Effect of drying methods on quality of dried white turmeric 
(*Curcuma amada*)

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Abstract. White turmeric (*Curcuma amada*) is a traditional medicine that contains phenolic as an antioxidant—usually processed into drinks or capsules. Currently, the drying method used is sunlight can reduce the quality of white turmeric. The study's objectives were to investigate the most optimal drying method based on physical and chemical quality and drying rate. There were seven drying methods employed: sun-drying (SD), cabinet drying with the heating temperature of 50°C, 60°C, and 70°C (namely CD50, CD60, and CD70, respectively), freeze-drying with the final heating temperature of 30°C, 40°C, and 50°C (namely FD30, FD40, and FD50, respectively). Quality parameters measured were moisture content, color, volume, particle density, morphological visualization, and total phenolic compound. The results showed that the drying method affected the observed parameters. The freeze-drying with a heating temperature of 30°C was the most optimal drying method, with moisture content reduced from 91.41% to 7.56%. After the drying process, the color change value was 19.18, with a volume shrinkage of 69.37% and particle density of 0.41 g/cm³. The total phenolic compound of freeze-dried white Turmeric was 8.427 mgGAE g⁻¹ solid⁻¹.

1. Introduction

With the scientific name *Curcuma amada* including the Zingiberaceae family, White turmeric is one of the traditional medicines widely used by the community as a source of antioxidants due to its high phenolic compounds function to ward off free radical attacks [1]. In pharmaceutical and food industries, white turmeric was usually processed into syrup, instant powder, or tablets [2]. White turmeric was harvested 10-12 months or 20-24 months after planting. After the harvesting process, white turmeric had a high water content (above 90%), making it susceptible to damage and difficult to be stored for a long time.

To avoid the quality decrease during storage, one of the treatments that need to be done is the drying process. Drying white turmeric has several advantages: preserving the quality, avoiding spoilage, and inhibiting microbial growth [3]. Studies have been done to dry white Turmeric using several methods such as the microwave drying method and the hot drying method [4,5]. This study aimed to evaluate the effect of different drying methods on white turmeric's physical and chemical properties. The drying methods used are sun drying, cabinet drying, and freeze-drying. Physical properties that were evaluated were moisture content, color, dimensions, particle density, and microstructure. The total phenolic content is evaluated as the chemical property of dried white turmeric.
2. Materials and methods

2.1. Materials
White turmeric was purchased at the Godean Traditional Market, Yogyakarta, Indonesia. Based on the analysis, the initial water content of white turmeric was 90-93%. White turmeric is separated from dust and dirt, before being peeled and sliced lengthwise with a thickness of 5 mm.

2.2. Drying methods

2.2.1. Sun drying (SD). Slices of fresh white turmeric were placed on a baking sheet around 200g. Then, they were dried under sunlight with an average temperature and relative humidity of 33.67 ± 4.02°C and 38.31 ± 7.41%, respectively. Drying was carried out until the moisture content reach below 10%.

2.2.2. Cabinet drying (CD). Slices of white turmeric were placed on a baking sheet with a mass of around 200g. Then, they were dried in a cabinet dryer (PSN-150, Shimizu Scientific Instruments MFG. CO., LTD., Tokyo, Japan) with temperature variations of 50°C, 60°C, and 70°C (namely CD50, CD60, and CD70, respectively). Drying was carried out until the moisture content reached below 10%.

2.2.3. Freeze drying (FD). The drying unit was a lab-made freeze dryer, constructed in the Laboratory of Food and Post-harvest Engineering, Faculty of Agrotechnology, Universitas Gadjah Mada (figure 1). This machine has a dimension of 0.7 x 0.5 x 1 m, with stainless steel as its primary material. White turmeric that has been prepared was spread on the sample tray of the freeze dryer. At the beginning of the process, the freezing phase employed with the temperature set to 18°C in vacuum condition for 6 hours. The next step was the primary drying (sublimation process), in which the heating temperature was set at 0°C for another six 6 hours [6,7]. Secondary drying process employed for 24 hours, with the variation of final heating temperature 30°C, 40°C, and 50°C (namely FD30, FD40, and FD50, respectively).

