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The Effect of Drying Method on Quality of MOCAF (Modified Cassava Flour) from Raw Material Beta-Carotene-Rich Bokor Genotype Cassava

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ABSTRACT

The high dependence on flour imports is a significant challenge to overcome by processing local food ingredients through diversification. To address this challenge, the use of MOCAF (Modified Cassava Flour) as a substitute for wheat flour has been carried out in the manufacture of wet and dry noodles, along with analog rice, and bread. The optimization of MOCAF production from beta-carotene-rich cassava depends on the selection of appropriate equipment technology and drying process. Therefore, this study aimed to analyze the effect of drying method on MOCAF characteristics of beta-carotene-rich cassava genotype. The analysis was carried out using two methods, namely sun drying for 3-4 days and oven drying at 60°C for 24 hours. Parameters analyzed included viscosity, solubility, syneresis, Near Infra-Red analysis, proximate analysis, and Scanning Electron Microscope (SEM). The results showed that drying affected the physicochemical properties of MOCAF, including viscosity, solubility, and syneresis. NIR (Near-infrared) and proximate analysis showed that drying process affected the decrease in moisture, ash, protein, and fat content, along with an increase in crude fiber, and dry fiber matter content. Furthermore, SEM microstructural analysis resulted in the reformation of starch granules, characterized by changes in morphology and structure, such as the separation of irregular spherical shapes, and hollowness.

Keywords: Beta-carotene; MOCAF; proximate; NIR (Near infrared); SEM (Scanning Electron Microscope); types of drying method

INTRODUCTION

Generally, cassava is sold raw and converted into processed products such as tape, alcohol, tapioca flour, and MOCAF (Modified Cassava Flour) (Akinrele, 1964). Among these products, MOCAF is cassava flour that has been physically, chemically, and biologically modified, possessing similar characteristics to wheat flour (Adegunwa et al., 2011). This product also has a rougher texture serving as a substitute for flour at a ratio of 30%-100, thereby reducing the cost of consuming wheat flour by 20%-30% (Alonso-Gomez et al., 2016, Julianti et al., 2011). In Indonesia, the consumption of wheat flour as a source of carbohydrates has reached 19.2 kg/capita/year, resulting in a corresponding increase in wheat imports to 6 million tonnes/year (Ariwibowo and Paramita, 2018). This high dependence on flour imports must be overcome by processing local food ingredients. Additionally, the population growth in the country occurs at aapproximately 1.5% each year, showing that over 3 million people require access to food annually (Ariwibowo and Paramita, 2018). This

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phenomenon poses a significant challenge in meeting the food needs of Indonesians.

An effective strategy to address this challenge is diversification by widening the types of food consumed, including sources rich in both energy and essential nutrients, to meet nutritional needs in terms of quantity and quality (Julianti et al., 2011 and Suriany et al., 2020). One of the non-rice food diversification is the use of carbohydrate-rich alternatives (Oyewole and Odunfa, 1989). In this context, the use of MOCAF as a substitute for wheat flour has been explored in the manufacture of wet and dry noodles, along with analog rice, and breads (Nakamura and Park, 1975). MOCAF is rich in fiber, gluten-free, and low in fat, capable of preventing colon cancer, with a hypoglycemic effect (Ihromi et al., 2018, Julianti et al., 2011). MOCAF does not contain gluten and can be processed to produce resistant starch type 3 (RS3), serving as food ingredient for people with diabetes (Julianti et al., 2011). The development of MOCAF as a functional food ingredient is attributed to innovations such as MOCAF beta-carotene flour. Specifically, beta-carotene abundant in cassava is used for various metabolic functions in humans as a source of provitamin A. According to Rahman et al. (2020) provitamin A is an antioxidant that protects cells from damage caused by free radicals.

The development of MOCAF production from beta-carotene-rich cassava can be optimized by selecting good equipment technology and drying processes. Generally, beta-carotene-rich cassava is used in the production process is attributed to antioxidant properties, which are relatively stable against high temperatures and heating (Diniyah et al., 2018; Julianti et al., 2011). In this study, oven drying and sun drying methods were selected due to their user-friendliness, ease of access, and cost-effectiveness. These methods have been widely applied by Micro, Small, and Medium Enterprises in the production of MOCAF (Diaz et al., 2018). Specifically, drying is used to reduce the moisture content in food ingredients and extend the shelf life of the material, lower deterioration caused by microorganism activity, and minimize postharvest losses (Diaz et al., 2018). Traditionally, drying using the sun heat depends on weather conditions, posing a challenge in controlling the quality of resulting MOCAF products. This limitation can be overcome by using oven dryer, which enables precise adjustments to time and temperature, thereby superior control over product quality (Diaz et al., 2018, Cardenas and De Buckle, 1980). According to Aisah et al. (2021), drying process is essential during the production of MOCAF, which requires a maximum moisture content requirement of 13%.

