EFFECT OF PRETREATMENT OF INTACT ‘KENT’ AND ‘TOMMY ATKINS’ MANGOES WITH ETHANOL VAPOR, HEAT OR 1-METHYLCYCLOPROPENE ON QUALITY AND SHELF LIFE OF FRESH-CUT SLICES

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Abstract. Treatments known to inhibit or delay ripening were applied to imported ‘Kent’ and ‘Tommy Atkins’ mangoes. Mangoes that were fairly firm, with some ground color development (‘Kent’) or hard with slight color blush (‘Tommy Atkins’) ripeness stage were treated with 1-methylcyclopropene (1-MCP) at 25 ppm for 24 or 12 hours, respectively, ethanol (5.0 g·kg⁻¹ fruit) for 24 or 8 hours, respectively, and heat (38 °C, 98% RH) for 24 or 12 hours, respectively. Treated fruit were cut 24 hours after treatment, and stored at 7 °C for 12 (‘Kent’) and 14 (‘Tommy Atkins’) days. For ‘Kent’ mangoes, 1-MCP and heat treatments decreased fruit firmness, while ethanol treatment maintained firmness similar to control. Similar differences between treatments were observed for cut fruit during storage. Heat treatment resulted in cut fruit with the lowest firmness and titratable acidity. Ethanol treatment significantly decreased the total soluble solids content of cut mangoes compared to all other treatments. After 12 days of storage, cut pieces from ethanol-treated mangoes maintained the best visual quality, and pieces from heat-treated fruit looked overripe. Informal tasting indicated off-flavor in pieces from ethanol-treated ‘Kent’ mangoes after 8 days in storage. For ‘Tommy Atkins’ mangoes, ethanol and 1-MCP treatments increased firmness, but only slices from 1-MCP-treated fruit remained firmer in storage. By reducing the duration of ethanol treatment to 8 hours on ‘Tommy Atkins’ intact mangoes, the off flavor noted for ‘Kent’ disappeared in stored slices, but other quality parameters were not improved. Heat and 1-MCP treatments resulted in higher L* value of cut pieces. Overall, no treatment extended fresh-cut mango shelf life for ‘Tommy Atkins’, but for ‘Kent’, spoilage was delayed by two days on all treated pieces.

Because they require peeling and are juicy, mango fruit are not convenient to eat; additionally, most North American consumers are unfamiliar with mangoes. Currently, fresh-cut fruit found on supermarket shelves include pineapples, melons, apples, and grapes (Cooperhouse, 2003). Therefore, developing the technology for fresh-cut mangoes would add to the variety of available fresh-cut fruit, and it would offer consumers convenience for an exotic fruit that is both delicious and nutritious.

Reports on the physiology and storage of fresh-cut mangoes are limited. Chantanawarangoon (2000) and Tovar et al. (2001) found that cut mangoes produced little CO₂ and ethylene in comparison to whole fruit, indicating that wounding would have a minimal impact on ethylene-induced ripening events. Lower storage temperatures (2 °C vs. 5 °C, or 5 °C vs. 10 °C) increased cut mango shelf life (Chantanawarangoon, 2000; Rattanapanone et al., 2001), and a controlled atmosphere with 10 kPa CO₂ extended potential marketability by 2 to 3 d (Chantanawarangoon, 2000; Limbanyen et al., 1998; Rattanapanone et al., 2001). Antibrowning and firming agents may help maintain the visual quality and firmness of mango pieces in storage (Chantanawarangoon, 2000; González-Aguilar et al., 2000).

Most of the research and applications to increase shelf life of fresh-cut produce focus on preventing decay and foodborne disease development, and retarding events associated with tissue senescence, including softening and browning (Alzamora et al., 2000). Treatments to prevent these effects are performed on the fresh-cut product. Another concept is to subject the intact fruit to ripening inhibitors before cutting, with the assumption that inhibition has a residual effect on the cut product senescence (Bai et al., 2003; Jiang and Joyce, 2002; Saftner et al., 2001).

