Texture and distribution of pectic substances of mango as affected by infusion of pectinmethylesterase and calcium

Panida Banjongsinsiri,† Stephen Kenney and Louise Wicker∗

Department of Food Science and Technology, Physical Properties Group, University of Georgia, Athens, GA 30602, USA

Abstract: Fresh cut mangos were infused with pectinesterase (PME) and calcium chloride, and the effect on textural properties, distribution of pectic substance and degree of esterification was determined. Temperature gradient infusion with PME and/or calcium chloride increased gumminess and chewiness, but had no impact on hardness and adhesiveness. The distribution of pectic substances, as protopectin or alkaline soluble pectin, was approximately twice that of water- or chelator-soluble pectin. The degree of esterification of water- and chelator-soluble pectic substances was near 50–60%, and less than 10%, respectively. Heat-sensitive PME inhibitor in mango was detected. The initial hardness of Kent mango was variable, and differences in distribution of pectic substances were observed. Texture of Kent mango is most likely moderated by changes in the solubility of insoluble pectin or by non-pectin components in the cell wall.

Keywords: mango; pectinmethylesterase; calcium chloride; texture profile analysis; pectin

INTRODUCTION

Softening and loss of texture is a problem in fresh cut and minimally processed fruits and vegetables. Mango (Mangifera indica L) is one of the most popular tropical fruits world-wide.¹ This fruit softens very rapidly in the mesocarp and, as the fruit approaches the fully ripened stage, becomes undesirable for consumption.² The softening is presumably related to the depolymerization and solubilization of pectic substances in the middle lamella of the cell wall, and is believed to involve cell wall hydrolases.³ The activities of polygalacturonase (PG) and cellulase progressively increase during ripening, and are likely to be responsible for the extensive softening of Nam Dokmai mango.⁴ β-Galactosidase activity also increases during the ripening of Harumanis mango, and is associated with increased solubility and depolymerization of cell wall pectin.⁵ In contrast, pectinmethylesterase (PME) and hemicellulase activities decrease in Tommy Atkins, Nam Dokmai, Harumanis and Keitt mango during ripening.¹,⁴–⁶

To minimize softening of fruits and vegetables, numerous process treatments are described in the literature. Low temperature blanching⁷–⁹ and stepwise blanching¹⁰ increase firmness. Low temperature blanching increases firmness in fruits and vegetables by stimulation of PME activity, which is activated between 50 and 70 °C. PME catalyzes the hydrolysis of methyl ester bonds along the pectin chain to produce free carboxyl groups, which bind with cations, such as calcium, to form salt-bridges between adjacent pectin molecules.¹¹ Calcium in combination with low temperature blanching improves the firmness in canned green beans, carrots⁸ and frozen sweet cherries.¹² However, low temperature blanching also activates detrimental enzymes, and may result in quality loss. Infusion of desirable, exogenous enzymes to improve quality or to inhibit deterioration is a useful technology and minimizes some of the deleterious reactions of low temperature blanching.¹³ Infusion of exogenous PME increases firmness of peaches¹⁴ as well as strawberry pieces in jam.¹⁵,¹⁶ Although infusion of exogenous PME into blanched fruits improves firmness of some fruits, it is not effective with others.¹⁷ In particular, fruits and vegetables with a skin or tough surface, such as peas, corn, cherries and blueberries, resist infusion. Furthermore, fruits that are too soft, too hard or without structural porosity or air voids, are not amenable to enzyme infusion.¹⁷ In addition, endogenous enzyme inhibitors may be present. For example, an inhibitor of PME in kiwi fruit (PMEI) inhibits PME from orange, tomato, apple, banana
and potato.\textsuperscript{18} PMEI in unripe fruits is present as an inactive precursor, and is transformed into the active protein by proteimase action during ripening.\textsuperscript{19} A PMEI is also found in jelly fig (\textit{Ficus awkeotsang} Makino) and rubbery banana (\textit{Musa sapientum} L.).\textsuperscript{20,21} Our objectives were to evaluate infusion of exogenous PME into mango, to determine the PME activity in tissue and to determine the effect on the textural properties of mango.

