Effect of various drying methods on the physical characteristics of arrowroot powder

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Abstract. Arrowroot (Maranta arundinacea) is a large herb found in rainforest habitats. In Indonesia, Arrowroot (or known locally as Ubi garut) is usually processed into a powder ingredient for many foods such as puddings and cookies. One of the crucial processes in producing arrowroot powder is drying. In this study, the effect of various drying methods on the characteristics of arrowroot powder was evaluated. They were solar drying (SD), cabinet drying (CD), and pneumatic drying (PD). The pneumatic dryer used was self-made with a total dimension of 1600×500×2500 mm. It was made from stainless steel plate with 3 mm thickness and equipped with heater, blower, feeder, cyclone, and drying chamber (heater fins of 4,500 watts). The moisture content showed that the CD sample has the lowest moisture content than other methods. The PD has a great potential to be used to produce arrowroot powder while retaining its color and nutritive values.

1. Introduction

Arrowroot (Maranta arundinacea) is a locally grown tuber crop in tropical countries. It has swollen roots from which the starch is extracted [1]. In Indonesia, the arrowroot tubers production reaches 9 – 12 tons per hectare, and produced 1.92 – 2.56 tons of starch [2]. Arrowroot contains 85.2% carbohydrate and 355 kcal energy and is often be used as a substitute for carbohydrates source [3]. Its bland taste and high digestibility make arrowroot starch suitable to be used as a thickener in many foods such as cookies, puddings, and other baked goods [4]. One study promoted the function of arrowroot as a functional food, because it possesses prebiotic potential by maintaining high viability of probiotics during the storage of fermented products [5]. Another study revealed that arrowroot rhizome possesses various chemical components such as flavonoids. It is known that flavonoids have medicinal properties such as anticarcinogenic, anti-inflammatory, anti-allergic, and antibacterial [6].

One of the principal processes to produce an arrowroot powder is by the drying process. Drying is a process to separate the water content of the material by evaporation [7]. Amidst its merits and function as food ingredients, the production of arrowroot powder is not yet massive. The drying process of arrowroot commonly conducted only using a cabinet dryer [8–10]. The purpose of this study was to evaluate the effect of different drying methods on the physical properties of arrowroot powder. Drying methods used are sun drying, cabinet drying, and pneumatic drying. Physical properties evaluated included moisture content, bulk density, fineness modulus, and color. Nutrient values of arrowroot...
powder such as carbohydrate, fatty acid, protein, as well as flavonoids as one of its chemical components were also investigated.

2. Materials and methods

2.1. Materials
Arrowroot was obtained from a traditional market in Delanggu, Klaten, Indonesia. One particular distributor was picked to maintain the same variety and quality of fruits used. Based on the analysis, the moisture content of arrowroot is 70-73% wb. The arrowroot was separated from dust and dirt. Arrowroot was processed on the same day it bought; to avoid any undesired changes in quality.

2.2. Drying methods

2.2.1. Sun drying (SD). The drying process began by cutting the arrowroot using a slicer to form uniform size. Fresh arrowroot slices were spread over the baking sheet and placed under direct sun on ground level at an average temperature and relative humidity of 31-35ºC and 60-65%, respectively. The arrowroot slices were turned after every one-hour interval for uniform drying. Finally, dried arrowroot was processed with a disk mill (FFC-23, Agrowindo, Malang, Indonesia) to form slices into powder.

2.2.2. Cabinet drying (CD). Fresh arrowroot slices were spread evenly on the baking sheet and placed in cabinet drying (PSN-150, Shimizu Scientific Instruments MFG. CO., LTD., Tokyo, Japan) at 60ºC for 8.5 hours. After the drying process, dried arrowroot was processed into powder using a disk mill.

