Effect of Different Osmotic Agents on the Physical, Chemical and Sensory Properties of Osmo-Dried Cantaloupe

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ABSTRACT
Effects of various osmotic agents (sucrose, maltitol, sorbitol, and invert sugar) on the physical, chemical and sensory properties of osmo-dried cantaloupe were evaluated. The cantaloupe slices were immersed in each osmotic agent (50°Brix) for 24 h (30°C). Thereafter, the slices from each process were dried by using hot air oven at 60°C until the moisture content was below 18%. Then, the physical, chemical and sensory properties of the final product were measured. During osmotic dehydration process, water loss and solid gain were monitored. Significantly higher solid gain and water loss were observed in the sample dipped in sorbitol solution, whereas sucrose-treated sample showed the lowest water loss and solid gain. The sorbitol- and maltitol-treated samples had higher L* value and lower a* and browning intensity than invert sugar and sucrose-treated samples. The highest brown color was found in invert sugar-treated sample. Hardness was found to be significantly lower in sorbitol- and maltitol-treated samples, while it was at a maximum in sucrose-treated sample. The use of sorbitol and maltitol could reduce a_{so}, reducing sugar, total sugar and 5-hydroxymethylfurfural (HMF) content in the finished product compared to sucrose. However, the loss of vitamin C, phenolic compound and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity was observed to be more in sorbitol-treated sample. The sensory attributes of osmo-dried cantaloupe were found to be better in the case of sorbitol- and maltitol-treated samples as evidenced by color, texture and overall acceptability scores.

Keywords: cantaloupe, osmotic dehydration, maltitol, sorbitol, invert sugar, osmotic agents

1. INTRODUCTION
Cantaloupe (Cucumis melo L.) is a very popular and widely consumed fruit in the world. The cantaloupe has high amounts of functional substances such as carotenoids, which act as an antioxidant, minerals and some amino acids. Due to the pleasant aroma and the high sugar content, cantaloupe is a suitable raw material for the food industry, however its shelf life is limited to approximately 15 days. This results in large losses of the crop and value [1-2]. Thus, preservation techniques should be applied to extend the shelf life of cantaloupe.

Dehydration of fruits is a well-known preservation method, which involves water removal to reduce the risk of microbial
growth and proliferation. Moreover, dehydrated fruits can be stored and transported at relatively low cost. However, water removal using high temperatures and extended dehydration times may cause a severe reduction in the nutritive value and adversely affect sensory properties, including flavor, color, texture, and other properties [3]. One way of producing good quality dehydrated fruits is by using pre-drying treatments, such as osmotic dehydration, which can reduce energy consumption and improve food quality [4]. Osmotic dehydration is a partial water removal technique by direct immersion of food pieces in hypertonic solutions. During osmotic dehydration, three mass transfer processes are established: (1) water diffusion from the food material to the surrounding osmotic medium due to the concentration gradient between them, (2) solute diffusion from the osmotic solution to the food, and (3) leaching of natural solutes from the food. This process can be applied as an intermediate dehydration step prior to further drying processes such as convective hot air drying, freeze drying, vacuum drying [5].

Osmotic agents used in food must comply with special requirements. They have to be edible with accepted taste and flavor, nontoxic, inert to food components, and if possible, highly osmoactive. The quality of the final product is the main aim of most experiments testing the suitability of different osmoactive substances. Their technological applicability is estimated on water loss rate and final water content in the material. There are two criteria to rate different osmoactive substances: water loss and the amount of the substance penetrating the material that is osmosed. The rate of sugar penetration is dependent on the molecular weight of the sugar (osmotic agent) and solution concentration. Different osmotic agents affected the properties of the final product. In addition, the types of osmotic agent play an important role in the products as it strongly affects both the water loss and solid gain [6-8].

