

# The Effect of Microwave-Assisted Extraction Temperature and Material to Solvent Ratio on the Characteristics of Pandan (*Pandanus amaryllifolius* Roxb.) Leaf Extract

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**Abstract**—Fresh pandan leaf fragrance has been applied to enhance the aroma of many traditional foods. However, the fresh leaf has a limited shelf life—only 1 day after harvest. Therefore, in liquid or powdered form, pandan extract can be utilized as an alternative aromatic component in food production. The purpose of this study was to determine the effect of extraction temperatures (50, 60, and 70°C) utilizing microwave-assisted extraction (MAE) and the ratio of pandan leaf as material to ethanol as solvent (1:3, 1:7, and 1:11) on the characteristics of pandan extract in liquid form. The study found that the properties of pandan extract treated at MAE 60°C with a material-solvent ratio of 1:7 were the best among all treatments. The pH of this liquid pandan extract was 5.31, the antioxidant activity was 32.86 ppm, and the chlorophyll content was 7.76 mg/L. The powdered pandan extract generated by drying the liquid pandan extract using a spray dryer and adding maltodextrin had properties such as water activity 0.45, solubility 96.09%, solubility rate 0.01 g/s, color L 85.65, a\* -6.68, b\* 8.51, yield 3.88%, and was detected to contain 0.17% of the aromatic compound 2-acetyl-1-pyrroline. Powdered pandan extract has the potential to be developed as an aromatic food additive. Panelists liked the *Lumpang cakes*, a traditional cake consisting of rice flour and coconut milk made by adding 1% pandan leaf extract powder.

**Keywords**— Pandan; extract; temperature; MAE; aroma.

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## I. INTRODUCTION

Pandan leaves are a natural ingredient commonly used as an aromatic ingredient in processed food products. The distinctive aroma of pandan leaves is obtained from aromatic compounds in the form of 2AP (2-acetyl-1-pyrroline) [1]. Fresh pandan leaves are traditionally knotted and added directly to food during cooking. In addition, fresh pandan leaves can be extracted by crushing them with water and then filtering and applying them to give a distinctive aroma and natural color to food products [2]. However, this method is less efficient, so making pandan extract powder that can be used directly in food products is necessary. Pandan extract in powder form can be used as an alternative for areas where it is difficult to obtain fresh pandan leaves. In powder form, pandan extract has a longer shelf life and is easier to store [3].

Various extraction methods can separate aromatic compounds from pandan leaves. The commonly used

extraction processes are maceration, reflux, and Soxhlet [4]. These conventional methods have disadvantages, including a long extraction time and low yield [5]. Therefore, the study must use more optimal methods, such as microwave-assisted extraction (MAE). This method can increase the efficiency and effectiveness of extracting active ingredients of various plant species because it utilizes electromagnetic waves to heat the solvent quickly and efficiently [6]. MAE can increase the amount of crude extract yield and use less solvent than conventional extraction [7].

The temperature of the extraction process and the *material: solvent* ratio are two variables that can impact the quality of pandan extracts. Pandan extracts had the best chemical properties when extracted at 50°C [8]. The *pandan: ethanol* ratio of 1:8 produced pandan leaf essential oil with the best aroma [9]. Therefore, this study aimed to determine the optimal extraction temperature and *material: solvent* ratio to produce pandan extract. A 95% concentration of ethanol was used as the solvent in this study. Because of its excellent

solubility, ethanol can effectively extract chlorophyll. The Environmental Protection Agency (EPA) has listed ethanol as one of the safest substances [10]. The extraction temperatures used were 50, 60, and 70°C, and the *material: solvent* ratios used were 1:3, 1:7, and 1:11 because, based on preliminary research, these extraction temperatures and *material: solvent* ratios showed good pandan extract results in terms of aroma, total chlorophyll, and color.

The best pandan extract was then processed into powder with 5% maltodextrin and dried with a spray dryer. Spray drying is often used in the food industry to convert liquid food ingredients into powder [11]. Spray drying produces products with good characteristics. The yield is quite high, suitable for heat-sensitive materials because the exposure time of materials with high temperatures is relatively short, and the resulting powder can be used immediately [12].

Pandan extract powder is then applied to *Lumpang* cakes. *Lumpang* cakes is a traditional Palembang snack that is green in color and shaped like a mortar in the middle. This study used pandan extract powder with concentrations of 1, 1.5, and 2% (b/v) to obtain *Lumpang* cakes with organoleptic characteristics on the best aroma, color, taste, and overall parameters. However, the green color of the pandan extract powder produced from this study tends to fade, so fresh Suji leaf extract was added to strengthen the mortar cake's green color.

## II. MATERIALS AND METHODS

### A. Material

The materials used in this research include fresh pandan leaves from Malang; ethanol pro analysis (*Smartlab*); distilled water (*Hydrobatt*); maltodextrin from CV Pratama Mandiri, DPPH; methanol pro analysis (*Merck*); rice flour (*Rosebrand*); tapioca flour (*Cap Pak Tani Gunung*); coconut milk (*Kara*); sugar (*Gulaku*); salt (*Cap Kapal*); and fresh Suji leaves from Malang.

### B. Research Design

The study was conducted following a randomized block design consisting of two factors: extraction temperature (50, 60, and 70°C) and the ratio of pandan leaves and ethanol (1:3, 1:7, 1:11). The experiments were repeated three times each to obtain 27 experimental units. Data were analyzed using ANOVA (Analysis of Variance) with a 95% confidence interval, followed by the Least Significance Different (LSD) test to see if factors are significant but have no interaction. Meanwhile, Duncan's New Multiple Range Test (DMRT) is used if there is significance and interaction between factors. Multiple Attributes Zeleny determined the best treatment. The hedonic test and Friedman data analysis method were used to obtain organoleptic results.

