Available online at www.sciencedirect.com
SCIENCE DIRECT®
Postharvest Biology and Technology 36 (2005) 127–134
Postharvest Biology and Technology
www.elsevier.com/locate/postharvbio

Ripening and quality responses of mamey sapote fruit to postharvest wax and 1-methylcyclopropene treatments

Muharrem Ergun [a,1], Steven A. Sargent [a,*], Abbie J. Fox [a,2], Jonathan H. Crane [b], Donald J. Huber [a]

[a] *Horticultural Sciences Department, University of Florida/IFAS, Gainesville, FL 32611, USA*
[b] *Tropical Research and Education Center, University of Florida/IFAS, Homestead, FL 33031, USA*

Received 2 September 2004; accepted 7 December 2004

Abstract

Mamey sapote (*Pouteria sapote* (Jacq.) H.E. Moore and Stearn) fruit is highly appreciated in the Caribbean region; however, marketable life is significantly limited by abrupt softening during postharvest handling. Postharvest wax and 1-methylcyclopropene (1-MCP) treatments were evaluated for potential of extending mamey sapote postharvest life. Fruit of the cv. Magaña were harvested at mature green (G), light orange (LO) and orange (O) stages of the pulp color, and brushed to remove excess epidermal fiber. Waxed (carnauba emulsion) and unwaxed fruit (G and LO stages) were held at 13 °C for 7 days, then transferred to 20 °C for ripening; those at O stage were held constantly at 20 °C. In a subsequent test, 'Magaña' fruit were harvested at a preclimacteric stage (LO), brushed, and treated with ±carnauba wax and ±1-MCP (1 μl l^{-1} at 20 °C for 24 h). Fruit from all treatments were subsequently stored at 20 °C and 85–90% relative humidity. Unwaxed 'Magaña' fruit reached climacteric maxima in 10–11 days, irrespective of harvest maturity or storage regime (Exp. 1). At 20 °C, peak CO_2 production ranged from 90 to 137 ml kg^{-1} h^{-1} and peak ethylene production from 116 to 209 μl kg^{-1} h^{-1}, respectively. Waxed fruit generally had higher CO_2 and C_2H_4 production rates than unwaxed fruit. When LO fruit was stored continuously at 20 °C (Exp. 2), wax treatment alone hastened the onset of respiration and ethylene climacteric peaks by 5 days over unwaxed fruit. 1-MCP treatment alone delayed the onset of respiration and ethylene climacteric maxima by 6 and 5 days, respectively. Marketable life for wax-only fruit stored continuously at 20 °C was 10 days, while that for control, wax + 1-MCP and 1-MCP-only fruit was 13, 14, and 14 days, respectively. Mamey sapote fruit treated with wax lost less weight during continuous storage at 20 °C. At the full-ripe stage, no treatment effects were noted for pulp soluble solids content (23.4%) or pH (5.7).

* Corresponding author. Tel.: +1 352 392 1928x215; fax: +1 352 392 5653.
E-mail address: sasa@ifas.ufl.edu (S.A. Sargent).
[1] Present address: Kahramanmaras Sutcu Imam University, Department of Horticulture, Kahramanmaras 46100, Turkey.
[2] Present address: Florida Department of Plant Industry, Gainesville, FL 32605, USA.

0925-5214/$ – see front matter
doi:10.1016/j.postharvbio.2004.12.002

Mamey sapote fruit treated with wax + 1-MCP, however, retained total titratable acidity (0.25%) and lost less acid during storage than wax-only fruit (0.14%).

Keywords: *Pouteria sapote* (Jacq.) H.E. Moore & Stearn; 1-MCP; Respiration; Ethylene; Marketable life; Carnauba wax coating; Tropical fruit; Storage

1. Introduction

Mamey sapote is a tropical tree that originated in Central America between southern Mexico and northern Nicaragua (Popenoe, 1948). A member of the Sapotaceae family, it is also listed in the literature as *P. mammosa* (L.) Cronquist, *Lucuma mammosa* Gaertn., and *Calocarpum mammosum* Pierre (Morton, 1987). It is not to be confused with mamey (*Mammea americana* L.), which belongs to the Guttiferae family. Although considered a minor tropical fruit in the commercial trade, mamey sapote is widely cultivated in Mexico, Central America, and the West Indies (Balerdi et al., 1996). The 'Magaña' variety is grown in the region and is commercially harvested from April to June. 'Magaña' fruit is ovoid, weighs up to 2400 g, has orange to red pulp when ripe, contains a single, large seed, and has excellent dessert quality. The fruit is harvested when the flesh starts developing salmon pink color (the turning stage) for commercial shipping, or when ripe for local markets (Balerdi et al., 1996). Carotenoids, mostly violaxanthin, are the major pigments in both the skin and flesh of mamey sapote fruit (Rodriguez-Amaya, 1999).