1-Methylcyclopropene (1-MCP), a competitive ethylene inhibitor, binds to the ethylene receptors in plant tissue much longer than ethylene (Sisler and Serek, 1997); therefore, it delays senescence of climacteric fruits long after its initial application (Fan et al., 1999; Roh et al., 2001). 1-MCP was recently approved by the Environmental Protection Agency for postharvest use on fruits and vegetables (Federal Register, July 26, 2002), and numerous publications showed its efficacy in retarding ripening events in fruits and vegetables. 1-MCP is therefore a good candidate as a pre-processing treatment for fresh cut products (Bai et al., 2003).

Ethanol is another candidate with an inhibitory effect on ethylene production, resulting in delayed ripening in tomatoes (Beaulieu and Saltviet, 1997; Saltviet and Mencarelli, 1988; Yanuriati et al., 1999), avocado, honeydew and muskmelon when injected in the seed cavity (Ritenour et al., 1997), and mangoes (Abdulah and Basiouny, 2000). The mode of action of ethanol in the fruit would be by conversion to acetaldehyde, which in turn acts as an inhibitor of ethylene production (Beaulieu and Saltviet, 1997; Beaulieu et al., 1997). However, in practice, it is safer to use ethanol, less hazardous than acetaldehyde, which is highly volatile and toxic.
Heat, primarily used as an alternative to chemicals to disinfect fruit surfaces of insects or fungi, can have positive or negative effects on commodities. In her review of the physiological effects of postharvest heat treatments, Lurie (1998) showed that in most cases, heat treatments (35-40 °C) inhibited ethylene synthesis, delayed fruit softening, but sometimes induced higher respiration rates resulting in lower acidity. In some instances, these effects were carried over after treatment (Klein and Lurie, 1990), or stopped as soon as the fruit were removed from heat (Lurie et al., 1996). For mango, however, the effects of heat treatments are variable and depend on cultivar, fruit maturity, preharvest environmental conditions, temperature, and duration of the treatment (Jacobi et al., 2001). Typical treatments of hot water above 45 °C tend to increase yellowing of the skin and fruit softening (Jacobi et al., 2001), although in some instances, inhibition of fruit ripening were observed (Mitcham and McDonald, 1997).

Imported mangoes are subjected to a quarantine hot water treatment and are the only material available to U.S. fresh-cut companies during the mango off-season. This study evaluates the residual effects of a second heat treatment on whole mangoes, as well as 1-MCP and ethanol vapors on the subsequent fresh-cut products.

**Materials and Methods**

*Treatments*. Imported Peruvian ‘Kent’ mango fruit, 360 g to 380 g each, were purchased through a local supermarket. Fruit were placed in a room at 25 °C for 24 h, until they reached the RS4 ripenness stage (Miller et al., 1986: fruit fairly firm, with some yellow ground color development). Fruit were then transferred to 15 °C (control), or treated. Treatment of whole fruit included ethanol, heat, and 1-MCP. Ethanol-treated fruit were placed in a 0.3-L sealed glass chamber for 24 h at 23 °C, with a beaker containing an initial 5.0 g ethanol (200 proof U.S.P., Millennium Petrochemicals, Inc., Tuscola, Ill.) per kilo of fruit, with a filter paper wick to aid evaporation. After treatment, ethanol remaining in the beaker in the liquid phase was 1.27 g/kg fruit. Heat treatment was at 38 °C and >98% relative humidity (RH) for 48 h in a Controlled Relative Humidity chamber (Vapor Temp®, General Signal, Blue Island, Ill.). Fruit for the 1-MCP treatment were transported to the University of Florida Horticultural Sciences Department facilities, and placed in a 174-L steel chamber at 20 °C with 25 ppm 1-MCP (SmartFresh®, Agrofresh, Inc., Springhouse, Pa.) vapors for 24 h. After treatment, ethanol- and 1-MCP-treated fruit were returned to 15 °C and cut the next day.

Imported Mexican ‘Tommy Atkins’ mangoes, 400 g to 450 g, were obtained through a local supermarket. Fruit at the RS2 ripeness stage (Miller et al., 1986: fruit hard, with slight blush of color), were selected and kept at 23-25 °C for 20 h, then treated with 100 ppm ethylene at 20 °C for 24 h to stimulate faster and more uniform ripening (Kader and Mitchell, 1999). Treatments were the same as for ‘Kent’ mangoes, except that exposure times were reduced by half or more. Ethanol treatment was 5 g·kg⁻¹ of fruit for 8 h at 20 °C; after treatment, liquid ethanol remaining in the beaker was 3.11 g·kg⁻¹ fruit. 1-MCP treatment was 25 ppm for 12 h at 20 °C. Heat treatment was 38 °C, >98% RH for 24 h. All treated fruit were maintained at 20 °C for 24 h post-treatment and before cutting. Control fruit were maintained at 20 °C until processed.