### C. Pandan Leaves Extraction

Fresh pandan leaves were washed using running water, and the surface of the leaves was dried with a paper towel. The pandan leaves were cut into 3x1 cm pieces and crushed with a blender for 1 minute. The crushing stage aims to expand the contact area between the solvent and the material to optimize the extraction process [13]. About 5 grams of crushed pandan leaves were put into a vessel and added with 95% ethanol 15

ml (1:3), 35 ml (1:7), and 55 ml (1:11). The mixture was then extracted using MAE at 50, 60, and 70°C for 15 minutes. The resulting pandan extract was filtered using filter paper and analyzed for aroma, total chlorophyll, pH, and color (L\*, a\*, and b\*).

### D. Pandan Extract Drying

Pandan extract was diluted with distilled water to obtain an extract with an ethanol concentration of 10%. The extract was then added with 5% maltodextrin and homogenized using a hot plate stirrer at 500 rpm for 10 minutes. The mixture was then dried using a spray dryer with an inlet temperature of 170°C to convert the pandan extract as a liquid into a powder product through hot air contact [12]. The resulting pandan extract powder was then analyzed for aroma, total chlorophyll, antioxidant activity, pH, aw, solubility, solubility rate, color (L\*, a\*, b\*), and yield.

### E. Lumpang Cakes Production

The liquid mixture was prepared by dissolving sugar (40g) and salt (1g) in warm coconut milk (80 ml). Meanwhile, the dry mixture was prepared by mixing tapioca (15g), rice flour (23g), and pandan extract powder (1, 1.5, and 2%). The liquid mixture was mixed with the dry mixture to form a thin batter. The batter was then put in a '*Lumpang*' mold and steamed at 95°C for 15 minutes.

### F. Analysis

Pandan extract was analyzed for color using a color reader (*Konica Minolta CR-10*). A 2-gram sample was put into a clear plastic and measured with a color reader until the Lab value was obtained. pH was measured using a pH meter. The 1-gram sample was dissolved in 20 ml of distilled water and then tested with a pH meter calibrated using pH 4, 7, and 10 buffer solutions. Total chlorophyll was analyzed using a method by Sun *et al.* [14]. 1 gram of pandan extract powder was added with 96% ethanol to the limit of a 10 ml volumetric flask and homogenized. The sample mixture was centrifuged at 1000 rpm for 10 minutes. 1 ml of filtrate was taken, and the absorbance was read using a UV-Vis spectrophotometer with a wavelength of 649nm and 665 nm. The amount of chlorophyll a, b, and total chlorophyll were calculated using the formulae below:

$$\text{Chlorophyll a } \left(\frac{\text{mg}}{\text{L}}\right) = (13.7 \times \text{OD } 665) - (5.76 \times \text{OD } 649) \quad (1)$$

$$\text{Chlorophyll b } \left(\frac{\text{mg}}{\text{L}}\right) = (13.7 \times \text{OD } 665) - (5.76 \times \text{OD } 649) \quad (2)$$

$$\text{Total chlorophyll (mg/L)} = 20 (\text{OD } 649) + 6.1 (\text{OD } 665) \quad (3)$$

Note: OD: optical density or chlorophyll absorption value.

The aroma of pandan leaf liquid extract was analyzed by 15 panelists using a descriptive test. This study aims to obtain the intensity of the difference in pandan leaf extract's aroma using a score of 1–15 [15]. Pandan extract powder was analyzed for color, pH, total chlorophyll, water activity using an AW meter (Pawkit), and antioxidant activity using the DPPH Method [16]. The following procedure analyzed antioxidant activity; as much as 10gram of pandan extract powder was dissolved in 100 ml of methanol and macerated for 4 hours, filtered with filter paper, and carried out a series of dilutions to 5 ppm, ten ppm, 15 ppm, 20 ppm, 25 ppm, and 30 ppm, and 35 ppm. Each sample dilution series was taken 2

ml and added 2 ml DPPH. Control was made by mixing 2 ml DPPH and 2 ml methanol and vortexed. Samples and control were incubated in a dark room for 30 minutes; then the absorbance was measured at a wavelength of 517nm.

$$\begin{aligned} & \text{Antioxidant activity (\%)} \\ & = \frac{[(\text{control absorbance}) - (\text{sample absorbance})]}{(\text{control absorbance})} \times 100 \end{aligned} \quad (4)$$

The solubility test is carried out in the following steps: Whatman filter paper was dried in an oven at 105°C for 30 minutes and weighed. 50 mL of distilled water was added to the beaker glass, followed by a magnetic bar, then homogenized with a magnetic stirrer at 500 rpm. One gram of pandan extract powder was added to the mixture, bit by bit, while the stirrer was still running. The mixture was stirred until homogeneous. After that, the sample was filtered with filter paper that had been dried. The residue and filter paper was dried in the oven at 105°C for three hours, cooled in a desiccator for 15 minutes, and then weighed. The following formula could measure the insoluble and extract powder solubility:

$$\text{Insoluble (\%)} = \frac{w_1 - w_2}{w} \times 100\% \quad (5)$$

$$\text{Solubility (\%)} = 100 - \text{insoluble part} \quad (6)$$

where w is the sample weight (g), w1 is the weight of residue and filter paper (g), and w2 is the weight of filter paper (g).

The dissolution rate of pandan leaf extract powder was measured using a modified method from Samborska and Bienkoska [17]. Fifty milliliters of distilled water were stirred with a magnetic stirrer at 500 rpm, and then one gram of extract powder was added. The time required to dissolve the sample was recorded, and its dissolution rate was measured using this formula.

$$\text{Rate of Dissolution} \left( \frac{g}{\text{second}} \right) = \frac{\text{sample mass (g)}}{\text{time dissolve (second)}} \quad (7)$$

The yield was quantified using the Hedayatnia and Mirhosseini methods [18]. The principle was to compare the weight of pandan extract powder from spray drying with the weight of pandan extract solution that has been added with maltodextrin

$$\text{Yield (\%)} = \frac{\text{pandan extract powder mass (g)}}{\text{the mixture of pandan and maltodextrin (g)}} \quad (8)$$

The aroma of pandan leaf extract powder represented by the compound 2-acetyl-1-pyrroline was analyzed using Gas Chromatography [19]. The principle of this machine is to separate compounds in the sample based on differences in distribution movement between the mobile and stationary phases [20]. A total of 0.3 g of pandanus extract powder plus 0.5 ml of 10% ethanol was vortexed; the filtrate was taken 0.5 ml, and 0.5 ml of toluene was. The sample was allowed to stand in the freezer for five days, and then as much as one  $\mu\text{L}$  of the sample was injected into the GC. In this study, analysis of the 2AP compound was carried out using GC at 150°C (injector and detector temperatures), a column temperature of 80°C, an FID (flame ionization detector), helium as the gas carrier, and the standard 2AP (2-acetyl-1-pyrroline).

