Effect of Freezing and Thawing on the Quality of Durian (Durio zibethinus Murray) Pulp

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Summary
The effect of freezing, and iced and hot water thawing on the quality of durian pulp was investigated. Mature durian pulp was removed with seeds, vacuum-packed, and frozen at -20°C. Thawing in iced water (~0°C) and hot water (~90°C) was then applied and the quality of the pulp was assessed based on physicochemical properties (pH, moisture content, soluble solids concentration (SSC), color, sugar content (sucrose, glucose, and fructose), and organic acid content (succinic acid and citric acid)), texture and smell profile. Overall, the freezing and thawing conditions, particularly the hot water thawing, posed an effect to the moisture content, color, and smell profile of the durian pulp. A significant increase in the moisture content, as well as a decrease in the color brightness was observed. Furthermore, the hot water-thawing process also induced slight variation to the smell attribute and strength of the entirety of smell. Although the sugar content significantly decreased after freezing and thawing, it was only affected by the freezing process but not by the thawing conditions. No significant variations were noted in the pH, SSC, organic acids and texture of the frozen durian pulp.

Keywords: Freezing, Thawing, Durian, Texture profile analysis, Smell analysis, E-nose

1. Introduction

Durian (Durio zibethinus Murr.) is a native and highly priced fruit in Southeast Asia due to its seasonality, unique smell, taste and texture. Its production and export are dominated by Thailand, followed by Malaysia and Indonesia. On the average, the edible portion of the fruit is only 26% of its weight and the composition of the rind and seeds are 60% and 14%, respectively. It is rich in carbohydrate, calcium, phosphorous, thiamin, riboflavin, niacin, and ascorbic acid. Its unique smell (volatiles) comes largely from thiols or thioethers, esters and sulphides. Ripe pulp is usually eaten raw, right after opening the fruit or as a frozen commodity. It is also further processed to sweet delicacies such as jams, candies, tarts, or used as a flavoring ingredient in ice cream and other products.

Because of its seasonality, durian fruit processing is one of the means to absorb the excess supply during peak season and also to widen its market. Particularly, it is during this season of surplus yields that producers look to the possibility of freezing the durian pulp to preserve the excess supply and provide durian during off-seasons. Moreover, freezing contributes to the reduction of the bulk nature of the fruit and concealing its unique but strong and aroma during shipping and distribution.

Frozen durian is achieved through individual quick freezing (IQF) technology and vacuum packing. In the Philippines, conventional freezing at -18 to -20°C using chest freezers is practiced by small-scale entrepreneurs. While the vacuum packing and blast freezing at -40°C and storage at -20°C is applied by large-scale manufacturers. The current packaging of frozen durian uses generic microwavable plastic and wax paper to individually wrap durian pulp for freezing. The frozen products are supplied in the local market for direct consumption and for further processing of durian processors.

Freezing is well known for keeping the quality of foods at a longer period, however, there are still quality concerns associated with it depending on the type and characteristics of the commodity. Studies have been reported for the quality changes related to the chemical and physicochemical properties, texture, color, and volatile profiles in frozen storage of fruits such as apples, mango, guava, passion fruit, peach, dates, and many others. On the other hand, thawing process is also important as it may further affect the food quality after freezing. Such in the study with strawberry frozen at -20°C and thawed at 4°C, which is a common practice, caused most pronounced pigment and ascorbic acid losses.

In durian, researches are focused on the fresh and minimally processed fruit. Limited information is provided for the quality changes in the frozen and thawed durian. Hence, this study aims to investigate the effect of freezing and thawing particularly on the physicochemical, textural and...
smell properties of durian pulp towards establishing a thawing protocol for frozen durian. Preliminarily, the extreme thawing conditions are tested in this study. The iced water thawing (with temperature of approx. 0°C), representing the slow process and hot water thawing (with temperature of approx. 92°C) for the fast process.

2. Materials and Methods

2.1 Durian samples and chemical reagents
Durian fruits were procured from an online shop that imports the fruit from Thailand, and stored in cool (approx. 20–22°C) area until the maturity is reached. The maturity was determined by the appearance of crevices in the fruit rind.

Pure grade chemical reagents such as the standards for sugar (sucrose, glucose, and fructose) and organic acid (citric acid and succinic acid) analysis, methanol, and sulfuric acid were purchased from Wako Pure Chemical Industries, Ltd., Osaka.

2.2 Freezing and thawing
The durian pulp was vacuum packed in a polyamide nylon/polyethylene bag, and conventionally frozen at -20°C inside a home freezer (GS-3120HC, Freezer Co., Ltd., Tokyo) for one or two weeks. The frozen samples were thawed using hot water (with temperature of approx. 92°C) or iced water (with temperature of approx. 0°C) until the internal temperature reached around 10–15°C (about 3 min.) and -2–0°C (about 30 min.), respectively.