*Processing*. Whole fruit were sanitized for 2 min in a solution of 2.7 mM (400 ppm) sodium hypochlorite adjusted to pH 6.5 with citric acid. Before cutting, fruit firmness was measured with a FT-327 fruit pressure tester (Wilson, Yakima, Wash.) mounted on a drill stand and equipped with an 11 mm probe. Each 30 (‘Kent’) or 24 (‘Tommy Atkins’) fruit were divided into three batches of 10 or eight fruit, respectively, before cutting (i.e., three replications per treatment). Fruit were peeled, halved, and cut into approximately 2.5 cm cubes (‘Kent’) or three longitudinal slices (‘Tommy Atkins’). Cubes or slices were dipped in a solution of 0.08 mM (5 ppm) chlorine dioxide (ClO₂) (Aquama, Bellingham, WA) for 30 s, then in a solution of 2% calcium ascorbate (Fluka Biochemika, Buchs, Switzerland) and 1% citric acid (Aldrich Chemical Company, Inc., Milwaukee, Wis.) for 30 s. Chlorine dioxide is an antimicrobial that may be used in wash water of fresh-cut produce (Hodges et al., 2000; Reina et al., 1995; Winniczuk and Parish, 1997; Zhang and Farber, 1996); calcium ascorbate with citric acid was found to have an anti-browning effect on cut mangoes in preliminary trials. After dipping, fruit pieces were drained, then randomly distributed in 970 ml (20 oz) clamshell containers (Pactiv Corp., Lake Forest, Ill.), with 10 pieces (‘Kent’) or 5 slices (‘Tommy Atkins’) per container (approximately 130 to 360 g, and 100 to 200 g, respectively). Cutting was performed in a 5-7 °C cold room, sanitizing and dip treatments were at 5 °C, and cut pieces stored at 7-8 °C in clamshells.

*Quality parameters*. Cut fruit were evaluated 1, 4, 8, and 12 d (‘Kent’), or 0, 3, 7, 10, and 14 d (‘Tommy Atkins’) after cutting. Ethylene and CO₂ production were measured by sampling 5-15 mL headspace of 100 to 300 g cut-fruit incubated for 1 h in 1-L sealed mason jars at 8 °C. CO₂ production (mL·kg⁻¹·h⁻¹) was measured on a Perkin Elmer XL (Perkin Elmer Analytical Instruments, Shelton, Conn.) gas chromatograph (GC) equipped with a thermal conductivity detector (TCD) and a CTR 1 column (1.8 mm × 0.32 cm) packed with porous polymer mixture (Alltech Associates Inc., Deerfield, Ill.). Conditions of the run were isothermal (85 °C), helium flow at 80 mL·min⁻¹, injection via a 120 µL loop. Ethylene was measured on a HP 5890 Series II GC equipped with a flame ionization detector (FID) and an activated alumina column. Oven, injector, and detector temperatures were 90 °C, 70 °C, and 250 °C, respectively.

Surface color of cut fruit was measured with a Minolta CR-300 Chroma Meter (Minolta, Tokyo, Japan) calibrated to a white plate using the CIE L*, a*, and b* system. Cut fruit firmness was determined using an XT2i texture analyzer (Stable Micro Systems, Surrey, England), calibrated with a 5-kg weight and equipped with a 1-cm diameter probe. The insert distance was 5.0 mm, with a stroke speed of 5.0 mm·s⁻¹. For color and firmness, one measurement was taken on each mango cube, and two on each slice. After firmness and color measurements, pieces were homogenized with 1 mL water per g of fruit tissue for 75 s, and frozen. The supernatant of thawed homogenates, centrifuged at 12,000 × g for 15 min, was analyzed for titratable acidity (TA), pH, and soluble solids concentration (SSC). For titratable acidity, a 10-ml sample of the supernatant was titrated with 0.1 N NaOH to a pH 8.1 endpoint using an Orion 950 titrator (Thermo Electron Corporation, Beverly, MA). Soluble solids were determined with a digital ATAGO PR-101 refractometer (Atago Co., Ltd., Tokyo, Japan).

