Enhancing Color Stability in Green-Colored Rice Flour through Alkaline Blanching of Suji and Pandan Leaves

Salwa Farahdiva Risaputri and Erni Sofia Murtini*

Department of Food Science and Biotechnology, Faculty of Agricultural Technology, Brawijaya University, Jl. Veteran No.1-2, 65145 Malang, Indonesia
*erni.murtini@ub.ac.id

Abstract. The innovation of green-colored rice flour (GCRF) was achieved by adding suji and pandan leaves. However, the green color of flour tends to be unstable, as indicated by the rapidly decreasing chlorophyll levels during storage. Blanching of the leaves in an alkaline solution may be helpful. This study aims to determine the effect of blanching of suji and pandan leaves in alkaline solution ($NaHCO_3$, $MgCO_3$, Na_2CO_3, and $Ca(OH)_2$) and control (water) on the stability of the green color of GCRF. Leaves were blanched at 90°C for 60 s. The GCRF was processed by grinding soaked rice and blanched leaves and filtering the flour through a 100-mesh sieve. The results showed that the type of alkaline solution significantly affected the color parameters (L*, a*, and b*), total chlorophyll, chlorophyll a and b contents, pH, and color stability of GCFR under temperature (4 °C and 100 °C), light, and pH conditions. The optimal treatment, determined using the Multiple Criteria Decision Making (MCDM) Zeleny method, was blanching leaves in $MgCO_3$ solution. This treatment produced GCFR with the following characteristics: L* = 71.8 ± 0.08, a* = –9.6 ± 0.24, b* = 30.5 ± 0.06, moisture content = 9.62 ± 0.30%, ash content = 0.60 ± 0.03%, yield = 90.10 ± 1.08%, pH = 7.85 ± 0.01, total chlorophyll = 17.01 ± 0.14 mg/L, ΔE at 4 °C = 0.74 ± 0.39, ΔE at 105 °C = 10.86 ± 0.13, ΔE in dark room = 0.92 ± 0.27, ΔE in lighted room = 4.18 ± 0.39, ΔE at pH 4 = 12.37 ± 0.39, ΔE at pH 7 = 4.51 ± 0.13, and ΔE at pH 9 = 13.99 ± 0.35. The ΔE value in GCRF made from rice and without treated leaves is higher than ΔE GCRF made from rice and treated leaves in $MgCO_3$ solution. It can be concluded that the pretreatment of suji and pandan leaves by blanching in an alkaline solution can enhance the color stability of GCRF.

Keywords: Color Stability, Pandan Leaves, Rice Flour, Suji Leaves

1 Introduction

Rice flour, on an international scale, is widely used in the production of gluten-free food products. In Indonesia, rice flour is also commonly utilized as a raw material for various traditional Indonesian food products such as kue putu, cendol, and kue lapis. Generally, rice flour is white and opaque after cooking[1]. However, since traditional

K. P. Candra et al. (eds.), *Proceedings of the International Conference of Tropical Agrifood Feed and Fuel 2024 (ICTAFF 2024)*, Advances in Biological Sciences Research 47,
https://doi.org/10.2991/978-94-6463-825-7_12

foods are often colorful, food coloring is typically added to make rice-flour-based products more appealing [2]. According to [3], color and appearance play crucial roles as quality parameters in food and influence consumer acceptance.

The practice of coloring food has long been a part of Indonesia's local wisdom and has been passed down through generations. This is evident in a variety of colorful traditional Indonesian snacks, ranging from green, red, blue, and purple. In the past, before the availability of commercial/synthetic food colorings, people traditionally used locally available materials, such as parts of plants, flowers, leaves, roots, tubers, seeds, stems, and fruits as natural colorants. For example, to prepare green-colored rice cakes, rice flour was prepared by first soaking the rice in water for several hours and then pounding it together with fresh leaves. Through this process, an interaction occurs between the pigments and components of the leaves with the components of the rice, and the color of the leaves becomes fixed in the rice flour. As stated in [4], components such as flavonoid polyphenols can interact with starch via hydrogen bonding and van der Waals forces. Natural colorants are increasingly being used because of food safety concerns and nutritional benefits. This traditional method was adopted in this study, but with a wide variety of natural colorants. Fresh suji leaves, with a moisture content of 73.25% (wet basis), contain 3773.9 ppm chlorophyll, consisting of 2,524.6 ppm chlorophyll a and 1250.3 ppm chlorophyll b, and can be used to produce green-colored rice flour. Additionally, pandan wangi leaves not only contain chlorophyll, but also have a distinctive aroma, partly due to the chemical component 2-Acetyl-1-Pyrroline (ACPY) [5].

According to research by [6] on the production of GCRF with the addition of pandan wangi and suji leaves, and [7], on the production of germinated brown rice flour with a mixture of pandan wangi and suji leaves, these methods can produce green rice flour with a distinctive aroma. However, the shelf life of GCRF is limited, necessitating treatment to improve its color stability.

Natural colorants, such as chlorophyll, are limited in that their color is unstable under heat, light, and pH. Chlorophyll can undergo a color change from bright green to dull olive or brown when it loses its central magnesium ion, forming a pheophytin form [8]. This transformation typically occurs under heat or acidic conditions, where the removal of magnesium disrupts chlorophyll's light-absorbing structure, leading to the loss of its vibrant green color

To prevent this, pretreatment such as blanching can be applied. Blanching reduces nutrient loss and inactivates enzymes. Under specific conditions, blanching can help stabilize chlorophyll. The addition of alkaline substances to the blanching solution can aid in stabilizing the chlorophyll. Alkaline like $NaHCO_3$, $MgCO_3$, Na_2CO_3, and $Ca(OH)_2$ can increase the pH of the blanching solution, making the chlorophyll more stable [9]. The aim of this study was to produce GCRF by adding Pandan wangi and suji leaves. The primary focus of this research is to stabilize the green color in the rice flour through the blanching pretreatment of pandan and suji leaves in an alkaline solution of $NaHCO_3$, $MgCO_3$, Na_2CO_3, and $Ca(OH)_2$, before the leaves are ground with the rice to produce GCRF. The alkaline compounds added to the blanching solution had a concentration of 1% in 100 ml of water.

