Original paper

Ultra-Sonication Effects on Quality Attributes of Maoberry (Antidesma bunius L.) Juice

Pittaya Chaikham¹, Pattaneeya Prangthip²* and Phisit Seesuriyachan³

¹Division of Food Science and Technology, Faculty of Science and Technology, Phranakhon Si Ayutthaya Rajabhat University, Phranakhon Si Ayutthaya 13000, Thailand
²Department of Tropical Nutrition and Food Science, Faculty of Tropical Medicine, Mahidol University, Bangkok 10400, Thailand
³Division of Biotechnology, Faculty of Agro-Industry, Chiang Mai University, Chiang Mai 50100, Thailand

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Maoberry (Antidesma bunius L.) juice is popularly consumed as a pasteurized juice because of its high levels of antioxidants. Although pasteurization is normally applied to extend the shelf life of fruit juices, this method damages the desired characteristics and antioxidant constituents of fruit juice products. Ultra-sonication is an alternative process to treat fruit juices without impairing their health benefits and consumer acceptance. This study is the first report on ultra-sonication effects on the physicochemical properties, bioactive components, antioxidant activities, and sensorial characteristics of maoberry juice. After ultra-sonication processing at a frequency of 20 kHz and amplitude levels between 20% and 80% for 30 min and when compared with fresh and heated (75°C, 30 min) juices, we found that the physicochemical properties viz. total soluble solids, pH, and viscosity of processed juices did not change. However, a noticeable effect on the color parameters of ultra-sonicated juices shown by decreased lightness and increased redness values was found. The highest chroma value ($C^*$) and total different colors ($\Delta E$) were observed in the heated one. Microbial count levels, polyphenol oxidase and peroxidase activities were low in all treatments, in particular thermally and 80% amplitude treated batches. Total anthocyanins and phenolic compounds increased in the ultra-sonicated maoberry juices treated at 60% and 80% amplitudes. The contents of ascorbic acid in maoberry juice decreased significantly at 80% amplitude and at 75°C. The antioxidant activities (DPPH and FRAP assays) of ultra-sonicated products still retained high levels with no significant difference from the fresh sample. The sensorial attributes of ultra-sonicated juice showed no difference from the control (fresh juice), but higher than the heated sample. In general, ultra-sonication technology could be an appropriate processing technique to maintain the desired quality attribute characteristics of maoberry juice.

Keywords: maoberry juice, Antidesma bunius L., ultra-sonication, bioactive compounds, antioxidative property

Introduction

In Thailand, maoberry or maoluang (Antidesma bunius L.) products are popularly consumed, particularly as pasteurized juice. Maoberry juice is commercially recommended as a functional beverage because of its high levels of antioxidants, particularly anthocyanins, phenolic acids, flavonoids, and ascorbic acid (Butkhup and Samappito 2008). These compounds are well known to help prevent cancer, diabetes, and cardiovascular and inflammatory diseases (Jorjong et al. 2015). The beneficial effects of maoberry by-products have also been reported in several studies.
Puangprontig et al. (2011) found that the extracts of maoberry seed and skin-pulp residue showed anti-apoptotic and anti-inflammatory effects in human breast epithelial cells, and also displayed inhibitory effects against some pathogenic and spoilage bacteria (Butkhop and Samappito 2011). Kukongviriyapan et al. (2013) illustrated that maoberry pomace supplementation reduced blood pressure and improved the hemodynamic status of induced hypertensive rats.

Consumers today favor natural fresh foods with high nutritional values. Although pasteurization is one of the most popular methods used to successfully extend the shelf life of numerous fruit juices, this method generally damages the original qualities (i.e. color, flavor, taste etc.) and also causes losses in the antioxidant constituents of the products (Aadil et al. 2013). Therefore, a non-thermal technique such as ultra-sonication is an alternative to pasteurize processed fruit juices, without impairing their health benefits and consumer acceptance (Zafra-Rojas et al. 2013).

The effects of ultra-sonication on the characteristics of various berry juices such as blackberry, strawberry, and mulberry have been investigated by Engmann et al. (2015), Tiwari et al. (2009a) and Wong et al. (2010). The frequency of ultra-sonication is applied at 20 kHz to maintain the fruit’s quality and reduce the incidence of decay and infection of microorganisms. However, no studies have investigated the effect of this novel processing technique on the qualities of maoberry juice. Hence, this study aimed to determine the alteration of physicochemical, antioxidative and microbiological properties, as well as sensory attributes of maoberry juice after ultra-sonic treatments at a frequency of 20 kHz and different amplitude levels of 20 – 80% for 30 min.