Postharvest life of mamey sapote fruit ranges from 3 to 7 days depending on maturity at harvest and storage temperature. The fruit has a high respiration rate (Diaz-Perez et al., 2000), and commercial quality is limited by the rapid onset of ripening and by internal or stem-end fruit rots from *Pestalotia* and *Botryodiplodia* (Bautista-Banos et al., 2002). To date, approaches to extend and preserve postharvest quality of mamey sapote have consisted of refrigerated storage (10–15 °C; Balerdi et al., 1996) and hot water treatment for postharvest decay control (60 °C for 60 min; Diaz-Perez et al., 2001).

Wax coatings have been shown to extend postharvest quality of many fruit and vegetable crops by limiting gas exchange and reducing discoloration, water loss and skin susceptibility to abrasion (Mellenthin et al., 1982; Hagenmaier and Baker, 1994; Baldwin et al., 1999). Delayed ripening and improved postharvest quality of several tropical fruits have been achieved with postharvest treatment of 1-methycyclcopropene (1-MCP) (Blankenship and Dole, 2003). The objective of the present study was to evaluate the effects of wax coating and 1-MCP on the postharvest biology and quality of 'Magaña' mamey sapote fruit.

2. Materials and methods

2.1. Experiment 1—effects of wax treatment

Mamey sapote fruit (cv. Magaña) were harvested on 22 April 2002, in Homestead, FL, using three commercial maturity stages based on pulp color. Pulp color was assessed by careful removal of a 3–5 mm portion of the rough epidermis while the fruit was attached to the tree, a commercial practice that does not affect postharvest quality. Fruit (700–1300 g) were harvested at these maturity stages: green (G), light orange (LO), and orange (O), and were transported under ambient temperatures to the Postharvest Horticulture Laboratory at the University of Florida, Gainesville. The following day the fruit surfaces were lightly brushed to remove excess fiber (a commercial practice); half of the fruit from each maturity stage were placed directly in storage and the other half were waxed with carnauba wax emulsion ($n = 4$/treatment) (Sta-Fresh 819F; FMC Corp., Texas). The light coating of wax was manually applied by brush at ambient temperature (23 °C) and air-dried. Fruit harvested at G and LO stages (±wax) were stored for 7 days at 13 °C (simulating commercial handling), then transferred to 20 °C and 85–90% relative humidity; fruit harvested at O stage were stored immediately and continuously at 20 °C.

2.2. Experiment 2—effects of wax and 1-MCP treatments

Fruit were harvested preclimacteric at the LO stage on 6 May 2002, in Homestead, FL, and were held at ambient temperature for during transfer to the laboratory in Gainesville. The following day the fruit were graded for uniform maturity (based on mesocarp color under epidermis) and size (1000–1500 g). Half of the fruit were lightly brushed and waxed as in Exp. 1.

Unwaxed and waxed fruit were treated with 1 $\mu l\,l^{-1}$ of 1-MCP for 24 h at 20 °C. The source of 1-MCP was a commercial powder formulation (0.14%) (AgroFresh, Philadelphia, PA), and was prepared by dissolving 3 mg powder in 50 ml deionized water in a 136 ml sealed vial and incubating on an oscillating shaker for 2 h at room temperature. The concentration of 1-MCP released in the vial headspace was determined using a gas chromatograph (Hewlett-Packard, Model 5890 II; Avondale, PA) fitted with a SP-1700 column (Supelco, Bellefonte, PA). Injector, oven and flame ionization detector temperatures were 150, 70 and 200 °C, respectively, and the carrier gas (nitrogen) flow rate was 30 ml min^{-1}. *Iso*-butylene gas was used as a standard to quantify 1-MCP concentration (Jiang et al., 1999). Fruit were placed in sealed, 18.9 l plastic containers (10 l void volume), into which 1-MCP was injected to establish a final 1-MCP concentration of 1 $\mu l\,l^{-1}$. At 8 h intervals the containers were vented (to avoid accumulation of CO_2), resealed, and fresh 1-MCP was reinjected. Unwaxed and waxed fruit ($n = 5$) were stored simultaneously in a separate cold room (1-MCP-free) at 20 °C. Following 1-MCP treatment, fruit from all treatments were stored at 20 °C until they reached table-ripe stage, defined as the limit of marketable life in which fruit were too soft to ship commercially (4 mm deformation, as described below) or with the appearance of decay.