![Figure 1. Laboratory freeze-drying system](image)

Description:
A. Sample tray
B. Coldtrap
C. Compressor
D. Heater
E. Vacuum pump
F. Manometer
G. Condensor
H. Filter dryer
I. Evaporator
J. Water valve

2.3. Analytical methods

Moisture content. Moisture content was measured using the International AOAC analysis method with slight modifications [8]. The samples were weighed and dried in an oven (Memmert UM-400, Memmert GmbH + Co.KG, Schwabach, Germany) at 105°C for 24 hours. The weight loss during the drying process is considered as the amount of water contained by the sample, which is presented in equation (1).
\[ MC = \frac{W - W_1}{W} \times 100\% \]  

Where \( M \) is the moisture content (%wb), \( W \) is the initial mass of the sample (g), and \( W_1 \) is the final mass of the sample after being in the oven for 24 hours (g).

2.3.1. Color. Color was measured using a Color Meter (Color Meter TES-135A, TES Electrical Electronic Corp., Taipei, Taiwan). The values obtained are lightness (\( L^* \)), redness/greenness (\( a^* \)) and yellowness/blueness (\( b^* \)). These parameters are then used to calculate the change in color (\( \Delta E \)), chroma, and hue angle.

\[ \Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \]  
\[ Chroma = \sqrt{a^*2 + b^*2} \]  
\[ Hue \ Angle = \tan^{-1}\left(\frac{a^*}{b^*}\right) \]  

2.3.2. Shrinkage ratio (DS). To analyze shrinkage ratio, samples was cut into blocks before drying process. The length, width, and height of each sample was measured using digital caliper. These parameters were then used to calculate the shrinkage ratio, which is presented in equation (5).

\[ DS = \frac{D - D_1}{D} \times 100 \% \]  

Where DS is shrinkage ratio (%), \( D \) is the initial dimension (mm), and \( D_1 \) is dimension of blocks after drying process (mm).

2.3.3. Particle density (PD). Particle density analysis was carried out by weighing the mass, then put it in a graduated cylinder that was filled with known volume of water. From this, the volume change was obtained. The mass and volume values obtained were then used to calculate particle density, which is presented in equation (6).

\[ Particle \ density = \frac{massa \ sampel}{volume \ sampel} \]  

2.3.4. Morphological visualization. The magnified image of the morphology of freeze-dried white curcumin was observed using Scanning electron microscopy (SEM; JSM 6510LA JEOL Ltd., Tokyo, Japan), with the magnification set to 500x.

Total phenolic compound. The total phenolic content was obtained using a Folin–Ciocalteu method adapted from A.J. Harborne [9] with some modifications. A total of 1 mL of the diluted extract of white turmeric were mixed with 0.5 mL of 1:1 diluted Folin–Ciocalteu reagent and then 1 mL of sodium carbonate solution were added, before the mixture was left for 10 min. After that, 10 mL aquadest was added and the mixture was shaken at medium speed. The absorbance was measured at 730 nm using the spectrophotometric method (Thermo Scientific Genesy 20, Thermo Fisher Scientific, MA, USA). The total phenolic value was calculated based on dry weight and expressed in mgGAE g\(^{-1}\).

3. Results and discussions

Physical properties of white turmeric produced from three different drying methods are shown in table 1. The physical properties observed were moisture content, color, dimensional shrinkage, and particle density. The results showed that the freeze-drying sample at 50°C showed the lowest moisture content of 3.11 ± 0.04%, while the highest moisture content of the sun drying sample was 8.94 ± 0.77%. The
lower the water content, the more suitable it is to extend the shelf life of white turmeric. The moisture content of dried herbs should not exceed 10% to inhibit fungal growth [10]. The value of ΔE represents the overall color change of fresh turmeric and after the drying process. The highest color change of white turmeric was in sun drying, which was 31.45 ± 1.02, while the lowest was at 70°C cabinet drying, 12.55 ± 2.18. However, the highest chroma and hue angle values were found in freeze-drying at 30°C. These results show that the result of freeze-drying has a better color intensity since lower temperature drop resulting in better sample color quality [11]. Figure 2 shows the morphological visualization between the results of cabinet drying and freeze-drying.

