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The Effects of Extraction Temperature on the Physicochemical Properties of Mangrove-Derived Glucomannan (*Bruguiera gymnorhiza*)

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Abstract. This study investigates the impact of different extraction temperatures on the physicochemical properties of glucomannan derived from mangrove fruits (*Bruguiera gymnorhiza*). Various extraction temperatures ranging from 45°C to 85°C were utilized. Significant differences ($p < 0.05$) were observed in solubility (58.41% ± 2.45), total reducing sugar content (0.39% ± 0.09), yield (35.13 ± 2.95), and L* color value (71.97 ± 1.53), while no significant differences ($p > 0.05$) were found in a* and b* color values. These findings have implications for expanding the applications of *Bruguiera* and advancing research on *Bruguiera* glucomannan. Scanning electron microscopy (SEM) analysis revealed an increase in the cross-linking density of glucomannan molecules

Keywords: extraction method, physicochemical analysis, food application, mangrove

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1. Introduction

Glucomannan, composed of D-mannose and D-glucose with an α-1,4-pyranoside bond and acetyl group substitution [1]; [2], is known for its beneficial properties in various sectors, especially in food and pharmaceutical applications [3]; [4]. As a water-soluble non-ionic polysaccharide, glucomannan serves as a natural and renewable polymer dietary fiber [5] and has been widely used as a nutritional supplement [6].

Several prior investigations have been conducted to extract glucomannan from diverse plant sources such as *Aspergillus oryzae* [7], aloe vera [8]; Salep (*Orchidaceae* family) [1], hyacinth orchid flowers (*Bletilla formosa*)) [9]; and Chinese bellflower (*Platycodon grandiflorum* [10]. Additionally, glucomannan is derived from the tubers of several members of the Araceae family, including taro (*Colocasia esculenta*), suweg (*Amorphophallus paeoniifolius*), and sente (*Alocasia macrorhiza*), salak seeds [11] and Xanthosoma [12]. Different plant sources and extraction techniques yield varied glucomannan characteristics [4]. Glucomannan belongs to the mannan family of polysaccharides, is abundant in nature, particularly in sources like tubers, softwoods (hemicellulose), roots, and various plant bulbs [3].

The plant identified as *Bruguiera gymnorhiza* of mangrove is one of Indonesia's numerous foods categorized as complex carbohydrate sources. Mangrove fruit boasts a high fiber and carbohydrate content [13][14]. The method of glucomannan collection plays a pivotal role since the functional attributes of the final product are linked to process parameters [1]. The heating temperature and pH level have a major impact on the gelation of konjac glucomannan, which is crucial for the use of konjac glocomannan-based products. Glucomannan composites showed a tendency to form gels as the incubation temperature increased from 40°C to 90°C [15]. Exploring the potential development of glucomannan from various plant sources abundant in coastal regions presents an opportunity to investigate effective and efficient extraction methods for enhancing the value of *Bruguiera* glucomannan. This study aimed to investigate a temperature-based extraction method for obtaining glucomannan from *Bruguiera gymnorhiza* and examine its physicochemical properties.

2. Methods

2.1. Bruguiera gymnorrhiza Flour

Mangrove fruits utilized in this research were from *Bruguiera gymnorrhiza*. The *Bruguiera* mangroves were sourced from the coastal mangrove area in Cilacap, Central Java. These were fruits of the old *Bruguiera* variety measuring around 10-15 cm, displaying a long brownish-green color. Fresh *Bruguiera* fruits were cleaned and peeled. The initial step involved boiling the mangrove *Bruguiera* in water at 80°C for 30 minutes, along with the incorporation of 15% (w/w) hush ash. Subsequently, the mangrove fruit was peeled, and soaked for 48 hours with water changes every 6 hours. The *Bruguiera* mangrove was then cut into 1 - 2 cm thick chips and dried using a cabinet dryer at 70°C for 7 hours. Finally, the dried sliced *Bruguiera* mangroves were ground, and the resulting powder was sieved using an 80-mesh sieve.

