The characteristics of dried Suji (*Dracaena angustifolia* (medik.) Roxb.) leaves powder produced by different drying methods and temperatures

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**Abstract.** Suji leaves (*Dracaena angustifolia* (medik.) Roxb.) is one of the chlorophyll sources for producing a dark green color. Suji, extracted with water, has been widely used as a natural colorant for traditional Indonesian food. This study aimed to evaluate the effect of drying methods (vacuum drying and cabinet drying), and temperature (40, 50, and 60˚C) on the physical and chemical characteristics of dried Suji leaves powder (DSLP). Results showed that the drying method and the temperature had a significant effect (p<0.05) on the color (L*, a*, b*), total chlorophyll, moisture, total phenolic content, pH, water absorption, oil absorption capacity, and bulk density of DSLP. Drying by vacuum drying at 50˚C was the best treatment based on Zeleny calculation with the physical characteristics were L* 49.98, a*7.78, b* 20.88, water absorption capacity 453.48%, oil absorption capacity of 252.25%, bulk density 0.32 g/cm³, and chemical characteristics were moisture content of 6.70%, total chlorophyll content 12.98 mg/g, total phenolic content 97.26 mg/g, and pH 5.60. DSLP still has a high chlorophyll content, a green color, even increasing the total phenolic after the drying process, confirming that DSLP has the potential as a natural colorant in food processing.

1. **Introduction**

The Suji plant leaves extract has been widely used as food coloring agents in various traditional Indonesian foods, but these extracts have a short shelf life. Chlorophyll is quickly degraded in high enzyme activity, heat, light, and an increase in acidic conditions, which cause the green color to turn yellowish and colorless [1]. Chlorophyll can be degraded into its derivative products. The cleavage of the phytol chain and chlorophyll caused the formation of green chlorophyllides [2], and if the chlorophyll lost the Mg²⁺ ions, the derivatives products are called pheophytin will be formed. Meanwhile, if pheophytin lost the phytol group and chlorophyllide loses the mg²⁺ ions, olive-brown pheophorbide will be formed [3, 4, 2]. Extensive heat treatment can also cause the loss of the C-10 carbomethoxy group from pheophytin, resulting in olive-colored pyropheophytin [2]. During heating, the release of organic acids can occur, results in the decrease of tissue pH and an increase in pheophytin formation rate [3, 4, 2]. The presence of oxygen and light can generate chlorophyll degradation, and the color will be bleached permanently, which is called photodegradation [6, 7]. So, it is necessary to process fresh Suji leaves into Suji leaf powder to be a natural green coloring agent for longer shelf life.
The fresh leaves can be dried into powder to reduce the majority of free water from the ingredients. The reduction of free water from leaves can inhibit several enzymes' activity and the growth of microorganisms that cause degradation of chlorophyll, resulting in stable chemical components and physical appearance. The drying rate needs to be considered to minimize the degradation process. Drying can be done by various conditions such as atmospheric pressure and vacuum condition. The drying method commonly used in this condition is the cabinet and vacuum dryer. Each drying method differs in terms of the mechanism, drying rate, characteristics, and quality of the dried material. Different methods of drying are associated with advantages and limitations. The temperature during drying can affect the quality and drying rate of the product. The temperature needs to be considered to minimize the possibility of heat damage [10]. The chlorophyll concentration in sugar beet leaves degrades at 60°C [11] so that the drying process needs to be done at a temperature below 60°C.

Studies on different drying methods and various temperatures for whole leaves had been carried out previously to get data about its effect on the final product. For example, studies of Phyllanthus amarus leaves drying using different methods and conditions, include vacuum and hot air dryer at atmospheric conditions. The phytochemical yield and antioxidant capacity were reported but had no total chlorophyll content and color [12]. The other study reported different drying methods on phytochemical, chlorophyll content, and color of green tea leaves [13] and Chinese cabbage and Nightshade [14]. Different drying temperatures of hot air drying on color change in lemon balm also studies [15]. Based on several studies, the drying method and temperature are an interesting factor that needs to be reviewed in drying material, especially leaves commodities that contain sensitive compounds like chlorophyll. Therefore, this study aimed to determine the effect of the method and drying temperature on dried Suji leaf powder's physicochemical characteristics as a natural colorant powder.

