Potential of microwave drying technology for increase drying rate and physical quality of kaffir lime (Citrus hystrix DC) leaves

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Abstract. The effects of microwave power on microwave drying rates and the physical quality of kaffir lime leaves were studied. Three power levels were used in this study, high (723 watts), medium (537 watts), and low (420 watts). The moisture content, drying rate, color (L,a,b), and organoleptic parameters of each power level will be compared with the oven drying method (60°C). The result shows that the final moisture content of the high, medium, and low power of microwave drying are 6.06%, 4.26%, and 6.16%db respectively, which is lower than oven drying, 16.62%db. Besides, the drying rate of microwave drying is 26.39-48.71%db/minute, higher than oven drying 0.32%db/minute. Dried kaffir lime leaves with medium level power (537 watt) has the lowest color difference (ΔE = 1.0 ± 0.29) compared to fresh leaves. While, the color and aromatic preference test dried kaffir lime leaves by microwave drying was preferable than oven drying.

1. Introduction
Kaffir lime leave (Citrus hystrix DC) is one of the herbs that grow in a tropical country. It widely uses as a spice to add a distinctive aroma and flavor of Asian dishes. The main producers of kaffir lime leaves are Thailand, Indonesia, Malaysia, and India [1]. It can be served as fresh, frozen, and dried. However, fresh leaves have a short shelf life of 3-4 days [2]. The dried form of kaffir lime leaves can be a good solution to prolong the shelf life, where the easy way to store in ambient condition.

Drying is a common way to preserved food or agricultural product, such as herbs and spices. By decreasing the water existence of food, the activity of spoilage microorganisms will be limited, inhibiting its growth, and the product can be stored longer. The important consideration of the drying process is to minimize quality degradation, such as color, chemical content, and sensory quality.

A previous study was conducted to produce dried kaffir lime leaves by some drying methods, such as freeze-drying, solar tunnel drying, and fluidized bed drying. Freeze-drying method resulting lower chlorophyll decrease and color deterioration, but has the highest Citronelal loss. Solar tunnel drying leads the higher color changes and takes a long time to dry [3]. Dried kaffir lime leaves by fluidized
bed drying can minimize the color change and essential loss but need more inert material to keep the product quality [4]. Microwave is one of modern technology that can be an alternative to drying kaffir lime leaves due to its capability to penetrate materials and heat products without the aid of thermal gradients, which has a positive effect on dehydration [5]. This study aimed to investigate the effect of the microwave drying method on the quality of kaffir lime leaves in terms of drying rate, color change, and sensory quality.

2. Material and methods

2.1. Material

2.1.1. Kaffir lime (Citrus hystrix DC) leaves. Fresh kaffir lime (Citrus hystrix DC) leaves were purchased from the local market in Jember, East Java, Indonesia. The fresh leaves were separated from the thorn and twigs, then washed under running water and drained before drying. The initial moisture content was measured for each sample of the experiment. 20 g of fresh kaffir lime leaves were used for each running.

2.2. Methods

2.2.1. Drying process. The experiment was set up as follows: 20 g of fresh kaffir lime leaves were put into a glass plate, then dried in a microwave oven. Three power levels were used in this study, 723, 537, and 420 Watts. The drying duration for 723 Watts was 3 minutes, and the other was 6 minutes. The weight of samples was recorded every 0.5 minutes at 723 watts and 1 minute for the others. Another 20 g of kaffir lime leaves were dried at 60 °C in an oven drying for 8 hours (480 minutes), and the weight was recorded every 30 minutes for the first 3 hours and 60 minutes for the next.

Moisture content $M$ (% dry basis) was calculated as Equation (1):

$M \text{(%db)} = \frac{m_o - m_{\text{dry matter}}}{m_{\text{dry matter}}} \times 100\% \quad (1)$

Where, $m_o$ and $m_{\text{dry matter}}$ are the initial mass of samples (g) and dry matter weight (g), respectively [6].