**MATERIALS AND METHODS**

**PME and inhibitor extraction**

For infusion, PME was extracted from Valencia orange pulp (Tropicana Products, Inc, Bradenton, FL) without sodium chloride using deionized water at a 3:1 ratio of water to pulp, homogenized using a Proscientific homogenizer (Pro300A, Proscientific Inc, Monroe, CT) at 4°C, and adjusted to pH 8.0 with 0.1 M and 10 M NaOH. The filtrate was collected through Miracloth (CalBiochem, La Jolla, CA) and used for infusion. The PME activity of the filtrate was analyzed by titration using a pH stat titrator (Brinkmann, Westbury, NY). The assay was conducted in 20 ml of 1.0% high methoxyl citrus pectin in 0.1 M NaCl, at pH 7.5 and 30°C. One unit of PME activity was defined as the amount of enzyme that released 1 µmol of carboxylic acid group per minute.

To determine the PME activity of mango, a 5-g aliquot of infused mango was homogenized (Proscientific homogenizer) in 20 ml of buffer solution (0.1 M NaCl, 0.25 M Tris, pH 8.0) for 20 s at 4°C. The homogenate was filtered through Miracloth. The PME activity of mango was determined using the titration method described above.

To test for mango PME inhibitor levels, mango (cv Kent) was peeled, cut in 1.5-cm\(^3\) cubes, and blanched in boiling water (100°C) at discrete time intervals between 60 and 150 s. Blanched or fresh mango cubes were homogenized and extracted (0.1 M NaCl, 0.25 M Tris, pH 8.0). The homogenate was filtered through Miracloth, and used as mango PME inhibitor. Valencia orange or mango PME extracts were mixed with fresh or heated mango extracts at different ratios.\textsuperscript{20}

**Raw material and process treatment**

Mango fruits were purchased from a local supermarket. Mangos were initially sliced around 1–3 mm in depth to remove the skin using a meat slicer (Hobart Model 1612E, Hobart Corp, Troy, OH) and slices of 1.5 cm were obtained in a second cut. Finally, 1.5-cm\(^3\) cubes were cut using a grid. Mango cubes without traces of peel were randomized for each process treatment.

In preliminary experiments to establish an infusion process, mangos (cv Tommy Atkins) were infused with PME and calcium chloride by three processes. In the first process, unblanched mango cubes were infused with Valencia PME (13–16 Unit ml\(^{-1}\)) under vacuum (85 kPa) for 600 s at room temperature. The second process consisted of pulsing infusion, in which the vacuum was pulled for 300 s, released, and then repeated for another 300 s. In the third process, a temperature gradient infusion method was evaluated. Mango cubes were blanched for 150 s at 100°C, and immediately submerged in Valencia PME (13–16 Unit ml\(^{-1}\)) with and without CaCl\(_2\)·2H\(_2\)O (100 or 1000 ppm) at 4°C for 2 h.

**Microscopy**

A previously published method\textsuperscript{22} was modified for preparation of sections for microscopy. A subsection (1.5 × 1.5 × 0.5 cm\(^3\)) was excised from the original sample using a razor blade. This subsection was further reduced to 1-mm\(^3\) cubes. The cubes were placed in glass vials, and fixed in 2% glutaraldehyde in 0.1 M phosphate buffer (pH 7.4) at 21°C for 2 h. The fixative was decanted from the vials; the cubes were washed three times with distilled water, then placed in fresh fixative for overnight fixation. Fixative was again decanted from vials, and the cubes were washed three times with distilled water. Cubes were post-fixed with OsO\(_4\) for 1 h. Prior to embedding in low viscosity Spurr resin, the cubes were dehydrated in a graded ethanol series (900 s per step).

Sections (60 µm) of the sample were obtained using a RMC Products MTX ultramicrotome (Research Manufacturing Company, Tucson, AZ). Sections were mounted on clean 200-mesh grids, and stained using uranyl acetate/lead citrate. Stained sections were visualized with a JEOL 100 CX II (Tokyo, Japan) transmission electron microscope (TEM).