Procedures used in both experiments are described below.

2.3. Respiration and ethylene production

Carbon dioxide and ethylene production of individual fruit were measured daily in the headspace of a closed system at 20 °C. Fruit were stored in 3.6 l plastic containers ($n = 4$) with the lid left unsealed. For each sampling the lid was sealed from 15 to 95 min, allowing CO_2 and ethylene to accumulate in the headspace. Care was taken to avoid CO_2 accumulation > 1% in the headspace during these measurements. For CO_2 measurements, 0.5 ml of headspace was sampled and analyzed by gas chromatography fitted with a Porapaq-Q column and a thermal conductivity detector (Gow Mac-580, Bridgewater, NJ). The carrier gas (helium) flow rate was 30 ml min^{-1}, the oven was set at 40 °C, and the detector and injector were set at 26–27 °C. For ethylene production, samples (1 ml) were injected into the gas chromatograph (Hewlett-Packard HP-5890, Avondale, PA) described above.

2.4. Quality parameters

2.4.1. Firmness and weight loss

Fruit firmness was measured non-destructively during storage using a digital deformation meter (Mitutoya-ID-F125E, Japan) in which a 1 kg load was applied to a flat, 11 mm diameter probe (Ritenour et al., 2002). The probe was positioned at the fruit surface, zeroed and released; deformation (mm) was recorded after 5 s of static load. Deformation was measured at two equidistant points on the equatorial region of each fruit. When the deformation value exceeded 4 mm, the fruit was considered at the table-ripe stage (limit of commercial shipping); fruit were also considered at the end of commercial life when external fungal growth was apparent. Weight loss during storage was determined by weight difference at days 7, 14 and 20 compared with day 0, and expressed as percent (fresh-weight basis).

2.4.2. Pulp color

At the end of marketable life, each fruit was sliced in half longitudinally, peeled and pulp color was determined on the outer surface at the equator by a colorimeter (Minolta chromameter, Japan). Color was reported as lightness (L^*, where 0 = black, 100 = white); hue angle (h, where 0° = red, 90° = yellow) and chroma value (C, where 0 = gray increasing to a pure hue) (McGuire, 1992). Fruit halves were sliced into pieces then stored at −20 °C until further analysis.

2.4.3. Soluble solids content, total titratable acidity and pH

Each frozen fruit sample (40 g) was thawed, blended in water (1:2, w/v) for 1 min and centrifuged at

Table 1
Effect of harvest maturity and wax coating on peak respiration and ethylene production rates of 'Magaña' mamey sapote fruit (Exp. 1)

Treatment	CO_2		C_2H_4	
	Days to peak[a]	Maximum (ml kg^{-1} h^{-1})[b]	Days to peak[a]	Maximum (μl kg^{-1} h^{-1})[b]
Green, unwaxed	7 + 3	93.5 ± 8.33	7 + 2	182.7 ± 75.9
Green, waxed	7 + 4	144.0 ± 33.7	7 + 2	335.0 ± 216.2
Light orange, unwaxed	7 + 4	104.1 ± 61.4	7 + 2	209.3 ± 105.2
Light orange, waxed	7 + 4	154.0 ± 84.6	7 + 2	241.2 ± 134.0
Orange, unwaxed	11	90.2 ± 34.0	8	116.2 ± 71.0
Orange, waxed	10	77.1 ± 44.4	10	303.2 ± 275.4

[a] Fruit harvested at green and light orange stages was stored for 7 days at 13 °C, then transferred to 20 °C; fruit harvested at orange stage was stored continuously at 20 °C.
[b] Value ± standard deviation ($n = 4$).

10,000 × *g* for 20 min at 4 °C. Soluble solids content (SSC, °Brix), total titratable acidity (TTA) and pH were quantified from the supernatant at room temperature. SSC was determined using a digital refractometer (Abbe Mark-10480, Buffalo, NY). TTA was quantified using a Fisher-395 dispenser and Fisher-380 electrometer (Pittsburgh, PA) in which the supernatant (6 ml) was titrated with 1N NaOH to an endpoint of pH 8.2. TTA was calculated from the volume of NaOH recorded from the dispenser and expressed as % malic acid. The pH was measured with a digital pH meter (Model 140, Corning Scientific Instruments, Medfield, MA).

2.5. Statistical analysis

Treatments were arranged using a randomized complete block design. Results were analyzed using the general linear model program of PC-SAS software package (SAS Institute, Carey, NC) and significant interactions were separated using Duncan's multiple range test ($P < 0.05$).

