Effect of various drying methods on the physical characteristics of purple yam powder

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Abstract. Purple yam (Dioscorea alata) is a type of plant that grown in almost all regions of Southeast Asia. In Indonesia, purple yam is one of the most popular types of sweet potatoes compared to other types of the genus Dioscorea. Purple yam is usually consumed directly as a side dish, or processed into a powder. One important process of making purple yam powder is drying. In this study, the characteristics of purple yam powder were evaluated from several drying methods, namely sunlight drying (SD), cabinet drying (CD), and pneumatic drying (PD). The pneumatic dryer used was self-made with a stainless steel plate (3 mm thickness) and has total dimension of 1600x 500x 2500 mm. The results showed that the CD sample had the lowest water content. The purple yam powder by CD and PD can produce brighter powder compared to that with SD method. From the FM test, the smallest FM value was obtained from CD sample. CD sample proven to be able to retain purple yam nutritive values after drying process.

1. Introduction
Purple yam (Dioscorea alata) is one of the staple foods that contain high carbohydrates, which can be used as a source of calories. The carbohydrate content in purple yam is classified as the Low Glycemic Index (LGI 54), which is a type of carbohydrate that is more slowly digested, causes a slower rise in blood glucose and insulin levels. Besides being high in carbohydrates, purple yam also contains higher anthocyanins than black soybeans, black rice, and eggplants. Anthocyanin functions as an antioxidant that can prevent premature aging and cancer. The purpler the color of purple yam, the higher the anthocyanin content [1]. Purple yam can be processed into several products, one of which is powder. Purple yam powder can promote easier storage and preservation, also as a substitute for wheat flour. One important process to make purple yam powder is drying.

Drying is a process to separate the water content of the material by evaporation [2]. Since the production of purple yam powder is not yet massive, the purple yam is simply dried under the sun immediately after harvest. The drying process is uneasy to maintain since temperature and humidity tend to fluctuate. Furthermore, there has been a risk of being contaminated due to dust, insects, birds, or other animals [3]. Therefore, the purpose of this study was to evaluate the effect of different drying methods on the physical properties of purple yam powder. Drying methods used are sunlight drying, cabinet drying, and pneumatic drying. Physical properties evaluated included moisture content, bulk density, fineness modulus, and color. Nutrient values of purple yam powder such as carbohydrate, fatty acid, protein, as well as anthocyanin for pigment analysis were also investigated.
2. Materials and methods

2.1. Materials
Purple yam 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 purple yam is 70-75 %wb. The purple yam was separated from dust and dirt. Purple yam was processed on the same day it bought; to avoid any undesired changes in quality.

2.2. Drying methods

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

2.2.2. Cabinet drying (CD). Fresh purple yam slices were spread evenly on the baking sheet and placed in cabinet drying at 60ºC for 8.5 hours. After the drying process, dried purple yam was processed into powder using a disk mill.

2.2.3. Pneumatic drying (PD). Firstly, the purple yam 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 1600x 500x 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 purple yam 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 [4]. 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. (2001) with slight modification [5]. 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 (\( \Delta E \)) [6], 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 (AOAC, 1970). Protein content was determined by the micro Kjeldahl distillation method. Fat content was determined by Soxhlet extraction method. Anthocyanin analysis was determined by the Glusti and Wrolstad method, and carried out using a spectrophotometer (Thermo Scientific Genesys 20, Thermo Fisher 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 mg.100g solid\(^{-1}\) for anthocyanin.

3. Results and discussion

Table 1 shows the physical properties of purple yam powder resulted from three different drying methods; sunlight, cabinet, and pneumatic drying. The results showed that the CD sample had the lowest water content, which was 5.00 ± 2.50%wb, meanwhile the moisture content of PD sample was 12.33 ± 0.38%wb. Lower moisture content are suitable for extended shelf life. Previous study found that low moisture content of wheat flour, 9 and 10% showed maximum resistance against fungal...
growth and insect infestation during long period of storage time [7]. C. Hsu et al. (2003) compared physical properties of yam flour by different drying methods, revealed that drum dryer resulted the highest moisture content than freeze drying and hot-air drying, which was ranged 6 – 8 % [8].

