Physical quality characteristics of the microwave-dried breadfruit powders due to different processing conditions

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Abstract. Production of breadfruit powder has been an option to make easy its uses in various food processing. Accordingly, there is a need recently to apply advanced drying method, i.e. microwave drying, for improving quality since conventional methods produced highly variable product quality and required longer process. The present work was aimed to study the effect of microwave power and grinding time on physical quality of breadfruit powders. The experiment was done initially by drying breadfruit slices in a microwave dryer at power level of 420, 540, and 720 W and then grinding for 3, 5, and 7 min to get powdery product of less than 80 mesh. The physical quality of breadfruit powders were measured in terms of fineness modulus (FM), average particle size (D), whiteness (WI), total color difference ($\Delta E$), water absorption (Wa), oil absorption (La), bulk density ($\rho_b$) and consistency gel ($G_c$). The results showed that physical quality of powders and its ranged-values included the FM (2.08-2.62), D (0.44-0.68 mm), WI (75.2-77.9), $\Delta E$ (7.4-10.5), Wa (5.5-6.2 ml/g), La (0.7-0.9 ml/g), $\rho_b$ (0.62-0.70 g/cm$^3$) and $G_c$ (41.3-46.8 mm). The experiment revealed that variation of microwave power and grinding time affected significantly the quality of the breadfruit powders. However, microwave power was more dominant factor to affect quality of breadfruit powder in comparison to the grinding time.

1. Introduction

Breadfruit (Artocarpus altilis) is a tropical fruit that consumed in Indonesia in various processed foods such as boiled, steamed, fried and grilled, due to its high carbohydrate content. Converting breadfruit into a powdery product is preferred recently to extend its shelf life and to ease its utilization. Previous authors used successfully breadfruit powder as main ingredient of cake, noodle and breadfruit bar [1, 2, 3]. Such powder may be made through drying, grinding and sieving process. Thus, insight of the processing effects on the powder quality can help to determine more effective production process.

Some studies on the application of different methods and various process conditions for breadfruit drying had been carried out previously to get data about its effect on final product and optimum operating condition [4, 5]. However, it was done using conventional drying methods that might cause a high variable product quality and a longer drying process. Accordingly, initiative to examine more advanced drying methods is still needed to get better quality products and to shorten drying time.

Application of microwave heating is becoming popular now in industrial food drying because it is faster, more uniform, more energy efficient and better final product quality when compared with other drying techniques [6]. The microwave drying influence on fruits and vegetables quality are reported in many literatures [7, 8], but very little of them concerning on physical quality properties of breadfruit
powders due to different processing conditions. Therefore, the present study aimed to investigate the effects of microwave power and grinding time on physical quality characteristics of breadfruit powders.

2. Materials and Methods

2.1. Preparation of breadfruit powders

Fresh breadfruit was bought from the local market in Jember, East Java, Indonesia. This was initially peeled, washed and cut to form sample slices with ~5 mm thickness. Initial moisture of sample was determined according to standard method [9].

About 150 g breadfruit slices were put on a glass dish and dried intermittently in a microwave oven using the following steps: during the first 8 min it was off every 4 min, for the next 4 min, off every 2 min and for the rest drying time, off each min. This step was ended when sample moisture reached 7.0±1.0% w.b. that was then powdered through grinding and sieving process. The sample prepared for this experiment was based on a full 3x3 factorial design, randomized completely and replicated. The microwave power (420, 540 and 720 W) and grinding time (3, 5 and 7 min) were two factors used in this experimental design. A control sample was a powder prepared by soaking breadfruit in 0.02% Sodium Bisulfite solution for 45 min before hot-air drying at 60°C and then grinding for 5 min.

2.2. Evaluation of the powder properties

The physical properties of breadfruit powder was evaluated in terms of the fineness modulus, average particle size, color attributes, water and oil absorption capacity, bulk density, and gel consistency. Fineness modulus (FM) was measured by sieving about 150 g ground powder in a Retsch sieve's shakers containing specific sieves with mesh number of 4, 8, 16, 30, 50, 100 and a pan. The FM was a one hundredth of the sum of powder percentages retained on designated sieves. The average particle size (D) of powder (mm) was calculated using Equation 1 as suggested by Henderson and Perry [10].

\[
D = 0.10414^{*}(2)^{FM}
\]  
(1)

Except for the FM and D measurements, each sample should be sieved through 80 mesh sieve prior to the physical properties analysis. Color attributes included whiteness (WI) and total color difference (ΔE) that were calculated using Equation 2 and 3, respectively based on L, a and b values recorded by a colorimeter (Konica CR-10). The ΔE value represents the total color difference between a control sample (subscript c) and tested sample.