Osmo-dried fruit is now commercially more available in many countries, including Thailand, but sugar crystal formation and a hard texture are common problems found during storage [9]. This phenomenon may be due to the formation of sucrose crystal. The use of humectants could be applied to prevent this problem. Invert sugar is used mainly by food manufacturers to retard the crystallization of sugar and to retain moisture in food. Sugar alcohols, such as sorbitol and maltitol, are bulk sweetener with good taste and reduced calories. They do not promote tooth decay. Sugar alcohols are suitable for a variety of products reduced in calories, sugar or fat and has been safely used for almost half a century. In addition to providing sweetness, sugar alcohol is an excellent humectant agent. Thus, the present study was conducted to determine the effect of different osmotic agents on the properties of osmo-dried cantaloupe.

2. MATERIALS AND METHODS

2.1 Materials

Cantaloupes (Cucumis melo L. cv. Sun Lady), at commercial maturity, with 10-11% total soluble solid as measured by refractive index, were purchased from a local wholesale market. Sucrose and invert sugar syrup (approximately 70°Brix) were purchased from Mitr Phol Sugar Corp., Supanburi Thailand. Sorbitol and maltitol were obtained from Thai Food and Chemical LTD, Thailand.

2.2 Sample Preparation

The fruits were washed, hand-peeled and cut into slices with 3×3.5×1.5 cm. Cantaloupe slices were pre-treated by soaking in a solution
of calcium lactate (2%, w/v) for 3 hours. After pre-treatment, cantaloupe slices were washed in water at 30°C and then used for osmotic dehydration process.

2.3 Osmotic Dehydration Process and Feature Air-Drying

The cantaloupe slices were transferred to a 50°Brix osmotic solution made up with different osmotic agents (sucrose, maltitol, sorbitol, and invert syrup) at a ratio of fruit to solution of 1:3 for 24 h (30°C). When the osmotic dehydration time reached 24 h, the slices were washed in water at 50°C. Thereafter, the slices were dried by using hot air oven at 60°C until their moisture content was below 18%. The experiment was undertaken in two replications.

To investigate the mass transfer of solutes and water between samples and osmotic solutions, water loss and solid gain were monitored at 3 h intervals and calculated using equations 1 and 2, respectively [10]:

\[
\text{Solid gain (\%)} = \frac{(Mt \times Xst) - (Mo \times Xso)}{Mo}
\]

\[
\text{Water loss (\%)} = \frac{(Mo \times Xwo) - (Mt \times Xwt)}{Mo}
\]

Where \( Mo \) is the initial mass of sample (g), \( Mt \) is the mass of osmosed sample at time \( t \) (g), \( Xso \) is the initial soluble solid content of sample (°Brix), \( Xst \) is the total soluble solid content of osmosed sample at time \( t \) (°Brix), \( Xwo \) is the initial water content of fruit sample (%, wet basis) and \( Xwt \) is the water content of osmosed sample at time \( t \) (%, wet basis).

2.4 Physical Properties Measurement

2.4.1 Color Measurement

The surface color on two sides of an individual piece was measured by using a colorimeter. A colorimeter was adjusted for reflectance, illuminant D 65, and angle of 10°. Instrumental color data was provided in accord with the CIE system in terms of \( L^* \) (lightness), \( a^* \) (redness and greenness) and \( b^* \) (yellowness and blueness).

2.4.2 Browning Measurement

Browning measurement was carried out using the method described by Koca et al. [11]. The sample (20 g) was rehydrated for 10 min in 50 mL acetic acid (1% v/v) and homogenized for 5 min, then diluted to 200 mL with acetic acid solution (1% v/v). After that, the mixture was filtrated through filter paper. After filtration, the clarified sample solution was measured for browning intensity by spectrophotometer at 420 nm.

2.4.2 Hardness Measurement

Texture measurement was carried out with a TAXT2i Texture Analyzer (Stable Micro Systems Ltd, Godalming, UK). The hardness (N) of the products was evaluated using a knife blade probe. Ten measurements were performed on each sample to obtain the mean measurement for that sample.

2.5 Chemical Properties Analysis

2.5.1 Determination of pH

The pH value was measured at ambient temperature with a pH meter (Sartorius, USA) which calibrated at pH 4.0 and 7.0.

