Handling and Processing Section


QUALITY OF COLD-TREATED ‘ARKIN’ CARAMBOLA COATED WITH WAX OR PLASTIC FILM

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Additional index words: postharvest, Averrhoa carambola L., market quality, Caribbean fruit fly, Anastrepha suspensa (Loew)

Abstract. ‘Arkin’ carambolas, (Averrhoa carambola L.) were coated with heat-shrinkable plastic film, 2% or 6% carnauba wax, and subjected to a quarantine procedure of cold-treatment for 15 d at 1°C and subsequent storage regimes that simulated distribution and merchandising to determine the effect of coatings on the maintenance of market quality characteristics. Cold-treatment increased slightly, but significantly, the severity of peel bronzing, stem-end breakdown, and fin browning of carambolas, but reduced weight loss and the severity of peel shriveling. Cold-treatment increased the incidence of ‘brown’ pitting predominantly on the surface of film-wrapped fruit. Film wrapping reduced the severity and incidence of peel bronzing, stem-end breakdown, and fin browning and shriveling, and reduced weight loss compared with other coatings with or without prior cold-treatment. In general, the quality of carambola with 2% or 6% wax was similar to that of non coated fruit, except that wax coating did reduce weight loss compared with non coated fruit. There were no practical effects of cold-treatment or coatings on total soluble solids, acidity, pH, peel color, flavor, or sensory texture by exposure to cold-treatment or by coatings. We conclude that the slight reduction in those quality characteristics due to cold-treatment will not likely reduce consumer acceptance of carambolas. However, the application of film wrapping to carambolas generally improved the maintenance of carambola quality with or without cold-treatment.

Carambolas must be certified free of the Caribbean fruit fly (CFF), Anastrepha suspensa (Loew), prior to entry into markets such as California, Arizona, and Texas that have quarantine restrictions on this pest. Considerable quarantine treatment research has been conducted on various methods such as hot air (Sharp and Hallman, 1992; Miller, et al., 1990), vapor heat (Hallman, 1990), hot-water immersion (Hallman, 1989, 1991; Hallman and Sharp, 1990), and methyl bromide fumigation (Hallman and King, 1992). Heat treatments have been largely unsuccessful due to excessive stress to carambolas at high temperatures and treatment durations that are required for insect quarantine security. Empirical testing of Florida carambolas showed that probit 9 security was achieved at 0.50 kGy by gamma irradiation without injury to the fruit (Gould and von Windeguth, 1991). Hawaiian carambolas at the yellow/orange color stage were successfully treated at 0.025 kGy, whereas injury did develop on fruit at the green/yellow color stage (Paul, 1992). Probit analysis estimated probit 9 with low-temperature treatment of carambolas at 1.1°C for 13.6 d; experimentation with large lots of fruit were successful without insect survivors and without injury to fruit (Gould and Sharp, 1990). The cold-temperature treatment was determined to be a viable treatment for quarantine security against the CFF on carambolas and was approved for use in domestic markets that have quarantine restrictions (Gould and Sharp, 1990). Commercial application of the cold treatment (CT) on carambolas has been largely successful. However, observations by the authors and reports by industry users (personal communications) indicate that fruit maturity (stage of ripeness) is important to the success of CT, and that on some CT lots, carambolas have excessive market loss during post-treatment shipping and/or storage. Research continues in an effort to seek additional manipulatory procedures that may be used in combination with low-temperature treatments that will aid in the successful application of CT to carambolas.

Recommended low-temperature treatment for security against the Caribbean fruit fly (Anastrepha suspensa Loew) requires holding carambolas for 15 d at 1.1°C (Gould and Sharp, 1990). This CT temperature is less than the recommended storage temperature of 5°C for carambolas (Campbell et al., 1987, 1989). Many fruits and vegetables are damaged by chilling injury when stored at lower than recommended temperatures. Chilling injury causes increased senescence and decay. Temperature manipulation such as a conditioning regime before exposure to a low-temperature treatment may modify the stress tolerance of a given commodity (Hatton, 1990). Temperature conditioning has been shown to reduce chilling injury in many horticultural crops (Wang, 1990). Conditioning, by subject-
ing a commodity to alternating high/low temperatures (also referred to as intermittent warming), was found to reduce chilling in peaches (Ben-Arie et al., 1970). Other methods, such as plastic film wrapping on grapefruit (Purvis, 1985), waxing (Morris and Platenius, 1958), and fungicides such as thiabendazole on grapefruit (Schiffman-Nadel et al., 1975), reportedly reduced chilling injury during storage at low temperatures.