3. Results

3.1. Exp. 1

3.1.1. Respiration and ethylene production

Mamey sapote fruit reached peak CO_2 production in 10–11 days, irrespective of harvest maturity, application of wax or storage regime (Table 1). Maximum CO_2 production for the six treatments ranged from 77 to 154 ml kg^{-1} h^{-1}, but these values were not significantly different. Ethylene production (116–335 μl kg^{-1} h^{-1}) peaked after 8 and 10 days, respectively, for unwaxed and waxed fruit (initially orange) held continuously at 20 °C, while fruit from the other treatments peaked after 9 days (7 days at 13 °C + 2 days at 20 °C) (Table 1).

3.1.2. Selected quality parameters

Fruit from all treatments maintained firmness at initial values for 9 days at 20 °C (data not shown). Marketable life was 12–13 days for all treatments due to softening or decay; at this point there were no treatment

Table 2
Overall means at the limit of marketable life for weight loss, pulp color, soluble solids content (SSC), pH and total titratable acidity (TTA of 'Magaña' mamey sapote fruit (Exp. 1))

	Weight loss (%)	Pulp color[a]			Pulp composition		
		L^*	Hue angle (°)	Chroma value	SSC (°Brix)	pH	TTA (%)[a]
Mean	6.8	61.5	52.4	42.4	25.0	6.2	0.12
S.D.	1.1	1.4	1.3	2.3	1.7	0.3	0.03

[a] Malic acid equivalent.

differences for the quality parameters measured. The treatment mean for weight loss was 6.8%; means for pulp color were: $L^* = 61.5$, hue angle = 52.4°, chroma value = 42.4; means for pulp composition were: soluble solids content (SSC) = 25 °Brix, pH 6.2, total titratable acidity (TTA) = 0.12% (Table 2).

3.2. Exp. 2

3.2.1. Respiration and ethylene production

The rates of CO_2 production varied by treatment and time, ranging from 14 ml kg^{-1} h^{-1} (1-MCP-only, day 1) to 153 ml kg^{-1} h^{-1} (wax + 1-MCP-treated fruit, day 15) (Fig. 1A). The climacteric rise began on day 2 for wax-only fruit, peaking on day 6 (126 ml kg^{-1} h^{-1}). In contrast, the climacteric rise of control (untreated) fruit was more gradual and extended, beginning on day 3 and peaking on day 11 (137 ml kg^{-1} h^{-1}). Respiratory climacterics of wax + 1-MCP and 1-MCP-only fruit began on day 10; the former attained the maximum by day 15 (153 ml kg^{-1} h^{-1}) and the latter by day 18, but at almost half the rate (82 ml kg^{-1} h^{-1}).

Mamey sapote fruit exhibited typical climacteric ethylene production patterns, ranging from an initial rate of 0.2 (control, day 1) to 173 μl kg^{-1} h^{-1} (control, day 11) (Fig. 1B). Wax-only fruit reached the climacteric peak on day 6 (155 μl kg^{-1} h^{-1}), control fruit on day 11 (174 μl kg^{-1} h^{-1}), wax + 1-MCP on day 15 (127 μl kg^{-1} h^{-1}) and 1-MCP-only on day 16 (121 μl kg^{-1} h^{-1}). Overall, ethylene production rates were the highest in control fruit, followed by wax-only, wax + 1-MCP, and 1-MCP-only fruit.

3.2.2. Marketable life, decay and weight loss

Softening limited the marketable life of wax-only fruit and control fruit to 10 and 13 days, respectively (data not shown). Wax + 1-MCP fruit and 1-MCP-only fruit remained firm until day 20, although marketable life was limited to 14 days due to the appearance of slight fungal decay on fruit surfaces. At day 20, 40% of wax + 1-MCP fruit had fungal decay in the seed cavity; however, fruit from the three other treatments did not develop internal decay during storage (data not shown).

After 7 days storage, weight loss was 5.4% (control fruit), 4.3% (wax-only fruit), 5.7% (1-MCP-only), and 4.1% (wax + 1-MCP) (Fig. 2). After 14 days, weight loss was 11.2% (1-MCP-only) and 7.7% (wax + 1-MCP). Minor shriveling was observed during storage but was not treatment-related.