2.2.3. Pneumatic drying (PD). Firstly, the arrowroot was grated then squeezed and drained prior to the drying process. The pneumatic dryer used was self-fabricated with a stainless-steel plate (3 mm thickness) and has a total dimension of 1600×500×2500 mm (Figure 1). PD was equipped with heater, blower, feeder, cyclone, and drying chamber (heater fins of 4,500 watts). The dryer was set to 70ºC. The drying process was repeated until the arrowroot powder formed.

![Figure 1. Schematic of pneumatic dryer](image-url)
2.3. Analytical methods

2.3.1. Moisture content. The moisture content of the samples was measured using the methods based on the Official Methods of Analysis of AOAC International with slight modification [11]. The samples were weighed for 3 g, and were dried in oven at 105°C for 24h (Memmert UM-400, Memmert GmbH + Co.KG, Schwabach, Germany). The loss of weight during the drying was considered as the water amount contained in sample, which is presented by equation (1).

\[ MC = \frac{W - W_1}{W_1} \times 100\% \]  

where \( M \) is the moisture content (%wb), \( W \) is the mass sample at the pre-determined time during drying (g), and \( W_1 \) is a dry matter of sample after 24 hours oven drying (g).

2.3.2. Fineness modulus. The fineness level of bulk materials such as powder is generally divided into coarse, medium, and fine aggregate. The finer the aggregate, the smaller fineness modulus (FM) value. FM is determined by the sifting process using a series of sieves with a specified mesh or hole size (named as Tyler mesh series). This sieve is driven by using a vibrator. As a result of these vibrations, the sifted particle escapes downward according to its escape ability, which depends on the particle diameter. FM of the material can be calculated by equation (2).

\[ FM = \frac{\sum \% \text{ oversize}}{100} \]

where \( FM \) is fineness modulus, \( \sum \% \text{ oversize} \) is total percentage of the sample of an aggregate retained on each of a specified series of sieves.

2.3.3. Bulk density. The bulk density of the samples was measured using the methods explained by Yan et al. [12] with slight modification. Powders were poured into a graduated cylinder and their initial (loose) bulk density (g/ml) determined by dividing the net weight of the powder by the known volume of the cylinder, as presented by equation (3).

\[ \text{Bulk density} = \frac{\text{powder weight}}{\text{powder volume}} \]

2.3.4. Color. Color analysis was performed using Color Meter (Color Meter TES-135A, TES Electrical Electronic Corp., Taipei, Taiwan). The lightness (L*), redness/greenness (a*) and yellowness/blueness (b*) were evaluated. These parameters were then used to calculate the color changes (ΔE) [13], which is presented by equation (4).

\[ \Delta E = \sqrt{(L* - L_0)^2 + (a* - a_0)^2 + (b* - b_0)^2} \]

where \( L_0, a_0 \), and \( b_0 \) are the lightness, redness/greenness, and yellowness/blueness of the fresh sample, respectively.

2.3.5. Nutrient and pigment analysis. Carbohydrate content was determined by direct aid hydrolysis method of AOAC. Protein content was determined by the micro Kjeldahl distillation method. Fat content was determined by Soxhlet extraction method. Flavonoid analysis was determined according to Ielciu et al. [14], and measured at 420 nm using a spectrophotometer (Thermo Scientific Genesys 20, Thermo Fisher Scientific, SCientific, MA, USA). All nutrient values were calculated on a dry weight basis, and expressed in g.100g solid -1 for carbohydrate, fat, protein, and flavonoid.

3. Results and discussion

Table 1 shows the physical properties of arrowroot powder resulted from three different drying methods; sun, cabinet, and pneumatic drying. The results showed that the CD sample had the lowest
water content, which was 3.59 ± 0.73%wb, meanwhile the moisture content of PD sample was 12.78 ± 0.64%wb. The lower moisture content is suitable for extended shelf life. In powders and flour, moisture contents must be less than 14% to refrain the mold growth, insect infestation, and agglomeration [15]. Previous studies reported that moisture content of arrowroot powder ranged from 7 to 15%wb [6,8,16,17].