Little research has been conducted specifically on carambolas to eliminate symptoms of chilling injury when low-temperature treatment is used. We conducted two preliminary tests during the 1990 season (data not published) that indicated no difference in the effect of either 3 or 7 d conditioning at 15 C in reducing peel discoloration during subsequent low-temperature treatment and storage. Exposing carambolas to 38 C for 24 or 48 h prior to CT increased pitting and darkening of peel at the margin of the fins. In 1991, carambolas were coated with plastic film, a coating of an edible composite of 1.5% Na carboxymethylcellulose or lanolin, and fruit were subjected to 3 d conditioning at 15 C, and then cold-treated for 15 d at 1.1 C (Miller et al., 1991). That study indicated film wrapping significantly reduced weight loss and reduced the development of all characteristic symptoms of chilling injury, whereas there were symptoms of chilling injury on control fruit and those with other coatings.

The purpose of this study was to determine the effect of fruit coatings such as carnauba wax or film wrapping on chilling injury development symptoms after carambolas are exposed to low temperatures required for CT and during subsequent storage.

**Materials and Methods**

Freshly harvested mature (with slight color break) carambolas were obtained on three occasions at 1-week intervals (October and November 1991) from a grove in Dade County, Florida. Fruit were wrapped in tissue paper and packed in standard commercial fiberboard carambola boxes, 20 count size, and transported to the U.S. Horticultural Research Laboratory in Orlando for treatment preparation and storage. Carambolas free of damage were randomized into four treatment groups of 135 each: 1) control fruit, 2) film wrapped, 3) 2% wax, and 4) 6% wax. For film wrapping, a polyolefin, heat-shrinkable, antifog, plastic film (Cryovac® RD-106, 60 gauge, W.R. Grace & Co., Duncan, S.C.) was applied individually to fruit using a hot wire application device, and the carambolas were placed in standard commercial carambola boxes. Fifteen fruit of each treatment were held at 1 C for 15 d plus 5 C for 7 d plus 15 C for 3 d, or at 5 C for 28 d plus 15 C for 3 d. The eight treatment/storage temperature combinations consisting of three boxes (20 fruit each) each were: 1) control, 1 C; 2) film wrapped, 1 C; 3) 2% wax, 1 C; 4) 6% wax, 1 C; 5) control, 5 C; 6) film wrapped, 5 C; 7) 2% wax, 5 C; and, 8) 6% wax, 5 C. All fruit were at ambient temperature (30 C) when put into storage at 1 C or 5 C, but CT did not begin until pulp temperatures reached 1 C, a lapse time of 72 hr.

Fruit of all eight treatments were inspected before and after application of coating, after CT, after 7 d of storage at 5 C, and after 3 additional d at 15 C. At each inspection, each fruit was evaluated subjectively for peel color, pitting, scald (bronzing or peel discoloration), stem-end breakdown (SEB), shriveling, fin browning, firmness and decay. Peel color was rated 1 to 5 based on the percentage of peel area showing yellow: 1 = 100% green, 2 = < 3% yellow, 3 = >3 to 75% yellow, 4 >75 to 100% yellow, and 5 = 100% yellow/orange color. Pitting and scald ratings were based on the percentage of surface area affected; 1 = no disorder, 2 = 1 to 10%, 3 = 11 to 25%, 4 = 26 to 50%, and 5 = > 50%. Pitting was identified as ‘brown’ or ‘clear’ depending whether lesions were visibly brown or natural peel color, respectively. Stem-end-breakdown was rated 1 = normal, 2 = 1 to 2%, 3 = 3 to 10%, 4 = 11 to 25%, and 5 = > 25% of surface area showing necrotic tissue. Shriveling was rated either 1 (no shrivel) or 2 (shrivel). Fin browning was scored; 1 = no discoloration, 2 = slight (1 fin with disorder), 3 = moderate (more than 1 fin, but discoloration less than 2 mm parallel from margin), 4 = severe (affected area >2 mm parallel from margin on at least 1 fin), and 5 = extremely severe (> 2 mm parallel from margin on more than 1 fin). Fin browning did not include surface area damaged due to wind scarring or mechanical injury. Subjective firmness was scored; 1 = firm to moderately firm, 2 = fairly firm (slight yield to MAFP), 3 = flaccid (moderate yield to MAFP), and 4 = soft (jelly like and rubbery, low resistance to MAFP). Decay was scored; 1 = no decay, 2 = decay on fruit, but without positive identification of causal organism. Objective peel color measurements were also made after each inspection on the same three ribs of five fruit of each box using a Minolta Chromameter (model 200, with an 8-mm aperture, Minolta Camera Co., Osaka, Japan). The CIE (1976) L*, a*, and b* color index scale was used. Initial subjective color and firmness (destructive) measurements were recorded on 15 fruit immediately after each harvest, for base comparisons with terminal inspection measurements.