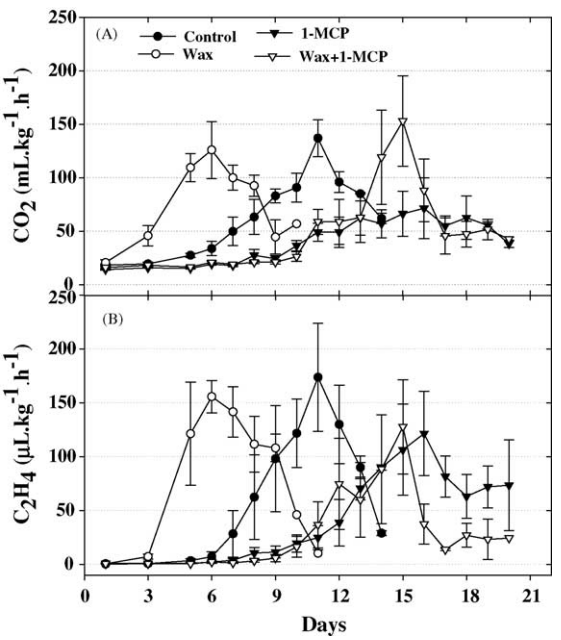

Fig. 1. Respiration (A) and ethylene production (B) of control, wax-only, 1-MCP-only and wax + 1-MCP-treated 'Magaña' mamey sapote fruit during storage at 20 °C. Vertical bars are standard errors ($n = 5$) (Exp. 2).

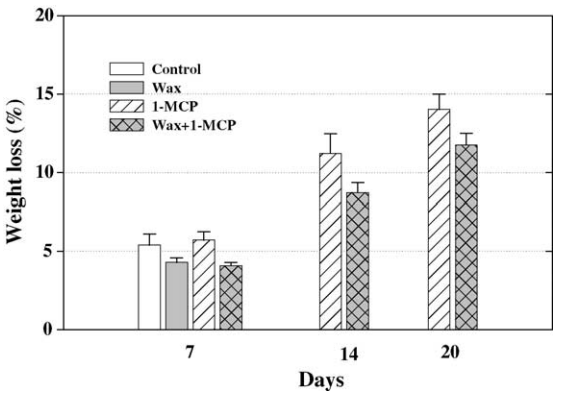

Fig. 2. Weight loss (%, fresh-weight basis) of control, wax-only, 1-MCP-only and wax + 1-MCP-treated 'Magaña' mamey sapote fruit during storage at 20 °C. Vertical bars are standard errors ($n = 5$) (Exp. 2).

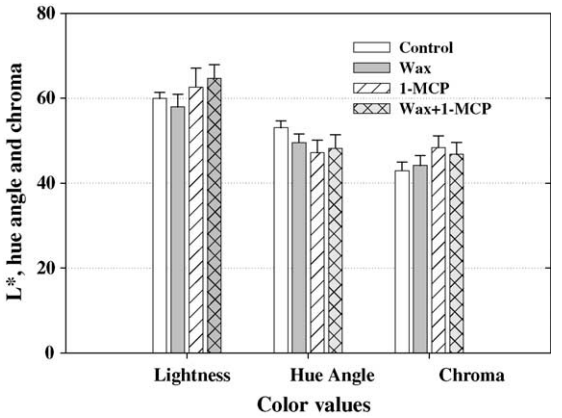

Fig. 3. Pulp color parameters (lightness, hue angle and chroma) of control, wax-only, 1-MCP-only and wax + 1-MCP-treated 'Magaña' mamey sapote fruit at the end of marketable life following storage at 20 °C. Vertical bars are standard errors ($n = 5$) (Exp. 2).

3.2.3. Pulp color

At the end of marketable life, the pulp color of control fruit was slightly darker, was less orange-red, and had less intense color than1-MCP-treated fruit. The hue angle of control fruit (53.3°) was significantly higher than that for the other treatments (wax-only fruit, 49.7°; wax + 1-MCP-treated fruit, 48.8°; 1-MCP-only fruit, 47.2°) (Fig. 3). The chroma values of 1-MCP-only fruit (48.4°) and wax + 1-MCP fruit (48.8°) were higher relative to control fruit (43.0°) (Fig. 3).

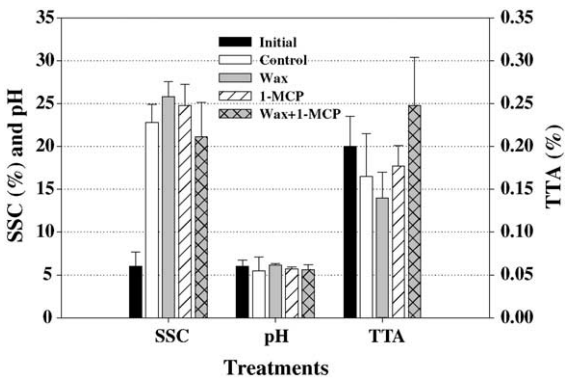

Fig. 4. Soluble solids content (SSC), total titratable acidity (TTA) and pH of control, wax-only, 1-MCP-only and wax + 1-MCP-treated 'Magaña' mamey sapote fruit at the end of marketable life following storage at 20 °C. Vertical bars are standard errors ($n = 5$) (Exp. 2).