2.5.2 Determination of Total Acidity

Total acidity was measured according to the procedure of Rangana [12] with a slight modification. Ten gram of sample was homogenized in 30 ml of distilled water and then made up to 50 ml. The homogenate was filtered and centrifuged at 5,000 rpm for 10 min. The supernatant was titrated with 0.01 N NaOH using a few drops of 1% phenolphthalein solution as an indicator.
The result was calculated as a percentage of citric acid.

2.5.3 Determination of Moisture Content

The moisture content of sample was measured using a hot air oven. About 2-5 g of the sample was placed in a pre-dried aluminum dish and dried in an oven at 110°C for 6 h. The dried sample was placed in a desiccator and cooled for 0.5 h to room temperature. The weight was recorded, and the percentage moisture based on the initial wet weight was calculated.

2.5.4 Determination of Water Activity

Water activity was measured at room temperature using a water activity meter (Novasina, Thermostanter). The sample was cut into tiny pieces and inserted into a sample cup and another water activity measurement was made immediately to restrict moisture transfer from the air to the samples.

2.5.5 Determination of Total Sugar and Reducing Sugar

The total sugar and reducing sugar content were quantified by the Lane and Eynon Volumetric method. The reducing sugar content was determined by titration with Fehling’s reagents while total sugar was analyzed after hydrolysis by HCl and then titrated with Fehling’s reagents. The results were expressed as grams of glucose per 100 g of sample [12].

2.5.6 Determination of Vitamin C (Ascorbic Acid)

Vitamin C was determined according to the method of Guimaraes et al. [13]. The sample (450 mg) was extracted with metaphosphoric acid (1%, 30 ml) for 45 min at room temperature and filtered through Whatman No.4 filter paper. The filtrate (1 ml) was mixed with 2,6dichloroindophenol (9 ml) and the absorbance was measured within 30 min at 515 nm against a blank. Content of vitamin C was calculated on the basis of the calibration curve of L-ascorbic acid, and the results were expressed as mg vitamin C per 100 grams dry sample.

2.5.7 Determination of HMF Content

The sample (10 g) was homogenized in 30 ml of distilled water and then made up to 50 ml. The homogenate was filtered and centrifuged at 5,000 rpm for 10 min. The supernatant was used to measure 5-hydroxymethylfurfural (HMF) content. To determine the HMF content, 2 ml of supernatant was introduced into the tube. Two ml of 12% trichloroacetic acid and 2 ml of 0.025 M thiobarbituric acid were subsequently added and mixed thoroughly. The tube with the sample was then placed in a water bath at 40°C. After incubating for 50 min, the tube was cooled immediately, using water, and the absorbance was measured at 443 nm. A calibration curve of HMF (Sigma-Aldrich) was utilized to quantify the HMF content [14].

2.5.8 Determination of Phenolic Compounds

Quantification of phenolic compounds in each sample was carried out according to the method of Balange and Benjakul [15]. The sample (10 g) was homogenized in 30 ml of distilled water and then made up to 50 ml. The homogenate was filtered and centrifuged at 5,000 rpm for 10 min. The supernatant was used to measure phenolic content. The sample (0.5 ml) was mixed with 0.5 ml of distilled water. Thereafter, 0.5 ml of Folin-Ciocalteu reagent (1:1 with water) and 2.5 ml of 2% sodium carbonate solution were added. The mixture was mixed thoroughly and placed in dark for 40 min and the absorbance was recorded at 725 nm. The
total phenolic content was calculated from the standard curve of gallic acid and expressed as μg gallic acid per gram dry sample after blank subtraction.