Materials and Methods

**Maoberry juice preparation**  
Maoberry fruits were harvested from an orchard in Sakon Nakhon province, Northeastern Thailand, from August to September of 2014. The fruits were washed and preserved at −20°C until further experiments. Juice was extracted using a fruit juice extractor. The extract was mixed with distilled water at a ratio of 1:1 (w/w) before adjusting to the total soluble solids of 12°Brix with fructose sugar. A 100-mL of maoberry juice was treated in a 150-mL glass bottle using a high intensity ultra-sonic processor (VCX 130 PB 130 W, Sonics & Materials Inc., Newtown, CT). The ultra-sonic probe was immersed into the juice sample which produced a 20 kHz wave frequency. The maoberry juice was exposed to different amplitude levels of 20 – 80% for 30 min. Afterward, all the processed juices were cooled down to 10.27 ± 1.40°C using an ice-water bath prior to analyzing.

**Color measurement**  
Color parameters of fresh, ultra-sonic and thermally treated juices were measured using a colorimeter (Minolta Chroma Meter CR-300, Kyoto, Japan). Analytical data were expressed as L* (lightness), a* (redness) and b* (yellowness) parameters. In addition, chroma value (C*) and total different colors (ΔE) were calculated using equations (1) and (2).

\[
\text{Chroma value (C*)} = \left( a^{*2} + b^{*2} \right)^{1/2} \quad \text{----- Eq. 1}
\]

\[
\text{Total different colors (ΔE)} = \left[ \left( \Delta L^{*2} \right) + \left( \Delta a^{*2} \right) + \left( \Delta b^{*2} \right) \right]^{1/2} \quad \text{----- Eq. 2}
\]

**Measurements of total soluble solids, pH, and viscosity**  
Total soluble solids and pH values of all the samples were determined using a refractometer (N-10E, Atago, Japan) and a Sartorius PB-20 pH meter (Sartorius, Gottingen, Germany). Dynamic viscosity of fresh and treated samples was measured using a control stress AR 2000 rheometer (TA Instruments, Inc., New Castle, DE) combined with commercial computer software (Rheology Advantage Analysis software Version 4.1). A concentric cylinder geometry (stator inner radius 15 mm, rotor outer radius 14 mm, cylinder immersed height 42 mm, gap 5,920 µm) was used. Juice (19.6 mL) was poured into the stationary cup and allowed to equilibrate to 25 ± 2°C, which was controlled by a circulating water system. Viscosity was calculated from the average of five points of the flow curves obtained in the shear rate range between 1 and 10 s⁻¹.

**Crude enzyme extraction**  
To extract the crude enzymes, 10 mL of samples were stirred with a mixture of 40 mL of 50 mM potassium phosphate, 1 M potassium chloride and 2% polyvinylpolypyrrolidone at 150 rpm for 20 min. The mixed solution was centrifuged at 4,200 rpm for 20 min before filtering through Whatman paper No. 1 (Apichartsrangkoon et al. 2013).

**Polyphenol oxidase (PPO) activity**  
PPO activity was determined according to the procedure described by Apichartsrangkoon et al. (2013). Briefly, 0.05 mL crude enzyme extract was poured into a mixture of 2.2 mL of 0.1 M potassium phosphate buffer (pH 6.5) and 0.25 mL of 0.2 M pyrocatechol. The absorbance of the mixed solution was recorded every 1 min for 5 min using a UV-Vis spectrophotometer (Perkin Elmer series Lambda 35, USA). One unit of enzymatic activity was defined as an increase of 0.1 unit of absorbance per min at 420 nm.

**Peroxidase (POD) activity**  
POD activity was measured following a modified method of Apichartsrangkoon et al. (2013) using a spectrophotometer at 470 nm. A 0.1-mL supernatant of crude enzyme extract was added into a mixture of 2.15 mL of 0.01 M sodium acetate buffer (pH 6), 0.25 mL of 0.1% hydrogen peroxide and 0.5% guaiacol. Subsequently, the increase in absorbance was recorded at every 1 min for 5 min. One unit of POD activity was defined as an increase of 0.1 unit of absorbance per min.