Organoleptic tests of the *Lumpang* cakes samples were carried out using hedonic tests involving 55 untrained panelists. The panelists consisted of 20 men and 35 women with an age range of 20-22 years. The samples consisted of control *Lumpang* cakes with commercial pandan flavor, and

*Lumpang* cakes with 1; 1.5; and 2% pandan extract powder. Panelists were asked to respond to the aroma, color, taste, and overall liking of the *Lumpang* cakes products. The assessment was conducted using a scale of 1-7 with a value range of strongly dislike to strongly like.

### III. RESULTS AND DISCUSSION

#### A. Pandan Extract Aroma

The aroma of the pandan extract was analyzed using a sensory test. Panelists gave the highest score (measuring how closely the extract's aroma resembles the aroma of fresh pandan leaves) to the liquid extract of pandan leaves processed using a temperature of 70°C with a material: solvent ratio of 1:3. The main compound contributing to pandan aroma is 2-acetyl-1-pyrroline (2AP) [21]. The 2-acetyl-1-pyrroline compound is maximally extracted at 70°C [23]. The aroma of the 2AP compound contained in the pandan extract with a 1:3 ratio is more robust because it includes less ethanol solvent, so the pandan extract is more concentrated and gives off a more intense aroma. Ethanol solvents can extract 2AP compounds more optimally than methanol and propanol solvents [22].

#### B. Total Chlorophyll of Pandan Extract

In this study, the total chlorophyll of pandan leaf extract was not affected by the temperature used in the extraction. However, Dissanayake et al. [23] say chlorophyll can be degraded into pheophytin compounds as the temperature increases. The material: solvent ratio treatment significantly affected the total chlorophyll of pandan extract. The pandan extract from a lower material: solvent ratio produced higher total chlorophyll. However, the results of Tran et al. [24] found that the greater the amount of solvent used in the extraction, it will cause more chlorophyll to be bound so that it can increase chlorophyll contents. A more significant amount of solvent also causes better mass transfer than a smaller amount [25]. Given that total chlorophyll is calculated per weight of pandan extract sample, the discrepancy between the results of this study and earlier research may be due to the possibility that chlorophyll in fresh pandan leaves as raw material has been maximally extracted even with the smallest amount of material: solvent ratio (1:3), meaning that more solvent will cause a dilution effect.

#### C. pH

The pH value of the pandan leaf extract increased along with the increase in the material: solvent ratio. Because more solvent is present, there is less overall acid in pandan leaves, which results in an elevation in pH. Acetic acid, butyric acid, furanone, and propionate are present in pandan leaves with a pH range of 5 to 5.8 [26]. The solvent utilized in the extraction, 95% ethanol in this study, with a pH range of 6.5-7, also affects the pH value of pandan extract. The pH value of the solvent affects the extraction process with ionic forces that can affect the solubility of compounds and interactions with the sample matrix [27].

#### D. $L^*$ , $a^*$ , and $b^*$ Value of Pandan Extract

$L^*$  Value: The brightness ( $L^*$  value) of pandan extract was significantly influenced by the extraction temperature and the

material: solvent ratio. The pandan extract's  $L^*$  value decreases with a lower material: solvent ratio (Table 1) because less solvent is used, resulting in a more concentrated pigment color. If the extracted material has more pigment, the color will be darker and more concentrated, lowering the brightness value [28]. From a heating temperature of 50 to 60°C, pandan extracts' brightness value increases in each ratio; nevertheless, at 70°C, the brightness decreases again. Pandan extracts get brighter as the temperature of extraction rises [29]. It is proposed that the solvent utilized has attained saturation when the brightness value of pandan extracts decreases at an extraction temperature of 70°C. In high-temperature heating, chlorophyll can also deteriorate and turn brown because of the release of magnesium ions that have been replaced by hydrogen [30].

1)  $a^*$  Value: The  $a^*$  value represents the color spectrum from green to red, with negative notations tending toward green. The  $a^*$  value of pandan extract was significantly influenced by the extraction temperature and material: solvent ratio. When the extraction temperature was raised from 50 to 60°C, the pandan extract's  $a^*$  value declined but climbed to 70°C. When the temperature rises from 50 to 60°C, more chlorophyll is extracted, but an increase in temperature can also modify the structure of chlorophyll.

Phytol groups, chlorophyll side chains, can be released during the extraction process using alcohol solvents, forming chlorophyllide [31]. Pheophorbide can also be produced during the extraction process using ethanol [31]. Chlorophyllide formation depends on temperature conditions

because the enzyme chlorophyllase is active between 60 and 82.2°C and is destroyed at temperatures over 100°C [32]. Chlorophyllide will lose its magnesium ions and transform into pheophorbide if there is acid in the extraction [32]. As mentioned, pandan leaves contain organic acids that may cause pheophorbide formation.

The decrease in  $a^*$  at higher temperatures indicates that the solvent can extract more chlorophyll pigments, such as in the extraction at 60°C with a ratio of 1:11. The solubility of extracted material compounds can increase with increasing extraction temperature [30]. The ratio of 1:15 produced the lowest  $a^*$  [33], indicating that the pandan extract contained a lot of chlorophyll at that ratio.