The chip drying method is prevalently used in MOCAF industry, but the dependence on sun heating has several limitations. These include reliance on weather conditions, difficulty in controlling and ensuring uniformity during drying process, requirement for large area, susceptibility to contamination, high risk of loss/shrinkage, longer time, and high drying rate (Diniyah et al., 2018; Mestres Rouau, 1997). The development of chip dryers has been carried out such as an oven-drying machine (Diaz et al., 2018). Although this method can increase work productivity and efficiency, the resulting MOCAF chip is brownish-white after 6 hours at 60°C due to the Maillard reaction on cassava (Diaz et al., 2018). The Maillard reaction is caused by an oxidation and dehydration between the amino group of the protein and the carboxyl of the reduced sugar contained in cassava, triggering a brown color due to the formation of melanoidin (Emannuel et al., 2012, Julianti et al., 2011). The effect of sun drying, oven, and their combination on the starch content of MOCAF and cassava flour shows a significant effect on the resulting products (Diaz et al, 2018; Demiate et al., 1999). The selection of cassava varieties, fermentation, and selection of the appropriate drying type can produce different characteristics of MOCAF. Therefore, this study aimed to further analyze the effect of drying type on the characteristics of MOCAF from beta-carotene-rich yellow cassava varieties to obtain optimal results.

METHODS

Materials

In this study, the sample used consisted of yellow cassava from the bokor genotype, characterized by high beta-carotene content, aged between 8 to 12 months from Boyolali, Central Java. Additionally, Bimo-CF was used in the starter fermentation process for 24 hours during MOFAC production. The equipment used included a knife, fermentation tub, chips slicer, spinner, thermometer, litmus paper, balance, hammer mill, and packaging. This study was conducted at PT. Solution MOCAF, Surakarta, Central Java. Meanwhile, the analysis of the physicochemical properties of MOCAF was carried out at the Muhammadiyah University of Surakarta Chemical Engineering Laboratory. Flour quality was examined at the Research Center for Food Technology, while processing was conducted at BRIN Gunungkidul, Yogyakarta, and the Research Center for Applied Microbiology at BRIN Bogor, West Java.

Production of MOCAF Rich in Beta-Carotene

The production of MOCAF started with sorting cassava of the Bokor genotype at the age of 8-12 months from the skin by peeling, followed by soaking in water and washing at 30ºC. Subsequently, clean cassava was sliced thinly to form a chip slicer, with a thickness of 0.2-

0.3 cm. Fermentation was carried out within 24 hours using a plastic container filled with water, where 10 g of Bimo-CF starter was added to 10 kg of cassava. After fermentation, cassava chips were soaked in 0.3% sodium bisulfite to protect against loss of beta-carotene content during drying process. Before drying, cassava chips were put into a spinner machine to reduce the moisture content, followed by drying process using sunlight for 3-4 days and oven at 60^{o}C for 24 hours. Cassava chip flouring process was carried out using a hammer mill, sifted with a 100-mesh sieve to obtain a fine quality, and packaged as MOCAF using aluminum (Cardenas and De Buckle, 1980; Martinez and Quiroga, 1988).

Viscosity Test

A total of 5 g of MOCAF was dissolved in 500 mL of distilled water and stirred for one minute. The solution was heated using a hot plate with a maximum temperature of 500 °C and stirred for 20 minutes to increase the temperature to reach the boiling point using thermometer (Moorthy et al., 1993). Subsequently, the hot plate was turned off, the gel formed was cooled to 50 °C, followed by viscosity tested using a viscometer with spindle number 4. Flour viscosity was measured at 29 °C with a concentration of 5% using using a Stormer viscometer.

Solubility Test

A total of 1 g of the sample was dissolved in 10 mL of distilled water and stirred for one minute. The solution was heated to 60°C for 30 minutes in a water bath, while the supernatant and paste were separated using a centrifuge at 3000 rpm for 20 minutes. Subsequently, 5 ml of the supernatant was collected, put in a crucible, and dried in an oven at 100°C, and the dry weight was recorded (Nakamura and Park, 1975). The following formula calculates the solubility value (Equation 1).

$$\%\,Solubility = \frac{weight\ of\ dry\ sediment}{supernatant\ volume} \tag{1}$$