**Textural analysis**

Samples of mango cubes were equilibrated to room temperature before textural analysis. Texture profile analysis (TPA) was used to evaluate mango texture using a Texture Analyzer (TA-XT2i, Texture Technologies Corp, Scarsdale, NY). TPA was performed using a cylindrical probe (35 mm diameter) with a 25 kg load cell. Samples were compressed in two consecutive cycles to 25% deformation from the initial sample height of 1.5 cm, at a compression speed of 2 mm s\(^{-1}\). The textural parameters determined were hardness, stickiness, cohesiveness, adhesiveness, springiness, gumminess and chewiness.\textsuperscript{23,24} Hardness, measured in newtons (N), is defined as the first maximum force necessary to compress the sample. Stickiness (N) is defined as the negative force to pull the probe from the sample after the first compression. Cohesiveness is assessed using the ratio of the area...
of work during the second compression divided by the area of work during the first compression. Adhesiveness (N × s) consists of the negative force area for the first compression, and represents the work required to overcome the attractive forces between the surface of a food and the surface of other materials. Springiness (mm) is defined as the distance the sample was compressed during the second compression to the peak force. Gumminess (N) is the product of hardness and cohesiveness, and chewiness (N × mm) is the product of gumminess and springiness. At least fifteen samples were analyzed for each treatment.

Alcohol-insoluble solid preparation
Alcohol-insoluble solids (AIS) were prepared using a modified method. Fruit tissue (50–100 g) was homogenized for 20 s with a Proscientific homogenizer in a ratio of one part of sample to four parts of 95% ethanol. The homogenate was boiled at 100°C for 300 s and cooled to room temperature. The residue was filtered through a sintered glass funnel (Fisher Scientific, Atlanta, GA) under vacuum. Based on the initial fresh weight, the residue was successively washed in four volumes of 95% ethanol and six volumes of acetone. Finally, the residue was dried under the hood overnight, weighed, ground with a mortar and pestle, and stored at −20°C.

Extraction of pectin fraction from AIS
The pectin from AIS was fractionated based on solubility into water, chelator- or alkali-soluble pectins according to a modified method. An aliquot of 0.5 g of AIS was extracted for 1.5 h at 60°C with 90 ml of 0.05M sodium acetate buffer at pH 5.2. The water-soluble pectin (WSP) was collected by centrifugation at 8000 × g for 20 min at 4°C, and filtered through Miracloth. The pellet was collected and resuspended for 1.5 h at 60°C in 90 ml of 0.05M EDTA, 0.05M ammonium oxalate and 0.05M sodium acetate buffer at pH 5.2. The extract was centrifuged at 8000 × g for 20 min at 4°C and then filtered through Miracloth. The supernatant, consisting of chelator-soluble pectin (CSP), was collected. The pellet was resuspended with 90 ml of 0.05M NaOH for 1.5 h at 60°C, and centrifuged and filtered as described above. The resulting supernatant was collected as alkali-soluble pectin (ASP). Pectin (galacturonic acid) content of each fraction was analyzed using a m-hydroxydiphenyl method.

Total pectin determination
Total pectin (TP) was extracted from AIS. A dried AIS aliquot (10 mg) was weighed into a 10-ml screw-capped tube. Concentrated sulfuric acid was incrementally added to the tube, vortexed for 2 s, and cooled in an ice bath, until a total of 10 ml of sulfuric acid was added. The dissolved sample was transferred into a volumetric flask, and deionized water was added to make a 50 ml volume of solution. This solution was then filtered through glass wool, and analyzed for TP.

Determination of degree of esterification (DE)
The percentage degree of esterification (%DE) was determined using a modification of the titration method. A volume of 15 ml of WSP and CSP fractions, with an estimated concentration between 0.1 and 0.4 mg ml⁻¹, was used. The free carboxylic acid groups were titrated with 0.01 N NaOH. Samples were saponified with 10 ml of 0.05 N NaOH for 30 min at room temperature and neutralized with an equivalent amount of 0.05 N HCl. The total carboxylic acids groups were estimated by a second titration with 0.01 N NaOH. The endpoint of titration was estimated in the presence of phenolphthalein, but was quantified by titration to an endpoint pH near 8.0. The %DE was estimated as the ratio of free to total carboxylic acid groups.