2)  $b^*$  Value: When the  $b^*$  value is higher, the pandan extract is more yellow; when it is lower, it is bluer. The extraction temperature and ratio significantly influence the  $b^*$  value of pandan extract, but their interaction has no appreciable impact. The most excellent  $b^*$  value ( $33.6 \pm 8.23$ ) was generated at an extraction temperature of 60 °C. This shows that the extracted chlorophyll B (yellow-greenish) concentration is relatively high at 60 °C. Using an ethanol solvent at 65°C, more chlorophyll b than chlorophyll a could be recovered from green microalgae [34]. Chlorophyll b and other polar compounds from Suji leaves can be extracted with 95% ethanol and water, while chlorophyll a is more selectively extracted with 80% acetone [35]. The highest mean  $b^*$  value of pandan extract ( $30.97 \pm 5.15$ ) was produced from a material: solvent ratio of 1:7. The  $b^*$  value of Suji leaf extract increased as the material: solvent ratio increased [36].

TABLE I  
CHEMICAL AND CHARACTERISTICS OF PANDAN EXTRACT

temperature (°C)	Material: solvent ratio	Aroma	Chlorophyll total (mg/L)	pH	Color ( $L^*$ )	color ( $a^*$ )	Color ( $b^*$ )
50	1:3	7,76±0,2 de	70,37±2,13 a	5,86±0,02 cd	26,4±0,35 d	-2,3±0,26 e	4,9±0,35
	1:7	7,73±0,18 de	63,80±0,43 c	5,87±0,09 cd	41,83±5,71 abc	-26,1±6,55 abc	30,2±5,59
	1:11	8,22±0,47 cd	58,51±2,47 d	6,19±0,06 a	30,97±1,06 d	-9,87±0,92 d	12,7±1,05
60	1:3	8,91±0,14 b	67,23±0,94 b	5,80±0,07 de	38±3,74 c	-21,6±5,41 bc	23,3±4,97
	1:7	8,58±0,67 bc	67,43±2,52 b	5,94±0,04 c	44,7±6,02 ab	-27,7±3,76 ab	36,5±5,21
	1:11	7,58±0,27 e	61,71±0,52 c	6,15±0,06 a	47,27±4,69 a	-29,47±3,76 a	41,0±4,07
70	1:3	9,98±0,14 a	71,26±1,22 a	5,76±0,05 e	30,67±0,7 d	-10,33±1,76 d	11,8±0,73
	1:7	8,49±0,44 bc	63,31±0,23c	6,05±0,03 b	39,1±1,99 bc	-23,67±2,42 abc	26,3±1,67
	1:11	8,53±0,18 bc	63,34±0,97 c	6,16±0,02 a	37,37±0,80 c	-19,63±2,67 c	22,3±2,18

### E. Best Pandan Extract

The best treatment for extracting pandan regarding extraction temperature and the ratio between material and solvent was determined using the Multiple Attribute Zeleny method. Based on the calculation, the best pandan extract was obtained at 60°C with a ratio of 1:7 (Figure 1). The best pandan extract was then added with 5% maltodextrin and processed into pandan extract powder using a spray dryer with an inlet temperature of 170°C. Pandan extract powder characteristics are shown in Table 2.



Fig. 1 Best Pandan Extract

TABLE II  
PANDAN EXTRACT POWDER CHARACTERISTIC

Parameter	Value
Aroma (%)	0.17±0.00
Total Chlorophyll (mg/L)	7.76±1.14
Antioxidant activity (ppm)	32.86±1.24
pH	5.31±0.42
Aw	0.45±0.05
Solubility (%)	96.09±0.27
Rate of Dissolution (g/s)	0.01±0.00
Brightness ( $L^*$ )	85.65±0.6
Redness ( $a^*$ )	-6.68±1.23
Yellowness ( $b^*$ )	8.51±0.63
Yield (%)	3.88±0.13

The aroma of Pandan extract powder was analyzed using gas chromatography (GC). The chromatogram of 2AP compounds in pandan extract powder can be seen in Figure 4. The detected 2AP content of pandan extract powder was

$0.17 \pm 0.00\%$ . The amount of 2AP in pandan extract powder is lower than the amount of 2AP in fresh pandan extract (1.15%). The decrease in 2AP compounds in pandan extract powder can be caused by drying at high temperatures.



Fig. 2 Pandan Extract Powder



Fig. 3 Pandan Extract Powder Spectrum Color

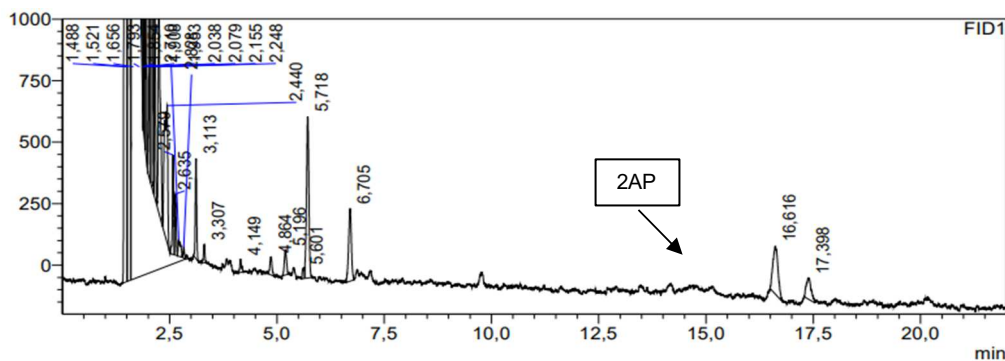


Fig. 4 Chromatogram of 2AP Compound in Pandan Extract Powder

Antioxidants are substances that inhibit oxidation reactions. The DPPH (2,2-diphenyl-1-picrylhydrazyl) technique was used to assess the antioxidant activity. This approach was selected because of its simplicity, ease of usage, and need for a few samples [16]. The DPPH radical capture test results are obtained from the relationship between the levels of pandan extract powder solution and the fractions in it with DPPH radical capture activity, which is described by a linear regression equation using the IC50 parameter [41]. The test findings are given as an IC50 value, representing the amount of antioxidants needed to lower the initial concentration of DPPH radicals by 50%. Pandan extract ( $20.12 \pm 0.67$  ppm) has higher antioxidant activity than pandan extract powder ( $32.86 \pm 1.24$  ppm). Some of the antioxidant components in the pandan extract undergo degradation during the high-temperature drying process [42]. Nevertheless, because pandan extract and pandan extract powder have an IC50 value of less than 50 ppm, their antioxidant activity is still considered to be highly potent.

