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Development of Freeze-Dried Coconut Drink and Its Nutrient Content, Sensory Profile, and Shelf Life

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ABSTRACT
This study aimed to determine the nutrient content, sensory profile, and shelf life of powdered coconut drink processed with freeze-drying method. The drink was made from a mixture of young coconut water and young coconut meat from freshly harvested fruit. The freeze-dried powdered coconut drink has high Mg and Fe but low Na content. The amino acid profile was dominated by lysine, leucine, valine, and arginine, while fatty acid profile contained mostly lauric, myristic, and oleic acids. The development of powdered coconut drink through freeze-drying showed that the process could maintain its sensory characteristics with a slight reduction in sweetness and loss of fermented aroma. It also could prolong the shelf life of the product to 59, 44, and 30 days at 25°C, 35°C, and 45°C, respectively. In conclusion, powdered coconut drink had nutritional content and sensory characteristics not significantly different to fresh products while having longer shelf life.

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Introduction

*Cocos nucifera* (L.) or coconut is an important agricultural commodity in Indonesia. Coconut water is high in antioxidants (Santos et al., 2013) and high in electrolytes, making it ideal for rehydration and supporting exercise performance (Kalman, Feldman, Krieger, & Bloomer, 2012). In addition, coconut water is also beneficial for preventing and lowering high blood pressure (Bhagya, Prema, & Rajamohan, 2012) due to its potassium (K) content and L-arginine amino acid. Moreover, the combination of L-arginine and its antioxidants can function as an antidiabetic agent (Preetha, Girja Devi, & Rajamohan, 2013). Therefore, the demand for coconut water continues to increase.

Fresh coconut water is a perishable food that is not easy to store, losing most of its nutritional benefits when exposed to air and hot temperatures. Therefore, various processing technologies are often carried out. However, the high-temperature process can damage the nutritional content and also change the taste (Tan, Cheng, Bhat, Rusul, & Easa, 2014). The freeze-drying process does not require high temperatures so that it is possible to obtain dry materials while maintaining the properties of the raw materials. The freeze-drying method maintains the quality of heat-sensitive materials such as phenolic acid compounds (Geetha, Bhavana, Chetana, Gopala, & G, 2016), nutrients (Boonnumma, Chaisawadi, & Suwanyuen, 2014), and sensory characteristics of samples such as the aroma (Nasution, Jirapakkul, & Lorjaroenphon, 2018). Previous studies have shown that powdered coconut water obtained using the freeze-drying process has similar nutrients and taste compared to fresh coconut water (Boonnumma et al., 2014; Bridgemohan & Bridgemohan, 2016). Additionally, the freeze-dried powder is more stable during handling and storage due to its low moisture content (Zafisah et al., 2018), and the process has been reported to be able to retain the aroma and taste of the sample. Therefore, it has become a popular method for food preservation (Shukla, 2011).

Young coconut meat is used as an added value to the product, which functions as a natural filler in the development of coconut powder drink by a freeze-drying process. The aluminous endosperm or coconut meat of young coconut is soft, edible, white, and jelly-like. The meat has a sweet taste and relatively high in minerals such as iron, zinc, and phosphorus (Silva & Bamunuarachchi, 2009). Considering the health benefits of coconut water and the high mineral content of young coconut meat, it is necessary to develop a functional drink made from coconut water and coconut meat. Furthermore, the freeze-drying process was chosen for this development to maximize its health benefits and preserve the natural sensory profile. This study aims to analyze the nutrient content, sensory profile, and shelf life of powdered coconut drink processed by freeze-drying method.
Materials and methods

Materials

Hybrid coconuts with a maturity level of about 6 months were selected from PT Perkebunan Nusantara (PTPN) VIII, Citepus Village, Pelabuhan Ratu Sub-district, Sukabumi District, West Java Province, Indonesia. Coconut varieties and degrees of maturity were selected based on previous research showing that they had better characteristics and were significantly higher in fat, crude fiber, protein, pH, viscosity, color, and texture acceptability, compared to other varieties and immature coconuts (Azra, Setiawan, Nasution, & Sulaeman, 2021). All chemical reagents used for the analysis were of analytical grade. Fresh coconut drink (FCD) and powdered coconut drink (PCD) were both analyzed for their nutritional content and sensory profile for comparison.

