The Effect of Coconut Water and Temperature on Carrageenan Extraction

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Abstract. Eucheuma cottoni J. is one type of seaweed that is widely cultivated in Indonesia. The economic value of seaweed can be increased by processing seaweed into semi-finished products such as carrageenan. This research was conducted to determine the effect of the amount of coconut water as a solvent and extraction temperature on the characteristics of carrageenan. This research consists of two stages. The first stage is carrageenan extraction using a factorial Randomized Block Design (RBD). The results of the observational data obtained will be processed using analysis of variance with confidence levels = 5 % and 1 %. Significantly different treatments will be subjected to further statistical tests using DMRT (Ducan's Multiple Range Test) with a significance level of 5 %. The results showed that the best treatment for carrageenan extraction was obtained from the amount of coconut water 25 mL g⁻¹ and the extraction temperature of 90 °C with a yield value of 52.95 %, gel strength of 483.86 g cm⁻², viscosity 50 cP, and water content 6.87 %.

Keywords: Eucheuma cottoni J Agardh, Kappaphycus alvarezii (Doty) Doty ex Silva, red edible seaweed, waste utilization, waste to solvent

1 Introduction

Seaweed is one of the largest commodities of the many marine products in Indonesia. There are various varieties of seaweed in Indonesia, one of which is the Kappaphycus alvarezii (Doty) Doty ex Silva—variety, commonly known by the trade name Eucheuma cottonii J. Agardh [1]. The extraction of red seaweed carrageenan K. alvarezii with 4 % NaOH and
5 % KOH solvent resulted in an average yield of 15.89 % and a gel strength of 79.4 g cm⁻² [2]. Previous research carried out carrageenan extraction using coconut water which resulted in an average yield of 32.27 % and gel strength of 235.51 g cm⁻² [3].

Based on these data, it can be concluded that coconut water has excellent potential as a solvent in the carrageenan extraction process. Old coconut water is generally just thrown away and is only considered waste. Therefore, the use of coconut water as a raw material for extraction solvents can increase added value. From an economic point of view, the use of coconut water is more profitable than using alkaline solvents. In addition to the solvent, an important aspect of the carrageenan extraction process is the temperature and time of extraction [4]. Temperature is also considered to have a considerable influence on the extraction process. Extraction temperature and time affect the yield and characteristics of carrageenan [5, 6]. The high temperature is considered to be able to optimize the extraction process because it degrades and can reduce sulfate levels [7].

Previous research that has been carried out on carrageenan extraction has used many expensive solvents and large equipment. For example, extraction with ultrasound which uses sonicator equipment was carried out in 2016 [8], and extraction using Microwave-assisted extraction [9]. Therefore, research on the use of coconut water solvents with variations in extraction temperature needs to be carried out to determine the optimum temperature for carrageenan extraction.

Carrageenan is generally used as a gelling agent for the food industry [10, 4] The wide use of carrageenan makes the price of carrageenan relatively expensive. Seaweed sold fresh tends to be cheaper. It is hoped that the extraction of carrageenan using old coconut water as a solvent can be carried out by coastal communities, thereby increasing the added value of seaweed compared to when they sell it in fresh form. Optimizing the extraction method by treating the amount of coconut water solvent and the extraction temperature is expected to find the most appropriate method to produce carrageenan with a high yield and good gel strength.

2 Material and methods

The materials used in this study were seaweed from the waters of Bontan, Kalimantan province, old coconut water of the type of Cocos viridis (12 mo to 14 mo) obtained from the Batu City market, carrageenan from Primarasa store, sugar, aquades, buffers 7 and 4.5, 96 % alcohol, methanol, isopropanol, iodine, DPPH, starch, NaOH, and H₂SO₄. All chemicals using pro analyses.

2.1 Carrageenan extraction

Carrageenan extraction refers to previous research by Yang and Yang [5] with modification. The dried seaweed was weighed, then the seaweed was washed with running water until it was clean. Then soak in 1:15 aquadest for 15 min. Then cut to reduce the size of the seaweed to 3 cm to 4 cm [5]. Seaweed was put into a 1 000 mL beaker glass and added with coconut water according to the treatment of 15 mL g⁻¹, 20 mL g⁻¹, and 25 mL g⁻¹, then extracted in a water bath with temperatures according to treatment 60 ºC, 75 ºC, and 90 ºC for 2 h. After the extraction process is complete, the seaweed is filtered using a filter cloth to obtain the filtrate. This filtrate was then precipitated with 1:2 isopropanol for 30 min, after which a second filtering was carried out to remove the dregs/sediment. The precipitate was washed with distilled water until the pH was neutral, then dried at 50 ºC for 24 h. The carrageenan sheets formed were then ground using a blender to form carrageenan powder. Carrageenan powder was packaged in zip-lock plastic, which was then analyzed for yield, moisture content, gel strength, and viscosity.
2.2 Analysis