Table 1. Treatment of drying method to produce MOCAF

Treatment	Drying methods	Fermentation time	Starter
1	Sun heat (3-4 days)	24 hours	Bimo CF
2	Oven (60 °C for 24 hours)	24 hours	Bimo CF
Control	Sun heat (3-4 days)	24 hours	-
Control	Oven (60 °C for 24 hours)	24 hours	-

Syneresis Test

The freeze-thaw method was used in the syneresis test by dissolving 5 g of MOCAF in 100 mL of distilled water and stirring for 1 minute. Subsequently, the solution was heated at 200 °C for 15 minutes and cooled to room temperature. The samples were frozen in the freezer for 24 hours and covered with aluminum foil, followed by thawing at room temperature, and in a water bath at 40 °C for 5 minutes. The paste and water obtained were separated using a centrifuge at 3500 rpm for 15 minutes and weighed accordingly (Julianti et al., 2011). To calculate the syneresis value, the formula used is expressed as follows (Equation 2).

$$Syneresis\ (g/g) = \frac{\text{weight of the water comes out}}{\text{wight of initial pasta}} \tag{2}$$

Near Infrared (NIR) Analysis

The NIR test for MOCAF was carried out using the MicroNIR 2200 spectrometer with a spectral range from 1150 to 2150 nm (Widyaningrum et al., 2022). This spectrometer consisted of a light source, optical spectrum collection, electronics, and a detector in a single 60 g package, supported by a USB 2.0 connection, with physical dimensions of 45-42 mm. The minimal size and weight were achieved through the use of a thin film called a linear variable film (LVF). Based on the thickness of the layer, only light of certain wavelengths can pass through, and the layer thickness on the LVF can be adjusted according to the desired wavelength range.

White and dark reference spectra were obtained once for all six samples to correct for environmental and instrumental influences before collecting spectra from MOCAF samples. Specifically, white reference spectrum was collected from a 99% diffuse reflectance panel, while the dark reference spectrum at approximately 0% reflectance by covering the sapphire glass with an opaque cap. When collecting the spectrum from the sample, a polyvinyl film covering was used to avoid contamination. The MicroNIR spectrometer was placed on the film for spectral contact in the absorbance mode for all MOCAF samples, at an integration time of 10 ms. As some noise was observed from the original spectra, a 5-point SavitzkyeGolay (SG) spectral smoothing pre-processing method was applied through control software to refine the original spectra. This was followed by selecting three different positions from each MOCAF sample Petri dish to obtain the spectrum. Subsequently, the average spectrum from the three positions was used to represent each MOCAF sample for further data analysis.

SEM (Scanning Electron Microscopy) Analysis

In the SEM test, the sputter coating (Hitachi E102 Ion Sputter, Tokyo, Japan) was used to cover MOCAF samples, which were analyzed with an accelerating voltage of 20.0 kV. A Hitachi S 2400 SEM (Hitachi, Tokyo, Japan) was used for recording and analysis. Subsequently, sample images were captured with a magnification of 1,000x (Ying et al., 2013) and the particle size of MOCAF was analyzed using the free Image-J software for processing digital images created at the Research Services Branch, National Institute of Mental Health, Bethesda (Maryland, USA) (Collins 2007).

Proximate Analysis

Proximate analysis for MOCAF, such as moisture, ash, fat, protein, crude fiber content, and dry matter carried out based on the method from AOAC (2010).

Statistical Data Analysis

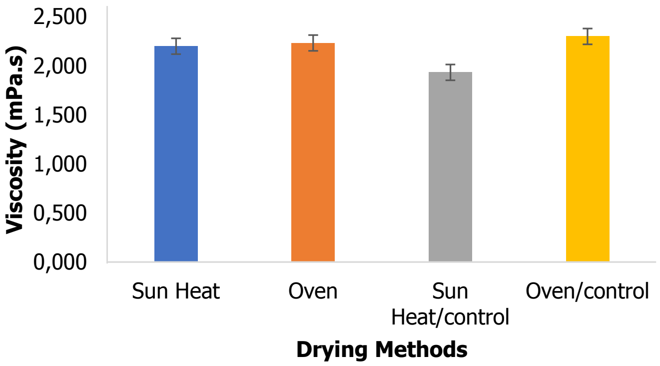
ANOVA analysis was conducted to assess the potential differences in the variables tested, namely viscosity, solubility, syneresis, Near Infra-Red (NIR), and proximate analysis. The test was carried out in triplicate at a significance level of 95% (α = 5%) with Duncan's further test (Multiple Range Test). Subsequently, the variance analysis was conducted using SPSS (Statistical Package for Social Science) 26.00 software.

RESULTS AND DISCUSSION

MOCAF Viscosity

Viscosity is an essential physical property of flour, defined as the internal frictional force in a liquid or fluid (Lopulalan et al., 2016). In this study, the viscosity of MOCAF sample ranged from 1.6 - 2.6 mPa.s, as shown in the graph below.