3.2.4. Soluble solids content, pH and total titratable acidity

SSC in preclimacteric fruit at harvest was 6%, and at the table-ripe stage (end of marketable life) treatment means ranged from 21 to 25% (Fig. 4). Preclimacteric fruit averaged pH 6, and at the end of marketable life there was no treatment effect with pulp pH 5.6–6.2 (Fig. 4). TTA in the preclimacteric fruit was initially 0.20%; at the table-ripe stage, TTA ranged from 0.14 to 0.24% among treatments (Fig. 4). TTA in wax + 1-MCP fruit was almost twice (0.24%) that of wax-only fruit (0.14%); other treatments were intermediate in TTA (1-MCP-only fruit = 0.19%; control fruit = 0.17%).

4. Discussion

Respiration and ethylene production data for 'Magaña' mamey sapote fruit were indicative of typical climacteric behavior and were consistent with the reports of Villanueva-Arce et al. (2000) and Diaz-Perez et al. (2000) (variety not indicated). During storage at 20 °C, 'Magaña' fruit produced very high amounts of CO_2 (>130 ml kg^{-1} h^{-1}) and ethylene (>170 μl kg^{-1} h^{-1}) at the climacteric peaks. Ethylene production values for LO-harvested fruit in Exp. 1 were 20 and 54% higher for unwaxed and waxed fruit, respectively, than for LO-harvested fruit from these treatments in Exp. 2 (Table 1; Fig. 1A and B). Internal fungal growth that began at day 14 was minor and, as such, was considered to have had minimal influence on subsequent measurement of CO_2 production.

Treatment with 1-MCP reduced the peak respiration rate by about 50% and reduced the peak ethylene production from 20 to 40%; time to peak production for ethylene in 1-MCP-treated mamey sapotes was delayed by 4–5 days. These data indicate that 1-MCP binds the ethylene receptors in mamey sapote fruit to restrict ethylene action. Similar effects of 1-MCP on climacteric behavior have been reported for other tropical fruit including mango (Jiang and Joyce, 2000) papaya (Jacomino et al., 2002; Ergun and Huber, in press) and avocado (Jeong et al., 2002).

The wax treatment did not accelerate softening in fruit from Exp. 1. However, the onset of ripening was accelerated in waxed fruit held continuously at 20 °C in Exp. 2. Waxed fruit reached both respiratory and ethylene climacteric peaks 5 days sooner than

unwaxed fruit. These results were consistent to those obtained in our previous tests with cv. Pantín, in which waxed fruit ripened faster and softened more uniformly within the individual fruit than unwaxed fruit (Sargent, unpublished results). The shorter marketable life of the waxed fruit in Exp. 2 may have been due to restricted permeability of the carnauba wax coating, allowing accumulation of ethylene within the fruit. Brushing the epidermis prior to waxing may have created a wound response (Rolle and Chism, 1987), allowing stress-induced ethylene to accumulate in the fruit during ripening, further stimulating ethylene biosynthesis. Stress due to thermal and wax treatments was reported to cause higher CO_2 production in guava fruit relative to untreated fruit before initiation of ripening (McGuire, 1997). In contrast, wax coating delayed ripening in guava (McGuire and Hallman, 1995), cherry (Yaman and Boyunduruk, 2002) and avocado (Jeong et al., 2003) fruit.

Decay was mentioned as one of the limiting factors for postharvest life of mamey sapote fruit (Bautista-Banos et al., 2002). In this study, only mamey sapote fruit treated with wax + 1-MCP had slight internal fungal growth. Some fruit from this treatment also exhibited slight external fungal growth at the stem end that did not infect the flesh. Despite delayed softening of 1-MCP treated fruit (±wax), marketable life was extended by only 1 day over non-1-MCP treated fruit due to the appearance of decay in the former treatments. 1-MCP was reported to promote decay in sliced apple, in which Bai et al. (2004) speculated that suppression of ethylene perception by 1-MCP either reduced disease resistance of the tissue or that 1-MCP interfered with disease resistance by another mechanism unrelated to ethylene perception.