2. Materials and Methods

2.1. Preparation of dried Suji leaves powder

The old fresh Suji leaves were taken from PT. Materia Medika, Batu, Indonesia. The leaves were shorted and cut 2 cm long, then chopped. The initial moisture and total chlorophyll content of the sample were determined according to the standard method.

The drying method and the drying temperature were the factors used in the experiment with four replications. About 200 g of chopped Suji leaves were put in two different dryers (vacuum drying and cabinet drying) at temperatures of 40, 50, and 60°C. Each drying treatment of the leaves was dried for 6 hours. The dried Suji leaves then crushed using a dry blender for 5 minutes, followed by a ball mill at 120 rpm for 30 minutes, and sieved at 100 mesh sieves. The Suji powder was then analyzed for physical and chemical properties.

2.2. Evaluation of physical properties

The physical characteristics of the dried Suji leaf powder (DSLP) evaluated were color (L*, a*, b*), water absorption capacity (WAC), oil absorption capacity (OAC), and bulk density. The color was measured using a Minolta color reader (Minolta NR200, Japan). 2 g sample was taken and placed in a petri dish, then put the color reader on the petri dish surface. The color was read as L*, a*, b* value [16]. WAC and OAC were measured by 1 g of each powder were mixed in a centrifuge at 2000 rpm for 30 minutes. The water was then removed from the tube, and the tube was weighed. WAC is the amount of water (mL) absorbed per gram of DSLP. The OAC value was obtained using a similar procedure, but the speed was changed to 3000 rpm for 15 minutes, and the water was replaced by soybean oil [17]. Bulk density is measured by weighing the powder on a known volume measuring glass; the bulk density was calculated using Equation 1 [18].

\[ \text{Bulk density } (\frac{\text{g}}{\text{cm}^3}) = \frac{M_p}{V_p} \]  

(1)
2.3. Evaluation of chemical properties
The dried Suji leaf powder (DSLP) physical characteristics are moisture content, total chlorophyll content, total phenolic, and pH. Moisture analysis using a gravimetric method [19]. Total chlorophyll was analyzed using the UV-Vis Spectrophotometry at wavelengths of 645 and 663 nm [20]. Total chlorophyll is obtained by calculating the absorbance using the formula:

\[
\text{Total chlorophyll content concentration (mg L}^{-1}) = (8.02 \times A_{663}) + (20.2 \times A_{645})
\]

\[
\text{Total chlorophyll content in powder (mg g}^{-1}) = \frac{(8.02 \times A_{663}) + (20.2 \times A_{645})}{10}
\]

Total phenolic was measured by 0.5 mL sample extract was mixed with 2 mL Na\textsubscript{2}CO\textsubscript{3} 7.5%, then incubated for 30 minutes. The absorbance of the mixture was measured using UV-Vis Spectrophotometry at wavelength 756 nm. The concentration (x) of the sample is measured using an equation obtained from a standard curve.

\[
TPC = CGAE \times FP
\]

pH analysis was measured using standardized pH meters use standard buffer pH 4.00, 7.00, and 9.00. about 1 g sample was mixed with 10 mL distilled water and stand for 10 minutes before analysis. The pH meter is dipped into the sample solution [19]

2.4. Best treatment evaluation
The best treatment evaluation was obtained using Zeleny Multiple Attribute methods; the lowest sums of L1, L2, and Lmax are the best treatment [22]. Ten parameters were calculated in the formula:

\[
(\chi) = \frac{1}{\sum \text{parameters}}
\]

\[
L1 = 1 - \sum (\chi^2 \times (1 - dk))
\]

\[
L2 = 1 - \sum (\chi^2 \times (1 - dk)^2)
\]

\[
L\infty = \text{maximum value at } (1 \times (1 - dk))
\]

The DSLP best treatment was analyzed for its total dietary fiber (TDF), soluble dietary fiber (SDF), and insoluble dietary fiber (IDF) using enzymatic-gravimetric methods [23].