The concentration of hydrogen ions in a solution, or its power of hydrogen (pH), represents the solution's acidity. With a pH of  $5.31 \pm 0.42$ , pandan extract powder is slightly more acidic than pandan extract ( $5.94 \pm 0.04$ ). The reduction of total acid from the leaves following evaporation during spray drying may cause the pH to decrease [43]. Pandan leaves have a pH range between 5 and 5.8 [26].

The quantity of free water that microbes may utilize in food

2-acetyl-1-pyrroline is a volatile compound that is easily damaged when exposed to high temperatures [22]. The solvent used in this pandan extract powder aroma analysis is 10% ethanol. The polarity of the solvent used plays a role in extracting 2AP compounds. Ethanol gives better results in extracting 2AP compounds from pandan leaves than methanol and propanol [21]. The results obtained by Bhatt et al. [37] showed that the 2AP detected in *Pandanus amaryllifolius* was 0.000438%. The total chlorophyll of pandan extract powder was  $7.76 \pm 1.14$  mg/L; the value was smaller than the total chlorophyll value of pandan extract. This is due to the addition of maltodextrin as a filler in pandan extract powder. Adding maltodextrin can increase the amount of pandan extract powder solids and reduce the proportion of chlorophyll [38]. Another factor that eases the total chlorophyll value is the high drying temperature. Chlorophyll is sensitive to temperature, light, and oxygen, so it can degrade into its derivative molecules [39]. Chlorophyll degradation occurs due to the loss of magnesium ions from the molecule or the loss of phytol side chains [40].

is measured by water activity ( $A_w$ ). The  $A_w$  value can determine food components' degree of stability and shelf life. The water activity value of a food material ranges from 0-1 [44]. The  $a_w$  value of pandan extract powder is  $0.45 \pm 0.05$ , which is relatively low. The use of a spray drier during the drying process and the inclusion of maltodextrin are two factors that contribute to the low  $a_w$  content of pandan extract powder. Spray drying is a process where liquid samples are converted into dry particles to reduce water activity in the product and extend shelf life [45]. Maltodextrin can reduce the contact between the mixture of ingredients and water so that it will evaporate more easily during drying. Maltodextrin can also increase the overall solid content of pandan extract powder, lowering the  $a_w$  content. Pandan extract powder has  $A_w$  in the safe range from microbial growth. Mold, yeast, and bacteria all require certain  $a_w$  levels to develop, ranging from 0.6 to 0.7 for mold, 0.8 to 0.9 for yeast, and 0.9 for bacteria [46].

The solubility value of pandan extract powder is relatively high at  $96.09 \pm 0.27\%$ . Maltodextrin's hydroxyl groups will interact with water to raise its solubility value. Due to an increase in the amount of water in the monolayer, adding maltodextrin will make the product more soluble in water [47]. A high solubility implies a high product quality level since it will make further applications easier.

The length of time needed for a specific quantity of pandan extract powder to dissolve in water is known as the dissolving rate. Pandan extract powder dissolves at a rate of  $0.01 \pm 0.00$



g/s. Maltodextrin addition and the moisture level of pandan extract powder are two factors that influence the dissolving rate. Maltodextrin can quickly disperse, increasing its solubility. As the free hydroxyl groups in the filler increase, food products will become more soluble [43]. A product becomes increasingly hygroscopic at low moisture levels, hastening solubility. If the moisture content in the product is relatively high, clumps can form so that the breaking of bonds between particles takes longer [48].

Compared to pandan extract powder, pandan extract powder has a green color with lower brightness ( $L^*$ ) and  $a^*$  values and higher  $b^*$  values. Generally, the powdered version of pandan extract is lighter green than the liquid form. The fading of the green color is due to the addition of maltodextrin filler with a concentration of 5% in the drying process to obtain pandan extract powder. The white powder maltodextrin will make the pandan extract powder lighter. Compared to maltodextrin concentrations of 5, 10, and 15%, adding 20% maltodextrin gave the maximum brightness value in *kuini* powder, which was near 100 [49]. The addition of maltodextrin also caused a decrease in the  $a^*$  value and decreased the pigment color in the product [50]. The high temperature during the spray drying procedure contributes to the pandan extract powder's fading green color. Chlorophyll pigments may degrade during drying, lighting the product's color [51]. Chlorophyll is very sensitive when exposed to high temperatures and light, so that it is easily degraded, and the color will turn yellowish [39]

The yield of pandan extract powder produced from the drying process using a spray dryer of liquid pandan extract with maltodextrin filler was  $3.88 \pm 0.13\%$ . Adding maltodextrin as a filler influences the yield of pandan extract powder, which can affect the total amount of solids. Maltodextrin is a mixture of glucose, maltose, oligosaccharides, and dextrin obtained from partial hydrolysis of starch by enzymes or acids [52]. The results obtained by Alfian et al. [53] also showed that adding maltodextrin as a filler can increase the yield of dragon fruit peel powdered dye.

#### F. Organoleptic Characteristics

The hedonic test findings of *Lumpang* cakes for aroma and taste criteria are highest when 1% pandan extract powder is added. In contrast, the color parameter has the highest preference value when 1.5% pandan extract powder is used (Fig. 5).