2.3 Physicochemical characteristics analysis

2.3.1 Moisture content
Five g of durian pulp was dried in an oven set at 105°C for 3 h and equilibrated at room temperature inside a desiccator. The process was repeated until a constant weight is obtained. The final weight was used to calculate the moisture content.

2.3.2 pH
Ten g of durian pulp was homogenized (Poly Tron 2100, Kinematica, Switzerland) with 100 ml distilled water for 2-3 min and subjected to pH determination using a compact pH meter (LAQUAtwin, Horiba Ltd., Kyoto).

2.3.3 SSC
One part of durian pulp was blended with 3 parts of water and filtered using No.2 Whatman filter paper. The soluble solids content (SSC) of the filtrate was determined by a pocket refractometer (Atago, Tokyo) and the reading was multiplied by 3 to give SSC (%) at 20°C.

2.3.4 Color
The surface color of the durian pulp was measured through a ZE 2000 Color Meter (Nippon Denshoku Industries Co., Ltd, Tokyo) in L*, a* and b* mode. The numerical values of a* and b* were converted into hue angle (H° = tan⁻¹ b*/a*).

2.3.5 Sugar content
Ten g of durian pulp was blended with 100 ml of 85% methanol. In a steam bath, the mixture was heated for 30 min and filtered. The residue was re-extracted twice with 75 ml of 85% methanol. The collected supernatant was evaporated using a rotary evaporator to remove the extraction solvent, and made up to 10 ml with deionized water. The extracted sample was filtered through 0.22 µm filter (FILSTAR Hydrophilic Nylon Syringe Filters, Starlab Scientific Co., Ltd, Shaanxi Province, China) and 50 µL of the supernatant was injected to HPLC system with a refractive index detector (RID-10A, Shimadzu, Kyoto) at 1.0 ml min⁻¹. The mobile phase was 5 mM aq H₂SO₄ and analytical column was Shodex SUGAR SH-G (6 mm ID x 50 mm) (Showa Denko K.K., Tokyo) with column guard SH1821 (8.0 mm ID x 300 mm) (Showa Denko K.K., Tokyo). Identification and quantification were performed by comparison of sample peaks with those of external standards' curve.

2.3.6 Organic acid content
Five g of durian pulp was blended with 100 ml deionized water and centrifuged (H-201FR, Kokusan Co. Ltd., Tokyo) at 4°C, 12,000 g for 20 min. The supernatant was filtered through 0.22 µm filter and 50 µL of the supernatant was injected to HPLC system attached with a UV-Vis detector (SPD-10A, Shimadzu, Kyoto) at 210 nm and 1.0 ml min⁻¹ flow rate. The same mobile phase and columns with the sugar analysis were used.

2.4 Texture analysis
The Texture Profile Analysis of the durian pulp was determined by a creep meter (Rheoner II, RE 2-3305B, Yamaden Co. Ltd., Tokyo) under the texture examination mode at 200 N load cell, 1 mm s⁻¹ rate of measurement, 10 times amplitude and using 12 mm (in diameter) plunger. The pulp was placed in a stainless container with 15 mm height and 40 mm diameter, and the hardness, cohesiveness and adhesiveness were measured.

2.5 Smell analysis
The smell/odor of the samples was analyzed using e-nose (electronic nose) device (FF-2A Fragrance and Flavor Analyzer, Shimadzu, Kyoto). Two point five g of durian pulp was contained in 20 ml autosampler glass vial and crimp sealed. The vial was then loaded in the tray and automatically transferred in the agitator or extraction control apparatus (30°C) attached to the sampling chamber of the e-nose. The headspace was extracted and pumped into the sensor chamber at injection volume.
of 2,500 µL and injector temperature of 110°C. The sample was measured in 3 trials.

An e-nose is a device that evaluates and expresses the quality and strength of the entirety of smell of the samples. It works through a simulated organoleptic analysis, with its ability to detect and describe the similarities (by similarity index) of nine smell components (hydrogen sulfide, sulfurs, ammonia, amines, organic acids, aldehydes, esters, aromatics, and hydrocarbons) related to the smell of the samples (in absolute value). In this study, the standard gases used were hydrogen sulfide (H2S), dimethyl disulfide (C2H6S2), ammonia (NH3), trimethylamine (C3H7N), propionic acid (C3H6O2), butylaldehyde (C4H8O), butylacetate, C6H12O2), toluene (C7H8), and heptane (C7H16). Meanwhile, the strength of the smell is represented by an odor index equivalent value that is correlated to the concentration of the smell10,11). The device also measures this value.

Radar chart of the smell similarity index and analogue value of the odor index plot were constructed to distinguish the similarity and strength of the smell of the fresh and frozen-thawed durian pulp. The analysis of the data was performed through the ASmell2 software, built-in to the device.