Statistical analysis
The randomized complete block design was need to evaluate the influence of treatments (water, PME, calcium chloride and PME plus calcium chloride). The analysis of variance was performed using Proc GLM with a mixed effect model and the SAS statistical package V8.2 (SAS Institution Inc, Cary, NC). Means and standard deviations were reported and differences between means were compared using Fisher’s least significant difference (LSD) at p ≤ 0.1.

RESULTS AND DISCUSSION
Vacuum infusion, pulsed vacuum infusion and temperature gradient infusion influenced the appearance of mango cubes. The firmness of unblanched, PME and calcium chloride vacuum-infused mango cubes was not significantly different from the control (no treatment) and control (water-infused mango cubes). Pulsed infusion of PME and calcium chloride also did not increase firmness (data not shown). Vacuum and pulsed infusion resulted in a swollen, water-logged appearance of mango cubes. Other studies have reported that vacuum infusion altered the appearance of produce. For example, vacuum infiltration of preservative solutions in apple slices resulted in a water-logged and translucent appearance. In addition, apple plugs infused with browning inhibitors under vacuum (68–98 kPa) resulted in extensive water-logging and development of dark color. Of the infusion methods evaluated, temperature gradient infusion gave the greatest effect on texture with minimal change of integrity of mango cubes. Temperature gradient infusion with Valencia PME and/or calcium chloride influenced firmness of mango with variable results. Mangoees have variable fiber content which may influence infusion efficacy and measurement of textural properties. Quantity and orientation of fiber may act as a barrier to infusion of exogenous compounds as well as obscure textural measurements. Tommy Atkins cv has moderate fiber and Kent cv has little fiber content. In subsequent experiments, Kent cv with temperature gradient infusion was used.
Microstructural studies
To evaluate further the impact of infusion on the texture, the ultrastructure of temperature gradient infused Kent mango was determined. The ultrastructure appeared intact in the untreated sample (Fig 1A). The ultrastructure of the samples treated with water (Fig 1B) appeared damaged compared with untreated controls. Furthermore, greater loss of structural integrity was observed in samples treated with PME plus calcium chloride (Fig 1C). The cell wall of the samples treated with a combination of PME and calcium chloride had a more undulating appearance than the untreated control or the water-infused control. The untreated control was the only sample in which the cytoplasm was closely associated with the cell wall (Fig 2A). The internal structures of cell wall from water- (Fig 2B) and PME plus calcium chloride- (Fig 2C) infused samples were not as clearly defined as the internal structure of the untreated samples. The cellular structures within the tissue of the PME plus calcium chloride-treated samples appeared ruptured. The cellular structures within the tissue of the water-treated samples appeared to be beginning the rupturing process as evidenced by the bleb (Fig 2B, arrow) protruding through the membrane of the organelle.

Texture profile analysis (TPA)
The hardness of the non-infused control samples was significantly different between replications (Table 1). The hardness of non-infused control samples measured in replication 1 (70 N) was greatest when compared with replications 2 (33 N) and 3 (50 N). Thus, results for each replication of analysis are presented separately. Significant differences \( p \leq 0.1 \) in adhesiveness, gumminess and chewiness were observed depending on treatment. For example, the gumminess and chewiness of water-treated mangos were significantly less than those values measured in other treatment groups (replication 1). Mango treated with calcium chloride was more adhesive and sticky than the water-infused control and PME with or without calcium chloride samples (replication 2). No significant differences \( p \leq 0.1 \) in treatment effects were seen for hardness, cohesiveness and springiness within replications.

PME inhibitor
When Kent mango was tested for the presence of a PME inhibitor, no PME activity was found in unblanched or blanched (60–150 s) mango cubes (Fig 3B). The PME activity values of mixtures of equal volumes of heated mango extract and Valencia extract were in the range of 13.1 to 13.7 Units \( \text{ml}^{-1} \) (Figs 3D–G), which are similar to that found in the control Valencia PME \( (11.6 \pm 1.6 \text{ Units ml}^{-1}) \) (Figs 3A and H). However, the PME activity in the mixture of unheated mango and Valencia PME decreased (Fig 3C). Thus, it is possible that a heat-sensitive inhibitor of Valencia PME is present in the mango extract. A PME inhibitor has been identified in kiwi fruit that inhibits PME from orange, tomato, apple, banana and potato. \(^{18}\) Recently, a PME inhibitor was also found in jelly fig (Ficus akeotsang Makino)\(^{20}\) and rubbery banana (Musa sapientum L).\(^{21}\) Based on these results, a PME inhibitor is likely to be present in fresh mango (cv Kent), as well.