**Determination of total anthocyanins**  
Total anthocyanins were analyzed according to the pH differential method (Lee et al. 2005). First, 0.2-mL of the juice was added into 1.8 mL of 0.03 M potassium
chloride buffer (pH 1.0) or into 1.8 mL sodium acetate buffer (pH 4.5). Consequently, the absorbance of the well-mixed solution was measured at 520 and 700 nm using a spectrophotometer. Total anthocyanins were expressed as cyanidin 3-glucoside equivalent (mg CE/100 mL).

**Determination of total phenolic compounds** Total phenolic compounds were determined following the modified method of Chaikham and Apichartsrangkoon (2012). Accordingly, 2 mL of the juice were mixed with 8 mL of 100% cooled ethanol for 20 min before centrifuging at 4,500 rpm for 10 min. After that, 0.5 mL of supernatant was poured into 2.5 mL of 10% Folin-Ciocalteu reagent (Sigma-Aldrich, St. Louis, MO) and allowed to react for 5 min. A 2-mL of saturated sodium carbonate solution was then added to the mixture and held for 2 h at room temperature. The apparent blue complex solution was measured at 765 nm using a spectrophotometer. Total phenolic contents were expressed as mg gallic acid equivalent per 100 mL sample (mg GAE/100 mL).

**Determination of ascorbic acid** The concentrations of ascorbic acid in fresh and ultra-sonic treated maoberry juices were determined using a HPLC system (Chaikham and Apichartsrangkoon 2012). Before injection, 2 mL of the juice were mixed with 18 mL of diluted sulphuric acid (pH 2.2; Merck, Munich, Germany) by stirring at 150 rpm for 15 min, and centrifuged at 4,500 rpm at 4°C for 10 min. Next, the supernatant was filtered through a 0.20-μm nylon membrane (Vertical, Bangkok, Thailand). The HPLC system (Shimadzu LC-10AD; Shimadzu, Kyoto, Japan) consisted of a low-pressure pump and a photodiode array detector (SPD-M20A; Shimadzu) adjusted to a λ_\text{max} 250 nm. Chromatographic separation was performed with a C18 column (YMC-Pack ODS-AM, 5 μm, 4.6 mm ID × 250 mm; YMC, Kyoto Japan). The isocratic system used 0.1 M acetic acid (Merck) in deionized water (RCI Lab-Scan, Bangkok, Thailand) as a mobile phase with a flow rate of 1.5 mL/min at 30°C. A 20-μL filtrate was injected into the column. The peak area of each component was determined and converted to concentration.

**Determination of 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity** DPPH radical scavenging activity was determined according to the procedure of Chaikham and Apichartsrangkoon (2012). In brief, 2 mL of maoberry juice were poured into 8 mL of 100% methanol for 10 min before mixing for 10 min, and then was centrifuged at 4,500 rpm for 10 min. Afterward, 1.6 mL supernatant or methanol (control) was well-mixed with 0.4 mL of 1.5 μM DPPH radical in methanol, and allowed to stand for 30 min at room temperature before measuring the absorbance at 517 nm. DPPH radical scavenging activity (% inhibition) was calculated using equation (3), where A_b = absorbance of the control and A_i = absorbance of the sample.

\[
\text{DPPH radical scavenging activity} = \left[1 - \left( \frac{A_i}{A_b} \right) \right] \times 100 \quad \cdots \cdots \text{Eq. 3}
\]

**Ferric-reducing antioxidant power (FRAP) assay** The ability to reduce ferric ions was analyzed using the method of Benzie and Strain (1996). Accordingly, 1 mL of the sample was mixed with 9 mL deionized water and filtered through a Whatman paper No. 1. After that, 3 mL of FRAP reagent (10:1:1 of 300 mM sodium acetate buffer at pH 3.6, 10 mM 2,4,6-tripyridyls-triazine solution and 20 mM FeCl_, H,O solution) was added into the filtrate before incubating at 37°C for 30 min. The absorbance of the mixture was measured at 593 nm. The antioxidant capacity based on the ability to reduce ferric ions was expressed as mM FeSO₄ per 100 mL sample (mM FeSO₄/100 mL).

**Microbiological assessments** Total plate counts, yeasts and molds, and fecal coliforms in fresh and processed maoberry juices were determined following the Bacteriological Analytical Manual (US Food and Drug Administration, 2001).