From the FM analysis, the smallest FM value was obtained from CD sample, which was 0.19 ± 0.03, while the highest FM value was obtained from the PD sample, which was 2.28 ± 0.12. This result was expected, since the presence of water created liquid bridges among the particles, thereby allowing particles stick to each other and agglomerate, shown by high value of FM [9]. The bulk density of purple yam powder revealed to be similar from one to another, which ranged from 0.3 – 0.45 g/ml [9]. The highest bulk density value is from the CD sample, with 0.44 ± 0.01 g/ml. Bulk density of purple yam powder showed high similarity to that of dry grits of cassava [9] and taro flour [10].

Table 1. Physical properties of purple yam powder.

| No. | Sample name | MC (%wb) | FM (-) | Bulk density (g/ml) |
|-----|-------------|----------|--------|---------------------|
| 1   | SD          | -        | 0.20 ± 0.00 | 0.35 ± 0.00 |
| 2   | CD          | 5.00 ± 2.50 | 0.19 ± 0.03 | 0.44 ± 0.01 |
| 3   | PD          | 12.33 ± 0.38 | 2.28 ± 0.12 | 0.32 ± 0.00 |

Figure 2 shows ∆E value of color analysis for purple yam powder. ∆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 PD sample experienced the highest discoloration, with ∆E value of 36.07 ± 6.85, far higher than that from SD and CD. Although browned yam flour diet is popular in some African countries [11], dark brown colour flour is not really acceptable in Asian countries, including Indonesia. In order to prevent the formation of dark colour during drying, fresh yams were blanched before drying process [8].

Purple yam is considered a functional food since it is rich in carbohydrates, protein. The distinctive feature is in its purple color, result of water-soluble vacuolar pigments called anthocyanins. Table 2 shows the nutritive values of fresh and powders of purple yam. In general, it was observed that degradation occurred for carbohydrate and protein contents of purple yam during the powder production. From carbohydrate, it was revealed that SD and CD process reduced the carbohydrate
content by 10 g.100g solid\(^1\), meanwhile PD sample proven can retain its carbohydrate content. The results of carbohydrates overall were similar to that of freeze drying, hot-air drying, and drum-drying of purple yam flours [8]. Especially for protein value, the degradation occurred significantly after the process. The protein content was ranged from 1 - 3 mg.100g solid\(^1\). In contrary to the carbohydrate value, PD samples revealed to have the least protein retained in powder, 1.04 ± 0.08 g.100g solid\(^1\).

Unlike the others, there was no significant difference between the fat content of fresh samples and powders of purple yam. All results were low, ranged from 1 – 2 g.100g solid\(^1\). It is more than likely because of the removal of the peel before the process, which could be the portion with more fat content. Some researchers reported that fruit peels could be a good source of lipid compounds [12]. Low fat contents obtained in the yam flours were in accordance with previous studies [8,13]. From anthocyanin analysis it can be seen that SD sample has the least anthocyanin content retained in powder. This result is similar to that done by Çoklar et al., who revealed that the anthocyanins in black grape after sun drying is the least compared to those resulted from oven and freeze drying [14].

| No. | Sample name | Carbohydrate (g.100g solid\(^1\)) | Protein (g.100g solid\(^1\)) | Fat (g.100g solid\(^1\)) | Anthocyanin (mg.100g solid\(^1\)) |
|-----|-------------|-----------------------------------|-------------------------------|-----------------|-------------------------------|
| 1   | Fresh sample | 92.49 ± 5.80                      | 4.93 ± 0.00                   | 1.10 ± 0.17     | 18.51 ± 0.90                  |
| 2   | SD          | 80.72 ± 1.61                      | 2.36 ± 0.14                   | 2.11 ± 0.06     | 14.38 ± 0.31                  |
| 3   | CD          | 84.36 ± 0.22                      | 2.51 ± 0.06                   | 2.04 ± 0.10     | 24.86 ± 0.13                  |
| 4   | PD          | 95.01 ± 0.31                      | 1.04 ± 0.08                   | 1.81 ± 0.26     | 21.19 ± 0.12                  |

### 4. Conclusions

This study investigated the effect of three different drying method to the physicochemical properties of purple yam powder. The drying methods were sunlight, cabinet, and pneumatic drying. In conclusion, different drying methods showed significant effects on the moisture contents and fineness modulus of purple yam powder. Higher moisture content results in larger particle sizes. Cabinet dryer showed the best results in terms of moisture removal, color, and nutritive values.

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