The results were calculated by dividing the weight of carrageenan by the weight of dry seaweed. Viscosity is measured by Ametek Brookfield Digital Viscometer (type LVDV2T, USA) as follows: carrageenan solution (1.5 %) was heated on a hot plate and stirred regularly until 80 ºC and then the viscosity was measured with a spindle. Gel strength was determined by preparing carrageenan. The solution was then analyzed with a texture analyzer at a speed of 100 mm min⁻¹. Moisture content was tested by the gravimetric method [11].

3 Result and discussion

3.1 Yield

The amount of coconut water as a solvent has a very significant effect on the yield of carrageenan. Extraction temperature significantly affects the yield of carrageenan space considerations. Based on the data in Table 1, shows that the higher the amount of coconut water and the higher the extraction temperature, the higher the yield. The yield of carrageenan based on the amount of coconut water as a solvent ranged from 40.89 % to 52.23 %. The highest yield based on the amount of coconut water was 52.05 % with the treatment with the amount of coconut water 25 mL g⁻¹, while the lowest yield was 40.89 % with the treatment with the amount of coconut water 15 mL g⁻¹. The yield of carrageenan based on the extraction temperature ranged from 44.57 % to 49.51 %. The highest yield based on coconut extraction temperature is 49.51 % with the extraction temperature treatment was 90 ºC, while the lowest yield was 44.57 % with the extraction temperature treatment at 60 ºC.

The selection of coconut water is based on the principle that acid treatment can optimize the extraction so as to increase the yield [3, 4]. The yield of carrageenan will increase as the concentration of coconut water used increases. This is because the presence of high acidity in coconut water is able to break down the cell walls of seaweed so that more carrageenan is extracted. The cell wall of seaweed is composed of polysaccharides which are the constituents of carrageenan. This is in accordance with the opinion, stating that the acidic nature of coconut water can hydrolyze seaweed cell walls composed of polysaccharides to increase the yield of carrageenan.

Table 1. The effect of coconut water on the physicochemical characteristics of carrageenan.

<table>
<thead>
<tr>
<th>Number</th>
<th>Coconut water (mL g⁻¹)</th>
<th>Yield (%)</th>
<th>Moisture content (%)</th>
<th>Viscosity (cP)</th>
<th>Gel strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>40.89a</td>
<td>7.39a</td>
<td>88.23c</td>
<td>387.03a</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>49.23ab</td>
<td>7.43a</td>
<td>66.78b</td>
<td>425.32b</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>52.05b</td>
<td>6.95a</td>
<td>51.34a</td>
<td>469.42c</td>
</tr>
</tbody>
</table>

Note: Numbers followed by different letters show significant differences according to Duncan's test ($\alpha = 5\%$).

Coconut water in this case serves to soften the cell walls of seaweed. This is evidenced by the increase in the amount of coconut water which causes the seaweed walls to become softer. The hydrolysis process causes the seaweed cell walls to become more permeable and softer so that the diffusion and extraction of carrageenan become easier. The high permeability of this cell wall will increase the yield of carrageenan because the components in the seaweed wall are more easily extracted [11].
The yield of carrageenan is also affected by the extraction temperature. The higher the extraction temperature, the higher the yield. The higher the extraction temperature, the greater the heating effect, thereby maximizing the cell wall permeability [12, 13, 10]. The increased permeability plays a role in accelerating the reaction process, increasing the rate of diffusion of compounds through the cell wall, and increasing the extraction yield and fluid from inside the cell.

3.2 Moisture content

Statistical analysis showed that the addition of various concentrations of coconut water and extraction temperature shown in Table 2, did not affect the water content of carrageenan. The water content in all treatments was not much different, ranging from 6.87% to 7.78%. The water content is in accordance with Food and Agriculture (FAO) standards, where the maximum water content of carrageenan is 12%.

Table 2. The effect of temperature extraction on the physicochemical characteristics of carrageenan.