Volatile compounds of the homogenate headspace (2 mL homogenate in 6-mL glass vials) were analyzed with a Perkin Elmer 8500 GC equipped with a 0.53 mm × 30 m, 1.0 µm film...
Results and Discussion

Before processing, ‘Kent’ peel color was visually estimated, and measured by colorimetry on ‘Tommy Atkins’ fruit. Ethanol, 1-MCP, and control intact ‘Kent’ fruit had a 66% yellow background with some red, and the heat-treated fruit were fully yellow with some red on the fruit surface. For ‘Tommy Atkins’, heat-treated fruit were also different from other treatments, with higher L*, a*, and b* values (data not shown), indicating more yellow in the background color. Therefore, for both cultivars, heat treatment (hot vapor) at 38 °C for 48 or 24 h seemed to accelerate ripening as measured by skin color. Likewise, skin color yellowing was accelerated with ‘Keitt’ (Pesis et al., 1997) and ‘Nam Dok Mai’ (Ketsa et al., 2000) mangoes under similar treatment conditions. In general, hot water dips or vapor heat above 46 °C has been reported to induce or accelerate yellowing of treated mangoes (Jacobi et al., 2001).

Fruit firmness was lower in 1-MCP and heat-treated ‘Kent’ fruit compared with control and ethanol treated fruit (Fig. 1A). These results were contrary to results reported for most fruit treated with 1-MCP, which generally maintains firmness after long periods of storage (Bai et al., 2003; Blankenship and Parker, 2001; Fan et al., 1999; Hofman et al., 2001; Jiang and Joyce, 2000). However, when banana ripening was first initiated with ethylene and then the fruit treated with 1-MCP, 1-MCP retarded ripening only when applied 1 d after the ethylene treatment, and had no effect when applied 3 or 5 d later (Jiang et al., 1999). This suggests that the ‘Kent’ mangoes may have been too ripe to respond to the 1-MCP treatment. Additionally, ‘Kent’ control fruit remained at 15 °C, while 1-MCP and ethanol-treated fruit were in chambers at 20 °C and 23 °C, respectively, during the duration of the treatment, and 1-MCP-treated fruit were exposed to 25-28 °C during transport to and from Gainesville, possibly explaining why 1-MCP-treated fruit softened faster than control. These differences in firmness were also observed on the cut fruit (Fig. 1B). To avoid this experimental inconsistency in the subsequent experiment with ‘Tommy Atkins’, control fruit were maintained at 20 °C, as were treated fruit. As a result, 1-MCP-treated ‘Tommy Atkins’ mangoes were as firm as ethanol-treated and control fruit on the day of processing (Fig. 2A); 1-MCP treatment also maintained higher firmness of cut slices during storage (Fig. 2B). Bai and co-workers (Bai et al., 2003) found a similar response with ‘Gala’ apple slices pre-treated with 1-MCP before cutting. Overall, firmness of cut mangoes decreased in storage for both cultivars (Figs. 1B and 2B).

Heat-treated ‘Kent’ fruit were softer than other treatments (Fig. 1A), and some fruit were discarded due to anthracnose rot. Based on these results, duration of heat treatment was decreased by half for ‘Tommy Atkins’. Heat-treated ‘Tommy Atkins’ were also softer (22 N) than ethanol- and 1-MCP-treated fruits (27 N and 25 N, respectively; Fig. 2A), without, however, reaching the low level of ‘Kent’ (17 N heat-, vs. 37 N and 25 N for ethanol- and 1-MCP-treated fruit, respectively, Fig. 1A).

Heat-treated fruit were similar to or firmer than control for both cultivars (Figs. 1A and 2A). Firmness of cut pieces from ethanol-treated ‘Kent’ mangoes was higher than 1-MCP- and heat-treated pieces during the 12-d experiment (Fig. 1B), but decreased to the levels of control and heat-treated fruit for cut ‘Tommy Atkins’ after 7 d in storage (Fig. 2B). In other experiments, ethanol vapors resulted in higher firmness of intact ‘Tommy Atkins’ (Abdulah and Basiony, 2000), but not ‘Keitt’ mangoes (Burdon et al., 1994). It appears that ethanol vapors may have different effects on fruit ripening, depending on the species (Ritenour et al., 1997) and the maturity stage at the time of treatment (Beaulieu and Saltviet, 1997). Ethanol applied to whole ‘Gala’ apples did not result in firmer slices compared with 1-MCP and heat treatments (Bai et al., 2003).