\[
WI = 100 - \sqrt{\left(100 - L\right)^2 + a^2 + b^2}
\] 
\[
\Delta E = \sqrt{\left(L - L_c\right)^2 + (a - a_c)^2 + (b - b_c)^2}
\]  
(2)  
(3)

Water absorption (Wₐ) and oil absorption capacity (Lₐ) were measured using minor modified method described by Traina and Breene [11]. About 1.05-1.36 g powder was mixed with 10 ml distilled water in a test tube. It was then shaken for 1 min and allowed to stand for 30 min at 24°C before it was centrifuged at 2000 RPM for 25 min. The retained water in a test tube after discarding the excess water was measured as Wₐ. The Lₐ value was obtained using similar procedure by replacing the distilled water with 3 ml palm oil. The bulk density (ρₚ) was measured by weighing powder that fully occupied a known-volume container. The gel consistency (G) of sample was quantified based on Cagampang et al. method [12]. About 100 mg powder was mixed with 0.2 ml 95% ethanol containing 0.025% thymol blue in test tubes and then added immediately about 2.0 ml of 0.2N KOH. Once the mixture has been dispersed, the tubes were covered with glass marbles and placed in a boiling water bath for 8 min. The samples released from a water bath were cooled at room temperature for 5 min and then followed using ice water for 15 min. The tubes were finally laid horizontally over a mm-paper for about 30-60 min. The
Gc value was the length of gel measured along test tube that indicated the following: hard (27-35 mm), medium hard (36-40 mm), medium (41-60 mm) and soft (61-100 mm).

3. Results and Discussion
Microwave drying was conveniently dried the sample from moisture content of 69.16% to 7.51% on wet basis. It appeared that an increase in microwave power from 420 to 720 W shortened the drying time from 24 to 16 min. Correlation analysis between physical properties of powders and processing condition i.e. microwave power and grinding time resulted in coefficients (r) as shown in Table 1. These r values labeled as significant by SPSS 14 software indicate the significant relationship between processing conditions and physical properties of powder as discussed in the following sections.

3.1 Fineness modulus and average size of powder
The uniformity of grind in the resultant product was expressed as FM, which a smaller value indicates a fine powder while a large value reveals a coarse powder. The FM value of breadfruit powder ranged between 2.08 and 2.62 depending on the processing conditions. It is shown in Table 1 that the grinding time (r = -0.937) and the microwave power (r = 0.075) showed respectively to be the most important factors affecting the FM values. Prolonged grinding time granted a longer phase of size reduction and thus produced a finer powder. However, the FM values of tested samples were significantly higher than a control sample, indicating a coarser powder than a control sample as shown in Figure 1. Variation of drying methods might cause changes in texture of dry breadfruit, which could affect the grinding performance in resulting in fine powder. Former study showed that the use of microwave drying tended to increase the hardness of vegetable material in comparison to sun drying [13].

| Table 1. Correlation coefficients between powder properties and processing conditions. | Response Variables | Values | Correlation Coefficients (r) |
|---|---|---|---|
| | Range | Mean | Microwave Power (W) | Grind time (min) |
| FM | 2.08-2.62 | 2.33 | 0.075 | -0.937 ** |
| D (mm) | 0.44-0.68 | 0.53 | 0.133 | -0.910 ** |
| L | 83.5-85.0 | 84.5 | -0.479 * | -0.440 |
| a | -2.7--0.5 | -1.9 | 0.569 * | 0.581 * |
| b | 15.9-18.5 | 16.9 | 0.570 * | 0.316 |
| WI | 75.2-77.9 | 76.9 | -0.569 * | -0.377 |
| ΔE | 7.4-10.5 | 8.5 | 0.577 * | 0.391 |
| Wa (ml/g) | 5.5-6.2 | 5.8 | 0.584 * | -0.611 ** |
| La (ml/g) | 0.7-0.9 | 0.8 | -0.371 | 0.654 ** |
| ρb (g/cm³) | 0.62-0.70 | 0.66 | -0.026 | 0.722 ** |
| Gc (mm) | 41.3-46.8 | 43.9 | 0.378 | 0.041 |

Note: * Significant (p<0.05); ** Significant (p<0.01)

The average particle size (D) of powders was in the range of 0.44-0.68 mm depending on the processing conditions. A small D-value indicated a fine powder and thus resulted from a small FM value. Table 1 presents that the grinding time (r= -0.910) and microwave power (r= 0.133) affected significantly the D value. An increase in grinding time decreased the D values as shown in Figure 2.