2 Material and Methods

2.1 Materials

The materials used in the production of green-colored rice flour (GCRF) included medium-grain white rice purchased from a local market in Malang, East Java, Indonesia. Pandan (*Pandanus amaryllifolius*) and suji (*Dracaena angustifolia*) leaves were freshly harvested from local farmers in the Selorejo area, Jatimulyo Subdistrict, Lowokwaru District, Malang City, Indonesia. The alkaline agents used for blanching included sodium bicarbonate ($NaHCO_3$), sodium carbonate (Na_2CO_3), calcium hydroxide ($Ca(OH)_2$), and magnesium carbonate ($MgCO_3$), all of analytical grade and obtained from local store. The materials used for the physicochemical and chlorophyll stability analysis of GCRF included methanol and ethanol (analytical grade), 2,2-diphenyl-1-picrylhydrazyl (DPPH) reagent for antioxidant activity analysis, and citrate-phosphate buffer solutions at pH 4, 7, and 10.

2.2 Equipment

The equipment used in this research included a dry food grinder (Fomac FCT-Z200), an automatic cabinet dryer (Local/Digital brand), a 100-mesh stainless steel sieve, an analytical balance (Ohaus Pioneer PA214), a color reader (Minolta CR-10 Tristimulus), a drying oven (WTB-Binder), a shaker water bath, a centrifuge (Hettich EBA 200), a vortex mixer, a UV-Vis spectrophotometer (Genesys 10S UV-Vis), a refrigerator, a pH meter (Crison), a desiccator, a gas stove (Rinnai Ceflon RI-522C), supporting glassware, a thermometer, cooking pots, scissors, 250 g heat-resistant plastic bags, plain white paper, plastic basins, aluminum foil, clear plastic bags, and a spray bottle for distilled water.

2.3 Experimental Design

Preliminary research was conducted to select the most suitable blanching method (hot water or steam, each for 60 s) for leaves before use in GCRF production. Selection was based on the final color (L, a*, and b*) of the GCRF.

The main research was conducted to investigate the effects of leaf blanching at 90°C for 1 min in a 1% alkaline solution on the physicochemical characteristics and chlorophyll stability of GCRF. The experimental design employed was a Randomized Block Design (RBD) with one factor, the type of alkali ($NaHCO_3$, $MgCO_3$, Na_2CO_3, and $Ca(OH)_2$) used in blanching, along with a control group (blanching with water only). The pH values of these solutions are listed in Table 1. Each treatment was repeated five times. Data were analyzed using ANOVA (Analysis of Variance) and Tukey's post-hoc test at a 95% confidence interval.

Table 1. pH of different alkaline solution

Alkaline (1%)	pH
Without alkaline	7.94±0.06[d]
$NaHCO_3$	8.52±0.01[c]
$MgCO_3$	9.34±0.03[b]
Na_2CO_3	9.00±0.05[a]
$Ca(OH)_2$	9.36±0.01[b]

Note: Data (mean±SD) were derived from five replications. Data were analysed by ANOVA. The data in pH column followed by different letters shows significantly different (Tukey test, $p<0.05$)

2.4 The Leaves Preparation

The leaves *(suji* and *pandan wangi*) were washed and cut into 3 cm pieces. The alkaline solution was prepared by dissolving 1 g each of $NaHCO_3$, Na_2CO_3, $MgCO_3$, and $Ca(OH)_2$ in 100 mL of water. The solution was then heated to 90°C. The leaves were blanched in solution for 1 min and then immediately rinsed in cold water. Rinsing the leaves immediately after the blanching process can help prevent overheating by rapidly stopping the cooking process. After rinsing, the leaves were drained to remove excess water and to dry the surface.

The GCRF was prepared by using 100 g of white rice soaked in water at a rice-to-water ratio of 1:1 for 3 h. The soaked rice was dried in a cabinet dryer at 60°C for 4 h. The rice and 10 g blanched-leaf mixture were ground together using a food grinder for 3 min, dried in a cabinet dryer at 60°C for 4 h, and sieved through a 100-mesh sieve.

2.5 Analytical Procedures

The following analyses were conducted on green-colored rice flour (GCRF) to evaluate its physicochemical and functional characteristics: color measurements were performed using a Color Reader (CR-10, Konica Minolta, Japan) based on the CIE Lab system (L^*, a^*, b^*), and the moisture content was determined following the AOAC method 925.10 [10] by oven-drying approximately 2 g of sample at 105 °C until a constant weight was achieved. pH was measured by dispersing 1 g of GCRF in 10 mL of distilled water using a digital pH meter. The ash content was analyzed using the dry ashing method (AOAC 923.03, 2005), where approximately 1 g of the sample was incinerated in a muffle furnace at 550 °C for 4–6 h until a white ash residue remained. The yield was calculated by dividing the weight of the final GCRF product by the initial weight of the rice used, expressed as a percentage. Antioxidant activity was evaluated using the DPPH radical scavenging method, as described previously [11], where a methanolic extract of the sample was reacted with DPPH solution and incubated in the dark for 30 min, and its absorbance was read at 517 nm using a UV-Vis spectrophotometer.

Chlorophyll a and b contents were measured using the method described in [12]. One gram of GCRF (dry powder) was placed in a 250 mL Erlenmeyer flask, to which 10 mL of analytical grade ethanol was added, and the mixture was refrigerated for 18 h. The mixture was then centrifuged at 4,000 rpm for 15 min. The absorbance of the supernatant was quantified using a spectrophotometer at wavelengths of 649 nm and 665 nm. The chlorophyll content was calculated using the following formula:

$$\text{Total Chlorophyll (mg/L)} = (20 \times A649\ \text{nm}) + (6.1 \times A665\ \text{nm}) \tag{1}$$

$$\text{Chlorophyll a (mg/L)} = (13.7 \times A665\ \text{nm}) + (5.76 \times A649\ \text{nm}) \tag{2}$$

$$\text{Chlorophyll b (mg/L)} = (25.8 \times A649\ \text{nm}) + (7.7 \times A665\ \text{nm}) \tag{3}$$

The stability of green-colored rice flour (GCRF) in response to various factors, including temperature, light exposure, pH, and storage conditions, was evaluated by measuring its color attributes: lightness (L*), redness/greenness (a*), and yellowness/blueness (b*). These values were recorded for both the untreated flour and treated samples. The overall color change (ΔE) was calculated to quantify the difference in color between the samples before and after treatment. The ΔE value represents the Euclidean distance between two points in the CIELAB color space and is widely used as an objective metric for color stability [13] given by the following formula:

$$\Delta ELab = \sqrt{(L_2+L_1)^2+(a_2+a)^2+(b_2+b_1)^2} \tag{4}$$

Different perceptions of color change are indicated by ΔE values. ΔE values greater than 1.0 indicates that the color change was not visible to the naked eye. Color changes visible under close inspection are indicated by ΔE values of 1-2. A color change visible to the eye at a glance was indicated by a ΔE value of 2-10. A ΔE value of 11-49 indicates that the color changed almost significantly. A ΔE value of 100 indicates that the color changed significantly.