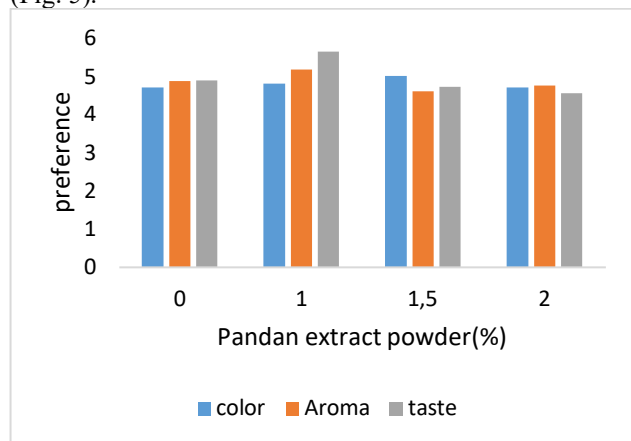


Fig. 5 Organoleptic characteristics of *Lumpang* cakes

Panelists preferred the aroma of *Lumpang* cakes with 1% pandan extract powder concentration over the other items. The aroma on the cake comes from the 2AP (2-acetyl-1-pyrroline) compound content of the pandan extract powder. Pandan has a pleasant aroma similar to vanilla and is frequently used as an aroma enhancer in various foods, including traditional snacks [54]. The aroma of *Lumpang* cakes is further influenced by the inclusion of coconut milk, which has a unique coconut aroma. *Lumpang* cakes' flavor is impacted by raw material components such as sugar, salt, coconut milk, and aroma. While the color of *Lumpang* cakes is desired if it is a sharper green, adding pandan powder at the most significant concentration (1.5%), which contains more chlorophyll, is preferred.

#### IV. CONCLUSION

The extraction temperature significantly affects the pandan extract's aroma and lab color, not the pH or total chlorophyll. The material: solvent ratio treatment significantly influenced the aroma, Lab color, pH, and total chlorophyll of pandan extract. The best pandan extract was obtained at 60°C with an ingredient: solvent ratio of 1:7, 7 with an aroma value of  $8.58 \pm 0.67$ , total chlorophyll  $67.43 \pm 2.52$  mg/L, pH  $5.94 \pm 0.04$ , antioxidant activity  $20.12 \pm 0.67$  ppm, extract brightness value of  $44.7 \pm 6.02$ , redness value of  $-27.7 \pm 3.76$ , and yellowness value of  $36.47 \pm 9.02$ . Pandan extract powder contained  $0.17 \pm 0.00\%$ , aroma compound 2AP,  $7.76 \pm 1.14$  mg/L mg/L total chlorophyll,  $32.86 \pm 1.24$  ppm antioxidant activity, pH  $5.31 \pm 0.42$ , water activity  $0.45 \pm 0.05$ , powder solubility  $96.09 \pm 0.27\%$ , powder dissolving rate  $0.01 \pm 0.00$  g/s, brightness value  $85.65 \pm 0.6$ , redness  $-6.68 \pm 1.23$ , yellowness  $8.51 \pm 0.63$ , and yield value  $3.88 \pm 0.13\%$ . Pandan extract powder has the potential to be applied in food products such as *Lumpang* cakes as an aroma and color enhancer. The results of the hedonic test of *Lumpang* cake products for aroma, taste, and overall parameters are highest when 1% pandan extract powder is added, whereas 1.5% pandan extract powder has the maximum favorability value for the color parameter.

#### REFERENCES

- [1] V. Surojanametakul et al., "Encapsulation of natural flavor from pandanus amaryllifolius roxb. In rice starch aggregates," *Food Science and Technology Research*, vol. 25, no. 4, pp. 577–585, Sept. 2019.
- [2] I. Viera, A. P. Gálvez, and M. Roca, "Green natural colorants," *Molecules*, vol. 24, no. 1, Jan. 2019.
- [3] O. Bashir et al., "Influence of anticaking agents and storage conditions on quality characteristics of spray dried apricot powder: shelf-life prediction studies using Guggenheim-Anderson-de Boer (GAB) model," *Foods*, vol. 12, no. 1, Jan. 2023.
- [4] R. G. Mahardika and O. Roanisca, "Microwave-Assisted Extraction of Polyphenol Content from Leaves of *Tristaniaopsis merguensis*," *Agriculture Journal*, vol. 19, no. 2, 2019.
- [5] C. Bidwell et al., "A review of modern and conventional extraction techniques and their applications for extracting phytochemicals from plants," *Scientific African*, vol. 19, Mar. 2023.
- [6] B. Pavlič et al., "Kinetics of microwave-assisted extraction process applied on recovery of peppermint polyphenols: experiments and modeling," *Plants*, vol. 12, no. 6, pp. 1–17, Mar. 2023.
- [7] C. Pengdee, B. Sritularak, and W. Putalun, "Optimization of microwave-assisted extraction of phenolic compounds in *Dendrobium formosum* Roxb. ex Lindl. and glucose uptake activity," *South African Journal of Botany*, vol. 132, pp. 423–431, Aug. 2020.
- [8] S. Margaretta et al., "Ekstraksi senyawa phenolic Pandanus amaryllifolius Roxb. sebagai antioksidan alami," *Jurnal Widya Teknik*,