2.5.9 Determination of DPPH Radical Scavenging Activity

DPPH radical-scavenging activity was determined by DPPH assay, as described by Binsan et al. [16] with a slight modification. The sample (10 g) was homogenized in 30 ml of distilled water and then made up to 50 ml. The homogenate was filtered and centrifuged at 5,000 rpm for 10 min. The supernatant was used to measure DPPH radical-scavenging activity. Sample (1.5 ml) was added to 1.5 ml of 0.15 mM 2, 2-diphenyl-1-picrylhydrazyl (DPPH) in methanol. The mixture was mixed vigorously and allowed to stand at room temperature in the dark for 60 min. The absorbance of the resulting solution was measured at 517 nm using a UV-1601 spectrophotometer (Shimadzu, Kyoto, Japan). The blank was prepared in the same manner, except that distilled water was used instead of the sample. A standard curve was prepared using ascorbic acid. The activity was expressed as mg ascorbic acid equivalents per gram dry sample.

2.6 Sensory Evaluation

The acceptance test was used for determining the quality and consumer acceptability of osmo-dried cantaloupe samples, based on their color, appearance, flavor, texture and overall acceptability. Color was evaluated by visual observation. Texture was evaluated by eating. Flavor was evaluated by smell and taste. The samples were presented to a test panel on a white plate labeled with three-digit number codes. Sixty untrained panelists were asked to rate each sensory attribute on a 9-point hedonic scale from 1 (dislike extremely) to 9 (like extremely) (1: extremely poor; 3: poor; 5: acceptable; 7: good; 9: excellent). The experiment was conducted under a controlled environment in an air-conditioned room (25°C), with cool white fluorescence office lighting.

2.7 Statistical Analysis

All analysis and measurements were performed in triplicates. The experimental designs for physical and chemical properties were a completely randomized design (CRD). The experimental design for sensory evaluation was a randomized complete block design (RCBD). Data was subjected to analysis of variance (ANOVA). Comparison of means was carried out by Duncan’s multiple-range test [17]. Analysis was performed using a SPSS package.

3. RESULTS AND DISCUSSION

3.1 Effect of Different Osmotic Agents on Water Loss and Solid Gain during Osmotic Dehydration

Cantaloupe provides a wide variety of nutrients and has commercial potential due to nutritive value and sensory attributes. During the osmotic dehydration of cantaloupe slices using the various osmotic solutions, water loss and solid gain were monitored, as presented in Figure 1 and 2. It was found that the immersion of cantaloupe slices in different osmotic solutions (50%Brix) for 24 h had a significant ($p \leq 0.05$) effect on solid gain and water loss during osmotic treatment. Solid gain and water loss of all treatments increased gradually as the osmosis dehydration time increased up to 18 h ($p \leq 0.05$). Thereafter, no change in solid gain and water loss of all treatments was observed ($p > 0.05$). Water loss and solid gain during osmotic dehydration were found to be highest in the case of sorbitol treatment, followed by invert sugar, maltitol and lowest in the case of sucrose. This is because of sorbitol having a lower...
Figure 1. Changes in water loss during osmotic dehydration (30°C) of cantaloupe in the osmotic solution containing different osmotic agents (50°Brix). Error bars represent standard deviation (n=3).

Figure 2. Changes in solid gain during osmotic dehydration (30°C) of cantaloupe in the osmotic solution containing different osmotic agents (50°Brix). Error bars represent standard deviation (n=3).
molecular weight than other osmotic agents. The use of low molecular weight osmotic agent, such as sorbitol, increased the osmotic pressure gradient and thereby increased the water loss. Sorbitol is obtained by reduction of glucose changing the aldehyde group to an additional hydroxyl group hence it can be named as sugar alcohol. Molecular weight of sorbitol \((\text{C}_6\text{H}_{14}\text{O}_6)\) is smaller than sucrose \((\text{C}_{12}\text{H}_{22}\text{O}_{11})\) [15]. Invert sugar contains equal amounts of fructose and glucose. Invert sugar used in this study contained 25% fructose, 25% glucose and 50% sucrose. Fructose and glucose have a lower molecular weight than sucrose, resulting in the promotion of mass transfer during osmotic dehydration [18]. Maltitol, consists of a glucose and a sorbitol unit, is sugar alcohol (polyol) used as a sugar substitute. Higher solid gain and water loss were observed in maltitol-treated sample compared to sucrose-treated sample. From the result, the use of low molecular weight osmotic agents could enhance mass transfer during osmotic dehydration. Due to a higher rate of penetration of low molar mass molecules, the solid enrichment occurred instead of dehydration during the process, resulting in the promotion of water loss. Low molecular weight solutions have higher corresponding osmotic pressures, which could favor plant cell plasmolysis. Consequently, the osmotic process facilitated uptake of low molecular weight solutes resulting in the spread of plasmolysis throughout the tissues and gradually dehydrating the different tissue layers. Low molecular weight solutes markedly penetrated the fruits, whereas those of higher molecular weight only showed a slight and slow inward motion. This effect could be interpreted in terms of respective solute diffusivities [7, 19]. Similar results were observed in the osmotic dehydration of mandarin that used a mixture of glycerol and sucrose as the osmotic agent. Increasing the glycerol ratio in the mixtures increased water loss and solid gain during osmotic dehydration [20]. Sritongtae et al. [21] also reported increasing low molecular weight osmotic agent, such as sorbitol, led to an increase in solid gain during osmotic dehydration of cantaloupe.