While CO₂ production of ‘Kent’ cut mangoes increased over time in storage at 7 °C (Table 1), there was no difference between treatments (Tables 1 and 2). On the other hand, for ‘Tommy Atkins’, cut pieces from heat-treated fruit generally had lower respiration rate during most of the experiment, but there was no increase in respiration during storage (Table 1). Bai and collaborators (Bai et al., 2003) found that heat-treat-
ed intact apples yielded slices that exhibited reduced fruit respiration. Ethylene production was at the lower limit of instrument detection and no differences were discernible (data not shown). By measuring respiration rate and ethylene production of whole and cubed mangoes, Chantanawaron-goan (2000) concluded that wounding had a minor effect on the physiology of fresh-cut mango.

Soluble solids content was lower in cut ‘Kent’ fruit treated with ethanol, indicating less starch degradation to soluble sugars (Fig. 3A). Levels of SSC declined for heat pre-treated cut fruit in storage (Fig. 3A). For ‘Tommy Atkins’, SSC of ethanol pre-treated fruit was initially higher than control (Fig. 3B); in storage, cut slices from 1-MCP-treated fruit had lower SSC compared to control (5.2% vs. 6.3%, 7 and 14 d in storage). While cut fruit from pre-treated mangoes maintained levels of SSC, SSC of control slices increased during storage for ‘Tommy Atkins’ (Fig. 3B).

Titratable acidity of ‘Kent’ cut mangoes was lower in heat-treated fruit compared with the other treatments (Fig. 4A); 1-MCP-treated fruit showed a decrease in TA over time. While a general decrease in acidity was observed in ‘Tommy Atkins’ cut fruit during storage (Fig. 4B), there was overall little significant difference between treatments (Table 2). Lower soluble solids and higher TA indicate slower ripening, since soluble sugar levels increase during ripening due to starch degradation, and citric acid is a metabolic substrate in respiration. Burdon et al. (1994) found an enhanced ripening effect from heat treatment on ‘Keitt’ mangoes (higher SSC and lower TA), and no effect from ethanol treatment. On the other hand, SSC was significantly less and TA higher (ripening delayed) in ethanol-treated ‘Tommy Atkins’ mangoes (Abdullah and Basiouny, 2000). These conflicting results indicate that the response of mango to these treatments is cultivar, and perhaps maturity dependent.

Cut pieces from heat-treated ‘Kent’ mangoes were darker as indicated by the L* value of the CIE Lab color space (Fig. 5A). The hue angle was also smaller (data not shown), and they appeared more orange or “overripe”, and had a lower visual appreciation (Fig. 5A insert). Pieces from ethanol-treated and control fruit were lighter at the end of storage than were pieces from heat- or 1-MCP-treated mangoes (Fig. 5A). For ‘Tommy Atkins’, there was no difference between treatments for L* value on the day of cutting, but L* value of control and ethanol pre-treated fruit slices decreased on the third day in storage, and remained lower than heat and 1-MCP pre-treated slices (Fig. 5B). This indicates that ‘Tommy Atkins’ responded positively to the 1-MCP and heat treatments for flesh color, but there was no difference in visual quality between treatments. ‘Tommy Atkins’ cut fruit showed more browning in the vascular tissue than was observed on ‘Kent’ cut fruit. Additionally, we noticed that spoilage (visual evaluation) was delayed by two days on all pre-treated ‘Kent’ cut pieces.