3.2. Color attributes
The color attributes of the breadfruit powder was expressed in terms of whiteness (WI) and the total color difference (ΔE). It is presented in Figure 3 that WI values were in a very narrow range between 75.2 and 77.9 for the powders produced from all treatments. There was no significant difference on WI.
values among the tested samples, except for those that produced using 420 W with 3 min and 720 W with 7 min of microwave power and grinding time, respectively. Table 1 confirmed that the most significant factors affecting WI was a microwave power \( r = -0.569 \). A control sample showed WI value higher than microwave-dried samples though exposing under longer heating. Soaking a control sample in Sodium Bisulfite solution might prevent darkening of this sample during convective drying. Total color difference (ΔE) between a control sample and microwave-dried-breadfruit powder is presented in Figure 4. The ΔE values were in the range of 7.4-10.5 depending upon processing conditions. The lowest and the highest ΔE values were shown by the samples that dried using the microwave power of 420 W and 720 W, respectively. This is verified in Table 1 that the ΔE values correlated strongly with microwave power \( r = 0.577 \). The increased color change in a microwave-dried-product was due to an increase in microwave power and exposure time [14].

3.3. Water absorption capacity
Water absorption capacity \( (W_a) \) of powders obtained in this study ranged between 5.5 and 6.2 ml/g as presented in Figure 5. It is shown in Table 1 that the \( W_a \) values increased with microwave power \( r = 0.584 \) and decreased with increasing of grinding time \( r = -0.611 \). The increased grinding time was
observed to produce a finer powder that possible to increase a particle surface area and facilitated more water absorption. It was comparable to the result found in palm kernel shell powders [15]. However, $W_a$ value of a control sample was lower than the tested samples as shown in Figure 5. It was indicated in former study that such differences in $W_a$ values might be due to the application of different drying methods [16]. Besides, application of microwave drying method showed a tendency to increase the product porosity and caused a more room space in powder to absorb water [17].

3.4. Oil absorption capacity
The effect of grinding time and microwave power on oil absorption capacity ($L_a$) of breadfruit powder is shown in Figure 6. The $L_a$ values obtained from all treatments were in the ranges of 0.7-0.9 ml/g, indicating a small variety among the tested samples. The grinding time ($r=0.654$) was observed more controlling $L_a$ values than microwave power ($r=-0.371$). The $L_a$ values showed a tendency to increase with grinding time, while decreased with increasing microwave power. The longer grinding process produced a finer powder that might enlarge powder surface area for absorbing more oil. Comparable phenomenon on the effect of particle size on $L_a$ value was found in cowpea flour [18]. The $L_a$ of a control sample was about 1.1±0.1 ml/g and significantly higher than the tested powders. However, it was concluded that the breadfruit powder preferred to absorb more water than palm oil.

**Figure 5.** Water absorption of powder as affected by grinding time and MW power

**Figure 6.** Oil absorption of powder as affected by grinding time and MW power

**Figure 7.** Bulk density of powder as affected by grinding time and MW power

**Figure 8.** Gel consistency of powder as affected by MW power and grinding time
3.5. Bulk density and gel consistency

Bulk density (ρb) is useful for characterizing, handling, and processing of powder system in the food industry. The ρb values for microwave-dried breadfruit powder are presented in Figure 7 and in the range of 0.62-0.70 g/cm³. Grinding time was found predictably to be the most factors affecting the ρb values because it correlated strongly to the particle size of powder. Longer grinding time resulted in more fine powder, which occupied less container volume and thus increased the bulk density.

Gel consistency (Gc) characterizes the tenderness or hardness of cooked breadfruit when cooling down. Figure 8 reveals that the Gc value of microwave-dried powders varied from 41.3 to 46.8 mm depending upon processing condition and classified as medium material. Table 1 shows that the effect of microwave power (r = 0.378) on Gc value was higher than grinding time (r = 0.041). The Gc value of control sample was lower than microwave-dried powder as illustrated in Figure 8. This suggested that the use of microwave drying method could increase the softness of cooked breadfruit powder.

4. Conclusion

Drying of breadfruit under exposure of microwave was successful to reduce the sample moisture content from 69.16% to 7.51% on wet basis. Variation of microwave power and grinding time proved to affect significantly the physical quality characteristics of breadfruit powders. The physical quality of microwave-dried breadfruit powders and its range values included the fineness modulus (2.08-2.62), average particle size (0.44-0.68 mm), whiteness (75.2-77.9), total color difference (7.4-10.5), water absorption capacity (5.5-6.2 ml/g), oil absorption capacity (0.7-0.9 ml/g), bulk density (0.62-0.70 g/cm³) and gel consistency (41.3-46.8 mm). It appeared that the breadfruit powder preferred to absorb more water than oil.

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