Development of coconut drink

The young coconut water and coconut meat from the fresh fruits were homogenized using a waring blender at room temperature with a ratio of 2:1 to produce FCD. Afterward, the mixture was poured into a 500 mL erlenmeyer flask (Pyrex), transferred to a freezer set at −20°C (RSA, Indonesia), and frozen at −20°C for 24 hr. The frozen coconut drink was then freeze-dried in a Vacuum Freeze Dryer (BUCHI, Lyovapor™ L-200) at ≤-50°C (Rodgers & Young, 2008) under vacuum pressure below 0.1 mbar for 90 ± 2 hr. Next, the dried coconut drink was ground into powder form, stored in aluminum foil and placed in a desiccator at −20°C to protect the sample from air and sun damage until further analysis.

Mineral content

The mineral contents (Ca, Mg, Na, Fe, and Zn) were determined using wet ashing method (AOAC, 2005). The mineral analysis was done using the atomic absorption spectrometer (Agilent Technologies, 200 Series AA) and air-acetylene flame.

Amino acid content

The amino acid profile was analyzed using high-performance liquid chromatography (HPLC) with a fluorescence detector. The sample containing 6 mg of protein was hydrolyzed in 2 mL of 6 mol/L HCl and nitrogen gas at 110°C for 24 h and further derivatized with potassium borate buffer and o-phthaldehyde (OPA) reagent. The derivatized samples were analyzed for amino acid profiling using HPLC (Shimadzu) with an automatic sampler and left until the
separation of all amino acids was completed in about 25 min. Afterward, the amino acid content was calculated in relation to the standards, which was also used to calculate the amino acid score (AAS) (WHO/FAO/UNU, 2007).

**Fatty acid content**

The fatty acid analysis was carried out using hydrolysis and esterification for sample preparation (AOAC, 2005). The liquid phase was separated, and the organic phase was injected into gas chromatography (GC-2010 Plus). The condition of the instrument was regulated using a capillary cyanopropyl methyl sil column with a split ratio and injection volume of 1:80 and 1 µl, respectively. Afterward, over 1 µl of the standard mixture of fatty acid methyl ester (FAME) was injected and when all peaks were out, 1 µl of the prepared sample was injected. Furthermore, the retention times and peaks of each component were measured. The retention time was compared to the standard to obtain information about the types of components in the sample.

**Descriptive sensory evaluation**

Twelve women, between the ages of 24 and 27 years, were selected as panelists and participated in the descriptive sensory evaluation. All panelists had provided their consent after receiving information regarding the study. The number of panelists was based on recommendations from previous studies, which were around eight (Villarino, Dy, & Lizada, 2007) and generally six-twelve panelists (Drake, 2007). They were recruited based on their previous experience in participating in sensory tests and accustomed to consuming coconut water. In addition, the panels were screened beforehand to determine their sensory sensitivity. Qualified panelists were then trained further in order to maintain the accuracy of their sensory attribute measurements. The sample was evaluated using descriptive sensory analysis with a consensus method with two replications for each sensory attribute (Chambers, 2018).

The panelist selection was carried out before the descriptive sensory analysis began with the introduction of several taste and aroma descriptors. The final list of descriptors and intensity for aroma standard were sweet (10 mL sucrose solution 7% = 3), coconut-like (10 g steamed mature coconut meat for 5 min = 14), fermented (10 mL solution of fermented black rice 1% = 5), nutty (Coconut shell with second layer kernel = 2), rancid (10 mL roasted coconut oil for 5 min = 3), and creamy (10 mL coconut milk with water-to-meat ratio of 2:1 = 12) (Nasution et al., 2018; Villarino et al., 2007). Meanwhile, the final list of descriptors and intensity for the taste standard were sweet (sucrose solution 2% = 6), salty (NaCl solution 0.2% = 5), sour (citric acid solution
0.03% = 7), coconut-like (steamed mature coconut flesh for 5 min = 14), creamy (10 mL coconut milk with water-to-meat ratio of 1.5:1 = 13), and bitter (green tea solution 0.25% = 5) (Assa, Prades, Konan, Nemlin, & Konan, 2013).

Each panelist assessed the reference intensity on a scale of 0 to 15 on all descriptors. Meanwhile, the panel was calibrated until consensus was reached. The rehydrated PCD was obtained by dissolving the powdered form with mineral water at room temperature with a ratio of 1:10. A liquid sample with the viscosity of 268.00 ± 2.00 and the total soluble solid of 6.00 ± 0.00 was produced, similar to freeze-dried coconut powder in the previous study (Azra et al., 2021). A total of 10 mL of the sample was transferred to a closed plastic container, given a 3 random digit number code, and kept at room temperature. The panelists were given 30 s delay between samples and standards. Afterward, they evaluated the samples using a form with 15 cm scale lines in individual booths.