- vol. 10, no. 1, pp. 21–30, 2011.
- [9] I. B. A. Wibawa, N. M. Wartini, and I. W. Arnata, “Karakteristik absolut minyak atsiri daun pandan wangi (*Pandanus amaryllifolius* Roxb.) hasil proses re-ekstraksi concrete dengan etanol,” *Jurnal Rekayasa dan Manajemen Agroindustri*, vol. 2, no. 2, pp. 67–76, Sept. 2014.
- [10] U. Babacan, M. F. Cengiz, M. Bouali *et al.*, “Determination, solvent extraction, and purification of artemisinin from *Artemisia annua* L.,” *Journal of Applied Research on Medicinal and Aromatic Plants*, vol. 28, no. 2022, Apr. 2022.
- [11] D. T. A. Dao *et al.*, “Optimization of spray-drying process to manufacture green tea powder and its characters,” *Food Science and Nutrition*, vol. 9, no. 12, pp. 6566–6574, Oct. 2021.
- [12] S. S. Costa, B. A. S. Machado, *et al.*, “Drying by Spray Drying in The Food Industry: Micro Encapsulation, Process Parameters and Main Carriers Used”, *African Journal of Food Science*, vol. 9 no. 9, pp. 462–470. Sept 2015
- [13] N. Alsaud and M. Farid, “Insight into the influence of grinding on the extraction efficiency of selected bioactive compounds from various plant leaves,” *Applied Sciences (Switzerland)*, vol. 10, no. 18, pp. 1–16, Sept. 2020.
- [14] H. Sun *et al.*, “Spectrophotometric determination of chlorophylls in different solvents related to the leaf traits of the main tree species in Northeast China,” *IOP Conference Series: Earth and Environmental Science*, vol. 836, no. 1, pp. 0–10, Jun. 2021.
- [15] G. R. Ziegler, G. Mongia, and R. Hollender, “The Role of Particle Size Distribution of Suspended Solids in Defining the Sensory Properties of Milk Chocolate”, *International Journal of Food Properties*, vol. 4, no. 2, pp. 353–370, 2007
- [16] S. Baliyan *et al.*, “Determination of antioxidants by dpph radical scavenging activity and quantitative phytochemical analysis of *Ficus religiosa*,” *Molecules*, vol. 27, no. 4, Feb. 2022.
- [17] K. Samborska and B. Bienkowska, “Physicochemical properties of spray dried honey preparations,” *Zeszyty Problemowe Postępów Nauk Rolniczych*, vol. 575, no. 2013, pp. 91–105, Jan. 2013
- [18] S. Hedayatnia and H. Mirhosseini, “Descriptive Food Science,” London: Intech Open, 2018.
- [19] H. L. Zuo *et al.*, “Preparative gas chromatography and its applications,” *Journal of Chromatographic Science*, vol. 51, no. 7, pp. 704–715, Apr. 2013.
- [20] D. K. Verma and P. P. Srivastav, “Extraction, identification and quantification methods of rice aroma compounds with emphasis on 2-acetyl-1-pyrroline (2-AP) and its relationship with rice quality: a comprehensive review,” *Food Reviews International*, vol. 38, no. 2, pp. 111–162, Feb. 2022.
- [21] N. Ngadi and N. Y. Yahya, “Extraction of 2-acetyl-1-pyrroline (2AP) in pandan leaves (*Pandanus amaryllifolius* Roxb.) via solvent extraction method: effect of solvent,” *Jurnal Teknologi (Sciences and Engineering)*, vol. 67, no. 2, pp. 51–54, Mar. 2014.
- [22] T. Yoshihashi *et al.*, “Effect of storage conditions on 2-acetyl-1-pyrroline content in aromatic rice variety, Khao Dawk Mali 105,” *Journal of Food Science*, vol. 70, no. 1, pp. 34–37, Jan. 2005.
- [23] P. Dissanayake, N. Yamauchi, and M. Shigyo, “Presence of pheophytin and its formation as a chlorophyll derivative in selected crop species,” *Journal of Agricultural Sciences*, vol. 7, no. 3, pp. 127–134, Nov. 2012
- [24] H. Q. Tran *et al.*, “Research on some factors affecting extraction of chlorophyll from mulberry leaves (*Morus alba*),” *IOP Conference Series: Materials Science and Engineering*, vol. 479, no. 1, pp. 1–9, Jan. 2019.
- [25] Z. Z. Abidin, W. N. Mohamad, and M. Samadi, “Optimization of chlorophyll extraction from *Gynura procumbens*,” *Malaysian Journal of Analytical Sciences*, vol. 20, no. 6, pp. 1421–1428, Dec. 2016.
- [26] G. N. P., Wiraguna, N. M. Wartini, and I. W. G. S. Yoga, “Pengaruh Metode dan Lama Curing Terhadap Karakteristik Daun Pandan Wangi (*Pandanus amaryllifolius* Roxb.),” *Rekayasa dan manajemen Agroindustri*, vol. 3, no.2, pp. 109–119, 2015
- [27] J. O. Chaves *et al.*, “Extraction of flavonoids from natural sources using modern techniques,” *Frontiers in Chemistry*, vol. 8, pp. 1–24, Sept. 2020.
- [28] L. Ngamwonglumlert, S. Devahastin, and N. Chiewchan, “Natural colorants: Pigment stability and extraction yield enhancement via utilization of appropriate pretreatment and extraction methods,” *Critical Reviews in Food Science and Nutrition*, vol. 57, no. 15, pp. 3243–3259, Oct. 2017
- [29] I. A. P. A. Cahayanti, N. M. Wartini, and L. P. Wrasati, “Pengaruh suhu dan waktu ekstraksi terhadap karakteristik pewarna alami buah pandan (*Pandanus tectorius*),” *Jurnal Rekayasa dan Manajemen Agroindustri*, vol. 4, no. 2, pp. 32–41, Jun. 2016
- [30] E. Kwartingsih *et al.*, “Chlorophyll extraction methods review and chlorophyll stability of katuk leaves (*Sauropus androgynous*),” *Journal of Physics: Conference Series*, vol. 1858, no. 1, Jan. 2021
- [31] X. Hu, A. Tanaka, and R. Tanaka, “Simple extraction methods that prevent the artifactual conversion of chlorophyll to chlorophyllide during pigment isolation from leaf samples,” *Plant Methods*, vol. 9, no. 19, Jun. 2013.
- [32] C. Yilmaz and V. Gokmen, “Chlorophyll,” in *Encyclopedia Food and Health*, Waltham, USA: Academic Press, 2016, pp. 37–41
- [33] M. Dwipayana, N. M. Wartini, and L. P. Wrasati, “Pengaruh perbandingan bahan pelarut dan lama ekstraksi terhadap karakteristik ekstrak pewarna daun pandan wangi (*Pandanus amaryllifolius* Roxb.),” *Jurnal Rekayasa dan Manajemen Agroindustri*, vol. 7, no. 4, pp. 571–580, Dec. 2019.
- [34] W. Kong *et al.*, “Optimization of ultrasound assisted extraction parameters of chlorophyll from *Chlorella vulgaris* residue after lipid separation using response surface methodology,” *Journal of Food Science Technology*, vol. 51, no. 9, pp. 2006–2013, Sept. 2014.
- [35] D. Cvitkovi, M. Repaji, and S. Pedisi, “Composition and antioxidant properties of pigments of extraction methods,” *Journal of Foods*, vol. 10, no. 2477, pp. 1–16, Oct. 2021
- [36] N. Aryanti, A. Nafiunisa, and F.M. Willis, “Ekstraksi dan Karakterisasi Klorofil dari Daun Suji ( *Pleomele Angustifolia* ) sebagai Pewarna Pangan Alami”, *Jurnal Aplikasi Teknologi Pangan*, vol. 5, no. 4, pp. 129–135, Oct 2016
- [37] V. Bhatt *et al.*, “Fragrance in *Pandanus amaryllifolius* roxb. despite the presence of a betaine aldehyde dehydrogenase 2,” *International Journal of Molecular Sciences*, vol. 22, no. 6968, pp. 1–18, Jun. 2021.
- [38] Y. F. Looi *et al.*, “Effects of pretreatment and spray drying on the physicochemical properties and probiotics viability of moringa (*Moringa oleifera* Lam) leaf juice powder,” *Journal of Food Processing and Preservation*, vol. 43, no. 4, pp. 1–15, Mar. 2019
- [39] O. O. Syvash and O. K. Zolotareva, “Regulation of chlorophyll degradation in plant tissues,” *Biotechnologia Acta*, vol. 10, no. 3, pp. 20–30, Jun. 2017.
- [40] T. P. Durrett and R. Welti, “The tail of chlorophyll: fates for phytol,” *Journal of Biological Chemistry*, vol. 296, no. 1, pp. 1–3, Jan. 2021.
- [41] S. B. Kedare and R. P. Singh, “Genesis and development of dpph method of antioxidant assay,” *Journal of Food Science and Technology*, vol. 48, no. 4, pp. 412–422, Feb. 2011.
- [42] I. S. C. Sulaiman *et al.*, “Effects of temperature, time, and solvent ratio on the extraction of phenolic compounds and the anti-radical activity of *Clinacanthus nutans* Lindau leaves by response surface methodology,” *Chemistry Central Journal*, vol. 11, no. 54, pp. 1–11, Jun. 2017
- [43] L. P. Pui and L. A. K. Saleena, “Effects of spray-drying parameters on physicochemical properties of powdered fruits,” *Foods and Raw Materials*, vol. 10, no. 2, pp. 235–251, Jun. 2022
- [44] C. Goudjinou *et al.*, “Optimization of the drying of moringa oleifera leaves by determination of thermophysical parameters,” *International Journal of Biological and Chemical Sciences*, vol. 11, no. 4, pp. 1627–1645, Dec. 2017.
- [45] T. T. A. Tran and H. V. H. Nguyen, “Effects of spray-drying temperatures and carriers on physical and antioxidant properties of lemongrass leaf extract powder,” *Beverages*, vol. 4, no. 4, pp. 1–14, Nov. 2018.
- [46] R. T. M. Novitasari, A. D. Anggo, and T. W. Agustini, “Pengaruh Kombinasi Bahan Pengisi Maltodekstrin dan Karagenan Terhadap Karakteristik Bubuk Flavor Lemi dari Ranjungan,” *Jurnal Ilmu dan Teknologi Perikanan*, vol. 3, no. 1, pp. 16–25, Jun. 2021.
- [47] S. Chuaychan and S. Benjakul, “Effect of maltodextrin on characteristics and antioxidative activity of spray-dried powder of gelatin and gelatin hydrolysate from scales of spotted golden goatfish,” *Journal of Food Science and Technology*, vol. 53, no. 9, pp. 3583–3592, Sept. 2016.
- [48] J. J. Fitzpatrick *et al.*, “Investigation of the rehydration behaviour of food powders by comparing the behaviour of twelve powders with different properties,” *Powder Technology*, vol. 297, no. 297, pp. 340–348, Sept. 2016
- [49] Y. V. G. Chang, L. S. Chang, and L. P. Pui, “Effects of maltodextrin concentration and inlet temperature on the physicochemical properties of spray-dried kuini powder,” *Asia-Pacific Journal of Molecular Biology and Biotechnology*, vol. 28, no. 4, pp. 117–131, Dec. 2020
- [50] A. Ekpong, W. Phomkong, and E. Onsaard, “The effects of maltodextrin as a drying aid and drying temperature on production of

