0 to 48.8%. At 1° and 4°C storage after 4 wks the yield had continued to decrease to 42.8 and 42.6% respectively. Carter (3) recently showed a decrease in juice yield for Valencia oranges remaining on the tree after a freeze. The reduction in yields of finished Murcott juice, found in our studies, is in agreement with their findings. Since juice yield diminished with increased storage time the cost of storage would have to be compared with the value of the processed juice to determine whether short term storage is worthwhile.

Percent acid and ascorbic acid (vitamin C) (Table 3) in juice from freeze damaged Murcotts decreased as either storage time or temperature increased. Others (11) have shown these same reductions in juice from citrus remaining on the tree. We found percent acid decreased from 0.89 initially to 0.58 (4°C for 4 weeks). Ascorbic acid content of the control juice (24 mg/100 ml) was reduced to 12 mg/100 ml (after 4°C for 4 wks). The increase in Brix-acid ratio was a result of the reduction in acid, since the soluble solids content was fairly constant. Although no trends are seen in the ethanol and acetaldehyde values, all were higher than values for undamaged Murcotts (10 mg/100 ml and 0.23 mg/100 ml respectively). Ethanol was much higher at the highest storage temperature (10°C) probably as a result of internal fermentation. Other juice characteristics of the stored Murcotts such as oil content, % pulp and color did not appear to be affected by the freeze damage since they showed no change from the control juice. From the flavor tests, Murcott juices (2 weeks at 4°C and 4 weeks at 1°C) blended at 10%, the maximum allowable level (13) in reconstituted commercial orange concentrate, were considered acceptable by 5 of 6 panelists.

Table 3. Juice characteristics of freeze-damaged Murcotts initially and after storage.

| Storage | °Brix | Acid % | Ratio | Ascorbic acid mg/100 ml | Ethanol mg/100 ml | Acetaldehyde mg/100 ml |
|---|---|---|---|---|---|---|
| Initial | 12.7 | 0.89 | 14 | 24 | 86 | 0.48 |
| After 2 wks @ | | | | | | |
| 1°C | 12.5 | 0.72 | 17 | 17 | 70 | 0.40 |
| 4°C | 12.6 | 0.70 | 18 | 15 | 75 | 0.38 |
| 10°C | 12.6 | 0.58 | 22 | 13 | 94 | 0.57 |
| After 4 wks @ | | | | | | |
| 1°C | 12.9 | 0.65 | 20 | 14 | 71 | 0.44 |
| 4°C | 12.8 | 0.58 | 22 | 12 | 71 | 0.35 |

In conclusion, it is not feasible to store freeze-damaged Murcotts for later release to the fresh fruit market. However, such fruit can be salvaged for the processed juice market and could be held up to 4 wks at 1°C and still produce satisfactory products. With higher storage temperatures the percentage of culls increased greatly with time, thus, the value of salvagable juice should be carefully considered against cost of storage. In any case Murcotts would need to be processed within a few weeks, but storage at 1°C might allow holding them until wide scale emergency processing of the most severely damaged oranges had been accomplished.

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