Wax coating retarded weight loss by restricting surface permeability as reported for citrus fruit (Rodov et al., 2000) and pear fruit (Amarante et al., 2001). In Exp. 1 weight loss for unwaxed fruit and waxed fruit stored at 20 °C was similar (Table 2), whereas in Exp. 2 unwaxed fruit lost more than twice the fresh weight of waxed fruit during storage (Fig. 2). However, 1-MCP exhibited a beneficial effect by maintaining the appearance of unwaxed and waxed fruit, even at day 20.

In Exp. 2 mamey sapote fruit treated with wax ± 1-MCP had a richer, salmon color in the pulp than that of control fruit (Fig. 3). This was in contrast to reports that 1-MCP inhibited color development in fresh-cut apple (Jiang and Joyce, 2002) and papaya fruit flesh (Ergun and Huber, in press), both of which support the link between carotenoids biosynthesis and ethylene exposure (Abeles et al., 1992). In the present study, the apparent opposite effect of 1-MCP on pulp color may actually have been due to the differences in fruit ripeness at marketable life; at this point the control fruit had reached the table-ripe stage, were soft and had lower L^* value than 1-MCP-treated fruit.

Upon reaching table-ripe stage, 'Magaña' fruit had approximately 25% SSC in these experiments (Table 2; Fig. 4), similar to values reported by Villanueva-Arce et al. (2000) and Diaz-Perez et al. (2000). SSC, pH and TTA of mamey sapote fruit were not significantly affected by wax-only treatment in this study; however, waxed orange (Baldwin et al., 1995) and cherry fruits (Yaman and Boyunduruk, 2002) were reported to have lower pH and higher TTA than unwaxed fruits. 1-MCP alone did not affect fruit SSC, pH or TTA, but in combination with wax, TTA was higher. Higher TTA in response to 1-MCP treatment has been frequently reported for climacteric fruit, although there have been no reports of changes in TTA affecting flavor (Blankenship and Dole, 2003).

In conclusion, preclimacteric mamey sapote fruit treated with carnauba wax coating maintained good visual appearance and had the lowest water loss during storage at 20 °C. However, wax treatment accelerated fruit softening, reducing marketable life by 3 days compared with unwaxed (control) fruit. 1-MCP alone or in combination with wax coating extended the marketable life by 1 day over untreated fruit. 1-MCP has the potential to delay ripening of mamey sapote fruit and extend marketable life beyond 14 days at 20 °C with adequate decay control.

Acknowledgements

This research was supported by the Florida Agricultural Experiment Station and approved for publication as Journal Series no. R-10409.

References

Abeles, F.B., Morgan, P.W., Saltveit, M.E., 1992. Ethylene in Plant Biology. Academic Press, San Diego, CA, 414 pp.

Amarante, C., Banks, N.H., Ganesh, S., 2001. Relationship between character of skin cover of coated pears and permeance to water vapour and gases. Postharvest Biol. Technol. 21, 291–301.

Bai, J., Baldwin, E.A., Fortuny, R.C.S., Mattheis, J.P., Stanley, R., Perera', C., Brecht, J.K., 2004. Effect of pretreatment of intact 'Gala' apple with ethanol vapor, heat, or 1-methylcyclopropene on quality and shelf life of fresh-cut slices. J. Am. Soc. Hort. Sci. 129, 583–593.

Baldwin, E.A., Nisperos, M.O., Shaw, P.E., Burns, J.K., 1995. Effect of coatings and prolonged storage conditions on fresh orange flavor volatiles, degrees Brix, and ascorbic acid levels. J. Agric. Food Chem. 43, 1321–1331.

Baldwin, E.A., Burns, J.K., Kazokas, W., Brecht, J.K., Hagenmaier, R.D., Bender, R.J., Pesis, E., 1999. Effect of edible coatings with different permeability characteristics on mango (*Mangifera indica* L.) ripening during storage. Postharvest Biol. Technol. 17, 215–216.

Balerdi, C.F., Crane, F.H., Campbell, C.W., 1996. The mamey sapote. Fact sheet FC-30. Horticultural Sciences Department, Florida Cooperative Extension Center, Institute of Food and Agricultural Sciences, University of Florida.

Bautista-Banos, S., Diaz-Perez, J.C., Barrera-Necha, L.L., 2002. Postharvest fungal rots of sapote mamey *Pouteria sapote* (Jacq.) H.E. Moore and Stearn. Postharvest Biol. Technol. 24, 197–200.

Blankenship, S.M., Dole, J.M., 2003. 1-Methylcyclopropene: a review. Postharvest Biol. Technol. 28, 1–25.