**Shelf life study**

The PCD samples were stored in aluminum foil with a zipper-lock (70 × 100 mm, 10–15 g capacity). Maximum air was removed from the pouch to minimize the rate of water vapor transmission to the sample, and it was placed in an oven operating at 25°C, 35°C, and 45°C for up to 4 weeks. It was then analyzed for water activity and browning index for 0, 7, 14, 21, and 28 days of storage with the Arrhenius approach (Robertson, 2010). The whole experiment was carried out in triplicate.

**Statistical analysis**

The data were reported as the mean ± standard deviation of three replicates. Independent t-tests were carried out using the SPSS 16.0 software, with the significance level set at p < 0.05.

**Results and discussion**

**Nutrient content of coconut drink**

Previous studies have found that the proximate composition, dietary fiber, pH value and titratable acidity, physical characteristics, and sensory acceptance of PCD are similar to the fresh ones (Azra, Setiawan, Nasution, & Sulaeman, 2020; Azra et al., 2021). In this study, it was found that the freeze-drying method also did not cause significant changes in terms of mineral content, amino acid profile, and fatty acid profile compared to the fresh sample as shown in Tables 1, 2, and 3.
Mineral content of coconut drink

Both coconut drinks, fresh (FCD) and powdered (PCD), were rich in various minerals. Table 1 shows that there was no significant difference (p > .05) for almost all mineral content between FCD and PCD. This indicates that the processing of PCD by freeze-drying could retain some minerals. Furthermore, the stability of the mineral content in the PCD in this study was similar to the results of previous studies regarding coconut water (Boonnumma et al., 2014; Bridgemohan & Bridgemohan, 2016). It had high in Mg (215.60 ± 13.00 mg/100 g or 72.11% label reference/100 g) and Fe (4.20 ± 0.50 mg/100 g or 35.29% label reference/100 g), but low in Na (29.20 ± 8.30 mg/100 g or 0.29 g/kg). Therefore, the product can be claimed to be high in Mg and Fe (>30% label reference/100 g) as well as low in Na (<0.40 g/kg) based on the regulation from The National Agency of Drug and Food Control Republic of Indonesia (2016). This suggests that the drink may benefit individuals with obesity and diabetes (Vaskonen, 2003).

The main minerals in FCD from the highest to the lowest value were Mg > K > Ca > Na > Fe while in the PCD were Mg > Ca > Na > Fe > K. This finding is different from that of kopyor coconut water (Santoso, Kubo, Ota, Tadokoro, & Maekawa, 1996), which had K as the highest mineral, followed by Ca, Mg, P, and Na. The mineral content of coconut drinks in this study was higher compared to that of coconut haustorium, which contains K (1450.00 mg/kg), Mg (1040.00 mg/kg), Ca (339.00 mg/kg), and Fe (25.30 mg/kg) (Manivannan et al., 2018), and hybrid variety coconut water, which contains Mg (24.30 mg/kg), K (1504.00 mg/kg), and Na (23.82 mg/kg) (Kailaku et al., 2015). Since there are no reports of similar products, the product that is closest to PCD in this study is the mineral content of coconut milk powder with Ca and Fe content of 5 mg/100 g and 0.67 g/100 g, respectively (USDA, 2021).

Amino acid content of coconut drink

The amino acid analysis showed that there was no significant difference (p > .05) in all amino acid content (mg/g sample) between FCD and PCD (Table 2). These results proved the superiority of the freeze-drying process, which was able to maintain the amino acid content of the sample. A previous study also showed that the freeze-drying method was able to maintain amino acid profile of milk product (Ibrahim & Khalifa, 2015).

### Table 1. Mineral content of coconut drink (dry basis).

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Fresh</th>
<th>Powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe (mg/100 g)</td>
<td>6.19 ± 1.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.15 ± 0.48&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ca (mg/100 g)</td>
<td>90.07 ± 11.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100.97 ± 2.03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mg (mg/100 g)</td>
<td>2,609.81 ± 817.95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>215.64 ± 12.99&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>K (mg/100 g)</td>
<td>225.03 ± 29.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.28 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Na (mg/100 g)</td>
<td>28.04 ± 6.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>29.16 ± 8.27&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values followed by similar superscripts within the same line are not significantly different (p > 0.05).
### Table 2. Amino acid content of coconut drink (dry basis).