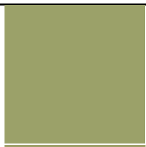
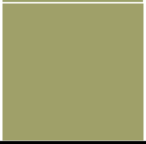
3 Result and Discussion

3.1 Determination of Blanching Method for *Suji* and *Pandan Wangi* Leaves

The blanching method was used to identify the most suitable blanching technique for preserving chlorophyll in the leaves before use in green-colored rice flour production. The colors of the green-colored rice flour are presented in Table 2.

Compared with steam blanching, hot water blanching produces a greener GCRF. During the blanching process, the sample comes into direct contact with the heating medium, leading to a more uniform outcome compared with steam blanching [14]. However, prolonged blanching can cause oxidation and chlorophyll degradation. An appropriate blanching time can inactivate enzymes that degrade chlorophyll, making chlorophyll more stable during storage.

Table 2. Color (L*, a*, b*) for 1-Minute Blanching Pretreatment

Treatment	Color	Color		
		L*	a*	b *
Hot water blanching		64.6±0.28	-9.9±0.13	31.8±0.21
Steam blanching		64.3±0.44	-6.4±0.19	30.6±0.96

3.2 Characteristics of GCR

Yield is one of the quality criteria listed in the Indonesian National Standard (SNI) for rice flour. The yield of GCRF ranged between 89.83 and 90.51% and was not significantly affected by the treatments (Table 3).

Table 3. Effect of alkaline solution type on yield, particle size, polydisperse index, zeta potential of blanched GCRF

Blanching solution	Yield (%)	Particle size (μm)	Polydisperse index (%)	Zeta Potential (mV)
Without alkaline	90.51±0.52	31.51	10.1	-21.0
$NaHCO_3$	89.94±0.38	100.98	27.9	-23.7
$MgCO_3$	90.10±0.50	33.99	32.6	-21.6
Na_2CO_3	89.60±0.49	53.90	29.5	-25.4
$Ca(OH)_2$	89.83±0.30	45.62	33.0	-24.6

According to SNI 3549:2009, which outlines the quality standards for rice flour, flour must be able to pass through an 80-mesh sieve with a minimum sieving yield of 90%. Therefore, the yield results from this study complied with the required quality standards, because the GCRF was filtered through a 100-mesh sieve. The yield analysis results showed no significant differences among treatments, which may be attributed to the fact that the pretreatment was applied to the leaves, whereas the majority of the GCRF composition consisted of rice. In this study, GCRF was filtered through a 100-mesh sieve. A 100-mesh sieve produces particles smaller than 149 μm, whereas particles larger than 149 μm do not pass through the sieve [15]. The particle size of GCRF increased in the following order: blanching without alkali had the smallest particle size, followed by $MgCO_3$, $Ca(OH)_2$, Na_2CO_3, and the largest was observed in $NaHCO_3$ treatment. A larger particle size indicates that larger particles were retained during sieving. Alkaline conditions can weaken or break down cell wall polysaccharides, leasing to softer tissues that are more easily grinded during grinding process and can cause reducing particle siz.

The polydispersity index (PDI) of the GCRF, from lowest to highest, was observed in the following order: blanching without the addition of alkaline compounds had the lowest PDI, followed by $NaHCO_3$, Na_2CO_3, $MgCO_3$, and the highest PDI was found in the $Ca(OH)_2$. Differences in particle size can influence the polydispersity index (PDI) of flour. PDI reflects the uniformity of particle size distribution within a sample; a low PDI indicates a narrow, homogeneous distribution, whereas a high PDI suggests a broad, heterogeneous size range. When particle sizes vary significantly within the flour because of the processing conditions or material properties, PDI tends to increase. Therefore, variations in particle size directly contribute to the PDI value, affecting the consistency and functionality of the final product. PDI analysis was used to assess the uniformity of particle size distribution. GCRF exhibited high polydispersity, indicating a broad range of particle sizes. This is because the grinding process uses a dry food grinder, which does not have a mechanism to homogenize the particle sizes. A higher PDI indicates that the system is polydisperse, indicating that it has a wide variation in particle size.

The zeta potential values for the green-colored rice flour, from lowest to highest, were observed in the following order: blanching without the addition of alkalin compounds had the lowest zeta potential, followed by $MgCO_3$, $NaHCO_3$, $Ca(OH)_2$, and the highest value was found in the Na_2CO_3 treatment. The application of different alkaline treatments did not significantly affect the zeta potential of flour. The zeta potentials of all the GCRF were between -30 mV and +30 mV. Zeta potential is a parameter of the electrical charge between colloidal particles. Zeta potential values between -30 mV and +30 mV indicated that the suspension of GCRF had low stability, and the colloids tended to coagulate or flocculate [16].

3.3 Color

The addition of suji and pandan wangi leaves, both rich in chlorophyll pigments, changed the natural white color of rice flour to green. The color values (L*, a*, b*) of green-colored rice flour are influenced by the stability and integrity of chlorophyll during processing, which is highly affected by the type of alkaline treatment used during blanching. Different alkaline compounds interact differently with the chlorophyll structure. In particular, alkaline conditions help preserve the green color by maintaining the central magnesium ion within the chlorophyll molecule, preventing its conversion to pheophytin, which has a dull olive-brown color. However, each alkaline compound has a different pH and buffering capacity, leading to variations in how effectively it stabilizes chlorophyll. GCRF was subjected to color measurement using a color reader, which measured the L*, a*, and b* values. The L* value represents the brightness level of the sample, ranging from to 0-100. A lower L* value indicates a darker color, whereas a higher L* value indicates a lighter color. The a* value represents the red-to-green color range, and the b* value represents the yellow-to-blue color range. The a* value represents the red-green axis in the CIELAB color space. A positive a* value indicates a tendency toward red, whereas a negative a* value indicates a tendency toward green. A positive b * value indicates yellow, while a negative b* value indicates blue [17].