Diaz-Perez, J.C., Bautista, S., Villanueva, R., 2000. Quality changes in sapote mamey fruit during ripening and storage. Postharvest Biol. Technol. 18, 67–73.

Diaz-Perez, J.C., Mejia, A., Bautista, S., Zavaleta, R., Villanueva, R., Gomez, R.L., 2001. Response of sapote mamey [*Pouteria sapote* z (Jacq.) H.E. Moore and Stern] fruit to hot water treatments. Postharvest Biol. Technol. 22, 159–167.

Ergun, M., Huber, D.J., in press. Suppression of ethylene perception extends shelf-life and quality of 'Sunrise Solo' papaya fruit at both preripe and ripe stages of development. Eur. J. Hort. Sci. 69, 184–192.

Hagenmaier, R.D., Baker, R.A., 1994. Wax microemulsions and emulsions as citrus coating. J. Agric. Food Chem. 42, 899–902.

Jacomino, A.P., Kluge, R.A., Brackmann, A., 2002. Amadurecimento e senescencia de mamao com 1-metilciclopropeno. Scientia Agricola 59, 303–308.

Jeong, J., Huber, D.J., Sargent, S.A., 2002. Influence of 1-methylcyclopropene (1-MCP) on ripening and cell-wall matrix polysaccharides of avocado (*Persea americana*) fruit. Postharvest Biol. Technol. 25, 241–256.

Jeong, J., Huber, D.J., Sargent, S.A., 2003. Delay of avocado (*Persea americana*) fruit ripening by 1-methylcyclopropene and wax treatments. Postharvest Biol. Technol. 28, 247–257.

Jiang, Y., Joyce, D.C., Macnish, A.J., 1999. Responses of banana fruit to treatment with 1-methylcyclopropene. Plant Growth Reg. 28, 77–82.

Jiang, Y., Joyce, D.C., 2000. Effects of 1-methylcyclopropene alone and in combination with polyethylene bags on the postharvest life of mango. Ann. Appl. Biol. 137, 321–327.

Jiang, Y., Joyce, D.C., 2002. 1-Methylcyclopropene treatment effects on intact and fresh-cut apple. J. Hort. Sci. Biotechnol. 77 (1), 19–21.

McGuire, R.G., 1992. Reporting of objective color measurements. HortScience 27, 1254–1255.

McGuire, R.G., Hallman, G.J., 1995. Coating guavas with cellulose- or carnauba-based emulsions interferes with postharvest ripening. HortScience 30, 294–295.

McGuire, R.G., 1997. Market quality of guavas after hot-water quarantine treatment and application of carnauba wax coating. HortScience 32, 271–274.

Mellenthin, W.M., Chen, P.M., Morgic, D.M., 1982. In-line application of porous wax coating materials to reduce friction discoloration of 'Barlett' and 'd'Anjou' pears. HortScience 17, 452–454.

Morton, J.F., 1987. Sapote. Fruit of Warm Climates. Media Incorporated, Greensboro, NC, pp. 398–402.

Popenoe, W. (Ed.), 1948. The sapotaceous fruit. In: Manual of Tropical and Subtropical Fruit. Hafner Press, London, pp. 334–350.

Ritenour, M.A., Lamb, E.M., Stoffella, P.J., Sargent, S.A., 2002. A portable, digital device for measuring tomato firmness. Proc. Fla. State Hort. Soc. 115, 49–52.

Rodriguez-Amaya, D.B., 1999. Latin American food sources of carotenoids. Archivos Latinoamericanos de Nutricion 49 (3), 74S–84S.

Rodov, V., Agar, T., Peretz, J., Nafussi, B., Kim, J.J., Ben-Yehoshua, S., 2000. Effect of combined application of heat treatments and plastic packaging on keeping quality of 'Oroblanco' fruit (*Citrus grandis* L. × *C. paradisi* Macf.). Postharvest Biol. Technol. 20, 287–294.

Rolle, R.S., Chism, G.W., 1987. Physiological consequences of minimally processed fruit and vegetables. J. Food Qual. 10, 157–177.

Villanueva-Arce, R., Evangelsita-Lazono, S., Arenas-Acampo, M.L., Diaz-Perez, J.C., Bautista-Banos, S., 2000. Biochemical and physics changes during development and postharvest of mamey sapote fruit (*Pouteria sapote* (Jacq) H.E. Moore and Stern). Revista Chapingo Serie Hort. 1, 63–73.

Yaman, O., Boyunduruk, L., 2002. Effects of an edible coating and cold storage on shelf-life and quality of cherries. Lebensm.-Wiss. u.-technol. 35, 146–150.