3.2 Effect of Different Osmotic Agents on the Physical Properties of Osmo-Dried Cantaloupe

The color of osmo-dried cantaloupe was measured as depicted in Table 1. The color characteristics of fresh cantaloupe using \(L^*\), \(a^*\) and \(b^*\) values were 62.70±1.06, 8.27±1.13 and 18.63±1.22, respectively. After drying process, the decrease in \(L^*\) value and increase in \(a^*\) value were observed in sucrose- and invert sugar-treated samples \(p \leq 0.05\) while no change in \(L^*\) value and \(a^*\) value was found in sorbitol and maltitol-treated samples. A decrease in \(L^*\) value and an increase in \(a^*\) values could be a result of browning reactions occurring during hot-air drying. The lowest \(L^*\) value and highest \(a^*\) value and browning intensity were observed in the samples dipped in invert sugar solution, whereas sugar alcohol-treated samples (sorbitol and maltitol) showed the highest \(L^*\) value and lowest \(a^*\) value and browning intensity. No significant difference in \(L^*\) value, \(a^*\) value and browning intensity was found in the sample immersed in either sorbitol or maltitol \(p > 0.05\). Generally, \(L^*\) value decreases while \(a^*\) value increases during browning reactions occur. Thus, a decrease in \(L^*\) value and an increase in \(a^*\) values indicate browning and may contribute to the nonenzymatic browning reactions as mentioned previously [22-24]. The Maillard reaction is mainly responsible for browning
development in osmo-dried cantaloupe during the drying process. The Maillard reaction starts with a condensation between a free amino group (of an amino acid or in protein, but also the a-amino groups of terminal amino acids) and an a-hydroxyl carbonyl moiety of a reducing sugar in foods. The use of invert sugar could promote the Maillard reaction during drying process, resulting in the highest brown pigment formation. On the other hand, the use of sugar alcohols in the osmotic solution could reduce brown color in osmo-dried cantaloupe. This can be related to the fact that sugar alcohols do not undergo the Maillard reaction [25]. In addition, the sample immersed in the osmotic solution containing sucrose became darker than those immersed in the osmotic solution containing either sorbitol or maltitol. Results suggested that, the hydrolysis of sucrose, called inversion reaction, could take place during drying process, resulting in the formation of reducing sugars (fructose and glucose) [26]. This phenomenon caused an increase in the substrate for participating in the Maillard reaction [27].

The effect of different osmotic agents on the hardness of osmo-dried cantaloupe was studied as shown in Table 1. The hardness was observed to be the highest in the case of sucrose-treated samples and the lowest in the case of sugar alcohols-treated samples (sorbitol and maltitol). No significant difference in the hardness was found in the sample immersion in either sorbitol or maltitol ($p > 0.05$). The highest hardness in the case of sucrose-treated samples could be due to the formation of sucrose crystal coating on the surface of the sample. On the other hand, the use of sugar alcohol including sorbitol and maltitol could reduce hard texture of the product. This could be explained by sugar alcohol acting as humectant that bind water to its molecule, thus $a_w$ was reduced while the sample still remained moist. Ronda et al. [28] found that the use of polyols such as sorbitol could reduce the hardness of sponge cake. Additionally, the invert sugar-treated sample had significantly lower hardness than the sucrose-treated sample. Generally, invert sugar is used mainly by food manufacturers to retard the crystallization of sugar and to retain moisture in food.