Table 4. Effect of alkaline solution type on color characteristics (L a b) and HEX of GCRF

Alkaline	L*	a*	b*	Color	
Without alkali	$74.5\pm0{,}11^{a}$	-6.1 ± 0.08^{e}	28.5 ± 0.12^{c}		HEX: B6B57E RGB 182 181 126
$NaHCO_3$	$73.7\pm0{,}06^{b}$	-7.2 ± 0.09^{d}	30.6 ± 0.08^{a}		HEX: B2B377 RGB 178 179 119
$MgCO_3$	$71.8\pm0{,}04^{d}$	-9.6 ± 0.23^{a}	30.5 ± 0.06^{a}		HEX: B1B77A RGB 177 183 122
Na_2CO_3	$72.9\pm0{,}05^{c}$	-9.0 ± 0.13^{b}	30.0 ± 0.15^{b}		HEX: B4B97D RGB 180 185 125
$Ca(OH)_2$	$72.8\pm0{,}08^{c}$	-7.8 ± 0.05^{c}	27.8 ± 0.08^{d}		HEX: B7BB83 RGB 183 187 131

Notes: Note: Data (mean±SD) were derived from five replications. Data were analysed by ANOVA. The data within the same column followed by different letters shows significantly different (Tukey test, $p<0.05$). Hex is the representation of color using the hexadecimal system, which indicates the intensity of the red, green, and blue colors. RGB refers to the code that shows the intensity of the three primary light colors (Red, Green, and Blue) with values ranging from to 0-255.

As shown in Table 4, L* values of GCRF subjected to blanching in alkaline compounds, arranged from lowest to highest, were observed in the following order: $MgCO_3$, Na_2CO_3, $Ca(OH)_2$, $NaHCO_3$, and the highest value was recorded in the treatment without alkaline compounds. In materials with high pigment content, the L* value tends to decrease because the pigments absorb light than they transmit[18]. Blanching treatments in an alkaline solution can preserve chlorophyll pigments in *the leaves of suji and pandan wangi*. Consequently, the GCRF with *suji* and *pandan wangi* leaves blanched with alkaline compounds had lower brightness (L*) than GCRF blanched without alkaline compounds, owing to the more intense green color from the chlorophyll. Alkaline stabilizes chlorophyll by increasing the pH of leaves. Additionally, blanching helps to preserve chlorophyll by inactivating the enzyme chlorophyllase, which degrades chlorophyll into pheophytin [14]. A lower a* value indicates a stronger green hue in the GCRF, which is primarily attributed to the presence of chlorophyll derived from the suji and pandan wangi leaves. Because chlorophyll is the pigment responsible for green coloration, a decrease in the a* value corresponds to an increase in chlorophyll content. This observation is supported by [19], who reported that suji and pandan wangi leaves were rich in natural pigments, particularly chlorophyll. Similarly, [7] found that increasing the amount of these leaves during rice flour processing enhanced the green intensity of the product, consistent with the higher levels of chlorophyll retained in the flour. The b* values, from lowest to highest, are $Ca(OH)_2$, rice flour without the addition of alkaline compounds, Na_2CO_3, and $MgCO_3$, which is similar to $NaHCO_3$. The addition of *suji* and *pandan wangi* leaves can impart a yellowish hue to rice flour owing to the presence of chlorophyll pigments. There are various types of chlorophyll in the leaves, such as chlorophyll a and b, where chlorophyll b has a yellowish-green color [20]. The higher the chlorophyll b content in the rice flour, the higher is the b* value. However, a higher b* value can also indicate the formation of pheophytin, resulting from the loss of magnesium ions (Mg^{2+}) and substitution with hydrogen ions (H^+) in the chlorophyll porphyrin ring, which causes the chlorophyll to turn brown. The formation of pheophytin is a sign of chlorophyll degradation, which can be triggered by acidic conditions, high temperatures, or exposure to light [21].

3.4 Chemical Analysis

The results of the chemical analyses presented in Table 5 include the measurements of pH, chlorophyll content (total, a, and b), moisture content, ash content, and antioxidant activity.

Table 5. pH, chlorophyll, moisture content, ash content, and antioxidant activity of GCRF

Alkaline	pH	Chlorophyl Total (mg/L)	Chlorophyl a (mg/L)	Chlorophyl b (mg/L)	Moisture content, wb (%)	Ash content, wb (%)	Antioxidant activity (mg TE/g)
Without alkaline	6.46±0.02^{e}	31.21±0.13^{e}	16.63±0.15^{bc}	14.34±0.21^{e}	8.91±0.46^{b}	0.68±0.02^{a}	6.52±0.04^{d}
$NaHCO_3$	7.73±0.06^{b}	35.56±0.27^{c}	17.39±0.87^{ab}	18.32±0.11^{c}	9.63±0.13^{a}	0.66±0.01^{ab}	6.79±0.04^{c}
$MgCO_3$	7.85±0.01^{a}	40.79±0.16^{a}	17.01±0.14^{abc}	23.66±0.14^{a}	9.62±0.30^{a}	0.60±0.01^{c}	7.13±0.08^{a}
Na_2CO_3	7.60±0.04^{c}	40.19±0.24^{b}	17.61±0.11^{a}	22.44±0.33^{b}	9.68±0.33^{a}	0.64±0.01^{ab}	6.93±0.08^{b}
$Ca(OH)_2$	7.34±0.05^{d}	33.26±0.20^{d}	16.58±0.09^{c}	15.62±0.07^{d}	9.67±0.21^{a}	0.63±0.01^{bc}	6.64±0.04^{d}

Note: Data (mean±SD) were derived from five replications. Data were analysed by ANOVA. The data within the same column followed by different letter shows significantly different (Tukey test, $p<0.05$)

3.5 pH

According to Table 5, the pH of the GCRF ranges from 6.46 to 7.85 and is affected by the alkaline solution used during leaf blanching. The pH values of GCRF, from lowest to highest, were observed in the following order: blanching without alkaline compounds resulted in the lowest pH, followed by $Ca(OH)_2$, Na_2CO_3, $NaHCO_3$, and the highest pH was observed in the $MgCO_3$ treatment. Blanching with alkaline solutions can increase the pH of chlorophyll extract [9]. The higher the concentration of alkaline compounds in the solution, the higher is the pH of the chlorophyll extract. The increase in pH due to the addition of alkaline compounds occurs because alkalis in water produce OH^- ions, which increase the pH of the environment. The alkaline compounds dissociate in water to form OH^- ions, which increase after the addition of alkaline substances and reduce the concentration of H^+ ions in the environment [22]. Under normal conditions, plant tissues are acidic and contain free H^+ ions that can increase over time during storage. Therefore, during prolonged storage, the conversion of chlorophyll to pheophytin can still occur owing to the presence of H^+ ions. The basic environment slows the conversion of chlorophyll into pheophytin [17].

3.6 Chlorophyll Content

The variation in chlorophyll content among the treatments can be attributed to the different chemical properties of the alkaline compounds used during the blanching process. Each alkaline solution has a unique pH level and ionic composition, which influence the stability of chlorophyll in the leaves. Alkaline conditions generally help to preserve chlorophyll by preventing the removal of the central magnesium ion, which would otherwise lead to the formation of pheophytin, a brownish pigment. However, excessively high alkalinity or prolonged exposure can also degrade chlorophyll or alter its structure through reactions such as isocyclic ring opening or oxidation.