**Sensory evaluation** Sensory evaluation was carried out by consumers recruited within a 5-km radius of the research center. Thirty trained volunteers were enrolled and asked to rate the degree of preference between the samples. A 9-point hedonic scale test; 9 = like extremely much, 5 = neither like nor dislike and 1 = dislike extremely much was applied. Triplicate sets of 20 mL of fresh, heated and ultra-sonicated maoberry juices were served at 4°C during the evaluation. Before starting the evaluation, participants were instructed to rinse their mouths with water after tasting the sample, as this could influence the result.

**Statistical analysis** Data consist of the means of six replications with standard deviations. Analysis of variance (ANOVA) was carried out using a SPSS Version 11.5. Differences among treatment means were compared by Duncan's multiple range tests with a level of significance of \( P < 0.05 \).

**Results and Discussion**

**Physicochemical qualities** Color is one of the most important visual criteria to which consumers refer with regards to the overall fruit juice quality. Table 1 depicts the effects of ultra-sonication and heating on color parameters in maoberry juice. For ultra-sonicated samples, it was found that the lightness (L) parameter in the juice tended to decrease with the rising wave amplitudes, while an increase in other parameters were observed. In overall, maoberry juices treated at 80% amplitude and at 75°C showed the lowest values of color parameters. As indicated by the reduction of the lightness parameter, the increasing darkness and yellowish color in the juices could be caused by enzymatic browning involving PPO and POD, because the residual activities of both enzymes still remained in the products (Table 2). In addition, the decreased lightness and increased redness values in the ultra-sound treated juices might be because of the better extraction of anthocyanin pigments. Anthocyanins are the predominant polyphenolic compounds present in maoberry fruits and are responsible for the redness and blueness of this fruit (Butkhp and Samappito 2008). These results were confirmed by the levels of total anthocyanins in the samples.
which were enhanced by ultra-sonic conditions (Table 3). Therefore, anthocyanins may also protect the darkness effects from PPO. The ultra-sonication effects on color parameters of other fruit juices were previously reported by several researchers. For instance, Abid et al. (2013) and Bhat et al. (2011) respectively illustrated that the \( L \) and \( a^* \) parameters of ultra-sonicated apple and kasturi lime juices were lower than the fresh juices, whereas the \( b^* \) parameters increased noticeably. The significant decreases of those parameters in both grapefruit and Chokanan mango juices (Aadil et al. 2013; Santhirasegaram et al. 2013) were also observed. Moreover, Engmann et al. (2015) discovered that the \( C^* \) and \( \Delta E \) values for most of the ultra-sonic treated mulberry juices were significantly higher than the control.

The influences of heat and ultra-sonic treatments on total soluble solids, pH and viscosity of maoberry juice are displayed in Table 2. The results indicated that thermal and ultra-sound processes did not induce any changes in the total soluble solids, pH and viscosity of the samples \((P > 0.05)\). These values remained stable when the wave amplitudes increased. Our findings are supported by several other studies. For instance, Zafra-Rojas et al. (2013) reported that ultra-sonication treatments had no effect on the pH of purple cactus juice. In addition, Tiwari et al. (2008a) and Bhat et al. (2011) respectively found that orange and kasturi lime juices showed no significant changes in total soluble solids and pH after ultra-sonic processing. Cruz-Cansino et al. (2013) illustrated that the ultra-sonic process induced slight changes in green cactus pear juice pH and total soluble solids. In this study, the dynamic viscosity of processed maoberry juices did not change when

<table>
<thead>
<tr>
<th>Samples</th>
<th>Color parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( L )</td>
</tr>
<tr>
<td>Fresh juice</td>
<td>16.59 ± 0.30°</td>
</tr>
<tr>
<td>HT 75°C</td>
<td>13.92 ± 0.27°</td>
</tr>
<tr>
<td>US 20%</td>
<td>16.55 ± 0.06°</td>
</tr>
<tr>
<td>US 40%</td>
<td>16.03 ± 0.11°</td>
</tr>
<tr>
<td>US 60%</td>
<td>15.90 ± 0.07°</td>
</tr>
<tr>
<td>US 80%</td>
<td>14.48 ± 0.15°</td>
</tr>
</tbody>
</table>

Means in the same column followed by the same letters are not significantly different \((P > 0.05)\). TSS is total soluble solids, HT is heat treatment and US is ultra-sonication.