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>g/100 g sample</th>
<th>mg/g protein</th>
<th>mg/g protein</th>
<th>AAS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh</td>
<td>Powder</td>
<td>Fresh</td>
<td>Powder</td>
</tr>
<tr>
<td>Essential</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threonine</td>
<td>0.36 ± 0.12a</td>
<td>0.26 ± 0.09a</td>
<td>45.78 ± 14.88</td>
<td>25.29 ± 9.09</td>
</tr>
<tr>
<td>Valine</td>
<td>0.60 ± 0.21a</td>
<td>0.44 ± 0.17a</td>
<td>75.84 ± 26.19</td>
<td>43.35 ± 16.93</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.06 ± 0.02a</td>
<td>0.09 ± 0.04a</td>
<td>7.38 ± 3.03</td>
<td>9.75 ± 3.75</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>0.48 ± 0.24a</td>
<td>0.28 ± 0.11a</td>
<td>60.14 ± 29.79</td>
<td>27.82 ± 10.69</td>
</tr>
<tr>
<td>Leucine</td>
<td>0.92 ± 0.52a</td>
<td>0.49 ± 0.19a</td>
<td>115.31 ± 65.13</td>
<td>49.13 ± 18.53</td>
</tr>
<tr>
<td>Histidine</td>
<td>0.29 ± 0.08a</td>
<td>0.20 ± 0.06a</td>
<td>36.74 ± 10.02</td>
<td>19.87 ± 6.25</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.75 ± 0.09a</td>
<td>0.56 ± 0.15a</td>
<td>93.98 ± 11.83</td>
<td>55.28 ± 15.05</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.43 ± 0.13a</td>
<td>0.34 ± 0.13a</td>
<td>54.44 ± 15.77</td>
<td>33.60 ± 13.18</td>
</tr>
<tr>
<td>Total EAA</td>
<td>3.89 ± 1.40</td>
<td>2.66 ± 0.94</td>
<td>489.64 ± 176.68</td>
<td>264.12 ± 93.51</td>
</tr>
<tr>
<td>Non essential</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>0.98 ± 0.21a</td>
<td>0.74 ± 0.31a</td>
<td>122.80 ± 26.49</td>
<td>73.34 ± 30.35</td>
</tr>
<tr>
<td>Serine</td>
<td>0.46 ± 0.10a</td>
<td>0.36 ± 0.14a</td>
<td>57.36 ± 13.54</td>
<td>36.13 ± 13.81</td>
</tr>
<tr>
<td>Glutamate</td>
<td>1.84 ± 0.32a</td>
<td>1.70 ± 0.66a</td>
<td>230.89 ± 40.37</td>
<td>168.73 ± 65.31</td>
</tr>
<tr>
<td>Glycine</td>
<td>0.42 ± 0.18a</td>
<td>0.32 ± 0.12a</td>
<td>52.94 ± 22.84</td>
<td>31.43 ± 12.21</td>
</tr>
<tr>
<td>Alanine</td>
<td>0.89 ± 0.25a</td>
<td>0.84 ± 0.34a</td>
<td>111.42 ± 31.51</td>
<td>82.74 ± 33.48</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.22 ± 0.15a</td>
<td>0.56 ± 0.15a</td>
<td>28.18 ± 19.44</td>
<td>12.64 ± 4.10</td>
</tr>
<tr>
<td>Arginine</td>
<td>2.39 ± 0.29a</td>
<td>1.74 ± 0.37a</td>
<td>300.52 ± 36.67</td>
<td>171.98 ± 37.14</td>
</tr>
<tr>
<td>Total NEAA</td>
<td>7.20 ± 1.52</td>
<td>5.62 ± 1.98</td>
<td>904.15 ± 190.89</td>
<td>577.02 ± 196.43</td>
</tr>
<tr>
<td>Total amino acid</td>
<td>11.10 ± 2.14a</td>
<td>8.48 ± 2.92a</td>
<td>1393.78 ± 269.26</td>
<td>840.41 ± 288.85</td>
</tr>
</tbody>
</table>

Values followed by similar superscripts within the same line are not significantly different (p > 0.05).
Source: *WHO/FAO/UNU (2007).*
Table 3. Fatty acid content of coconut drink (dry basis).