As shown in Table 5, total chlorophyll content of GCRF, from lowest to highest, was obtained from treatments in the following order: blanching without alkaline compounds yielded the lowest chlorophyll content, followed by $Ca(OH)_2$, $NaHCO_3$, Na_2CO_3, and the highest content was observed in the $MgCO_3$ treatment. This indicated that the total chlorophyll content in the GCRF increased when the leaves were blanched in an alkaline solution. When the total chlorophyll content of GCRF increased, its brightness decreased and the green color intensified. Among the treatments, $MgCO_3$ yielded the highest chlorophyll content, likely due to its moderate alkalinity and additional magnesium ions, which may reinforce chlorophyll stability. In contrast, treatments with $Ca(OH)_2$ resulted in lower chlorophyll levels, possibly due to stronger alkalinity or less favorable ionic interactions, leading to pigment degradation. These differences indicate that the type and strength of the alkali significantly affects the preservation of chlorophyll during processing [9].

Blanching the leaves with all alkalines except $CaOH_2$ can preserve both chlorophyll a and b better than blanching without alkalinity. The lowest levels of chlorophyll a and b observed in the $Ca(OH)_2$ treatment may be attributed to the oxidative degradation of chlorophyll, leading to the formation of derivatives, such as pheophytin, pyropheophytin a, and pyropheophorbide a. Chlorophyll changes can be attributed to the duration of contact between the leaves and alkaline solution; the longer the contact time, the more chlorophyll undergoes transformation, as indicated by the opening of the isocyclic ring in the chlorophyll structure. This structural alteration disrupts the conjugated double-bond system responsible for the green color, resulting in pigment degradation and the formation of brownish derivatives such as pheophytin or oxidized products, ultimately reducing the green intensity and stability of the pigment [23].

These results indicate that the addition of alkaline compounds can preserve chlorophyll b pigments in green-colored rice flour [24]. Chlorophyll a is typically more abundant than chlorophyll b in suji leaves. However, based on chlorophyll calculations, the chlorophyll b content was higher than that of chlorophyll a. [25] Reported that chlorophyll a degrades 12-18 times faster than chlorophyll b at high temperatures. In this study, heating was applied during both the blanching and drying processes, which likely caused a significant degradation of chlorophyll a, resulting in lower chlorophyll a levels compared to chlorophyll b.

3.7 Moisture Content

Based on Table 5, the moisture content of the GCRF ranged from 8.91% to 9.68%. According to SNI No. 3549 of 2009 regarding the quality standards for rice flour, one of the testing criteria for rice flour is a maximum moisture content of 13%. In this study, the moisture content of the produced GCRF met the quality requirements for rice flour. The moisture content of green-colored rice flour without the addition of alkaline compounds was lower than that of rice flour treated with alkaline blanching. However, the differences in moisture content between the green-colored rice flours treated with various alkaline compounds were not statistically significant. The addition of alkaline compounds may increase the moisture content of the green-colored rice flour, possibly due to enhanced water retention in rice starch. Alkaline treatment can increase the pH of flours and promote starch degradation. Changes in starch structure may increase its water-holding capacity [26]. In addition, other factors, such as the raw materials used, may also contribute to variations in the moisture content. Different types of leaves may contain varying levels of moisture, which can influence the final moisture content of green-colored rice flour. There were no significant differences between the individual alkaline treatments.

3.8 Ash Content

Ash content is one of the chemical characteristics of rice flour and is a key quality requirement for rice flour. The ash content of green-colored rice flour ranges from 0.60% to 0.68%. Based on the results of the analysis, the treatment had an effect but was not statistically significant.

Ash content is one of the key criteria specified in the quality standards for rice flour, according to SNI No. 3549 of 2009. All the GCRF complied with the quality standard for ash content, which must be less than 1.0%. The addition of alkaline compounds to the blanching solution can reduce ash content [27]. Alkaline compounds may cause minerals to leach out (from the material) and form complexes with OH- ions. The formation of these complexes can lower the ash content.

3.9 Antioxidant Activity

According to Table 5, antioxidant activity of the GCRF ranges from 6.52 to 7.13 mg TE/g. The antioxidant compounds in GCRF are attributed to the addition of *suji* and *pandan wangi* leaves, where an increase in the ratio of *suji* and *pandan wangi* leaves leads to higher antioxidant content in the green-colored rice flour [6]. Chlorophyll is one of the types of antioxidants present in the leaves. The addition of alkaline compounds during the blanching process can reduce the rate of chlorophyll degradation in leaves [20]. In this study, it was observed that a higher total chlorophyll content was associated with increased antioxidant activity. However, alkaline blanching treatments may also lead to antioxidant degradation owing to heat and alkaline hydrolysis [28]. Differences in antioxidant activity may be influenced by the chlorophyll content of each GCRF sample. However, the overall antioxidant activity remained low, likely because of the limited amount of leaf material incorporated into the flour.

3.10 Color Stability of Green Colored Rice Flour (GCRF)

The color stability of GCRF at different conditions is presented at Table 6. All the conditions affected significantly the color stability of GCRF except the condition of 4°C-storage.

At Different Temperatures. Color stability analysis of GCRF at different temperatures was conducted using two treatments: storage at 4°C and 105°C. Storage at 105°C was used to assess the stability of the green color during high-temperature cooking processes, whereas storage at 4°C was used to evaluate color stability under low-temperature storage conditions. GCRF was stored under specific conditions for 72 h (3 days). The color difference in the GCRF before and after treatment was analyzed by observing the ΔE value. Based on the ΔE value, the impact of the treatment on color stability at low and high temperatures can be determined.