### Table 2. Physicochemical properties and enzymatic browning activities of fresh, heated and ultra-sonicated maoberry juices

<table>
<thead>
<tr>
<th>Samples</th>
<th>Physicochemical properties</th>
<th>Enzymatic browning activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSS (°Brix)</td>
<td>pH</td>
</tr>
<tr>
<td>Fresh juice</td>
<td>12.77 ± 0.21°</td>
<td>3.46 ± 0.03°</td>
</tr>
<tr>
<td>HT 75°C</td>
<td>12.79 ± 0.05°</td>
<td>3.46 ± 0.02°</td>
</tr>
<tr>
<td>US 20%</td>
<td>12.73 ± 0.12°</td>
<td>3.44 ± 0.02°</td>
</tr>
<tr>
<td>US 40%</td>
<td>12.80 ± 0.08°</td>
<td>3.45 ± 0.02°</td>
</tr>
<tr>
<td>US 60%</td>
<td>12.84 ± 0.10°</td>
<td>3.45 ± 0.01°</td>
</tr>
<tr>
<td>US 80%</td>
<td>12.81 ± 0.05°</td>
<td>3.47 ± 0.04°</td>
</tr>
</tbody>
</table>

Means in the same column followed by the same letters are not significantly different \((P > 0.05)\). TSS is total soluble solids, HT is heat treatment and US is ultra-sonication.

### Table 3. Bioactive components and antioxidant capacities of fresh, heated and ultra-sonicated maoberry juices

<table>
<thead>
<tr>
<th>Samples</th>
<th>Total anthocyanins (mg CE/100 mL)</th>
<th>Total phenolics (mg GAE/100 mL)</th>
<th>Ascorbic acid (mg/100 mL)</th>
<th>DPPH inhibition (%)</th>
<th>FRAP value (mM FeSO₄/100 mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh juice</td>
<td>44.32 ± 5.02°</td>
<td>274.65 ± 9.16°</td>
<td>26.14 ± 2.12°</td>
<td>56.52 ± 5.45°</td>
<td>24.18 ± 1.27°</td>
</tr>
<tr>
<td>HT 75°C</td>
<td>44.65 ± 5.68°</td>
<td>280.04 ± 6.37°</td>
<td>16.09 ± 1.38°</td>
<td>50.47 ± 6.02°</td>
<td>18.68 ± 2.42°</td>
</tr>
<tr>
<td>US 20%</td>
<td>45.80 ± 3.61°</td>
<td>290.16 ± 5.62°</td>
<td>25.35 ± 1.05°</td>
<td>58.91 ± 2.11°</td>
<td>25.60 ± 2.00°</td>
</tr>
<tr>
<td>US 40%</td>
<td>48.12 ± 4.30°</td>
<td>288.59 ± 8.12°</td>
<td>24.05 ± 3.16°</td>
<td>60.43 ± 4.07°</td>
<td>26.08 ± 3.49°</td>
</tr>
<tr>
<td>US 60%</td>
<td>50.63 ± 3.18°</td>
<td>300.12 ± 1.89°</td>
<td>25.07 ± 2.08°</td>
<td>62.14 ± 1.92°</td>
<td>23.95 ± 2.68°</td>
</tr>
<tr>
<td>US 80%</td>
<td>49.01 ± 6.75°</td>
<td>292.88 ± 5.21°</td>
<td>18.19 ± 2.33°</td>
<td>59.12 ± 2.85°</td>
<td>22.32 ± 0.86°</td>
</tr>
</tbody>
</table>