### Table 1. Physical properties of osmo-dried cantaloupe.

<table>
<thead>
<tr>
<th>Properties/Treatments</th>
<th>Sucrose</th>
<th>Maltitol</th>
<th>Sorbitol</th>
<th>Invert sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color L*</td>
<td>57.48 ± 0.25$^b$</td>
<td>61.77 ± 0.49$^a$</td>
<td>62.51 ± 0.37$^a$</td>
<td>56.05 ± 0.31$^c$</td>
</tr>
<tr>
<td>a*</td>
<td>13.45 ± 0.92$^b$</td>
<td>8.11 ± 0.57$^c$</td>
<td>8.05 ± 0.43$^c$</td>
<td>15.11 ± 0.76$^a$</td>
</tr>
<tr>
<td>b*</td>
<td>20.84 ± 1.13$^c$</td>
<td>23.17 ± 0.86$^a$</td>
<td>22.53 ± 0.49$^b$</td>
<td>19.54 ± 0.52$^c$</td>
</tr>
<tr>
<td>Browning Intensity</td>
<td>0.30 ± 0.00$^b$</td>
<td>0.07 ± 0.03$^c$</td>
<td>0.05 ± 0.05$^c$</td>
<td>0.42 ± 0.01$^a$</td>
</tr>
<tr>
<td>Hardness (N)</td>
<td>20.24 ± 0.77$^a$</td>
<td>16.43 ± 0.91$^c$</td>
<td>15.31 ± 0.81$^c$</td>
<td>18.84 ± 0.51$^b$</td>
</tr>
</tbody>
</table>

Note: Values represent mean and standard deviation (n=3). Means with different superscripts in the same row are significantly different ($p \leq 0.05$).
Table 2. Chemical properties of osmo-dried cantaloupe.

<table>
<thead>
<tr>
<th>Properties/Treatments</th>
<th>Sucrose</th>
<th>Maltitol</th>
<th>Sorbitol</th>
<th>Invert sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (%)</td>
<td>14.65 ± 0.25</td>
<td>14.95 ± 1.12</td>
<td>14.83 ± 0.38</td>
<td>14.11 ± 0.58</td>
</tr>
<tr>
<td>Water activity (a_w)</td>
<td>0.71 ± 0.01</td>
<td>0.67 ± 0.02</td>
<td>0.65 ± 0.02</td>
<td>0.64 ± 0.03</td>
</tr>
<tr>
<td>pH</td>
<td>5.82 ± 0.03</td>
<td>5.97 ± 0.02</td>
<td>6.02 ± 0.05</td>
<td>5.92 ± 0.02</td>
</tr>
<tr>
<td>Total acidity (% as citric acid)</td>
<td>0.10 ± 0.01</td>
<td>0.11 ± 0.02</td>
<td>0.07 ± 0.01</td>
<td>0.08 ± 0.01</td>
</tr>
<tr>
<td>Reducing sugar (%)</td>
<td>12.94 ± 0.34</td>
<td>7.35 ± 0.63</td>
<td>7.55 ± 0.24</td>
<td>37.88 ± 1.26</td>
</tr>
<tr>
<td>Total sugar (%)</td>
<td>40.05 ± 0.70</td>
<td>24.66 ± 0.01</td>
<td>24.73 ± 0.40</td>
<td>39.57 ± 0.48</td>
</tr>
<tr>
<td>Vitamin C (mg/100 g)</td>
<td>28.45 ± 0.31</td>
<td>28.42 ± 0.37</td>
<td>21.15 ± 0.53</td>
<td>25.79 ± 1.02</td>
</tr>
<tr>
<td>HMF content (mg/kg)</td>
<td>7.56 ± 0.45</td>
<td>2.21 ± 0.76</td>
<td>2.04 ± 0.56</td>
<td>10.33 ± 1.11</td>
</tr>
<tr>
<td>Phenolic content (µg/g)</td>
<td>665.52 ± 1.53</td>
<td>657.34 ± 1.15</td>
<td>620.34 ± 1.21</td>
<td>628.76 ± 1.38</td>
</tr>
<tr>
<td>DPPH radical scavenging activity (µg/g)</td>
<td>25.32 ± 1.38</td>
<td>23.89 ± 0.61</td>
<td>20.67 ± 1.01</td>
<td>31.45 ± 1.39</td>
</tr>
</tbody>
</table>