From the FM analysis, SD and CD produced powder with lowest FM values, which were 0.09. Meanwhile, FM value was of PD sample were quite distinctive, which was 1.19 ± 0.43. This result was expected, since the presence of more water in PD sample created liquid bridges among the particles, thereby allowing particles to stick each other and agglomerate, as shown by the higher value of FM [18]. The bulk density of arrowroot powder revealed to be similar from one to another, which ranged from 0.4 – 0.55 g.ml⁻¹. The highest bulk density value is from the CD sample, with 0.51 ± 0.02 g.ml⁻¹. Bulk density of arrowroot powder showed high similarity to that of dry grits of cassava flour [18].

Table 1. Physical properties of arrowroot powder.

| Sample Name | MC (%wb)   | FM (⁻) | Bulk Density (g.ml⁻¹) |
|-------------|------------|--------|-----------------------|
| SD          | 13.30 ± 0.81 | 0.09 ± 0.00 | 0.50 ± 0.00          |
| CD          | 3.59 ± 0.73  | 0.09 ± 0.01 | 0.51 ± 0.02          |
| PD          | 12.78 ± 0.64 | 1.19 ± 0.43 | 0.44 ± 0.16          |

Figure 2 shows ∆E value of color analysis for arrowroot powder. According to previous study, arrowroot starch had a similar color to others starch isolated from cassava, potato, and achara [19]. ∆E represents the overall color difference before and after drying process of that may indicate the extent of discoloration during the drying process of food product. From the graph it can be seen that in general arrowroot powder produced by all drying methods exhibited lower ∆E and typically white color. This color characteristics of arrowroot indicates that it could be applied in food products with uniform color such as ice creams, juices, and candies [19].
significant change. PD process reduced the protein content by almost 90%. There was no significant difference between the fat content of fresh samples and powders of arrowroot. All results were low, ranged from 1–2 g.100g solid\(^{-1}\), which may be due to the removal of the peel before the process, which could be the portion with high fat content. Some researchers reported that fruit peels could be a good source of lipid compounds [15]. Low fat contents obtained in the recent study were in accordance with previous studies [20,21]. The flavonoid analysis did not show significant difference of flavonoid content in arrowroot before and after drying process. This result is different from that done by Sukrasno et al. [22], who revealed that the flavonoid of Cosmos leaves after drying was lower compared to fresh leaves.

### Table 2. Nutritive values of raw sample and powders of arrowroot powders

| Sample Name | Carbohydrate (g.100g solid\(^{-1}\)) | Protein (g.100g solid\(^{-1}\)) | Fat (g.100g solid\(^{-1}\)) | Flavonoid (g.100g solid\(^{-1}\)) |
|-------------|-----------------------------------|-------------------------------|-------------------------------|----------------------------------|
| Fresh sample| 88.84 ± 18.27                     | 7.47 ± 1.29                   | 1.59 ± 0.13                   | 0.10 ± 0.02                     |
| SD          | 82.55 ± 0.10                      | 4.26 ± 0.08                   | 1.98 ± 0.09                   | 0.09 ± 0.00                     |
| CD          | 85.03 ± 0.18                      | 5.04 ± 0.06                   | 1.82 ± 0.11                   | 0.10 ± 0.00                     |
| PD          | 101.43 ± 0.55                     | 0.97 ± 0.07                   | 1.95 ± 0.04                   | 0.10 ± 0.00                     |

### 4. Conclusion

This study investigated the effect of three different drying methods to the physicochemical properties of arrowroot powder. The drying methods were sun, cabinet, and pneumatic drying. In conclusion, different drying methods affect the moisture contents and fineness modulus of arrowroot powder. Higher moisture content results in larger particle sizes. Cabinet dryer showed the best results in terms of moisture removal. Pneumatic dryer has great potential to be used to produce arrowroot powder while retaining its color and nutritive values.

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