2.6 Statistical analysis

Mean values for the fresh and frozen thawed (iced and hot water) durian samples were statistically compared through ANOVA followed by Tukey analysis for further test of significance.

3. Results and Discussion

3.1 pH, moisture content, and SSC

The effect of freezing and different thawing conditions on the physicochemical properties of durian pulp is presented in Table 1. The values obtained are within the reported values in the references for fresh durian, although variations can be attributed to the variety and maturity of the fruit. Some Malaysian durian varieties have a pH range of 6.8-7.612,13). Meanwhile, Philippine durian varieties have moisture content values of 62 - 84% depending on the period of harvest 14). For Thailand varieties, 14% (immature) to 24% (mature) SSC values were reported15).

As shown in Table 1, a significant change was only observed in the moisture content of the pulp particularly after freezing and thawing using hot water (FT_Hot water). In this condition, the moisture content significantly increased after the process. On the other hand, the moisture in iced water thawed sample (FT_Iced water) did not significantly change with that of the fresh sample. Previous studies revealed that the effect of freezing and thawing on the moisture content depends on the type of food materials. It is either decreased or maintained after freezing and thawing. Such in the case for apples and mangoes, wherein the water content significantly decreased and did not vary, respectively, after the freezing/thawing process16).

Table 1 Physicochemical properties of fresh and frozen-thawed (FT) durian pulp (N= 3-6)

<table>
<thead>
<tr>
<th>Physicochemical property</th>
<th>Sample condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>64.83±0.89*a</td>
</tr>
<tr>
<td>pH</td>
<td>6.61±0.16</td>
</tr>
<tr>
<td>SSC (%)</td>
<td>24.42±1.35</td>
</tr>
</tbody>
</table>

The moisture loss can be associated in the loss of the water holding capacity of the food material in effect to the disruption of the cell wall after the formation of ice crystals during freezing. After thawing, moisture can leak out of the cells resulting in drip loss. Different types of fruit have different levels of drip loss such that apple and mango demonstrated the highest and lowest drip loss, respectively after freezing and thawing16). However, the reverse was noted in the present study as shown by the increase in moisture content following hot water thawing. This variation might be due to the different levels of maturity of the samples upon processing, accounting to the inconsistency of the indicator for maturity (by the appearance of crevices in the fruit rind). On the other hand, the discordance between the observed moisture contents of thawed durian pulp in iced water and in hot water can be partly explained by their different thawing rates as the degree of thawing is directly correlated to the increase in temperature.

3.2 Color

Table 2 Color measurements of fresh and frozen-thawed (FT) durian pulp (N = 6)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample condition</th>
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<tbody>
<tr>
<td></td>
<td>Fresh</td>
</tr>
<tr>
<td>L*</td>
<td>82.35±1.99**</td>
</tr>
<tr>
<td>a*</td>
<td>-1.04±0.47**</td>
</tr>
<tr>
<td>b*</td>
<td>37.59±3.64r</td>
</tr>
<tr>
<td>H°</td>
<td>88.43±0.67ab</td>
</tr>
</tbody>
</table>

For the color of the durian pulp, as shown in Table 2, changes are prominent in hot water thawing
condition than in iced water thawing. In general, the brightness (L*) has significantly reduced after freezing, regardless of the thawing method. Furthermore, the green (a*) and yellow (b*) hues were decreased following the hot water thawing. Although no significant difference in the overall hue angle (H°) was found between the hot water thawed and fresh samples, the difference in H° between the iced and hot water thawed samples was statistically significant. These outcomes can be accounted to two possible reactions that must have taken place in the process: enzymatic activity and degradation of heat-sensitive components of the fruit.

Phytochemicals, such as carotenoid, polyphenol and anthocyanin, provide fruits and vegetables their color [17]. Polyphenols are known to be more sensitive to enzymatic browning reactions. After freezing, cell decompartmentalized, permitting reactions between enzyme activities and their corresponding substrates, such in the case for apple and mango freezing and thawing wherein more pronounced color change (to brown) was observed for apples than for mangoes [5]. In frozen strawberries, polyphenoloxidases were mainly made responsible for anthocyanin degradation in the fruit. With this assumption, considerable pigment losses were reported after freezing and thawing of strawberries [18]. It can be assumed that these reactions might have also occurred after freezing and thawing of durian pulp since it has been reported that the fruit contains the substantial amount of phytochemicals, especially the polyphenols and anthocyanins [19,20].

Meanwhile, the changes in the color can be also associated with heat sensitive components in the fruit. Wherein the extent of effect depends on the heat sensitivity of the product component [21]. β-carotene is the main contributor to the yellow color of durian pulp [22]. In a study on the thermal processing of tomato, a significant decreased in its β-carotene content after 2 min boiling was reported [23].