- tamarind powder and consumer acceptance of the powder,” *International Food Research Journal*, vol. 23, no. 1, pp. 300–308, Jan. 2016.
- [51] Y. Zheng *et al.*, “Effect of heat treatment, pH, sugar concentration, and metal ion addition on green color retention in homogenized puree of Thompson seedless grape,” *Food Science and Technology*, vol. 55, no. 2, pp. 595–603, Mar. 2014.
- [52] R. A. Arfrah *et al.*, “Utilization of  $\alpha$ -amylase enzyme from *Bacillus stearothermophilus* RSA11B for maltodextrin production from sago starch,” *Journal of Physics: Conference Series*, vol. 979, no. 1, pp. 1–7, Mar. 2018.
- [53] Y. Alfian, Emanauli, and D. Fortuna, “Pengaruh konsentrasi maltodekstrin terhadap karakteristik pewarna bubuk dari ekstrak kulit buah naga (*Hylocereus costaricensis*),” *Seminar Nasional LPPM Universitas Jambi*, vol. 1, no. 1, pp. 357–362, 2015.
- [54] A. Ningrum and M. Schreiner, “Pandan Leaves: “Vanilla of The East” as Potential Natural Food Ingredient”, *Agro Food Industry Hi-Tech*, vol. 25, no. 3, pp. 10–14, May 2014