Means in the same column followed by the same letters are not significantly different \((P > 0.05)\). HT is heat treatment and US is ultra-sonication.
PPO and POD activities PPO and POD are the principal enzymes involved in the browning reactions of non-thermally processed fruit juices. Browning is an important aspect that influences consumer acceptance. The residual PPO and POD activities in fresh, thermally and ultra-sonic treated maoberry juices are described in Table 2. It was found that increasing the wave amplitudes reduced the activities of both enzymes, especially the enzymatic inactivation of POD. Inactivation levels of PPO and POD by thermal and ultra-sonic processing at 80% amplitude were markedly higher than those of the other juices (P < 0.05). The application of ultra-sonication with different amplitudes of 20%, 40%, 60% and 80% inhibited PPO by 1.14%, 5.66%, 18.62% and 47.82%, and POD by 10.83%, 15.41%, 34.20% and 73.02%, respectively. In this case, we noted that wave amplitudes had inhibitory effects on both of PPO and POD, but these were more pronounced for POD activity. Likewise, Rithmanee and Intipunya (2012) found that ultrasonic treatment at 100% amplitude and a frequency of 20 kHz for 30 min could inhibit PPO and POD activities in longan pulp by 70.68% and 94.06%, respectively, compared to an untreated sample. Costa et al. (2013) treated pineapple juice at 75% amplitude for 10 min, and they discovered that the PPO activity diminished by 20%. Moreover, Ercan and Soysal (2011) reported that POD activity in tomato extracts noticeably declined with increased ultrasonic amplitude power, and the reduction of POD activity was achieved at 50% and 75% amplitudes for 2.5 and 1.5 min, respectively. They revealed that physical stress because of bubble collapse can contribute toward enzymatic inactivation. Enzymatic inhibition can be affected by high shear generated by the interaction of cavitating bubbles with the acoustic field. da Rocha Cordeiro Dias et al. (2015) also explained that the extreme agitation created by microstreaming can disrupt Van der Waals interactions and hydrogen bonds in the polypeptide, resulting in protein denaturation. Temperatures above 60°C can also denature the protein structures of the enzymes, but may negatively affect consumer acceptance and nutritional values of the products.

Bioactive components and antioxidant activity We investigated the effect of heat and ultra-sonic treatments on the concentrations of some phytochemicals viz. total anthocyanins, total phenolic compounds and ascorbic acid in maoberry juice. The results in Table 3 depicted that the processing conditions had no significant influence on the total anthocyanins in maoberry juice (P > 0.05). Alighourchi et al. (2013) found that the contents of anthocyanins in ultra-sonicated pomegranate juices did not decrease substantially; in fact they increased slightly at some amplitude levels and times. However, Engmann et al. (2015) and Tiwari et al. (2008a) respectively reported the reduction of anthocyanins after ultra-sonic treatments in mulberry and strawberry juices. They explained that the degradation of these compounds might be related to oxidation reactions promoted by the interaction of free radicals formed during ultra-sonication.

Moreover, our results also demonstrated that an increase (P < 0.05) of total phenolic compounds occurred in the juices treated at 60% and 80% amplitudes compared with the other samples (Table 3). These components were also found to increase significantly in kasturi lime juice (Bhat et al. 2011), grapefruit juice (Aadil et al. 2013) and purple cactus pear juice (Zafra-Rojas et al. 2013) after ultra-sonic processing, compared with the fresh juices. The increased phenolic compounds in the products might be a result of the higher intensities of wave amplitudes which could enhance the interruption of plant-cell walls to facilitate the release of their contents (Chaikham and Prangthip, 2015).

Besides anthocyanins and phenolics, the results in Table 3 illustrated that the contents of ascorbic acid in maoberry juices treated at 20 – 60% amplitudes did not show any significant change (P > 0.05). At a higher amplitude however, it decreased significantly (P < 0.05). In this case, after processing at 80% amplitude for 30 min, the temperature of the sample markedly increased to roughly 75.46°C. The declining level of this component was also observed in the heated juice. Therefore, the reduction of ascorbic acid could be primarily because of degradation from the heat. Previously, Abid et al. (2013) found no significant change in ascorbic acid concentration in apple juice after ultra-sonication at a 70% amplitude, frequency of 25 kHz and a controlled temperature of 20°C for 30 min. This finding was similar to a report of Bhat et al. (2011) with kasturi lime juice. Under the same conditions, Aadil et al. (2013) revealed that sonication significantly improved ascorbic acid levels in grape juice by ~ 14.30% compared with the control. In contrast, Adekunte et al. (2010) found a significant decrease of this component in tomato juice. Similarly, Lee and Feng (2011) depicted that ascorbic acid in orange juice was also reduced by processing, possibly because of the generation of free radicals. This suggests that heat and oxidation reactions are mainly responsible for ascorbic acid degradation during ultra-sonication treatments (de São José et al. 2014). Furthermore, several researchers compared the effects of ultra-sonic and thermal processing on the retention of ascorbic acid in fruit juices, such as tomato juice (Ercan and Soysal, 2011) and orange juice (Tiwari et al. 2009b). They concluded that thermal treatments on juices resulted in a significantly lower level of ascorbic acid than ultra-sonication treatment.
Antioxidants are reducing agents which possess the ability to protect humans and organisms from cell damage and homeostatic disruption caused by free radical-induced oxidative stress. The reducing properties of plant phytochemicals are related to the presence of phenolic constituents and some vitamins which exert their action by breaking the free-radical chain by donating a hydrogen atom (Jorjong et al. 2015). In this study, the antioxidant capacities including DPPH radical inhibition and FRAP values of fresh, thermally and ultra-sonic treated maoberry juices were investigated. Table 3 shows that the DPPH radical scavenging activities of ultra-sonicated maoberry juices were not significantly different ($P > 0.05$) from the fresh sample, and the percentages of radical inhibition ranged from $59.12 \pm 2.85\%$ to $62.14 \pm 1.92\%$; whereas this value was apparently lower in heated sample ($P < 0.05$). In this case, the lowest FRAP value was found in the juices treated at $80\%$ amplitude and at $75^\circ\text{C}$ respectively, which had significantly lower reducing power than the other batches ($P < 0.05$). This phenomena was interpreted by Namiesnik et al. (2013), who revealed that the DPPH method is generally employed with aqueous-organic extracts containing hydrophilic and lipophilic compounds, while FRAP assay is appropriate only for hydrophilic compounds. However, the processed juice still retained a high level of antioxidant activity. Identical results were found with ultra-sonicated kasturi lime juice (Bhat et al. 2011) and purple cactus pear juices (Zafra-Rojas et al. 2013).