2.5. Statistical analysis
The analysis was conducted in four replications. The data obtained were analyzed using Minitab statistics version 17 for Windows (Minitab Inc. Chicago, USA). Significant differences between the mean values were evaluated with analysis of variance (ANOVA) followed by Tukey’s multiple comparisons test (P<0.05).

3. Results and Discussion

3.1. Characteristics of fresh Suji leaves
Table 1 shows the color of fresh Suji leaves. Suji leaves have a dark green color. The low L* value of the Suji is caused by chlorophyll pigment, while the redness value indicates the presence of pigments (anthocyanin/carotene/ chlorophyll) involved in leaf coloring [24]. The dark color of leaves indicates a high chlorophyll content [25]. The total chlorophyll content in fresh Suji leaves was 3.04 mg/g. When converted into ppm, the chlorophyll content of fresh leaves is 3040 ppm. This result is slightly lower
than other studies, which have the total amount of chlorophyll of fresh Suji leaves is about 3773.9 ppm [26]. Leaves that contain high chlorophyll have a deep dark green color.

| Table 1. Physical and chemical characteristics of fresh Suji leaves. |
|---------------------------------------------------------------|
| **Parameters** | **Results** |
| Colour (L*, a*, b*) | 41.45±0.37; -6.05±0.39; 6.23±0.54 |
| Total Chlorophyll (mg/g) | 3.04±0.28 |
| Moisture content (%) | 76.46±0.66 |

Values are means of quadruplicate determination ± standard deviation

The moisture content of fresh Suji leaves was 76.46%, slightly higher than other studies at 73.25% [26]. Moisture can decrease the percentage of total chlorophyll in fresh leaves. The high moisture content in fresh leaves can increase the chance of biological and enzymatic damage. Several enzymes played a role in the degradation process of chlorophyll in the presence of water are chlorophyllase, causing the cleavage of the phytol chain from chlorophyll forming green chlorophyllides, pheophytinase can removes phytol chain from Mg-free pheophytin forming olive-brown pheophorbides [2]. Mg-dechelatase can be caused the replacement of Mg$^{2+}$ by hydrogen atoms from chlorophyll, results in the formation of olive-brown pheophytin [3][4][2].

3.2. Physical properties of DSLP

The color attributes of DSLP was express in lightness (L*), redness (a*), yellowness (b*) value are presented in Table 1. The L* value was ranged between 49.04-51.40. The a* values were between -6.48 and -8.28. The b* value was between 20.08-22.66 (Table 2). The drying method has a significant effect ($\alpha = 0.05$) on a* and b* values. The greenest Suji powder value was obtained from the vacuum drying with a lower a* value than cabinet drying. The drying temperature has a significant effect ($\alpha = 0.05$) on L*, a, and b* value of DSLP. The higher the drying temperature, the L* value, will be increased. The drying rate at 40°C temperature will run slower and increase enzymatic degradation of chlorophyll, and the color of leaves turned brown and increased a*& b* value. Drying in vacuum conditions can increase the drying rate by decreasing the boiling point so that the water will evaporate faster. Increasing drying temperature can increase the L* value of powder [27], and drying in vacuum conditions can decrease the a* value of powder compared to the atmospheric condition [28].