Pectic substances and DE
The measured total pectin, solubilized from AIS with sulfuric acid, ranged from 0.027 to 0.062 g kg\(^{-1}\) dry weight. In all cases, infusion significantly increased the amount of total pectin. The range of percentage total soluble pectin (TSP) from non-infused control, water-infused control, PME, calcium chloride and calcium chloride plus PME temperature gradient infusion (three replications) was 70%–125% (Table 2). Values
Infusion of pectinesterase

Table 1. Texture profile analysis of Kent mango after temperature gradient infusion

<table>
<thead>
<tr>
<th>Test ID</th>
<th>Hardness (N)</th>
<th>Stickiness (N)</th>
<th>Cohesiveness (unitless)</th>
<th>Adhesiveness (N s)</th>
<th>Springiness (mm)</th>
<th>Gumminess (N)</th>
<th>Chewiness (N mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>RW</td>
<td>70.07±21.90a</td>
<td>−2.03±0.70a</td>
<td>0.42±0.04a</td>
<td>8.18±3.40a</td>
<td>2.13±0.14a</td>
<td>30.2±10.76a</td>
<td>65.26±25.63a</td>
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<td>Water</td>
<td>29.71±8.21a</td>
<td>−0.71±0.41a</td>
<td>0.31±0.05a</td>
<td>−3.44±2.59a</td>
<td>2.05±0.30a</td>
<td>8.86±1.50a</td>
<td>18.19±3.38b</td>
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<tr>
<td>PME</td>
<td>31.09±8.61a</td>
<td>−0.66±0.36a</td>
<td>0.33±0.04a</td>
<td>−2.97±2.22a</td>
<td>2.12±0.29a</td>
<td>9.94±2.01a</td>
<td>21.02±4.92a</td>
</tr>
<tr>
<td>CaCl₂</td>
<td>30.22±6.59a</td>
<td>−0.52±0.15a</td>
<td>0.34±0.04a</td>
<td>−1.79±1.04a</td>
<td>2.27±0.25a</td>
<td>10.05±2.18a</td>
<td>23.05±6.64a</td>
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<td>PME + CaCl₂</td>
<td>32.50±7.69a</td>
<td>−0.61±0.21a</td>
<td>0.33±0.03a</td>
<td>−2.59±1.28a</td>
<td>2.11±0.24a</td>
<td>10.59±2.46a</td>
<td>22.52±6.76a</td>
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<tr>
<td>Replication 2</td>
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<tr>
<td>RW</td>
<td>33.34±7.92y</td>
<td>−2.37±1.03y</td>
<td>0.37±0.03y</td>
<td>10.15±6.72y</td>
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<td>12.32±2.79y</td>
<td>24.46±6.39y</td>
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<tr>
<td>Water</td>
<td>19.31±2.65a</td>
<td>−0.53±0.18b</td>
<td>0.36±0.03b</td>
<td>−2.46±1.13a</td>
<td>2.07±0.25a</td>
<td>6.98±0.83a</td>
<td>14.35±1.57a</td>
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<td>PME</td>
<td>19.91±4.14a</td>
<td>−0.72±0.34b</td>
<td>0.37±0.04a</td>
<td>−3.54±2.23a</td>
<td>2.04±0.38a</td>
<td>7.16±1.11a</td>
<td>14.55±3.42a</td>
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<td>CaCl₂</td>
<td>20.31±3.66a</td>
<td>−0.84±0.37a</td>
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<td>−4.43±2.52b</td>
<td>1.83±0.28a</td>
<td>6.88±0.79a</td>
<td>12.62±2.39a</td>
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<tr>
<td>PME + CaCl₂</td>
<td>20.14±3.23a</td>
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<td>RW</td>
<td>48.90±10.11z</td>
<td>−3.04±1.38z</td>
<td>0.39±0.04z</td>
<td>7.05±13.16z</td>
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<td>19.46±4.43z</td>
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<td>Water</td>
<td>21.44±4.40a</td>
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<td>0.35±0.03a</td>
<td>−2.39±1.47a</td>
<td>2.14±0.28a</td>
<td>7.42±1.31a</td>
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<tr>
<td>PME</td>
<td>22.97±6.16a</td>
<td>−0.52±0.25a</td>
<td>0.36±0.03a</td>
<td>−2.35±1.53a</td>
<td>2.21±0.31a</td>
<td>8.09±1.76a</td>
<td>18.00±5.27a</td>
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<tr>
<td>CaCl₂</td>
<td>21.38±4.93a</td>
<td>−0.50±0.21a</td>
<td>0.36±0.04a</td>
<td>−2.13±1.20a</td>
<td>2.18±0.30a</td>
<td>7.54±1.43a</td>
<td>16.39±3.59a</td>
</tr>
<tr>
<td>PME + CaCl₂</td>
<td>23.18±5.92a</td>
<td>−0.58±0.21a</td>
<td>0.35±0.04a</td>
<td>−2.69±1.26a</td>
<td>2.12±0.36a</td>
<td>7.94±1.85a</td>
<td>16.91±5.13a</td>
</tr>
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</table>