After the final inspection, objective firmness, flavor, sensory texture, soluble solids concentration (SSC), acidity, and pH of carambolas were measured. Firmness was measured on two fins of five fruit/box with an Instron Food Testing System (model 3200, Instron Inc., Canton, Mass.) set to record 98 newtons (N) full scale, penetrating the pulp 3 mm, at a speed of 5 cm min⁻¹. Flavor and texture were independently determined by an informal taste panel of nine members using a modified hedonic type scale ranging from 1 to 100, extremely unacceptable to extremely acceptable, respectively. Soluble solids were measured by a refractometer (model AO MK 11AO, Scientific Instruments, Keene, N.H.). Acidity was determined by titration to pH 8.1 with 0.01 N NaOH and expressed as percent of anhydrous oxalic acid.

All data were averaged over the three harvests and subjected to ANOVA procedures (SAS, 1982) and Duncan's multiple range test when appropriate. The experimental
design was a 2 by 4 factorial; two storage temperature regimes (CT or no-CT) by four fruit treatments (control, film, 2 or 6% wax) with three replications represented by the three harvest dates.

### Results

**Condition of carambolas after cold treatment and storage:**

**Weight loss.** Weight loss of carambolas was significantly less with film wrapping compared with control or waxed fruit after the final inspection (Table 1). Cold-treated fruit also had less cumulative weight loss than fruit stored continuously at 5C.

**Peel pitting.** There was very little peel pitting observed (mean index 1.2) on any fruit immediately after CT and no effect was indicated by fruit coating (data not shown). However, the severity of total pitting increased subsequent to CT, and after 7 additional d at 5C, CT fruit were slightly less pitted than non CT fruit (Table 1). After the final storage regime, pitting was not affected by CT and the severity of pitting did not exceed 10% of fruit surface area. The severity of pitting was less in film-wrapped fruit than with fruit of other coatings following CT plus 7 d of storage at 5C. Most fruit developed pitting as either clear (natural peel color) or brown (necrotic) stippled lesions, but generally not both. Averaged over all treatments, less than 2% of fruit developed both clear and brown pitting after the final inspection and there was no difference by treatment or storage regime (data not shown). After storage for 7 d at 5C following CT, 8.6 and 8.1% of cold-treated fruit and 20.8 and 1.8 of non cold-treated fruit had clear or brown pitting, respectively. The percentage of fruit that developed clear pitting increased substantially during the 3 additional d of storage at 15C. After 7 d at 5C storage following CT, the percentage of film-wrapped fruit with clear pitting was significantly less (1.4%) than the amount observed on fruit with other coatings. However, after the final inspection, a higher percentage of film-wrapped fruit had brown pitting compared with control or waxed fruit, and CT increased the incidence of brown pitting, especially for film-wrapped fruit. Clear pitting developed most often with film-wrapping compared with control or waxed fruit, 2 or 6% wax) with three replications represented by the three harvest dates.

### Table 1. Quality characteristics of ‘Arkin’ carambolas after cold treatment (CT) of 1.1C for 15 d plus 7 d at 5C, or no CT (5C), and after 3 additional d at 15C

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<thead>
<tr>
<th>df</th>
<th>WT LOSS %</th>
<th>CLEAR PIT %</th>
<th>BROWN PIT %</th>
<th>BRNZ*</th>
<th>SHRVL*</th>
<th>FIN BRN*</th>
<th>SEB*</th>
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<tr>
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<td>3.6cd*</td>
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**Mean square values**

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### Table 1. Quality characteristics of ‘Arkin’ carambolas after cold treatment (CT) of 1.1C for 15 d plus 7 d at 5C, or no CT (5C), and after 3 additional d at 15C

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<th>FIN BRN*</th>
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<td>67bcd</td>
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<td>70bc</td>
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**Mean square values**

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<th>TRT*</th>
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<th>WT LOSS %</th>
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1Values in column groups followed by the same letter are not significantly different by Duncans' multiple range test at p≤0.05.