Ethanol content was significantly higher in ethanol pre-treated ‘Kent’ cut fruit (414-927 µL·L⁻¹ for ethanol-treated fruit, vs. 30-89 µL·L⁻¹ for control). This imparted a distinct fermented-like flavor to the cut pieces, as indicated by informal tasting. Ethanol content in ethanol pre-treated ‘Tommy Atkins’ cut fruit was also initially higher than in the control and 1-MCP treatments (84 µL·L⁻¹, vs. 28 µL·L⁻¹ and 34 µL·L⁻¹, respectively), and this was also perceived as an off-flavor. However, it decreased to the levels found in the control and 1-MCP treated fruit after 3 d in storage, and off-flavor was no longer perceived. Also, the level of ethanol in ‘Kent’ tissue from fruit exposed to ethanol vapor for 24 h was initially 10-fold higher than ethanol in ‘Tommy Atkins’ tissue from fruit exposed to ethanol vapor for 8 h. Heat treatment resulted in higher ethanol content than control in both cut ‘Kent’ and ‘Tommy At-

<table>
<thead>
<tr>
<th>Days after cutting</th>
<th>Control</th>
<th>Ethanol</th>
<th>1-MCP</th>
<th>Heat</th>
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</thead>
<tbody>
<tr>
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<td>4</td>
<td>12.2 bc</td>
<td>10.4 c</td>
<td>14.7 abc</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>18.6 ab</td>
<td>16.0 abc</td>
<td>18.0 ab</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>20.6 a</td>
<td>17.0 ab</td>
<td>20.8 a</td>
</tr>
<tr>
<td>‘Tommy Atkins’</td>
<td>3</td>
<td>8.6 bcd</td>
<td>10.6 ab</td>
<td>13.8 a</td>
</tr>
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<td>7</td>
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<td>10</td>
<td>11.1 ab</td>
<td>7.5 bcd</td>
<td>11.3 ab</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>11.0 ab</td>
<td>10.0 abc</td>
<td>10.8 ab</td>
</tr>
</tbody>
</table>

*Means (n = 3) followed by the same letter are not significantly different by the Duncan’s multiple range test at the 5% level.
kins’ fruit, with no trend during storage (75-250 µL·L⁻¹). Cut mangoes from heat-treated intact fruit also tasted over-ripe. Acetaldehyde was higher in the tissue of ethanol pre-treated ‘Kent’ mangoes than in control, heat-, and 1-MCP pre-treated fruit (42-50 µL·L⁻¹ vs. 7-19 µL·L⁻¹); it was also higher in ‘Tommy Atkins’ ethanol-treated fruit at day 0, and in the tissue of heat pre-treated ‘Tommy Atkins’ slices 0, 7, 10, and 14 d in storage, in comparison with control and other pre-treated slices (14-30 µL·L⁻¹ vs. 1-9 µL·L⁻¹). Acetaldehyde is converted from excess ethanol in plant tissue when ethanol is exogenously applied or resulting from anaerobic environment (Beaulieu et al., 1997). Increased acetaldehyde was found in mango (Burdon et al., 1994) and tomato (Beaulieu and Saltviet, 1997; Beaulieu et al., 1997) tissue exposed to exogenous ethanol vapor, and in mango tissue exposed to high N₂, low O₂ (Burdon et al., 1994). High ethanol from heat treatments, seen in both cultivars, resulted in increased acetaldehyde in ‘Tommy Atkins’ mangoes only, suggesting the conversion of ethanol to acetaldehyde may be cultivar or maturity dependent. Beaulieu and Saltviet (1997) proposed a mechanism by which acetaldehyde, at low concentration in the tissue, could enhance ripening by stimulating non-enzymatic ethylene production, or at high concentration, denature and inhibit ACC oxidase activity and therefore, retard ethylene synthesis and ripening. In this study, there was a residual ripening inhibition effect (higher firmness, lower SSC, higher L*) of a 24-h ethanol application on ‘Kent’ pre-treated mango pieces compared with heat and 1-MCP treatments, but the ripening effect of increased acetaldehyde from the heat treatment in ‘Tommy Atkins’ was only seen as a lower respiration rate (Table 1) and higher L* value (Fig. 5B). These results support Beaulieu and Saltviet’s proposed mechanism, and suggest that the effect of acetaldehyde may be concentration dependent.

In summary, ethanol vapor applied for 24 h to intact ‘Kent’ mangoes had some delayed ripening effect on cut pieces (color, firmness, SSC), but induced unacceptable off-flavor. Decreasing the application of ethanol with ‘Tommy Atkins’ to 8 h resulted in firmer fruit after treatment, without residual effect.