Table 6. The difference of color stability (ΔE) at different storage conditions of GCRF produced with different blanching solution

Blanching solution	4°C	105°C	Dark room	Light-exposed	pH 4.0	pH 7.0	pH 10.0	During 21-day storage
Without alkaline	1.61±0.10^{a}	13.22±0.18^{a}	1.54±0.29^{a}	9.49±0.63^{a}	13.50±0.40	8.25±0.39^{a}	13.95±0.78^{a}	2.16±0.20^{a}
$NaHCO_3$	0.77±0.14^{b}	12.16±0.12^{b}	0.90±0.09^{b}	4.71±0.29^{cd}	13.39±0.84	5.23±0.48^{c}	12.39±0.19^{b}	0.95±0.20^{b}
$MgCO_3$	0.73±0.18^{b}	10.86±0.30^{d}	0.92±0.59^{ab}	4.18±0.39^{d}	12.37±0.39	4.51±0.13^{d}	13.99±0.35^{a}	0.99±0.48^{b}
Na_2CO_3	0.86±0.25^{b}	12.07±0.22^{bc}	0.79±0.35^{b}	5.30±0.59^{c}	13.21±0.83	7.96±0.19^{ab}	13.71±0.41^{a}	0.90±0.12^{b}
$Ca(OH)_2$	0.66±0.17^{b}	11.49±0.54^{cd}	1.05±0.24^{ab}	7.66±0.17^{b}	13.34±0.07	7.54±0.14^{b}	14.52±0.77^{a}	1.13±0.12^{b}

Note: Data (mean±SD) were derived from five replications. Data were analysed by ANOVA. The data within the same column followed by different letter shows significantly different (Tukey test, $p<0.05$)

At a storage temperature of 4°C, the highest ΔE value was observed for GCRF subjected to blanching without the addition of alkaline compounds. There was no significant difference in the ΔE values among the treatments with $NaHCO_3$, $MgCO_3$, Na_2CO_3, and $Ca(OH)_2$ based on Table 7. The ΔE values show that blanching the leaves in an alkaline solution can improve the stability of the GCRF at 4°C, as the ΔE values were <1, indicating no visible color change in the GCRF. Temperature and pH are key factors in chlorophyll stability, as chlorophyll can degrade at high temperatures and acidic pH, forming derivatives that alter chlorophyll color [8].

At 105°C, the highest ΔE value was also observed in GCRF produced using blanched leaves without the addition of alkali. Although the GCRF treated with $MgCO_3$ showed a lower ΔE value, all the GCRF samples stored at 105°C had ΔE values >5, indicating a noticeable color change. Although GCRF treated with $MgCO_3$ showed a lower ΔE value, this may be attributed to the enhanced color stability of chlorophyll under moderate alkaline conditions. $MgCO_3$ not only provides a suitable pH that minimizes chlorophyll degradation but also supplies magnesium ions, which can help maintain the structural integrity of chlorophyll molecules. Consequently, the color change (ΔE) between the initial and treated samples remained minimal, indicating better retention of the green pigment. This was likely due to prolonged exposure to high temperatures, which led to the degradation of chlorophyll into derivatives, such as pheophytin. Pheophytin converts chlorophyll a into a grayish color and chlorophyll b into a brownish hue [8].

Under Light Exposure. Light can also cause chlorophyll degradation. The color stability analysis of the GCRF under light exposure was conducted using two light conditions: a closed dark room and a light-exposed room. The light-exposure treatment was performed by placing the GCRF in a box illuminated by a 7-watt lamp. GCRF was stored under these conditions for 72 h (3 d).

GCRF was more stable in a dark room, which was not exposed to light. Light is a significant factor in chlorophyll degradation. The higher the intensity of light exposure, the greater the degradation of chlorophyll [29].

In the light-exposed treatment, all the GCRF made from blanched leaves in alkaline solution showed a lower ΔE than GCRF made from blanched leaves without alkaline solution. As shown in Table 6, $MgCO_3$ has the lowest ΔE, which can be attributed to several factors. First, $MgCO_3$ has a moderate alkalinity compared to other alkalis used in this study. This level of alkalinity is sufficient to preserve the central magnesium ion in the chlorophyll molecule, which is essential for maintaining its green color without being too strong to cause structural damage or chlorophyll degradation. Second, $MgCO_3$ naturally supplies magnesium ions, which may further stabilize chlorophyll by reinforcing its molecular structure. This is particularly important under light exposure, when chlorophyll is susceptible to photooxidation. The presence of Mg may help mitigate this degradation pathway by maintaining the integrity of chlorophyll molecules. In contrast, stronger alkalis like Na_2CO_3 or $Ca(OH)_2$ can cause excessive chlorophyll saponification or hydrolysis, leading to the breakdown of the pigment and greater color change (higher ΔE values). Therefore, the relatively low ΔE in the $MgCO_3$ treatment suggests that it provides an optimal environment for preserving the green color of the GCRF, especially under room light conditions. However, at the end of exposure, the value of ΔE for all GCRF is still high. The use of alkaline compounds in the blanching solution of *suji* and *pandan wangi* leaves may preserve chlorophyll stability by increasing pH [30] and inactivating chlorophyllase, which becomes inactive at temperatures between 75-100°C [31]. Chlorophyll can be degraded through both enzymatic and non-enzymatic processes. Therefore, blanching does not directly protect chlorophyll from degradation owing to exposure to light.

At Different pH. pH is one of the factors influencing chlorophyll degradation, and it alters the color of chlorophyll, with chlorophyll degrading more easily under acidic conditions. A color stability test under different pH conditions was conducted by storing GCRF in buffer solutions with pH values of 4.0, 7.0, and 10.0. The GCRF was stored under these conditions for 72 hours (3 days).

GCRF is sensitive to pH. Either treated at pH 4.0, 7.0, or 10.0, had ΔE values greater than 5, indicating a more visible difference in color, as shown in Table 6. However, GCRF produced using blanched leaves without alkaline had a higher ΔE value compared to GCRF treated with blanching and the addition of alkaline compounds at pH 7. GCRF is also more stable at neutral pH than at acidic and basic pH. Chlorophyll becomes increasingly unstable under acidic conditions. In an acidic environment, Mg^{2+} in the chlorophyll core becomes less stable and can be replaced by two H^+ ions, forming pheophytin, which has a brown color. Further degradation can lead to the formation of pheophorbide through the de-esterification of pheophytin, which involves removal of the phytol chain [32]. At alkaline pH, all the GCRF samples showed high ΔE values (>5), indicating very noticeable color changes. Although chlorophyll is more stable in alkaline environments, degradation can still occur if the pH is too high for chlorophyll stability.

During 21-Day Storage. The stability of green color in GCRF was also evaluated over a 21-day storage period. The color stability test was conducted by storing the GCRF in a closed container for 21 d, and the color changes were monitored.

The use of alkaline compounds in the blanching solution of *suji* and *pandan wangi* leaves in the GCRF significantly affected the ΔE value. As shown in Table 6, the highest ΔE value was observed for GCRF without the addition of alkaline compounds, whereas no significant differences were found among GCRF samples treated with alkaline compounds. Blanching treatments using alkaline compounds are commonly employed to enhance the stability of chlorophyll because the addition of alkaline compounds increases the pH of the chlorophyll environment, preserving its stability. Furthermore, blanching can inactivate enzymes responsible for enzymatic degradation of chlorophyll [8]. However, even under normal conditions, chlorophyll may still degrade because of factors such as pH reduction, light exposure, oxygen, and moisture content in the flour. The degradation of chlorophyll alters its structure and subsequently its color, affecting the appearance of rice flour [33].