| Table 2. Average color attribute of DSLP in various drying method and temperature. |
|---------------------------------------------------------------|
| **Drying method** | **Drying temperature (C)** | **Lightness (L*)** | **Redness (a*)** | **Yellowness (b*)** |
|---------------------------------------------------------------|
| **Cabinet drying** | 40 | 49.33±0.22$^{id}$ | -6.76±0.08$^{a}$ | 20.26±0.22$^{id}$ |
| | 50 | 50.47±0.65$^{bc}$ | -7.02±0.24$^{a}$ | 19.73±0.59$^{c}$ |
| | 60 | 51.29±0.12$^{a}$ | -6.62±0.09$^{a}$ | 21.90±0.25$^{c}$ |
| **Vacuum drying** | 40 | 49.77±0.33$^{cd}$ | -6.90±0.15$^{a}$ | 21.21±0.25$^{bc}$ |
| | 50 | 49.98±0.27$^{cd}$ | -7.78±0.56$^{b}$ | 20.88±0.26$^{c}$ |
| | 60 | 50.75±0.06$^{ab}$ | -6.69±0.19$^{a}$ | 22.47±0.18$^{b}$ |

Values are means of quadruplicate determination ± standard deviation.
Means in the same column with different letters are significantly different ($p < 0.05$).

Table 3 shows the average value of WAC, OAC, and bulk density of DSLP with different drying methods and temperatures. The WAC of powder were ranged between 354.05 and 500.21%. The OAC was ranged between 201.57-279.93%. The bulk density was in ranges of 0.31-0.40 g/cm$^3$. Different drying methods have a significant ($\alpha=0.05$) effect in WAC, OAC, and bulk density; however, the drying temperature has a significant effect in WAC and bulk density, but has no significance in OAC. Vacuum
drying results in higher WAC, OAC, and lower bulk density. Furthermore, increasing the drying temperature, the WAC was increased, and the bulk density was decreased. The powders were drying in a vacuum condition, and higher temperature results in powder with lower moisture content, for absorbing water and oil more.

### Table 3. Average WAC, OAC, and bulk density of DSLP in various drying method and temperature.

| Drying method | Drying temperature (°C) | WAC (%)    | OAC (%)    | Bulk density (g/cm³) |
|---------------|-------------------------|------------|------------|----------------------|
| Cabinet drying| 40                      | 363.91±11.67b | 211.84±9.10f | 0.39±0.01a           |
|               | 50                      | 444.45±6.09a | 226.63±19.96c | 0.35±0.02b           |
|               | 60                      | 439.47±14.80a | 233.19±17.23bc | 0.33±0.01bc          |
| Vacuum drying | 40                      | 458.33±6.99a | 250.22±10.81ab | 0.33±0.02bc          |
|               | 50                      | 453.48±31.87a | 252.25±5.29ab | 0.32±0.01c           |
|               | 60                      | 464.79±21.92a | 260.93±16.27a | 0.33±0.01bc          |

Values are means of quadruplicate determination ± standard deviation. Means in the same column with different letters are significantly different (p < 0.05).

Some studies found that leaves are dried under vacuum drying had higher water absorption than hot air drying [29]. Plant fibers have many free hydroxyl groups that are quickly bonded with oil or water [30]. The low drying temperature promotes lower powder absorption capacity [31]. Increasing the drying temperature can increase absorption capacity and also bulk density [32]. The higher bulk density might also be caused due to the high moisture content because the weight of powder in each volume (cm³) is higher with the high moisture content. In other studies, the vacuum drying condition results in lower bulk density than the atmospheric condition [33]. Bulk density is related to the final moisture content and the rate of shrinkage [34].

### 3.3. Chemical properties of DSLP

Table 4 shows the chemical properties of DSLP were dried with different drying methods and temperatures. The moisture content of powder was ranged from 5.50 to 8.96%. Vacuum dried powder has lower moisture than cabinet but has no significant difference (α=0.05). However, the temperature was significant. The higher the drying temperature, the lower the moisture content. The higher drying temperature can increase the drying rate, the lower moisture was reached. The same trend found that higher temperatures can decrease moisture content [35].

