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Color, Microstructure and Crystallinity of Red Rice Flour with Differences in Drying Times and Temperatures

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Abstract*— One effort to develop red rice as food is to process it into flour. Drying is one of the stages in the flour processing that must be considered to get flour with good physicochemical characteristics. Time and temperature of drying are some of the factors that influence the physicochemical characteristics of dried food products. This research aimed to study the color changes, microstructure and crystallinity properties of red rice flour which were dried with different times and temperatures. The factors were drying time (1 hour, 2 hours, and 3 hours) and drying temperature (50, 55, and 60 ^{o}C). The results showed that interaction of drying time and drying temperature significantly increased lightness and yellowness, but reduced the redness of red rice flour. Granular morphology images and crystallinity pattern showed that differences in drying time and temperature did not affect the shape of the granules and type of starch of red rice flour. Based on the crystallinity pattern, red rice flour was classified as A- type.

Keywords—color, crystallinity, drying, microstructure, red rice flour

I. INTRODUCTION

Red rice (*Oryza nivara*) is one variety of rice in Indonesia, besides white and black rice. The differences in color of rice are due to the process of polishing and the content of phytochemical compounds as natural pigments found in the pericarp, sees coat, and aleuron [1][2]. The red color in red rice is caused by anthocyanin compounds found in the pericarp [1]. The function of anthocyanin are as natural pigment, and antioxidant [2]. The anthocyanin content of red rice ranges from 6.79 to 12.23 mg per 100 g [3].

Processing red rice into flour is one of alternative products because the flour will be more resistant to storage, makes it easier when mixing with other ingredients (composites), can be enriched with nutrients (fortification), and accelerates in subsequent processing. The flour product will be in accordance with the demands in life with high mobility that is very practical [4].

Drying is one of the stages in flour processing. Drying is the process of reducing the water content of a material to a certain amount [5]. If heating occurs in every part of the material so that all the moisture contained in the material will evaporate when drying takes place [4]. Temperature and drying time are several factors that influence the drying process. The temperature and drying time will be directly proportional to the rate of evaporation of water. The higher the temperature and the longer the drying time can cause faster the rate of evaporation of water, but will affect the quality of the material produced. Drying will cause changes in physical, chemical, and sensory characteristics of material [6][7]. Previous research on drying red rice flour stated that red rice flour with drying treatment for 2 hours had the best physical, chemical, and sensory characteristics [4]. Therefore it is necessary to conduct research on the effect of drying time and drying temperature (using an oven) on the color, structure of the granules and the crystallinity of red rice flour.

II. METHODS

A. Material

Red rice obtained from a supermarket in Palembang, Indonesia.

B. Method

This study consisted of 2 factors, namely (A) the drying time (1 hour, 2 hours, 3 hours) and (B) the drying temperature (50 ^{o}C, 55 ^{o}C, 60 ^{o}C). Red rice sorted to separate deformed or not intact. Red rice was dried using an oven with a temperature and drying time according to treatment, then it milled using a blender for ± 3 minutes. The next step was sieving (80 mesh) to obtain red rice flour [4].

Parameters observed were color (lightness, redness, and yellownes) [8], microstructure (granular morphology) [9], and crystallinity pattern [10] of red rice flour. Data of microstructure

(granular morphology) and crystallinity pattern of red rice flour were presented in image. Color parameters used a Randomized Block Design factorial and repeated three times. Data of color (lightness, redness, and yellowness) were evaluated using analysis of variance (ANOVA) and honestly significant difference (HSD) test at the 5% level.

III. Results

A. Color

The measurement of red rice flour color consisted of lightness (L*), redness (a*), and yellowness (b*). The results showed that the average values of L*, a*, and b* of red rice flour ranged from 73.92% to 76.96%, +2.44 to +4.2, and +15.16 to +18.26, respectively (Table 1.).

Table 1. Average Values of Lightness, Redness, and Yellowness of Red Rice Flour

Treatments	Lightness (%)	Redness	Yellowness
A1B1 (1 hour; 50 ºC)	73.92[a]	4.29[a]	15.16[a]
A1B2 (1 hour; 55 ºC)	74.90[ab]	3.92[ab]	16.30[b]
A1B3 (1 hour; 60 ºC)	75.16[ab]	3.93[ab]	16.52[b]
A2B1 (2 hours; 50 ºC)	74.83[ab]	3.96[ab]	16.66[b]
A2B2 (2 hours; 50 °C)	76.40[b]	3.47[b]	16.83[bc]
A2B3 (2 hours; 60 ºC)	77.23[bc]	2.92[bc]	17.08[bc]
A3B1 (3 hours; 50 °C)	75.89[b]	2.85[c]	16.36[b]
A3B2 (3 hours; 55 °C)	78.18[c]	2.75[c]	17.86[c]
A3B3 (3 hours; 60 °C)	78.96[c]	2.44[c]	18.26[c]

Numbers followed by the same letter in the same column mean different

B. Granular Morphology

Analysis of granular morphology aimed to investigate the microstructure of red rice flour with differences in drying times and drying temperatures. The morphology of red rice flour granules was analyzed using SEM (Scanning Electron Microscopy). The results showed that red rice flour with differences in drying times and drying temperatures had same granule shape.Granular morphology of red rice flour presented in Fig. 1.