3.11 Best Treatment

The determination of the best treatment for green-colored rice flour, with different blanching solutions (without alkaline, $NaHCO_3$, $MgCO_3$, Na_2CO_3, and $Ca(OH)_2$), was conducted using the Multiple Criteria Decision Making (MCDM) Zeleny method based on 17 parameters. The analysis revealed that the best treatment, with the most favorable performance in terms of expected value, was the GCRF made with the blanched leaves in 1% of $MgCO_3$ solution shown in Table 7.

Table 7. Different of GCRF characteristics derived from blanching treatment (using $MgCO_3$ solution) compared to control (without alkaline solution)

Characteristics of GCRF	Without alkaline	$MgCO_3$
L*	74.5±0.11[a]	71.8±0.08[b]
a*	-6.1±0.08[b]	-9.6±0.24[a]
b*	28.5±0.12[b]	30.5±0.06[a]

Moisture content, wb (%)	8.91±0.46[b]	9.62±0.30[a]
Ash content, wb (%)	0.68±0.02[a]	0.60±0.03[b]
Yield (%)	90.51±0.52	90.10±1.08
pH	6.46±0.02[b]	7.85±0.01[a]
Chlorophyll total (mg/L)	31.21±0.13[b]	40.79±0.16[a]
Antioxidant activity (mg TE/g)	6.52±0.04[b]	7.13±0.04[a]
ΔE at 4°C	1.61±0.10[a]	0.74±0.39[b]
ΔE at 105°C	13.22±0.18[a]	10.86±0.30[b]
ΔE at dark room	1.54±0.29[a]	0.92±0.27[b]
ΔE at exposed to light	9.49±0.63[a]	4.18±0.39[b]
ΔE at pH 4.0	13.50±0.40	12.37±0.39
ΔE at pH 7.0	8.25±0.39[a]	4.51±0.13[b]
ΔE at pH 10.0	13.95±0.78	13.99±0.35

Note: Data (mean±SD) were derived from five replications. Data were analysed by ANOVA. The data within the same row followed by different letters shows significantly different (Tukey test, $p<0.05$). In a comparison across several parameters, blanching the leaves in $MgCO_3$ solution produced better GCRF characteristics (except moisture content) than without the addition of alkaline compounds.

Conclusion. The type of alkaline compound added to the blanching solution had a significant effect (p-value < 0.05) on color L*, a* b*, moisture content, ash content, total chlorophyll content, chlorophyll a content, chlorophyll b content, pH, antioxidant activity, color stability at 4°C and 100°C, color stability in dark and light conditions, and color stability at pH 7.0 and pH 10.0. However, it did not have a significant effect on the yield and color stability at pH 4.0. The best treatment for producing GCRF is blanching the leaves in a 1% $MgCO_3$ solution. Comparing to the control, blanching the leaves in $MgCO_3$ solution produced better and more stable GCRF characteristics. This finding suggests that the use of $MgCO_3$ in the blanching process is a promising approach for enhancing the quality and stability of natural green colorants in food applications. Further studies may explore its use in the development of green colored functional food products, such as bakery items, beverages, or instant powders, to promote plant-based formulations.

Acknowledgments. The authors would like to thank the department of Food Science and Biotechnology at Universitas Brawijaya for supporting this publication.

Disclosure of Interests. The authors declare that they have no conflicts of interest.

References

[1] C. A. Afgani, I. Nairfana, R. N. Sari, and N. A. Komarudin, "Pelatihan Pembuatan Tepung Beras di Desa Parate Kecamatan Samapuin Kabupaten Sumbawa," *Jurnal Agro Dedikasi Masyarakat,* vol. 4, no. 1, pp. 23-28, 2023.

[2] Ridawati and Alsuhendra, "Pembuatan Tepung Beras Warna Menggunakan Pewarna Alami dari Kayu Secang," *Edusaintek,* vol. 1, no. 1, pp. 408–419, 2019.

[3] E. Contreras-Lopez, A. Castañeda-Ovando, L. G. González-Olivares, J. Añorve-Morga, and J. Jaimez-Ordaz, "Effect of Light on Stability of Anthocyanins in Ethanolic Extracts of *Rubus fruticosus,*" *FNS*, vol. 05, no. 06, pp. 488–494, 2014, doi: 10.4236/fns.2014.56058.

[4] T. Wu *et al.*, "Effect of Milling Methods on The Properties of Rice Flour and Gluten-Free Rice Bread," *LWT*, vol. 108, pp. 137–144, Jul. 2019, doi: 10.1016/j.lwt.2019.03.050.

[5] A. Ningrum and M. Schreiner, "Pandan Leaves: 'Vanilla of the East' as Potential Natural Food Ingredient," *Agro Food Industry Hi-Tech*, vol. 25, pp. 10–14, May 2014.

[6] J. Syarendra, "Inovasi Tepung Beras Hijau dengan Pewarna Alami Daun Pandan (*Pandanus amaryllifolius* Roxb.) dan Daun Suji (*Pleomele angustifolia*)," Brawijaya University, Malang, 2022.

[7] W. Kurniawan, "Inovasi Tepung Berkecambah Beras Pecah Kulit Berwarna dengan Penambahan Daun Pandan Wangi dan Daun Suji," Brawijaya University, Malang, 2023.

[8] D. Indrasti, N. Andarwulan, E. H. Purnomo, and N. Wulandari, "Stability of Chlorophyll as Natural Colorant: A Review for Suji (*Dracaena angustifolia* Roxb.) Leaves' Case," *Curr Res Nutr Food Sci*, vol. 6, no. 3, pp. 609–625, Dec. 2018, doi: 10.12944/CRNFSJ.6.3.04.

[9] H. K. N. Cao and T. A. D. Dong, "Study on The Effect of Metal Salts on Chlorophyll Pigment Extraction from Fresh *Sauropus androgynus* Leaves," *Journal of Agriculture and Food Research*, vol. 14, p. 100699, Dec. 2023, doi: 10.1016/j.jafr.2023.100699.

[10] Association of Official Analytical Chemists (AOAC), *Official Methods of Analysis (18 Edn)*, Association of Official Analytical Chemist Inc. Mayland. USA, 2005.

[11] J. Sochor *et al.*, "Content of Phenolic Compounds and Antioxidant Capacity in Fruits of Apricot Genotypes," *Molecules*, vol. 15, pp. 6285–6305, Sep. 2010, doi: 10.3390/molecules15096285.