### Table 1. Physical properties of dried white turmeric

|        | MC(%wb) | ΔE (-) | Chroma (-) | Hue Angle (°) | DS (%)  | PD (g/ml) |
|--------|---------|--------|------------|---------------|---------|-----------|
| CD50   | 5.74 ± 0.34 | 13.28 ± 1.42 | 48.04 ± 3.78 | 72.62 ± 1.59 | 90.02 ± 0.77 | 0.82 ± 0.00 |
| CD60   | 4.60 ± 0.53 | 12.84 ± 1.07 | 49.05 ± 1.79 | 72.74 ± 1.46 | 92.54 ± 0.59 | 0.76 ± 0.00 |
| CD70   | 3.34 ± 0.08 | 12.55 ± 2.18 | 44.94 ± 3.17 | 72.49 ± 2.96 | 93.37 ± 1.21 | 0.72 ± 0.00 |
| FD30   | 7.56 ± 0.74 | 19.18 ± 2.24 | 51.04 ± 3.15 | 79.11 ± 1.56 | 69.37 ± 0.89 | 0.44 ± 0.01 |
| FD40   | 3.98 ± 0.07 | 13.76 ± 3.46 | 48.49 ± 0.66 | 76.28 ± 0.32 | 74.77 ± 0.26 | 0.56 ± 0.00 |
| FD50   | 3.11 ± 0.04 | 14.66 ± 1.35 | 49.57 ± 2.42 | 78.82 ± 1.88 | 81.02 ± 1.27 | 0.65 ± 0.00 |

**Abbreviations:** SD, sun drying; CD50, Cabinet drying 50°C; CD60, Cabinet drying 60°C; CD70, Cabinet drying 70°C; FD30, Freeze drying 30°C; FD40, Freeze drying 40°C; FD50, Freeze drying 50°C;

**Figure 2. Scanning Electron Microscopy** Kunyit Putih pada (a) Cabinet drying 70°C, (b) Freeze Drying 30°C, (c) Freeze Drying 40°C, dan (d) Freeze Drying 50°C

These results show that the microstructure of dried white turmeric from the cabinet drying process has irregular and denser pores than that from freeze-drying. A sizeable dimensional shrinkage and cell damage during evaporation were assumed to be the cause of this phenomenon. Freeze-dried white
Turmeric has a porous microstructure with thin pore walls, so it can be seen that freeze-drying can maintain the porous cellular microstructure of plant tissue [12,13]. Freeze drying pores are formed by freezing and sublimation processes in a vacuum [14].

Figure 3 shows the total phenolic content of dried white turmeric samples. On average, fresh white turmeric has a total phenolic content of 57.61 ± 0.34 mgGAE g⁻¹. From the figure, it can be seen that the total phenolic content increased at higher temperatures for all drying methods. This result indicates that higher temperatures can cause damage to cellular structures and increase the release of phenolic compounds bound to cell wall macromolecules [15].

![Figure 3. The total phenolic content of dried white turmeric samples](image)

The highest total phenolic content was from cabinet drying at 70°C, 14.21 ± 0.02 mgGAE g⁻¹, while the lowest was freeze-drying at 30°C, 8.44 ± 0.03 mgGAE g⁻¹. The loss of soluble phenolic compounds could occur due to oxidation reactions. In the freeze-drying process, enzymatic oxidation by polyphenol oxidase and peroxidation is more likely to happen due to lower oxygen exposure and damage to cell structures caused by ice crystallization [16].

4. Conclusions
Based on the results of this research, the drying method showed a significant effect on white turmeric’s physical and chemical properties. High moisture content can reduce dimensional shrinkage. Freeze drying at 50°C showed the best results in terms of removing the moisture content of white turmeric. However, freeze-drying at 30°C showed the best results in maintaining color intensity, dimensional shrinkage ratio, particle density, and microstructure.

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