RW = unblanched non-infused control, Water = water-infused control, PME (13–16 Unit ml⁻¹), CaCl₂ 2H₂O (1000 ppm), and PME (13–16 Unit ml⁻¹ + CaCl₂ 2H₂O (1000 ppm)).

* Columns with the same letter within each replication are not significantly different

** Different letters (x,y,z) in the same column of RW indicate significant differences (p < 0.1) among replications.


regardless of infusion treatment. Of the solubilized pectin, the levels of WSP (17–38%) and CSP (12–28%) were lower than the content of ASP (47–60%) (Table 2). The values are in contrast to a previous report⁶ that the amount of water-soluble (29–46% of AIS) was greater than alkali-soluble pectins (4–10% of AIS) and declined, while oxalate-soluble pectin (3–4.5% of AIS) increased, during mango ripening. The authors suggested that pectin depolymerization increased the amount of alcohol-soluble material in mangos and influenced the extraction and distribution of pectin fractions.⁶ Others reported that ASP is the major pectic substance in Keitt and Tommy Atkins mangos, regardless of the ripening stage.¹ In this study, ASP also represented the major pectic substance in Kent. After infusion treatment, alkali-soluble pectin remained about twice water- or chelator-soluble pectin. Water- and chelator-soluble pectin were extracted in similar amounts.

Infusion is probably not only influencing the relative distribution of pectin fractions in water, chelator or alkali, but also influencing the extent of hydrolysis in sulfuric acid (g kg⁻¹ total pectin) and relative amounts of total soluble pectin to total pectin. Most values of %TSP were close to 100%.

The %DE of water-soluble pectin in all treatments ranged from 38% to 61%. The range of %DE for water-soluble pectin extracted from the water-infused control fruit (52–61%), PME-infused fruit (52–53%), calcium chloride-infused fruit (54–57%) and PME plus calcium chloride-infused fruit (38–50%) was generally lower than typical of water-soluble pectin. Water-soluble pectin from PME-treated mango tended to have lower %DE values than

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controls or calcium-infused fruit. The range of %DE for pectin soluble in EDTA/oxalate buffer was low, 4–8%DE, regardless of treatment. Previously reported values for average %DE of mango pectin range from 68% to 80–90%DE. In addition, %DE values between 70 and 80% were typical in water-soluble apple and citrus pectins and %DE values greater than 75–80% were not naturally present. The lower %DE of water-soluble pectin in PME-treated fruit in this experiment was interesting. De-esterification of pectin occurred, in the absence of detectable PME in mango extracts as well as in the presence of a PME inhibitor in mango. Moreover, water-soluble, low %DE pectin may occur if low molecular weight pectins were present. To measure the MW of pectin fractions, WSP was precipitated with ethanol to concentrate the samples for gel permeation chromatography. However, no solids were recovered (data not shown), which suggested depolymerization of pectin and an increase of alcohol-soluble material, as previously reported.