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Sample (g/kg)</th>
<th>In total fatty acid (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh</td>
<td>Powder</td>
</tr>
<tr>
<td><strong>Saturated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caproic acid, C6:0</td>
<td>0.42 ± 0.17a</td>
<td>0.68 ± 0.11a</td>
</tr>
<tr>
<td>Caprylic acid, C8:0</td>
<td>6.87 ± 2.72a</td>
<td>10.19 ± 1.28a</td>
</tr>
<tr>
<td>Capric acid, C10:0</td>
<td>5.49 ± 2.45a</td>
<td>7.47 ± 0.81a</td>
</tr>
<tr>
<td>Undecanoic acid, C11:0</td>
<td>0.03 ± 0.01a</td>
<td>0.06 ± 0.07a</td>
</tr>
<tr>
<td>Lauric acid, C12:0</td>
<td>61.28 ± 28.70a</td>
<td>80.37 ± 7.78a</td>
</tr>
<tr>
<td>Tridecanoic acid, C13:0</td>
<td>0.04 ± 0.02a</td>
<td>0.05 ± 0.01a</td>
</tr>
<tr>
<td>Myristic acid, C14:0</td>
<td>27.11 ± 13.73a</td>
<td>34.56 ± 4.89a</td>
</tr>
<tr>
<td>Palmitic acid, C16:0</td>
<td>11.11 ± 5.46a</td>
<td>17.60 ± 1.98a</td>
</tr>
<tr>
<td>Heptadecanoic acid, C17:0</td>
<td>0.00 ± 0.00a</td>
<td>0.03 ± 0.02a</td>
</tr>
<tr>
<td>Searic acid, C18:0</td>
<td>2.57 ± 1.34a</td>
<td>4.57 ± 0.69a</td>
</tr>
<tr>
<td>Arachidic acid, C20:0</td>
<td>0.03 ± 0.02a</td>
<td>0.13 ± 0.03b</td>
</tr>
<tr>
<td>Behenic acid, C22:0</td>
<td>0.00 ± 0.00a</td>
<td>0.04 ± 0.01b</td>
</tr>
<tr>
<td>Lignoceric acid, C24:0</td>
<td>0.06 ± 0.02a</td>
<td>0.06 ± 0.01a</td>
</tr>
<tr>
<td>Subtotal</td>
<td>115.05 ± 54.55a</td>
<td>155.84 ± 17.75a</td>
</tr>
<tr>
<td><strong>Unsaturated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palmitoleic acid, C16:1</td>
<td>0.04 ± 0.01a</td>
<td>0.19 ± 0.17a</td>
</tr>
<tr>
<td>Oleic acid, C18:1n9c</td>
<td>8.88 ± 3.66a</td>
<td>16.16 ± 4.14a</td>
</tr>
<tr>
<td>Linoleic acid, C18:2n6c</td>
<td>1.70 ± 0.76a</td>
<td>2.41 ± 0.51a</td>
</tr>
<tr>
<td>Cis-11-Eicosenoic acid, C20:1</td>
<td>0.02 ± 0.01a</td>
<td>0.10 ± 0.07a</td>
</tr>
<tr>
<td>Subtotal</td>
<td>10.63 ± 4.43a</td>
<td>18.88 ± 4.90a</td>
</tr>
<tr>
<td>Total</td>
<td>125.67 ± 5,896.22a</td>
<td>174.71 ± 13.795a</td>
</tr>
</tbody>
</table>

Values followed by similar superscripts within the same line are not significantly different (p > 0.05).

Meanwhile, heat treatment showed a detrimental effect on coconut water’s amino acid content by lowering the arginine content (Nasution, Jirapakkul, Tongkhao, & Chanput, 2020). The L-arginine, alanine, leucine, lysine, and glutamate amino acids were present in both the FCD and PCD containing coconut meat. These amino acid contents were higher compared to young coconut water, which contains 1.18 g/kg L-arginine, 0.37 g/kg alanine, 0.53 g/kg leucine, 0.32 g/kg lysine, and 1.65 g/kg of glutamate amino acids, respectively, based on the United States Department of Agriculture data 2019 (USDA, 2019), or fresh mature coconut water, which contains 2.02 mg/100 mL of arginine (Nasution et al., 2020). Respectively, the amino acid content of the coconut drink in this study for all amino acids tested was higher compared to those present in haustorium (Manivannan et al., 2018) except for aspartic acid and alanine with values of 305 mg/g and 117.00 mg/g. Table 2 shows that the amino acid profile of PCD through freeze-drying process was dominated by lysine (5.60 ± 1.50 g/kg), leucine (4.90 ± 1.90 g/kg), and valine (4.40 ± 1.70 g/kg) for essential amino acid (EAA). As for non-essential amino acid (NEAA) it was dominated by arginine (17.40 ± 3.70 g/kg) and glutamate (17.00 ± 6.60 g/kg).