[12] J. F. G. M. Wintermans and A. De Mots, "Spectrophotometric Characteristics of Chlorophylls a and b and Their Phenophytins in Ethanol," *Biochimica et Biophysica Acta (BBA) - Biophysics including Photosynthesis*, vol. 109, no. 2, pp. 448–453, Nov. 1965, doi: 10.1016/0926-6585(65)90170-6.

[13] W. Mokrzycki and M. Tatol, "Color Difference Delta E - A survey," *Machine Graphics and Vision*, vol. 20, pp. 383–411, Apr. 2011.

[14] R. Moscetti, F. Raponi, D. Monarca, G. Bedini, S. Ferri, and R. Massantini, "Effects of Hot-Water and Steam Blanching of Sliced Potato on Polyphenol Oxidase Activity," *Int J of Food Sci Tech*, vol. 54, no. 2, pp. 403–411, Feb. 2019, doi: 10.1111/ijfs.13951.

[15] M. Arshadi and S. M. Mousavi, "Multi-Objective Optimization of Heavy Metals Bioleaching from Discarded Mobile Phone Pcbs: Simultaneous Cu and Ni Recovery Using

Acidithiobacillus ferrooxidans," *Separation and Purification Technology*, vol. 147, pp. 210–219, Jun. 2015, doi: 10.1016/j.seppur.2015.04.020.

[16] R. C. Murdock, L. Braydich-Stolle, A. M. Schrand, J. J. Schlager, and S. M. Hussain, "Characterization of Nanomaterial Dispersion in Solution Prior to In Vitro Exposure Using Dynamic Light Scattering Technique," *Toxicological Sciences*, vol. 101, no. 2, pp. 239–253, Feb. 2008, doi: 10.1093/toxsci/kfm240.

[17] N. Aryanti, A. Naifunisa, and F. M. Wilis, "Ekstraksi dan Karakterisasi Klorofil dari Daun Suji (*Pleomele angustifolia*) sebagai Pewarna Pangan Alami," *JATP*, vol. 5, no. 4, 2016, doi: 10.17728/jatp.196.

[18] A. Morina and A. Shehaf, in *CIELAB Color Parameters and Pigments Contents in Virgin Olive Oil from Different Areas of Production in Albania*, Trakya University, Sep. 2022, pp. 217–223.

[19] A. E. Wiyono, W. Amilia, and R. A. Mulyana, "Optimasi Formula Serbuk Pewarna Alami Berbasis," *Jurnal Rekayasa dan Manajemen Industri,* vol. 11, no. 2, pp. 315-330, 2023.

[20] D. Indrasti *et al.*, "Suji Leaf Chlorophyll: Potential and Challenges as Natural Colorant," *JIPI*, vol. 24, no. 2, pp. 109–116, Apr. 2019, doi: 10.18343/jipi.24.2.109.

[21] G. L. V. Kusmin, M. F. Sumual, L. E. Lalujan, and J. R. Assa, "Pengaruh Blansir Terhadap Karakteristik Fisikokimia Daun Leilem (*Clerodendrum minahassae* Teisjm. & Binn)," *JTP,* vol. 14, no. 1, 2023.

[22] Y. Ernaini, A. Supriadi, and Rinto, "Pengaruh Jenis Pelarut terhadap Klorofil dan Senyawa Fitokimia Daun," *Fishtech,* vol. 1, no. 1, pp. 1-13, 2012.

[23] M. Berlanga Del Pozo, L. Gallardo-Guerrero, and B. Gandul Rojas, "Influence of Alkaline Treatment on Structural Modifications of Chlorophyll Pigments in NaOH—Treated Table Olives Preserved without Fermentation," *Foods*, vol. 9, no. 701, pp. 1-17, Jun. 2020, doi: 10.3390/foods9060701.

[24] N. Aryanti and A. Nafiunisa, "Extraction Characteristic and Degradation of Chlorophyll from Suji Leaves (*Pleomele angustifolia*)," *Orient. J. Chem*, vol. 33, no. 6, pp. 3185–3190, Dec. 2017, doi: 10.13005/ojc/330663.

[25] H. Erge, F. Karadeniz, N. Koca, and Y. Soyer, "Effect of Heat Treatment on Chlorophyll Degradation and Color Loss in Green Peas," *GIDA*, vol. 33, pp. 225–233, Jan. 2008.

[26] R. Ali, M. S. Khan, S. A. Sayeed, R. Ahmed, S. M. G. Saeed, and L. Mobin, "Relationship of Damaged Starch with Some Physicochemical Parameters in Assessment of Wheat Flour Quality," vol. 46, no. 6, pp. 2217-2225, 2014.

[27] J. E. Aston, B. D. Wahlen, R. W. Davis, A. J. Siccardi, and L. M. Wendt, "Application of Aqueous Alkaline Extraction to Remove Ash from Algae Harvested from An Algal Turf Scrubber," *Algal Research*, vol. 35, pp. 370–377, Nov. 2018, doi: 10.1016/j.algal.2018.09.006.

[28] G.-C. Yen and C.-Y. Hung, "Effects of Alkaline And Heat Treatment on Antioxidative Activity and Total Phenolics of Extracts from Hsian-tsao (*Mesona procumbens* Hemsl.)," *Food Research International*, vol. 33, no. 6, pp. 487-492, 2000.

[29] J. Ma *et al.*, "Analysis of Chlorophyll A Fluorescence and Proteomic Differences of Rice Leaves in Response to Photooxidation," *Acta Physiol Plant*, vol. 39, no. 46, pp. 1-14, Feb. 2017, doi: 10.1007/s11738-016-2342-0.

[30] I. Mahfudh, G. W. Santosa, and R. Pramesti, "Stabilitas Ekstrak Kasar Klorofil-a dan b Rumput Laut *Caulerpa racemosa* (Forsskal) J. Agardh 1873 pada Suhu dan Lama

Penyimpanan yang Berbeda," *J. Mar. Res.*, vol. 10, no. 2, pp. 184–189, May 2021, doi: 10.14710/jmr.v10i2.29685.

[31] Y. Zhao *et al.*, "Effect of Ph and Calcium Chloride on The Thermal Inactivation Kinetics and Stability of Chlorophyllase in Mulberry Leaves," Mar. 28, 2024. doi: 10.21203/rs.3.rs-4126800/v1.

[32] D. Heldman, D. Lund, and C. Sabliov, *Handbook of Food Engineering Third Edition*. Boca Raton: CRC Press.

[33] A. Díez-Betriu *et al.*, "Effect of the Storage Conditions and Freezing Speed on the Color and Chlorophyll Profile of Premium Extra Virgin Olive Oils," *Foods*, vol. 12, no. 1, pp. 1-11, Jan. 2023, doi: 10.3390/foods12010222.