The drying rate is determined by Equation (2):

$$\frac{dM}{dt} = \frac{M_{t1} - M_{t2}}{\Delta t} \quad (2)$$

Where $dM/dt$ is drying rate, $M_{t1}$ is moisture content at n point recorded, $M_{t2}$ is moisture content at (n+1) point recorded, and $\Delta t$ is time interval in each point recorded.

2.2.2. Color measurement. The color of fresh and dried samples was determined by color reader Konica Minolta CR-10 (Konica, Japan) in L*, a*, and b* color scales. L* represents brightness (darkness-lightness), a* values determine the greenness (-) and redness (+), while b* determines blueness (-) and yellowness (+). The instrument was calibrated against a white standard. Fresh kaffir lime leaf was measured for comparison purposes. The color difference ($\triangle E$) was calculated by equation (3).

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (3)$$

2.2.3. Sensory evaluation. Sensory evaluation was performed for fresh kaffir lime leaves as control and samples that have been dried by microwave and hot air drying. Fresh and dried samples were sliced into small pieces. Thirty-three untrained panelists evaluated the sensory acceptability
parameters color and smell of the samples by giving scores from 1 (very unpleasant) to 5 (very pleasant).

2.2.4. Statistical analysis. All experiments were performed in triplicate, the results are presented as mean ± standard deviation. Color parameters for all experiments were analyzed with ANOVA, while organoleptic was using Pearson correlation. Statistical analysis was done by SPSS 16.0, with a 95% confidence interval.

3. Results and discussion

3.1. Moisture content
Decreasing moisture content of kaffir lime leaves during drying is shown in Figure.1 and Figure. 2. The initial moisture content of samples ranged from 152.18 – 189.95 %db, while the final moisture content ranged from 4.26 – 6.62 %db. The fastest drying time was conducted to Microwave 723 W (3 minutes), while the longest was oven drying at 60°C, for 480 minutes. Besides, the oven drying produced the highest final moisture content (6.52 %db). In microwave drying, the high level (723 W) has a shorter drying duration than others (537 W and 420 W) to reach a similar moisture content. According to Murthy et al. [8] the higher power generates more heat and the significant vapour pressure difference between centre and surface of samples. Hence, the water molecule mobility was higher, and the drying process occurred faster than the lower microwave power.

Both Figure 1 and Figure 2 showed a similar trend in the decreasing of water. At the beginning of drying, the water decreases rapidly and gets slower at the end of drying. In this period, the samples contained high water, and water was removed from center to surface area by capillarity due to different vapour pressure between samples area. It is in accordance Hawa et al. that the decrease of moisture content is inversely proportional with the drying time [9,10].

![Figure 1. The mean moisture content of kaffir lime leaves during microwave drying.](image-url)
3.2. Drying rate
The drying rate of kaffir lime leaves is present in Figure 3 and Figure 4. The drying rate behaviour in microwave drying was similar to moisture decrease. On the contrary, the drying rate in oven drying was opposite to moisture decrease, where the drying rate was increased at the beginning and decrease at the end of drying. This result is consistent compared with previous studies for dried potato using 4 different microwave power levels [11]. Figure 3 was shown that increasing the microwave power level speeds up the drying process, thus shortening the drying time.

Comparing both Figure 3 and 4, it is found that oven drying take almost 100 times longer drying time than microwave drying. It is probably because of the different heat transfer systems between microwave and oven. In microwave drying, the heating process was proceeded by the interaction of the electrical charge between food molecules, while heat transfer on oven drying was due to the convection process [12, 13]. When the drying rate decreases (indicated by falling rate), water bounds to the primary water bond in the active group of food. Water molecules bind to other water molecules containing O atoms and N atoms, as in carbohydrates and protein. Primary water bound in the monolayer is mostly difficult to evaporate. Hence, the water removal in this state happened by capillarity process and took more time to get low moisture content [14].

Figure 2. The mean moisture content of kaffir lime leaves during oven drying.