**Microbiological assessments** The microbiological count results are exhibited in Table 4, where the initial amounts of microorganisms present in fresh maoberry juice were $6.71$, $4.81$, and $2.54 \log \text{CFU/mL}$ for total plate counts, yeasts and molds, and fecal coliforms, respectively. After ultra-sonication at $80\%$ amplitude and heating at $75^\circ\text{C}$, all the indicator microbes in the treated juices were acceptably eliminated by the processing and complied with the limits of the Thai Community Product Standard (TCPS No. 486/2004) for ready-to-drink maoberry juice (Thai Industrial Standard Institute, 2004). Our results were similar to that observed by Abid et al. (2013) with apple juice. The microbial reduction was because of the enhancement of biocides by cavitation. The formation of free radicals and hydrogen peroxide
during ultra-sonication treatment can lead to microbial elimination. In addition, cavitation also creates shock waves that ultimately cause damage to the living microbes, in particular vegetative cells (Abid et al. 2013; Bhat et al. 2011).

Sensory evaluation With regards to the microbiological assessments, it was found that ultra-sonication at 80% amplitude and heating completely eliminated the general microorganisms in maoberry juice (Table 4). Therefore, these samples were selected for sensory evaluation compared to control (fresh juice). Figure 1 elucidates the sensorial attributes of fresh and processed juices which were evaluated by 30 trained panelists. The data showed that the liking scores of appearance, color, odor, taste, and overall acceptability of ultra-sonicated treated juice were not significantly different \( (P > 0.05) \) compared to the fresh sample \( (appearance = 7.53 - 7.58, \text{color} = 7.82 - 8.03, \text{odor} = 7.54 - 7.76, \text{taste} = 7.85 - 7.90, \text{overall acceptability} = 7.88 - 8.01) \), and were significantly higher \( (P < 0.05) \) than those from the heated product \( (appearance = 7.02, \text{color} = 6.83, \text{odor} = 7.25, \text{taste} = 7.32, \text{overall acceptability} = 7.39) \). Although an alteration of color parameters was observed after ultra-sonication (Table 1), there were no major changes in the appearance of the juice, as indicated by the sensorial scores. Similar outcomes were observed between fresh, pasteurized and ultra-sonicated apple juice, where ultra-sonic treated juice was also more accepted than thermally treated juice (Ertugay and Başlar 2014).

Conclusion The results from this experiment revealed that no significant changes in total soluble solids, pH, and viscosity of thermally and ultra-sonic treated maoberry juices could be observed. Ultra-sonication had a noticeable effect on color parameters, but sensorial characteristics of treated juice were no different from fresh juice. However, variations in the ripeness of maoberry used in this study could be a limitation on the parameters investigated in this study. Although pasteurization is normally applied to extend shelf-life of fruit juices, this method damages the desired characteristics and antioxidant constituents of fruit juice products. Ultra-sonication could be an alternative maoberry processing method to obtain a juice with high retention of bioactive compounds and antioxidant capacities, and low residual PPO and POD activities as well as microbial counts.

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