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2.2. Glucomannan Extraction

Extraction of glucomannan from *Bruguiera* flour was performed following the method outlined by [16] with slight modification. *Bruguiera flour* was mixed with distilled water in a ratio of 1:10 (v/w). To optimize glucomannan characteristics, various temperatures ranging from 40 to 90 °C were explored during the extraction process as suggested by previous research [15], The mixing process was conducted at different temperatures, including 45, 55, 65, 75, and 85°C. Subsequently, centrifugation was carried out at 2,800 rpm for 5 minutes. The resulting mixture was treated with 70% technical ethanol at a ratio of 1:5 (v/w) relative to the initial *Bruguiera* mangrove flour weight. The solution was then filtered using filter paper and dried in a drying cabinet at 60°C for 6 hours. The obtained dried *Bruguiera* glucomannan was sieved through an 80-mesh

2.3. The Reducing Sugar Measurement

The assessment of reducing sugar content in *Bruguiera* glucomannan was conducted using the Somogyi-Nelsen method, as detailed in the prior study by [17]. Quantifying the reduction of sugar in *Bruguiera* glucomannan was achieved using a spectrophotometer set at a 540 nm wavelength. To determine the reduced sugar content, a standard curve of glucose was established.

2.4. The Solubility Measurement

The determination of *Bruguiera* glucomannan solubility followed the methodology outlined by [18] , with some modifications introduced into the procedure. The solubility of glucomannan was subsequently assessed.

$$\text{The solubility (\%)} = 1 - \left(\frac{\text{the total sample and the paper} - \text{the initial paper}}{\text{sample initial weight}}\right) \times 100\%$$

2.5. *The Colour Measurement of Bruguiera Glucomannan*

The Minolta spectrophotometer method was used to determine the color of *Bruguiera* glucomannan using coordinates L* (black/white), a* (red/green), and b* (yellow/blue) [19]. The device will be calibrated using a whiteboard (standard reference supplied by Konica Minolta) and a standard blackboard before being used. The color characteristics of *Bruguiera* glucomannan (including both control and treatment groups) were evaluated and repeated four times.

2.6. The Total Yield Measurement

The *Bruguiera* glucomannan yield was determined according to the method by [4]. The yield is calculated by comparing the initial weight to the final weight of glucomannan multiplied by 100%.

2.7. Morphology of Glucomannan SEM

The SEM EXD analysis revealed the fine structure of *Bruguiera* glucomannan [9]. Specifically, the dried *Bruguiera* glucomannan sample was affixed to a copper platform using conductive adhesive and imaged at different magnifications to investigate its morphology.

2.8. Statistical Analysis

All *Bruguiera* glucomannan measurement results underwent one-way ANOVA analysis using SPSS statistical software. Results were presented as mean ± standard deviation (SD). Significance between group means was assessed using Duncan's tests with a statistical significance threshold set at $p < 0.05$.

3. Results and Discussion

3.1. The Reducing Sugar of Bruguiera Glucomannan

The linear backbone of glucomannan consists of glucose and mannose units, classified as a type of reducing sugar [20]. The reduced sugar of *Bruguiera* glucomannan is depicted in Figure 1. There were significant differences in the total reducing sugar content of *Bruguiera* glucomannan based on extraction temperature ($p < 0.05$). Glucose levels slightly increased with higher temperatures. The total reducing sugar content of *Bruguiera* glucomannan ranged from 0.21 to 0.43%. As stated in [17], extraction temperature influences the hydrolysis process, resulting in changes in the fructose and glucose structure as reducing sugars. In literature [21] glucomannan primarily comprises glucose and mannose units; variations in the ratios of glucose to mannose are attributed to species differences and disparities in processing and treatment methods. The mannose-to-glucose ratio in glucomannan varies depending on the specific source of origin [22].