Note: Values represent mean and standard deviation (n = 3). Means with different superscripts in the same row are significantly different (p ≤ 0.05).

Acids into the medium during osmotic dehydration process. The lowest total acidity was found in sorbitol- and invert sugar-treated samples. The highest water loss in sorbitol treatment may enhance the diffusion of acids into the osmotic solution due to organic acids presented in fruit easily dissolve in water.

The water activity (a_w) is an intrinsic product characteristic that influences the microbial ecology of a sugar-rich product. It is defined as free moisture content in product. Both moisture content and a_w are highly important for the shelf life of osmo-dried cantaloupe during storage. No difference in moisture content was found among all treatments. The sucrose-treated sample had significantly higher a_w values. This likely reflects that invert sugar could form hydrogen bond with water and retain water in the final product. Thus, more bound water was found when the sugar alcohols and invert sugar were used as an osmotic solution [30].

The highest total sugar content was found in the case of sucrose- and invert sugar-treated samples. Lower total sugar content was observed in the case of sorbitol- and maltitol-treated samples. This result indicated that the use of sugar alcohol could reduce sugar content in the product, resulting in the reduction of calories. Higher reducing sugar content was found in the case of sucrose-treated sample compared to sugar alcohols-treated samples. This could be attributed to the hydrolysis of sucrose during drying process. The highest reducing sugar content was observed in the case of invert sugar-treated sample, resulting in the promotion of Maillard reaction. This result was in accordance with the highest browning intensity that was found in the case of invert sugar-treated sample. The reducing sugar content is an important parameter that affects the
properties of osmo-dried cantaloupe during storage since it can act as a substrate of Maillard reaction.

After drying process, the amount of vitamin C in all treatments was lower than fresh cantaloupes (51.22 mg per 100 g for fresh sample). This could be explained by a combination of two factors: leaching with water diffusion due to the high degree of vitamin C solubility in water and chemical degradation (enhanced by drying temperature). The lowest vitamin C content was observed in the case of sorbitol-treated sample. Result suggested that, increasing the water loss caused an increased leaching of vitamin C during the osmotic dehydration process [31].

HMF is a recognised indicator of quality deterioration, as a result of excessive heating in a wide range of foods containing carbohydrates. Its content is practically zero in fresh fruit. During drying process, the dehydration of carbohydrates, especially hexose, causes the formation of HMF. Moreover, the formation of HMF was induced by the Maillard reaction. HMF is used as an indicator of heat stress for sugar based foods because of its toxicological status. The highest HMF content was detected in the case of invert sugar-treated sample. Result suggested that, invert-sugar treated sample contained high reducing sugar content, resulting in the promotion of Maillard reaction. The lowest HMF content was detected in the case of sorbitol- and maltitol-treated samples. This probably is due to sorbitol and maltitol not able to participate in the Maillard reaction as mentioned previously.

Phenolic compounds are one of the most important groups of compounds in plant including cantaloupe [1]. The phenolic compounds of all osmo-dried cantaloupes were analyzed as shown in Table 2. The phenolic content of fresh cantaloupe was 1023 μg GAE/g sample. Different osmotic solutions induced loss of phenolic compounds by migration into the osmotic solution. The lowest phenolic compounds were found in the case of sorbitol-treated samples. This could be attributed to small phenolic molecules diffusing into the osmotic solution [31]. Increasing the water loss resulted in an increased leaching of solutes such as acids, water soluble vitamin and small phenolic molecules into the osmotic solution.