Figure 3. Drying rate of kaffir lime leaves dried by microwave drying.
Figure 4. Drying rate of kaffir lime leaves dried by oven drying.

3.3. **Effect of microwave drying on color parameters of kaffir lime leaves**

The color parameter of fresh and dried kaffir lime leaves is present in Table 1. The $L^*$ value of oven drying is highest, followed by fresh leaves and microwave drying, respectively. In microwave drying, $L^*$ value decreases as well as decreasing power level, which high power (723W) is the closest value to fresh leaves. $a^*$ value describing red (-) to green (+) color. In Table 1, all the treatments showed a negative value, which indicates the greenness direction of kaffir lime leaves. Low level of microwave drying and oven drying results low $a^*$ value, which indicates pigment degradation during drying and browning reaction. This outcome is consistent with a previous study about the discoloration of kaffir lime leaves under air drying [15]. Another study also shows that $L^*$ value decreased and color degradation with increasing power level, probably as a result of high energy transferred into the inside of samples, which led to the rapid increase in temperature during drying [16,17].

| Sample Set | $L^*$       | $a^*$       | $b^*$       | ΔE         |
|------------|-------------|-------------|-------------|------------|
| Fresh      | 39.24 ± 1.22a | -4.90 ± 0.46c | 9.04 ± 1.19c | -          |
| Mw-723     | 38.93 ± 0.33b | -4.48 ± 0.61b | 8.41 ± 1.02a | 1.3 ± 0.83a |
| Mw-537     | 38.48 ± 0.33c | -4.40 ± 0.33c | 8.81 ± 0.52a | 1.00 ± 0.29a |
| Mw-420     | 38.34 ± 0.42d | -3.92 ± 0.55d | 7.79 ± 0.47a | 1.91 ± 0.68a |
| Ov-60      | 40.67 ± 0.72e | -2.91 ± 0.90e | 8.68 ± 0.25a | 2.64 ± 0.37b |

Note: different letter shows that the treatment is significance in p>0.05

Table 1 also shows changing of $b^*$ values during drying. All the drying methods show positive values, which indicates the yellowness of kaffir lime leaves. The microwave drying method takes a shorter drying time than oven drying, which can preserve the chlorophyll (the pigment responsible for leaves color) [18]. According to the total color difference (ΔE), oven drying showed the highest color change among microwave drying. These high values are probably due to a longer drying time which leads to chemical reaction and oxidation on samples [4]. The ANOVA analysis result that drying methods were significantly different in $L^*$ and $a^*$ value.
3.4. Effect of microwave drying on the sensory parameter of kaffir lime leaves
The result of color and aromatic preference of fresh and dried kaffir lime leaves is shown in Figure 5. According to color preference, the high power level has the highest score of preference, followed by medium and low power levels. Meanwhile, the lowest score was found in oven drying, which is comparable to high color differences (ΔE). It indicates that consumers prefer a product that has a similar appearance with a fresh form. When compared to fresh leaves, microwave products are preferable by panelists. Thus, give the positive value of dried kaffir lime leaves.

Figure 5. Mean of color (a) and aromatic (b) preference on kaffir lime leaves.

Figure 5(b) shows different phenomena compared to color preference. It can be found that the panelist’s preference was decrease with decreasing power. But, the microwave method present higher preference score than oven drying. This results might be due to loss of essential compound of kaffir lime leaves, for example citronellal and citronellol which responsible to raise identical aromatic and antimicrobial activity [4]. Pearson correlation test was used to determine the correlation between 3 level power with sensory acceptability. It is found that power level was proportionally with color preference and inversely proportional to aromatic parameter.

4. Conclusions
Microwave drying method could increase the drying rate of Kaffir lime leaves. Based on color measurement, dried kaffir lime leaves were dried by microwave have smaller ΔE than 60°C oven drying as a common drying method. Dried kaffir lime leaves by microwave drying was more accepted by panelists than oven drying, which the best acceptance in color and aroma were 723 and 420 watts, respectively.

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