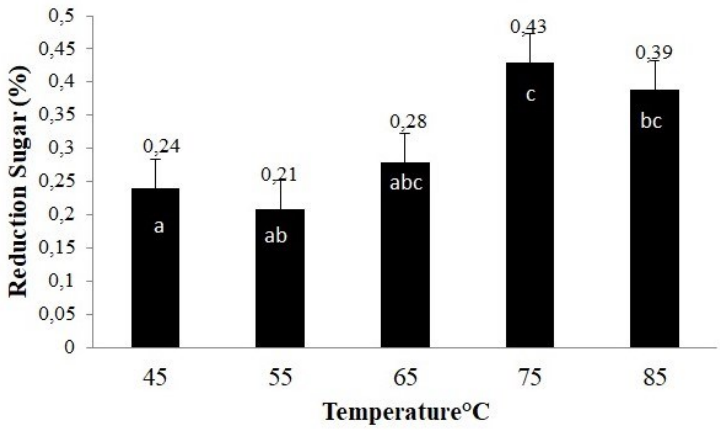

Figure 1. The Result of Reducing Sugar

3.2. The Total Solubility of Bruguiera Glucomannan

In Figure 2. the solubility of glucomannan from *Bruguiera* was significantly influenced by extraction temperature ($p < 0.05$). The results revealed an overall increase in solubility of *Bruguiera* glucomannan due to variations in extraction temperature. Specifically, an extraction temperature of 85°C demonstrated higher total solubility compared to other treatments. Solubility progressively increased with higher temperatures but no significant difference ($p > 0.05$) was observed among extraction temperatures of 45, 55, 65, and 75°C. These findings suggest that total solubility is impacted by the extraction temperature. As the temperature increases, the solubility of *Bruguiera* glucomannan typically increases, allowing it to dissolve more easily in water. As the temperature rises, the molecular interactions change, leading to greater solubilization and a smoother, more uniform dispersion in the liquid. This relationship between temperature and solubility is crucial in applications where precise control over the consistency of glucomannan-based solutions or gels is required. The higher the solubility of glucomannan, the more convenient it is for use in products. In the literature [16] that the effectiveness of utilizing glucomannan in food relies significantly on its solubility, as it becomes functional upon dissolving in water. According to [3] acetyl groups in glucomannan can hinder intramolecular hydrogen bond formation, thus improving the solubility of glucomannan.

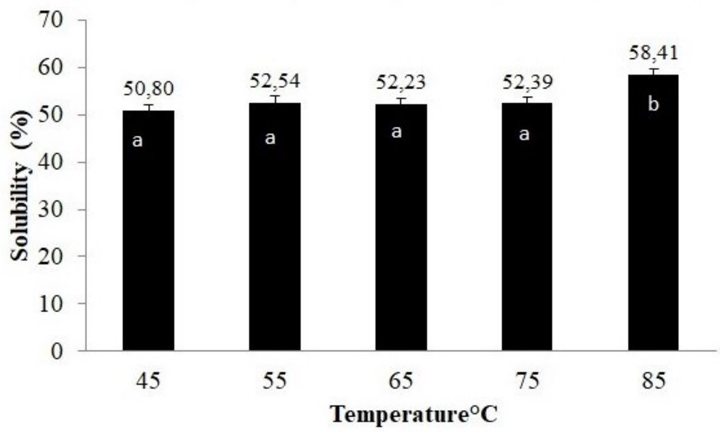

Figure 2. The Result of Solubility

3.3. The Total Yield of Bruguiera Glucomannan

The total yield of *Bruguiera* glucomannan is shown in Figure 3. Significantly higher total yields were observed at extraction temperatures of 65°C and 75°C compared to 45°C and 55°C ($p < 0.05$). The extraction at 85°C yielded the highest overall glucomannan extraction from *Bruguiera*. The yield of glucomannan from *Bruguiera* ranged from 26.34% to 35.17%. Increasing the extraction temperature had a significant impact on the extraction yield ($p < 0.05$). The yield is subject to fluctuations based on the chosen extraction technique. At higher temperatures, the cell walls of plant materials *Bruguiera* containing glucomannan tend to break down more easily, allowing for greater polysaccharide release. This often leads to an increased yield. Yanuriati *et al*. (2017) reported the the total glucomannan yield of fresh porang tubers produced from the direct isolation process ranges from 50 - 65%.