The protein quality of FCD and PCD was determined by comparing amino acids in the coconut drinks and the need for adults based on a recommended value (WHO/FAO/UNU, 2007). AAS determines the efficiency to meet the needs of EAA at a safe level of protein intake. Table 2 shows that most of the
AAS from FCD were high and met the requirement for the amino acids in adults, namely threonine, valine, histidine, and lysine. The limiting amino acid for FCD was methionine with the AAS of 46. The AAS for the PCD had slightly lower isoleucine (AAS = 93) and leucine (AAS = 83) compared to FCD, while the limiting amino acid was also methionine. However, it has a higher AAS compared to the FCD with the score of 61 and 46 for the PCD and FCD, respectively.

**Fatty acid content of coconut drink**

The fatty acid analysis showed that there was no significant difference (p > .05) for almost all fatty acid components between FCD and PCD (Table 3). These results indicated that processing PCD by freeze-drying method was able to maintain the quality of the fatty acids in the PCD sample as it was also shown in a previous study done in camel’s milk (Ibrahim & Khalifa, 2015). Further, fatty acid analysis showed that both FCD and PCD were dominated by lauric acid (61.28 g/kg and 80.37 g/kg), myristic acid (27.11 g/kg and 34.56 g/kg), palmitate (11.11 g/kg and 17.60 g/kg), oleic acid (8.88 g/kg and 16.16 g/kg), and caprylate (6.87 g/kg and 10.19 g/kg) (Table 3). These results are similar to previous studies conducted for coconut oil, coconut milk powder, and coconut (Bhatnagar, Prasanth Kumar, Hemavathy, & Gopala Krishna, 2009; Karunasiri, Gunawardane, Senanayake, Jayathilaka, & Seneviratne, 2020; Manivannan et al., 2018; Santoso et al., 1996), which also indicated that lauric acid is the highest fatty acid content followed by palmitic, myristic, and oleic. The types of fatty acids present in 1 kg of coconut drink (g/kg) and the percentage or proportion (%) of each type of fatty acid are presented in Table 3.

Table 3 shows that coconut drinks’ fatty acid content was dominated by saturated fatty acids (SFA) followed by monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA). The SFA contents for lauric, myristic, and palmitic fatty acids in coconut drinks were the highest, following previous studies regarding the fatty acid content of coconut fat (Kostik, Memeti, & Bauer, 2013), which showed that the percentage of those fatty acids was 47.70, 19.90, and 4.60–20%, respectively. This SFA is present in the coconut drinks because it utilizes coconut flesh as a filler material. Therefore, the composition of fatty acids present in coconut drink was similar to those in the oil obtained from coconut flesh. However, the SFAs present in PCD were lower than the content in coconut milk powder (43.33 g/100 g) (USDA, 2021), and it mostly contains medium-chain fatty acids (MCFA).

The coconut drink in this study was also contained high MCFA, as mentioned earlier regarding the similarity of fatty acid content between the current coconut drink and coconut oil due to the use of coconut meat as fillers. This was similar to coconut oil, which is rich in MCFA (59.70%), consisting of 92.70% SFA, 6.10% MUFA, and 1.2% PUFA (Bhatnagar et al., 2009). This
composition was different from vegetable oil, which has lower MCFA (0.00%). However, the MUFA (18.70–65.80%) and PUFA (7.80–71.10%), which are a part of MCFA content in vegetable oil, were higher compared to coconut oil (Bhatnagar et al., 2009). The high SFA in coconut oil makes it more stable during oxidation; therefore, it is not susceptible to peroxide formation and has an extended shelf life. In addition, the composition of fatty acids in coconut drinks was also quite different from those in animal products, which had higher long-chain fatty acid (LCFA) content in the form of palmitate and stearic. Furthermore, both the FCD and PCD only contain one essential fatty acid, which is linoleic, as a precursor of the omega 6 fatty acid such as arachidonic acid.