<table>
<thead>
<tr>
<th>Number</th>
<th>Temperature (℃)</th>
<th>Yield (%)</th>
<th>Moisture content (%)</th>
<th>Viscosity (cP)</th>
<th>Gel strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>60</td>
<td>44.57a</td>
<td>7.35a</td>
<td>72.45b</td>
<td>411.22a</td>
</tr>
<tr>
<td>2.</td>
<td>75</td>
<td>48.09ab</td>
<td>7.11a</td>
<td>70.34b</td>
<td>427.87ab</td>
</tr>
<tr>
<td>3.</td>
<td>90</td>
<td>49.51b</td>
<td>7.1a</td>
<td>63.56a</td>
<td>442.68b</td>
</tr>
</tbody>
</table>

Note: Numbers followed by different letters show significant differences according to Duncan's test (α = 5%).

The low water content of carrageenan can occur due to the use of acidic coconut water as a solvent. Extraction of carrageenan using coconut water which has an acidic pH produces a fairly low water content (6% to 7%). This can be because the high content of K⁺ cations in coconut water will replace the sulfate in carrageenan more and more so that the sulfate group that can bind to water will be less and the water content will be low [14].

3.3 Viscosity

The results of the viscosity strength based on the amount of coconut water as a solvent ranged from 51.34 cP to 88.23 cP. The highest viscosity based on the amount of coconut water was 88.23 cP with the amount of coconut water 15 mL g⁻¹, while the lowest gel strength was 51.34 cP with the amount of coconut water 25 mL g⁻¹. The results of carrageenan viscosity based on the extraction temperature ranged from 63.56 cP to 72.45 cP. The highest viscosity based on coconut extraction temperature was 72.45 cP with 60 °C extraction temperature treatment, while the lowest gel strength was 63.56 cP with 90 °C extraction temperature treatment.

Extraction temperature also affects the viscosity of carrageenan. The viscosity value decreases with increasing extraction temperature. This shows that the extraction temperature treatment has an effect on the viscosity value. The effect of extraction temperature on viscosity is that the higher the temperature, the lower the viscosity. The higher the extraction temperature, the lower the levels of carrageenan sulfate. Higher extraction temperatures lead to a reduction in sulfate, resulting in decreased viscosity values. As the temperature increases, the charge throughout the polymer chain decreases, leading to a reduction in the repulsion force between the sulfate groups. This weakens the hydrophilic nature of the polymer and results in a decrease in the viscosity of the solution. The same thing was conveyed by Hudha et al. [15] where the decrease in the repulsion force between the sulfate groups so that the hydrophilic properties of the polymer became weaker and caused the viscosity of the carrageenan to decrease with increasing temperature.
3.4 Gel strength

Based on the data in Table 1 and Table 2, it is known that the higher the amount of coconut water and the higher the extraction temperature, the higher the gel strength produced. The results of the strength of the carrageenan gel based on the amount of coconut water as a solvent ranged from 387.03 g cm⁻² to 469.42 g cm⁻². The highest gel strength based on the amount of coconut water was 469.42 g cm⁻² with the amount of coconut water being treated at 25 mL g⁻¹, while the lowest gel strength was 387.03 g cm⁻² with the amount of coconut water being treated at 15 mL g⁻¹. The results of carrageenan gel strength based on the extraction temperature ranged from 411.22 g cm⁻² to 442.86 g cm⁻². The highest gel strength based on coconut extraction temperature was 442.86 g cm⁻² with an extraction temperature of 90 ℃, while the lowest gel strength was 411.22 g cm⁻² with an extraction temperature of 60 ℃.

The higher the extraction temperature, the higher the gel strength value. This is because the higher the extraction temperature, the more the sulfate content will decrease so that the gel strength value increases. The low value of gel strength is influenced by high sulfate. The decrease in sulfate occurs where the higher the extraction temperature, the lower the sulfate content as a result the value of gel strength is high [11]. Greater quantities of sulfate ester groups result in the binding of sulfate to water [16, 12, 13]. Therefore, when the sulfate level in carrageenan is minimal, the resulting three-dimensional structure exhibits little water absorption. Consequently, when subjected to pressure, the carrageenan retains its shape well, leading to a high gel strength value. [17].

4 Conclusion

The quantity of coconut water used as a solvent has a substantial impact on the production, gel strength, and thickness of carrageenan. The carrageenan's yield, gel strength, and viscosity were considerably influenced by the extraction temperature. The optimal conditions for carrageenan extraction were achieved using a coconut water sample ratio of 25 mL g⁻¹ and an extraction temperature of 90 ℃. Under these conditions, the yield value of carrageenan was 52.95%, with a gel strength of 483.86 g cm⁻² and a viscosity of 50 cP. These results comply with the carrageenan standards set by the Food and Agriculture Organization (FAO).

References