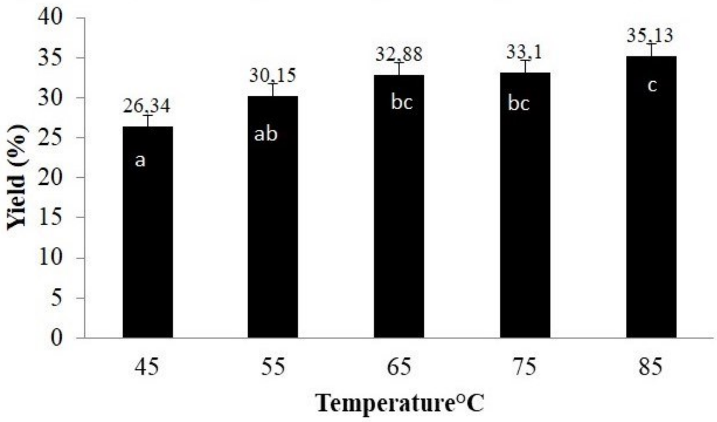

Figure 3. The Result of Yield

3.4. The Color of Bruguiera Glucomannan

The color of *Bruguiera* glucomannan is a crucial factor that plays a significant role in shaping consumer preferences and decisions. The L* value color of *Bruguiera* glucomannan is depicted in Figure 4. Different extraction methods yielded varied whiteness degrees of *Bruguiera* glucomannan, as shown in Figure 5, ranging between 71.96 and 74.95. Increasing the extraction temperature significantly impacted the whiteness degree of *Bruguiera* glucomannan ($p < 0.05$), decreasing it due to the Maillard reaction. The redness (a*) color of *Bruguiera* glucomannan is illustrated in Figure 6, indicating the redness of the product. Variation in extraction temperature had no significant effect ($p > 0.05$) on the redness color of *Bruguiera* glucomannan, which displayed values of 4.04 ± 0.32, 4.95 ± 0.46, 5.07 ± 0.48, 4.93 ± 0.45, and 5.23 ± 0.87 at temperatures of 45, 55, 65, 75, and 85°C, respectively. The yellowness (b*) color of *Bruguiera* glucomannan is also depicted in Figure 6. Changes in extraction temperature did not significantly influence the yellowness color of *Bruguiera* glucomannan, with values of 22.35 ± 0.58, 22.83 ± 0.72, 22.37 ± 2.01, 21.61 ± 1.62, and 22.09 ± 2.09 at temperatures of 45, 55, 65, 75, and 85°C, respectively. In the literature [19] the coloration of glucomannan can be linked to its heightened solubility and blending capacity, leading to the achievement of a homogeneous texture in composite gels.