*BRNZ = Bronzing of peel
*SHRVL = Shriveling
*BRN = Browning of fins, Index value
*SEB = Stem-end breakdown
**ns = significant at P≤0.05 or nonsignificant, respectively, by ANOVA procedures, with mean square value.
**TRT = among eight treatments
**TRTc = by treatments combined CT + NoCT
**TMP = CT vs NoCT
differences in means were observed by coating (data not shown). Immediately after CT, film-wrapped fruit had significantly less peel bronzing than fruit from other treatments, 25% (index = 1.6) and 44% (index = 2.3), respectively (data not shown). Cold treatment increased peel bronzing after all storage durations, although after the final inspection about 74% of all fruit were bronzed (Table 1) with an average index of 3.4. Film wrapping consistently reduced both the severity and incidence of bronzing after each storage regime. Wax-coated fruit did not significantly differ from control fruit.

Stem-end-breakdown and shriveling. No fruit were affected with SEB before CT. However, after CT, 95% of all fruit subjected to CT had SEB, whereas 18% of all non cold-treated had some SEB, and only 6% of film wrapped fruit had SEB. After subsequent storage at 5°C, cold-treated fruit had a higher incidence of SEB compared with fruit not cold-treated (Table 1). Film wrapping consistently reduced SEB throughout all storage regimes compared with wax coating, and wax reduced SEB compared with non-coated fruit, indicating that SEB was reduced as the moisture barrier increased.

Shriveling was not influenced by CT (Table 1). Shriveling was observed on about 3 and 17% of film-wrapped fruit compared with about 61 and 63% for all other fruit following CT plus 7 d storage at 5°C or after 3 additional d at 15°C, respectively. There was, however, a tendency for reduced shriveling in wax coated fruit compared with control fruit after each storage regime.

Fin browning. Most carambolas had slight (average index value 1.5) fin browning at harvest. Cold treatment increased fin browning compared with continuous 5°C storage, 3.0 versus 2.5 index values, respectively; film wrapping reduced the severity of fin browning compared with other coatings, whereas the effect of wax on fin browning was not different from that for control fruit. Cold-treated fruit also had more severe fin browning during subsequent storage than non cold-treated fruit (Table 1). Fin browning was slightly but significantly reduced only by the plastic film following CT.

Total soluble solids, acidity, and pH. Total soluble solids, acidity and pH were 8.5%, 0.15% and 4.1%, respectively, at harvest. Only TSS percentage changed slightly to 8.2 after the final storage regime. Storage temperature or coatings did not influence TSS, acidity, or pH (data not shown).

Sensory flavor, texture, and firmness. After the final storage regime, mean flavor index for all fruit was 69 (very acceptable), and there was no effect of storage temperature or coatings. Mean sensory texture for all fruit was 73.4 (very acceptable), and there was also no effect of storage temperature or coating (data not shown). After the final storage regime, cold-treated fruit were significantly firmer (28N) compared with non cold-treated fruit (21N), but no differences in means were observed by coating (data not shown).

Color. Initially after harvest, mean values for 'L*', 'a*' and 'b*' were 43.0, -4.2 and 20.0, respectively, and chroma (C*) = 20 and hue angle (h°) = 102. After the final inspection, mean CIE* values for 'L*', 'a*' and 'b*' were 41.4, -1.2 and 20.8, respectively (C* = 21, h° = 93), with no difference indicated for storage temperature or coating (data not shown). These values indicate peel color darkened slightly, with a loss of green color, indicating a lessening of vivid yellow during the total storage duration.

There was no difference in subjective peel color ratings by coating, but there was a significant, although slight, difference by storage temperature (4.3 and 4.6 for cold-treated and non cold-treated fruit, respectively).