**Descriptive sensory evaluation of coconut drink**

*Aroma*

In this study, the sensory test was carried out using descriptive analysis with the consensus method. The aroma descriptors identified by the panelists include sweet, coconut-like, fermented, creamy, nutty, and rancid. These sensory characteristics were based on previous studies, which showed that coconuts and coconut products have the aroma of fresh coconut, nutty, rancid (Ferrentino, Belscak-Cvitanovic, Komes, & Spilimbergo, 2013; Villarino et al., 2007; Wattanapahu, Suwonsichon, Jirapakkul, & Kasermsumran, 2012), and sweet (Wattanapahu et al., 2012). The panelists identified that the dominant aroma descriptors in both the FCD and refined PCD samples, were coconut-like and creamy, while the lowest were nutty and rancid (Figure 1).

The aroma in coconut water consisted of various volatile compounds (De Marchi et al., 2015). The sweet aroma was caused by ethanol, 2-methyl-1-propanol, and 1-octanol (Nasution et al., 2018). The nutty and fermented aroma was caused by acetaldehyde and acetoin (Nasution et al., 2018). The coconut-like aroma was caused by lactones such as butyrolactone, δ-hexalactone, δ-octalactone, and δ-decalactone, which are widely present in coconut products. Besides producing a coconut-like scent, lactones also produce a creamy aroma in coconut products (Nasution et al., 2018). The FCD and PCD have a rancid aroma, presumably due to the high water content and presence of natural microflora, which facilitates the reaction of hydrolytic rancidity in a relatively short time (Villarino et al., 2007). Another factor suspected of causing rancidity is the degradation of oil into ketones by microorganisms, this can occur even though hot temperatures are not used as in the production of virgin coconut oil (VCO) (Villarino et al., 2007).
Figure 1 shows that the freeze-drying treatment is able to maintain the aroma attribute of the sample except for the fermentation aroma (p < .05). The decrease observed in the fermentation aroma in coconut drinks after freeze-drying was in accordance with results for processed coconut water products (Nasution et al., 2018). This can be associated with a reduction in acetoin through oxidation (Nasution et al., 2018).

**Taste**

The taste descriptors identified by the panelists were sweet, salty, sour, coconut-like, creamy, and bitter (Figure 1). The dominant tastes identified were coconut-like and creamy, while the weakest tastes were bitter and salty. The flavors identified by the panelists were in line with the results from previous studies, namely coconut-like, sweet flavors, acid, and salty (Assa et al., 2013; Ferrentino et al., 2013).

Figure 1 shows that the flavor contained in the coconut drinks can be maintained by the freeze-drying process, except for the sweet taste. The decreased sweetness in PCD compared to the FCD was associated with structural changes in sugar. This structural change from crystalline to the amorphous state of sugar-rich product after processing using the drying methods affects water solubility of powder (Jaya, 2009), which leads to reduced solubility (Seth, Mishra, & Deka, 2017). Therefore, it may reduce the intensity of the sweet taste.

The moderately weak acidic taste found in the coconut drinks was thought to be related to the pH and titratable acidity, which is majorly represented by the malic acid content (Tan et al., 2014). The sour taste of the FCD and PCD was similar to that of hybrid coconut (Assa et al., 2013). The saltiness of coconut drinks was very low and usually expressed by the NaCl levels. The salty taste from the PB121 + hybrid coconut variety such as that used in this study decreased until the age of 21 weeks and increased to the maximum salinity level at 26 weeks (Assa et al., 2013).

![Figure 1](image_url)

**Figure 1.** Effect of freeze-drying on aroma (left) and taste (right) of coconut drink. *Significant difference (p < .05) was found between fresh and powdered samples.
Shelf life of PCD

Predicting shelf life is a complex task, as the nature of the sample tested must be considered. The PCD is white in color and contains sugar and protein. The quality parameters tested for shelf life were \( a_w \) and browning index. The \( a_w \) is related to product safety, while the browning index is related to product quality and acceptance. Therefore, water activity or \( a_w \) measurement should be carried out first to obtain more information related to the safety of a product, especially for perishable foods such as coconut. This is because the \( a_w \) information obtained is related to the possibility of microbial growth on the product surface. Consequently, it is used to determine product stability and durability (Alzamora, Tapia, López-Malo, & Welti-Chanes, 2003). Meanwhile, the browning index is usually analyzed to assess the extent to which the Maillard reaction has occurred in food. A decrease in product quality due to browning is generally caused by heating temperatures, especially during the drying process of the product (Chou & Chua, 2001). Therefore, controlling the browning index is necessary to maintain PCD quality and to be acceptable to customers.