DPPH assay is one of the most widely used methods for screening the antioxidant activity of plant. The assay is based on the measurements of the antioxidants ability to scavenge the stable radical DPPH. DPPH is a stable nitrogen-centred free radical, which produces violet color. DPPH radicals react with suitable reducing agents, during which the electrons become paired off and the solution loses color stoichiometrically depending on the number of electrons taken up [32]. DPPH radical scavenging activity of osmo-dried cantaloupes was also investigated as presented in Table 2. The invert sugar-treated samples exhibited the highest DPPH radical scavenging activity. Components such as phenolic compounds and vitamin C might be responsible for its powerful antioxidant capacity. Moreover, the Maillard reaction has been associated with the formation of compounds with strong antioxidant activity. On the other hand, the lowest DPPH radical scavenging activity was observed in the case of sorbitol-treated sample because high leaching of soluble antioxidant components during osmotic dehydration process.

3.4 Effect of Different Osmotic Solutions on the Sensory Properties of Osmo-Dried Cantaloupe

The sensory evaluation of osmo-dried cantaloupe was shown in Table 3. Higher
mean score of color and texture was observed in the case of sugar alcohols-treated samples compared to the sucrose-treated samples. This was due to the use of sugar alcohols in the osmotic solution reduced brown color and hard texture of osmo-dried cantaloupe. The result of sensory evaluation was in agreement with the result of color and hardness. The sample treated with invert sugar showed lower mean score of color as compared to other samples as it possessed brown color. Thus, the use of sugar alcohol could improve the sensory quality of osmo-dried cantaloupe.

Table 3. Sensory evaluation of osmo-dried cantaloupe.

<table>
<thead>
<tr>
<th>Sensory attributes/Treatments</th>
<th>Sucrose</th>
<th>Maltitol</th>
<th>Sorbitol</th>
<th>Invert sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>6.70b</td>
<td>7.12a</td>
<td>7.05a</td>
<td>6.68b</td>
</tr>
<tr>
<td>Appearance</td>
<td>6.34a</td>
<td>6.52a</td>
<td>6.31a</td>
<td>6.79a</td>
</tr>
<tr>
<td>Texture</td>
<td>6.03b</td>
<td>7.05a</td>
<td>7.21a</td>
<td>6.79ab</td>
</tr>
<tr>
<td>Flavor</td>
<td>6.33a</td>
<td>6.68a</td>
<td>6.59b</td>
<td>6.56a</td>
</tr>
<tr>
<td>Overall</td>
<td>6.45b</td>
<td>7.04a</td>
<td>7.15a</td>
<td>6.35b</td>
</tr>
</tbody>
</table>

Note: Values represent mean and standard deviation (n=3). Means with different superscripts in the same row are significantly different (p ≤ 0.05).

4. CONCLUSIONS

The type of osmotic agents used during the osmotic dehydration process in the development of osmo-dried cantaloupe had significant effects on the mass transfer, physical, chemical and sensory properties of the finished product. Solid gain and water loss during osmotic dehydration were higher in sorbitol-treated samples compared to other osmotic agents. The use of sugar alcohol could reduce brown color, hardness, $a_w$, total sugar, reducing sugar and HMF content of the finished product. However, the loss of nutritional components such as vitamin C and phenolic compounds during osmotic dehydration process should be considered. The use of invert sugar could also reduce $a_w$ and retard crystallization of sugar, however more brown color was formed, hence decreasing the acceptability of the product. Thus, sugar alcohol could improve physical, chemical and sensory properties of osmo-dried cantaloupe compared to conventional osmotic agent such as sucrose. Further work is needed to study the combination of osmotic agents in the treatment on the characteristic of osmo-dried cantaloupe.

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REFERENCES


and water mobility, *Dry Technol.*, 2011; **29**: 527-535.