Table 2. F-value and significance for physiological and quality parameters of ‘Kent’ and ‘Tommy Atkins’ cut mangoes treated with 1-MCP, ethanol or vapor heat prior to cutting and stored for 12 and 14 days, respectively.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>CO₂</th>
<th>firmness</th>
<th>TA</th>
<th>pH</th>
<th>SSC</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>a*/b*</th>
</tr>
</thead>
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<tr>
<td>‘Kent’ Treatment</td>
<td>3</td>
<td>2.0</td>
<td>115.3***</td>
<td>19.6***</td>
<td>29.8***</td>
<td>17.4***</td>
<td>61.6***</td>
<td>9.7***</td>
<td>7.4***</td>
<td>12.8***</td>
</tr>
<tr>
<td>Day</td>
<td>3</td>
<td>10.9***</td>
<td>32.3***</td>
<td>4.6***</td>
<td>11.7***</td>
<td>3.2*</td>
<td>17.3***</td>
<td>29.7***</td>
<td>37.9***</td>
<td>33.2***</td>
</tr>
<tr>
<td>Trt × day</td>
<td>9</td>
<td>0.26</td>
<td>1.6</td>
<td>0.72</td>
<td>0.77</td>
<td>1.16</td>
<td>1.61</td>
<td>1.42</td>
<td>2.69</td>
<td>1.27</td>
</tr>
<tr>
<td>‘Tommy Atkins’ Treatment</td>
<td>3</td>
<td>8.0***</td>
<td>11.8***</td>
<td>1.89</td>
<td>0.25</td>
<td>4.0*</td>
<td>23.8***</td>
<td>6.0***</td>
<td>11.0***</td>
<td>7.4***</td>
</tr>
<tr>
<td>Day</td>
<td>4</td>
<td>4.1*</td>
<td>34.2***</td>
<td>9.0***</td>
<td>0.44</td>
<td>0.98</td>
<td>19.7***</td>
<td>54.7***</td>
<td>21.1***</td>
<td>44.4***</td>
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<tr>
<td>Trt × day</td>
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<td>2.5**</td>
<td>1.78*</td>
<td>3.1***</td>
<td>2.1*</td>
</tr>
</tbody>
</table>

***: sign. at P < 0.001; **: sign. at P < 0.01; *: sign. at P < 0.05

Fig. 3. Changes in soluble solids concentration (SSC) in ‘Kent’ (A) and ‘Tommy Atkins’ (B) cut mangoes. Different letters indicate significant differences between treatments and between observation days by Duncan’s multiple range test, 5% level.

Fig. 4. Changes in titratable acidity (TA) in ‘Kent’ (A) and ‘Tommy Atkins’ (B) cut mangoes. Different letters indicate significant differences between treatments and between observation days by Duncan’s multiple range test, 5% level.
on cut pieces in storage. Off-flavor in slices from ethanol-treated 'Tommy Atkins' fruit was only perceived on the first day. 1-MCP applied to intact fruit was effective at retarding softening of cut fruit for 'Tommy Atkins' but not 'Kent'. Cut slices from 1-MCP-treated whole 'Tommy Atkins' fruit remained firmer and lighter during storage. Heat treatments increased fruit softening in both cultivars, and decreased titratable acidity and visual quality in 'Kent' cut pieces, which appeared overripe, and had a fermented taste. Temperature before and during the treatment, as well as fruit maturity appear to be important factors influencing the effect of ripening inhibitors on mangoes. In future research, it is hoped that 1-MCP and ethanol pre-treatments could be fine-tuned to benefit the shelf life and quality of fresh-cut mangoes.

**Literature Cited**


In this study we report on the effect of 1-MCP on volatile profile of ‘Gala’ apple in comparison to apples stored in air addition to proper temperature management, for extending shelf life of commodities, but they can be toxic to fruit tissue and expressed. Sisler and coworkers (1996, 1999) have discovered a very effective ethylene action inhibitor—1-methylcyclopropene (1-MCP) during their searches for the ethylene receptor level: Recent developments. Physiol. Plant. 100:577-582.

1-MCP can be synthesized easily (Magid et al., 1971), and has been recently approved by Environmental Protection Agency (2002) for postharvest use on apples. Although most of the ethylene inhibitors, such as amiprophuron and decreased sensitivity when products are exposed to ethylene. Although most of the ethylene inhibitors, such as amiprophuron and decreased sensitivity when products are exposed to ethylene.