3.3 Sugars and organic acids

Table 3 and 4 present the changes in the organic acid and sugar content of the fresh and frozen-thawed durian pulp, respectively. In the data, freezing and thawing did not affect the organic acids analyzed. However, the sugar content was generally affected by freezing but not by the thawing method. After freezing, the sugars, particularly sucrose and glucose, were significantly reduced. These may have dissolved in the liquid that exuded from the pulp (drip). As the cell wall is degraded due to ice crystal formation after freezing, this facilitates extraction of soluble solid extraction (especially sugars) from cells [4]. Moreover, freezing and high temperature thawing caused the hydrolysis of sucrose [18]. To avoid sugar loss in further processing of the frozen durian, it is suggested to include the drip during processing.

<table>
<thead>
<tr>
<th>Organic acid (g kg⁻¹)</th>
<th>Sample condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh</td>
</tr>
<tr>
<td>Citric</td>
<td>4.12±2.03</td>
</tr>
<tr>
<td>Succinic</td>
<td>0.07±0.00</td>
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<table>
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<tr>
<th>Sugar (g kg⁻¹)</th>
<th>Sample condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh</td>
</tr>
<tr>
<td>Sucrose</td>
<td>46.34 ± 0.11a</td>
</tr>
<tr>
<td>Glucose</td>
<td>12.00 ± 0.35a</td>
</tr>
<tr>
<td>Fructose</td>
<td>9.01 ± 3.02a</td>
</tr>
</tbody>
</table>

means in row with different letters are significantly different at P < 0.01

3.4 Texture

In Table 5, it can be noted that freezing and thawing did not significantly affect the texture of durian pulp based on the parameters tested. This result is in contrast to reports that generally, freezing and thawing caused reduction in the texture (firmness) of fruits due to the damaged cell structure and colloidal systems after the formation of ice crystals. The maturity of the durian sample can be the reason for the slight variation in the texture profile. It has been reported that variety and maturity of fruits minimized the effect of freezing in its textural properties. A higher maturity reduced the degradation observed on firmness following freezing. Such in the frozen apple of the same variety, the ripe exhibited firmness degradation about two times lower than that of the unripe [7].

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sample condition</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Fresh</td>
</tr>
<tr>
<td>Hardness (N)</td>
<td>0.89±0.33</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>0.24±0.26</td>
</tr>
<tr>
<td>Adhesiveness</td>
<td>339.22±291.1</td>
</tr>
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</table>

3.5 Smell analysis

To qualitatively assess the effect of freezing and different thawing conditions to the smell quality of the durian pulp, a radar chart on the similarity index...
of smell was constructed (Fig.1). The chart revealed the slight variations in the smell quality of the fresh and frozen-thawed samples. Particularly, in hot water thawing, the variations were observed in the aldehyde, organic acid, and hydrocarbon components of the pulp, although they were not statistically significant.

Moreover, during sample preparation, stronger smell was qualitatively observed after thawing the frozen samples compared to the fresh samples. In this connection, it can be inferred in Fig.2 that the smell strength of the durian pulp slightly increased after hot water thawing. The difference can be attributed to the disruption of the cell structure of the fruit during freezing causing the release of its volatile components. The application of heat during thawing could also have contributed to the faster diffusion of volatile compounds from the fruit.

In studies related to the analysis of the volatile components of durian, mostly esters, acids, and sulfur containing compounds were detected. It is thus suggested to conduct the aroma profiling of fresh and frozen-thawed durian by other analytical methods such as gas chromatography-mass spectrometry (GC-MS) to verify and identify the specific compounds that altered during processing.

4. Conclusion

The effect of freezing and different thawing conditions on the physicochemical, textural, and aromatic attributes of durian was evident in this study. Overall, the freeze-thawing conditions have a significant impact on the moisture content, color, sugar content, and aroma profile of the durian pulp. The moisture content of the pulp increased while the brightness of the pulp color decreased significantly after hot water thawing. However, it is also necessary to consider the effect of maturity of the fruit on the observed change in the moisture content of the samples. Meanwhile, for the organic acid and sugar contents, generally, the sugar content was affected by the freezing process but not by the thawing conditions. The sugar content was significantly decreased after freezing and thawing. Furthermore, the smell profile and strength of the frozen and thawed durian pulp is generally affected by hot water thawing according to the radar plot of smell similarity index and odor index plot, respectively. No significant variations were noted in the pH, SSC, organic acids and texture of the durian pulp after freezing and thawing. With these, the study is worthy of further investigation to provide relevant basic knowledge on the quality changes of durian after freezing and thawing. Other thawing conditions in between iced and hot water can be explored to determine the condition under which the quality variations occur. In addition, literatures reported that variety and maturity could cause variation on the effect of freezing in the fruit, thus it would be also an interesting area for further study of durian. Lastly, correlation of the quality changes to consumer sensory evaluation would also be relevant to the frozen durian industry.

5. Acknowledgment

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