### Table 4. Chemical properties of DSLP with different drying method and temperature (wet basis).

| Drying method | Drying temperature (°C) | Moisture content (%) | Total chlorophyll (mg/g) | Total phenolic (mg/g) | pH         |
|---------------|-------------------------|----------------------|--------------------------|-----------------------|------------|
| Cabinet drying| 40                      | 7.90±0.73a           | 9.37±0.64d               | 60.05±3.31c           | 5.45±0.13bc|
|               | 50                      | 7.23±0.37ab          | 10.96±0.63bc             | 73.06±4.08d           | 5.53±0.10abc|
|               | 60                      | 6.78±0.63bc          | 10.11±0.94cd             | 86.08±3.69c           | 5.55±0.06ab|
| Vacuum drying | 40                      | 7.62±0.62a           | 11.38±0.53b              | 83.28±3.82c           | 5.40±0.08c |
|               | 50                      | 6.70±0.33bc          | 12.98±1.23a              | 97.26±5.93b           | 5.60±0.08a |
|               | 60                      | 6.26±0.55c           | 10.97±0.69bc             | 111.94±5.41a          | 5.58±0.10ab|

Values are means of quadruplicate determination ± standard deviation. Means in the same column with different letters are significantly different (p < 0.05).

The total chlorophyll content of powder was ranged between 8.74 and 14.40 mg/g, different drying method and temperature has given a significant effect (α=0.05). Cabinet drying has lower chlorophyll
content compared to vacuum. Drying in vacuum conditions can lower the risk of damage to heat and oxygen-sensitive components. The lowest total chlorophyll was found in the treatment using a cabinet dryer at 40°C. At 40°C under atmospheric conditions, the drying rate will run slower and increased enzymatic activity, which caused chlorophyll degradation. The optimum temperature of chlorophyllase activity is between 30-40°C [36].

The total phenolic content ranged from 56.13 to 117.20 mg/g, showing that the drying method and temperature significantly impact total phenolic content. Vacuum drying at 60°C had the highest phenolic content, however, drying at a lower temperature can maintain the activity of enzymes that cause oxidation of phenol compounds. In the range of 10-50 °C the polyphenol oxidase can maintain 80% of its activity [37]. The vacuum condition process can minimize the damage of heat and oxygen-sensitive components. The higher the drying temperature, the higher the phenolic content. The release of linked phenolic compounds and oxidase enzyme inactivation will be faster at high temperatures [38, 39].

The pH value of the powder was ranged from 5.30 to 5.70. The different drying method has no significant effect on pH. However, the increasing temperature caused the pH to increase. The higher drying temperatures, the evaporation of some acidic components will be faster and decrease powder's pH [40]. Similar results are reported in other studies [41].

### 3.4. The best treatment of dried Suji leaves powder making

The selection of the best treatment for dried Suji leaves making was made using the Zeleny Multiple Attribute method based on a color attribute, WAC, OAC, bulk density, moisture content, total chlorophyll, total phenolic, and pH of the various powder. Based on the calculation, the Suji powder's best treatment dried using vacuum drying at 50°C with the lowest sums of L1, L2, and Lmax.

This dried Suji leaves powder contains 7.69% soluble and 34.28 % insoluble dietary fiber. The presence of dietary fiber content such as hemicellulose and pectin play a role in water absorption capacity. At the same time, cellulose and lignin have low water absorption capacity but also can absorb oil [42, 43, 44]. Plant fiber contains many free hydroxyl groups at the molecular level that easily bind to oil or water [45]. Therefore, it generally shows a good affinity for oil and water. For food applications, water absorption capacity is important in increasing the mass and consistency of bread product applications [46]. Meanwhile, the absorption of oil by food products can improve mouth taste and retention [47].

### 4. Conclusions

Drying Suji leaves with different drying methods and temperatures in the present studies significantly affected dried Suji leaves powder's physical and chemical characteristics. The redness (a*), yellowness (b*), WAC, OAC, bulk density, total chlorophyll, total phenolic was significantly affected by the drying method. However, the L*, moisture content, and pH have no significance. The different drying temperature has a significant effect in lightness (L*), redness (a*), yellowness (b*), WAC, bulk density, moisture content, total chlorophyll, total phenolic, and pH, but has no significant in OAC. The best treatment of Suji leaves powder is based on Zeleny Multiple Attribute, which is dried in the vacuum drying method at 50°C based on the desired physical and chemical characteristics of DSLP.

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