Discussion

In general, these results confirm our previous findings (Miller, et al, 1991) that film wrapping reduced the degradation of carambolas during CT for 15 d at 1.1°C and during subsequent storage simulating transport and merchandising. Some carambolas in the present study developed distinctive peel pitting, whereas pitting was not generally observed in the 1991 study, indicating a seasonal physiological response, and the severity of 'clear' pitting was independent of CT or coating at the final inspection. Present results also indicate that carnauba wax at 2% or 6% did not significantly reduce senescence following any storage regime compared with control fruit. However, there was a trend for the 6% wax coating to reduce bronzing, fin browning, and shriveling more than 2% carnauba wax. Cold treatment had a slight, but significant, detrimental effect on both the severity and incidence of bronzing and stem-end breakdown, and in the severity of fin browning. Cold-treated fruit also had a higher incidence of pitting which developed into 'brown' compared with 'clear' pitting, and 'brown' pitting affected 24% of film-wrapped fruit compared with 12%, 8%, and 6% for 6% wax, 2% wax, and control, respectively. The reason for the increased incidence of 'brown' pitting on cold-treated, film-wrapped fruit is unexplained. Pitting is usually a classic indicator of low-temperature stress, and previous research indicated that film wrapping may alleviate chilling injury symptoms such as pitting (Forney and Lipton, 1990). Except for 'brown' pitting, film wrapping was generally beneficial for carambola quality whether cold-treated or not, whereas wax coating had little positive effect. There were no differences observed in rates of respiration of carambolas irrespective of type of coating. As expected, rates of respiration were higher for carambolas stored at 15°C than at 5°C. We conclude that CT had a slight negative effect on the quality of carambolas following treatment and storage, but because the effect is slight, the expected practical impact on marketing will most likely not be of major importance. Additional experiments may be warranted for coatings with greater than 6% carnauba wax, and for evaluating the physiological response of carambolas to CT by harvest maturity and time of harvest throughout an 8-month season.

Literature Cited


Citrus Fruit with Single or Layered Coatings Compared with Packinghouse-Coated Fruit

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Citrus and Subtropical Products Laboratory
600 Ave. S, NW
Winter Haven, FL 33881

Additional index words. Oranges, grapefruit, microemulsion, shrinkage rate, ethanol, internal gases.

Abstract. Oranges, grapefruit and tangerines that were coated with hydrocarbon-containing wax microemulsions had weight loss and internal CO2 values less than half those coated commercially in Florida packinghouses. Valencia oranges coated in layers with two wax microemulsions had weight loss only 20-30% of washed control. High levels of gloss were not imparted by the microemulsions, but could be attained by application of a high-gloss coating as second coating. The high-gloss coatings, whether applied alone or as second coating, tended to inhibit gas exchange and elevate ethanol content.

Fresh citrus fruit is coated primarily to give gloss to the surface, thus improving market appeal, with weight loss a secondary goal (Kaplan, 1986; Hall, 1981). Our work has shown that weight loss and gloss are related: low weight loss helps to preserve gloss, and both can be achieved with layered coatings, the first of which is a wax microemulsion (Hagenmaier and Baker, 1993b; 1993c). The second coating can either be a wax selected for gloss (rather than shrinkage control) or a high-gloss shellac or resin coating. The present work shows how commercially coated Florida citrus fruit compares with fruit having single or layered coatings.

Materials and Methods

Fruit. The fruit coated in our laboratory were from groves near Winter Haven, Fla., maintained by the Florida Department of Agriculture. The Hamlin and Navel oranges, the Ruby Red grapefruit and the Murcott tangerines were harvested May 11-June 1, 1993. The commercially coated fruit was all harvested Jan 25, 1993. The Valencia oranges were harvested Jan 25, 1993. The commercially coated fruit were from packinghouses located within 25 miles of Winter Haven, Florida. For comparisons of laboratory-coated fruit with packinghouse-coated fruit, the fruit was all harvested and coated within a two-day period. Fruit coated in our laboratory were washed with rotating polyethylene brushes (type PSE, made by Industrial Brush Corp., Lakeland, Fla.) with a citrus cleaner containing sodium o-phenylphenate (Freshgard 5, FMC Corp., Lakeland, Fla.).

Coatings. Wax microemulsions AC3 and PE4 were supplied by Allied Signal (Morristown, N.J.). Formulation reduction a secondary goal (Kaplan, 1986; Hall, 1981). Our work has shown that weight loss and gloss are related: low weight loss helps to preserve gloss, and both can be achieved with layered coatings, the first of which is a wax microemulsion (Hagenmaier and Baker, 1993b; 1993c). The second coating can either be a wax selected for gloss (rather than shrinkage control) or a high-gloss shellac or resin coating. The present work shows how commercially coated Florida citrus fruit compares with fruit having single or layered coatings.

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