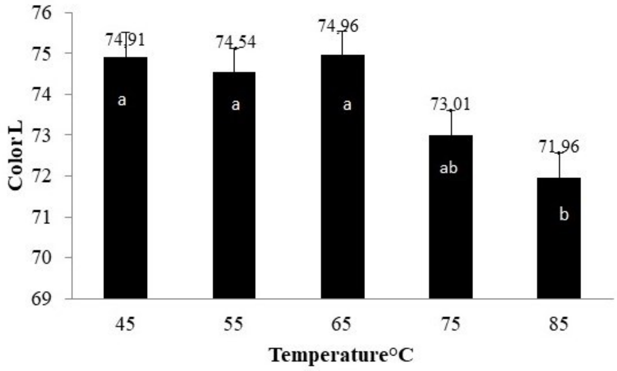

Figure 4. The Color of L* value

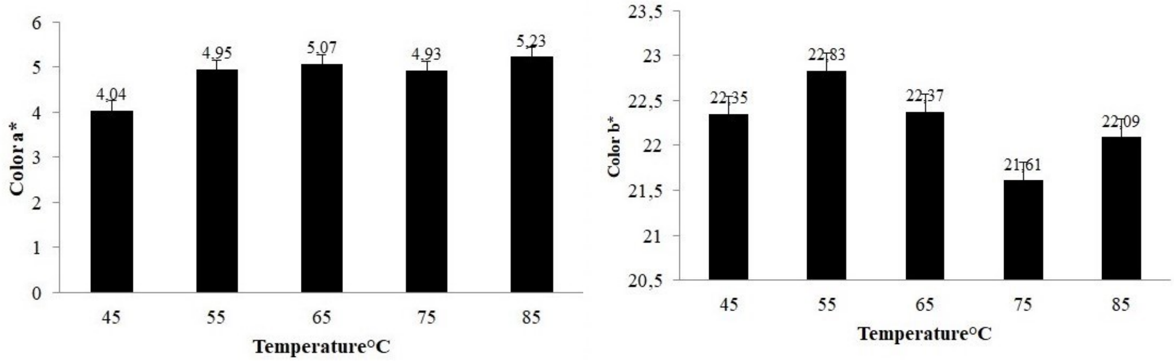

Figure 5. The Redness (a*) and Yellowness (b*) Color

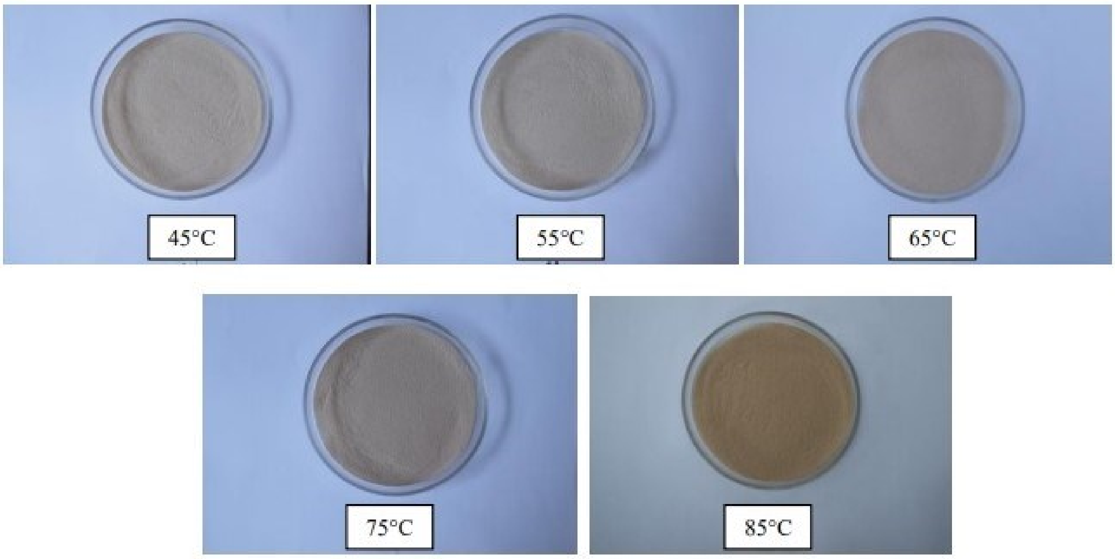

Figure 6. The Color of Glucomannan

3.5. The SEM of of Bruguiera Glucomannan

The differences in surface morphology played a crucial role in shaping the varied functional properties observed in the samples of glucomannan[24]. Figure 7 depicts the structures of glucomannan from *Bruguiera* obtained through varying extraction temperatures. SEM was employed to characterize the morphologies of all *Bruguiera* glucomannan, enabling the observation of particle shapes. Observations of the morphology of *Bruguiera* glucomannan were presented at a magnification of 3000x. The structure was comprised of a tightly woven network created by glucomannan. The diverse shapes observed in *Bruguiera* glucomannan suggest the onset of the shift from the amorphous to the crystalline phase. [25] reported the transition from the amorphous phase to the crystalline phase in particles derived from glucomannan extracted from fresh porang occurs through the utilization of technical-grade ethanol.

Based on the research findings, there was a significant rise in the cross-linking density of glucomannan molecules at higher extraction temperatures. The microstructure densifies as the extraction temperature increases, aligning with the study [15] that the composites demonstrated a network structure that intertwined as the temperature ranged between 40 and 90°C. The higher incubation temperatures resulted in a relatively elevated cross-linking density of glucomannan molecules [26].

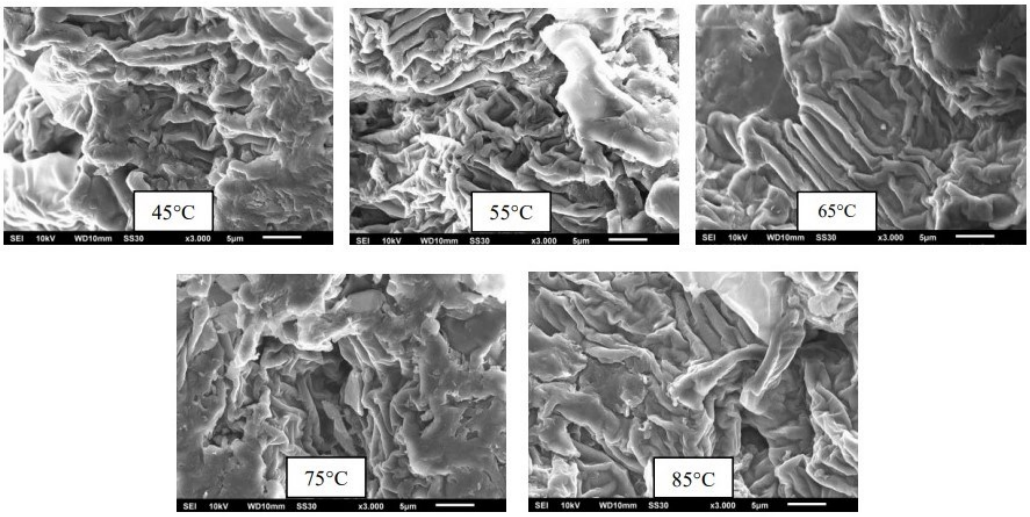

Figure 7. The Morphologies of Glucomannan

4. Conclusions

The *Bruguiera* glucomannan content was determined using temperature-based extraction methods. The *Bruguiera* glucomannan was extracted at a temperature of 85°C, resulting in higher levels of total reducing sugar, solubility, and total yield, but lower levels of L*, a*, and b* color values. Varying extraction temperatures can improve the characteristics of *Bruguiera* glucomannan. SEM analysis revealed a significant increase in the density of cross-linking among glucomannan molecules.

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