Determination of shelf life at several temperatures including higher than room temperature is important because it provides more information about how long the sample should be stored under some conditions with higher temperature. Figure 2 shows that the levels of \( a_w \) during sample storage increased at temperatures of 25°C, 35°C, and 45°C. This indicates that there was a significant change in \( a_w \) level based on the length of storage time at all storage temperatures (\( p < .05 \)). The change in \( a_w \) level based on the length of storage time was due to the high hygroscopic nature of the PCD samples. However, despite being stored for 4 weeks at critical temperatures, the PCD’s \( a_w \) levels were still below the safety level limit of 0.6 (Kha, Nguyen, & Roach, 2010) and the critical limit of 0.7 (Carter, Galloway, Campbell, & Carter, 2015). However, changes in temperature had an effect on its shelf life. Those stored at 45°C had a longer shelf life compared to those stored at 25°C and 35°C. This is because high temperatures lower the water content, which leads to lower \( a_w \). This low \( a_w \) can be maintained as long as the sample is stored in a package capable of protecting it.

The coconut drink samples on the first day of observation had white color with very little or almost no browning index value. Meanwhile, when PYCD stored for 4 weeks at critical temperatures, especially 45°C, it produced browning index values that exceed the critical limit of 0.6 (Cernişev, 2010). These results were in accordance with those of previous studies (Cernişev, 2010; Yun, Zzaman, & Yang, 2015), which stated that the browning index value, time, and temperature, are in direct proportion, leading to samples having a darker color. The browning pigment formed in this study was thought to be due to the non-enzymatic browning reaction from the
Maillard reaction. This type of reaction occurs when amino acids and reducing sugars, including proteins and/or other nitrogen-containing components, are heated simultaneously. The results of the Maillard reaction are more visible in white samples such as PCD.

The results of an estimated shelf life of PCD on the browning index parameter also showed different shelf life values (days) at various storage temperatures. The PCD stored at 25°C had a longer shelf life compared to those stored at 35°C and 45°C. The higher storage temperature caused the reaction rate ($k$) of the browning process to be higher and the shelf life based on the value of the browning index to be shorter. In addition, the increase in $a_w$ levels along with the storage time was thought to be influenced by the increase in the browning index of the sample. These results were in line with previous studies (Sandulachi, 2012.), which stated that a low $a_w$ helps to minimize browning reactions in the sample. Therefore, the levels of $a_w$ were responsible for minimizing non-enzymatic browning reactions and spontaneous autocatalytic lipid oxidation reactions related to shelf life (Sandulachi, 2012.).

The shortest shelf life of the product at different temperatures based on $a_w$ and the browning index were considered as the benchmark for the product's shelf life at each temperature. Hence, the PCD has a better shelf life of 59 days when stored at 25°C ($k$ value 0.025320939) based on $a_w$ parameter compared to 44 days when stored at 35°C ($k$ value 0.113636781) and 33 days at 45°C ($k$ value 0.139636599) based on the browning index. The shelf life of PCD was long enough for samples without food additives and is better compared to the shelf life of coconut water treated with ultrafiltration and ultraviolet, which was about 15 days at 25°C (Kailaku, Setiawan, & Sulaeman, 2017). This was because the $a_w$ of PCD was much lower compared to that of coconut water in liquid form. Furthermore, the shelf life of PCD dried with the freeze-drying method was better compared to powdered coconut milk dried with vacuum drying technology with a shelf life of 30 days at 38°C based on moisture and lipid

Figure 2. Changes in $a_w$ (left) and browning index (right) of coconut drink during storage. *Significant difference ($p < .05$) was found at different storage time for the set temperature.
peroxidation indicators (Jena & Das, 2012). In addition, the prolonged shelf life of PCD compared to coconut milk powder was associated with a lower fat content, which prevents the rapid oxidation process from occurring.

**Conclusion**

The PCD processed with the freeze-drying method showed no significant difference in the content of most minerals, amino acids, and fatty acids compared to the fresh coconut drink. Furthermore, the development of PCD through the freeze-drying method showed that the process could retain its sensory characteristics similar to that of fresh product with a slight reduction in sweetness and loss of fermented aroma. The PCD by freeze-drying also could prolong the shelf life of the product to 59 days at 25°C, 44 days at 35°C, and 30 days at 45°C in storage temperatures.

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