Pectinesterase and calcium infusion had some influence on mango texture and properties of pectic substances. Previous research reported that calcium chloride has a minimal effect on the texture of canned mango fruit if the stage of ripeness was past that suitable for canning. In addition, softening of different mango cultivars during ripening was related to the cell wall degrading enzymes PME, PG, cellulase and β-galactosidase. The PME activity decreased continuously during ripening of Kitchner and Dr Knight mango. However, in Abu-Samaka, PME activity increased and subsequently decreased. In contrast, PG and cellulase activity progressively increased during ripening of all three cultivars and was highly correlated with the loss of fruit firmness. In Pakistani mangoes, no correlation between ripening and changes in PME activity was observed due to the inconsistent pattern of the PME during ripening.

### Table 2. Distribution of pectic substance of Kent mango after temperature gradient infusion

<table>
<thead>
<tr>
<th>Treatment</th>
<th>%TP (mg 100 mg⁻¹ dry wt)</th>
<th>Pectin fraction</th>
<th>%TSP (mg 100 mg⁻¹ dry wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RW</td>
<td>3.71d</td>
<td>20.44c</td>
<td>54.93b</td>
</tr>
<tr>
<td>Water</td>
<td>6.15a</td>
<td>24.97ab</td>
<td>52.62c</td>
</tr>
<tr>
<td>PME</td>
<td>4.25c</td>
<td>27.61a</td>
<td>52.23c</td>
</tr>
<tr>
<td>CaCl₂</td>
<td>5.44b</td>
<td>18.59c</td>
<td>60.11a</td>
</tr>
<tr>
<td>PME + CaCl₂·2H₂O</td>
<td>4.40c</td>
<td>22.06bc</td>
<td>56.89b</td>
</tr>
</tbody>
</table>

Replication 2

| RW        | 2.66d                    | 25.16b          | 47.15b                   | 91.36c        |
| Water     | 3.73b                    | 26.99ab         | 51.87b                   | 101.99b       |
| PME       | 3.74b                    | 28.41a          | 50.41b                   | 105.07b       |
| CaCl₂     | 4.00a                    | 20.18c          | 58.83a                   | 97.93bc       |
| PME + CaCl₂·2H₂O | 3.07c | 25.43c          | 50.15b                   | 125.38a       |

Replication 3

| RW        | 3.39c                    | 25.18c          | 55.15b                   | 70.01b        |
| Water     | 5.69a                    | 30.08b          | 55.60b                   | 67.20b        |
| PME       | 4.05b                    | 37.29a          | 47.22c                   | 97.30a        |
| CaCl₂     | 5.37a                    | 23.29c          | 58.98a                   | 76.08b        |
| PME + CaCl₂·2H₂O | 4.22d | 28.42d          | 59.09a                   | 75.37c        |

RW = unblanched non-infused control, Water = water-infused control, PME (13–16 Unit ml⁻¹), CaCl₂·2H₂O (1000 ppm), and PME (13–16 Unit ml⁻¹ + CaCl₂·2H₂O (1000 ppm)).

Three replications of extraction are presented separately. Data presented within one replication is the average of three assays.

TP = total pectin, TSP = total soluble pectin, WSP = water-soluble pectin, CSP = chelator-soluble pectin, ASP = alkali-soluble pectin.

TSP = WSP + CSP + ASP, %WSP = (WSP/TSP) × 100, %CSP = (CSP/TSP) × 100, %ASP = (ASP/TSP) × 100, %TSP = (TSP/TP) × 100,

%TP = uronic acid/dry wt

a,b,c,d Columns with the same letter within each replication are not significantly different (p < 0.1).

**CONCLUSION**

Mango cubes infused with Valencia orange PME and calcium chloride had greater gumminess and chewiness, but displayed no difference in firmness compared with mango cubes without treatment. AIS extracted from treated and untreated mangos was high in insoluble pectin. Water-soluble pectins had degree of esterification values near 38–60%. The incongruity in pectin distribution and the presence of a PME inhibitor suggests altered solubility of pectin by infusion treatment. Kent mango texture is most likely moderated by the change in solubility of large molecular weight, insoluble pectin. Other components in the cell wall, such as cellulose and hemicellulose, may contribute to softening or inhibition of firming by infusion of PME and calcium chloride.

**REFERENCES**

Infusion of pectinesterase