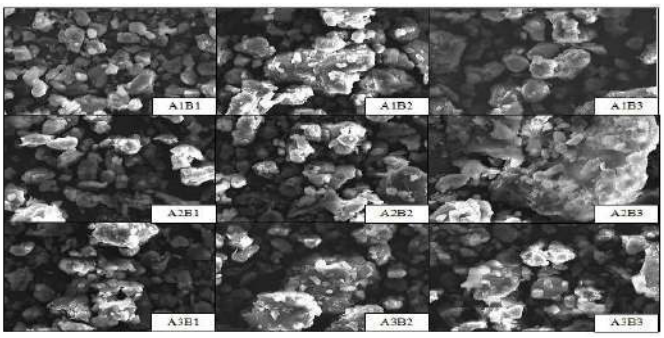

Fig. 1. Granular morphology (microstructure) of red rice flour with differences in drying times and drying temperatures

C. Crystallinity Pattern

The crystallinity pattern of red rice flour was determined by X-ray Diffraction (Fig. 2.). The results of X-ray Diffraction analysis or crystallinity pattern showed that red rice flour was a A-type starch.

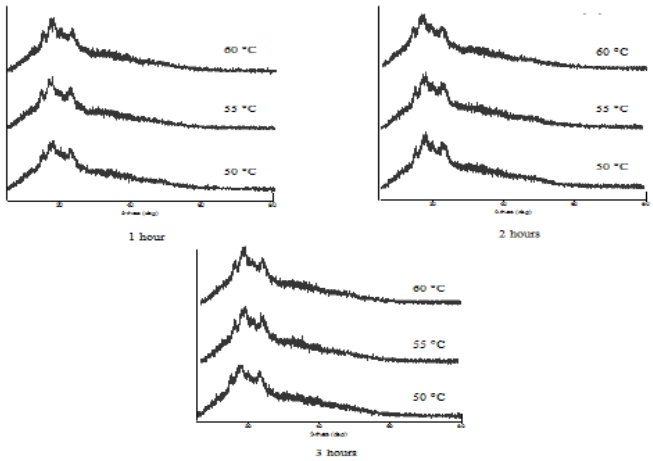

Fig. 2. Crystallinity pattern of red rice flour with differences in drying times and drying temperatures

IV. Discussion

The L* value shows the brightness of a material and its value ranges from 0 to 100. The L* value that approaches 0 indicates that the sample has a low brightness value (dark), whereas the L* value approaches 100 indicates that the sample has a high level of brightness (white) [11]. Redness (a*) value shows the red to green color of a product. Redness values range from 0 to +80 for red and 0 to -80 for green [12]. Yellowness (b*) value indicates yellow to blue in a product. Yellow has a range of values from 0 to +70, while blue has a range of values from 0 to -70 [13].

The results of analysis of variance showed that drying time, drying temperature, and interaction of both had significant effects on the L*, a*, and b* values of red rice flour (Table 1). The higher drying time and drying temperature would increase L* and b* values of red rice flour, but decrease a* value of red rice flour. Previous study stated that drying time had significant effects on increasing of brightness and reducing of red color in red rice flour [4]. Increased temperature and drying time would make red rice flour brighter, which was indicated by increasing of L* value and decreasing of a* value. It was caused by the anthocyanin pigment being damaged with higher temperatures and longer drying times.

Temperature has a very important role and influence on the stability of anthocyanin [14]. The presence of oxygen and high temperatures can damage the anthocyanin pigment even though its degradation is not very affected by oxygen, but is greatly influenced by heat accumulation [15]. Anthocyanin is a compound which in alkaline, high temperature, light, and oxygen conditions is unstable [16]. Based on the previous study, decreasing of anthocyanin levels in black glutinous rice occurred at temperatures above 30 °C. The increasing of temperature to 70 °C for more than 30 minutes caused anthocyanin damage up to 50% [17].

The increasing of yellow color in red rice flour was caused by decreasing of red color due to long drying time and high

temperature. The higher temperature and the longer drying time caused decreasing of the red color concentration of red rice flour. According to previous research, the heating process could increase the value of b* in red bean flour [18]. Other research stated that the higher temperature that used in the processing would cause the anthocyanin was damaged and would form chalcone compound (yellow) [19].

Based on granular morphology of red rice flour, the differences in drying times and drying temperatures did not affect the shape of granules of red rice flour. Increasing of drying time and drying temperature did not change the red rice flour starch granules. The drying process in this study used an oven. Previous study stated that oven drying did not significantly affect the morphology and fine structure of the starches [20].

The results of this research showed that red rice flour was a A-type starch. Starches derived from cereals or grains such as corn starch and wheat starch were classified in A-type. Starches derived from tubers such as potatoes and banana starch were classified in B-type, while root-derived starches such as cassava starch and starch derived from legumes were classified in C-type [21].

The results showed that red rice flour had a strong peak at 16^o, 17^o, 18^o, 19^o, 20^o, 22^o, and 23^o (2θ). The XRD pattern of A-type starches has peaks at 15° and 23° (2θ), and imperfect peaks at 17° and 18° (2θ) [22]. Increasing of drying time and drying temperature did not change the type of starch of red rice flour (A-type). The starch exhibited the A-type crystalline diffraction pattern which was not affected by drying temperature in the range of 40-60°C [23].

A-type had amylose with smaller molecular weight, shorter amylopectin branches and higher crystallinity, whereas B-type had amylose with greater molecular weight, longer amylopectin branches and lower crystallinity [24][25]. A-type starch had a double helical chain in the middle of the granule [26].

V. CONCLUSION

The interaction of drying time and drying temperature had significant effects on increasing of lightness and yellowness values, and also had significant effect on reducing of redness value of red rice flour. Differences in drying time and drying temperature did not affect the shape of the granules (microstructure) and type of starch of red rice flour. Based on the crystallinity pattern, red rice flour was classified as A-type.

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