The results of MOCAF viscosity test showed that the viscosity value of the sun-dried sample was higher than the control, at 2.2 mPa.s and 1.93 mPa.s, respectively. Oven drying method showed a greater viscosity value in control sample at 2.3 mPa.s, as presented in Figure 1. This difference is attributed to the effect of temperature at 60 °C and 70 °C, where the starch granules started absorbing water, resulting in minimal swelling and low viscosity. At 80 °C and 90 °C, the viscosity increased, showing that the starch granules were experiencing maximum swelling along with viscosity. This process continued until the peak viscosity, followed by a decrease due to the bonding forces between the expanded and gelatinized starch granules which were reduced by high heating and vigorous stirring. According to de Barros Mesquita et al. (2016), the parameters of starch paste provided evidence that starch was cooked during heating and cooling cycles. This was because excess water in the starch granules passed through a transition phase known as gelatinization during heating at a significant temperature (Al-Fa'izah et al., 2017).



Notes: The same letters in the bar chart show values that are not significantly different with a significance level of 95% (α = 5%), after statistical testing with Duncan on SPSS 26.0

Figure 1. The effect of drying process on the viscosity of MOCAF

The viscosity results showed that the highest value was 2.3 mPa.s in the control sample using the oven drying method. Meanwhile, the lowest value was 1.93 mPa.s was obtained in the control with the sun drying method. The relatively stable values for the sun and oven-drying samples were 2.2 mPa.s and 2.23 mPa.s. Generally, starch has a high absorption capacity when the water suspension is heated at 55 °C to 65 °C, and the point where starch granules break down is called gelatinization temperature. In this study, gelatinization temperature affected changes in the viscosity of the starch solution, with increasing heating temperature resulting in reduced viscosity. Similarly, Erni et al. (2018) reported that gelatinization caused the amylose bonds to come closer together due to hydrogen bonds. Based on the results, drying process was observed to cause shrinkage due to the release of water, leading to the formation of stable bioplastic gel.

MOCAF Solubility

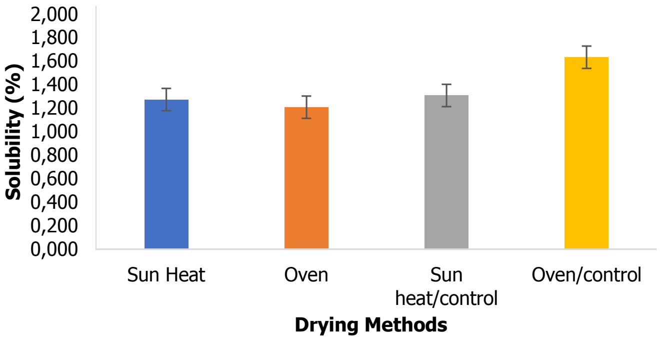
Solubility is the ability of a material including starch to dissolve in water due to the presence of non-covalent bonds between starch molecules. When starch is heated, hydration occurs within starch granules, causing molecules to disperse into the media with short chains. Consequently, higher temperature facilitates more starch molecules from the starch granules. According to Mulyandari (1992), there would be a breakdown of starch granules during heating, showing that higher amylose content facilitated the release of more amylose granules. In this study, solubility of MOCAF samples with the variation of drying method ranges from 1.16 to 1.72%. The measurement results of MOCAF solubility test are shown in the graph below.

The results of solubility test for MOCAF sample by sun drying had a lower value of 1.27%, while the control showed a higher value of 1.4%. Similarly, oven drying also had lower results than the control samples, with values of 1.2% and 1.63%, respectively. Hersoelistyorini et al. (2015) reported that solubility value of MOCAF fermented with Bimo-CF starter would produce a lower value compared to the control without a starter, resulting in an acquisition value of 1 4% and 1.9%, respectively. This difference in viscosity was influenced by the non-uniformity of drying time used during MOCAF manufacturing process. Therefore, increasing drying temperature and time would significantly improve solubility of MOCAF. Diaz et al. (2018) reported that longer drying time and higher temperature increased solubility due to high amylose content.

Based on Figure 2, the highest value of 1.63% in solubility test was in the control sample using the oven drying method, while the lowest value at 1.2% was obtained using oven drying method. Solubility value in the sample using sun drying and the control were found to be 1.27% and 1.4%, respectively. These results showed that the interaction between drying time and temperature significantly affected high solubility. The significant difference observed showed variations in the structure and solubility of starch, indicating varied chain length and distribution (Diniyah et al., 2018).

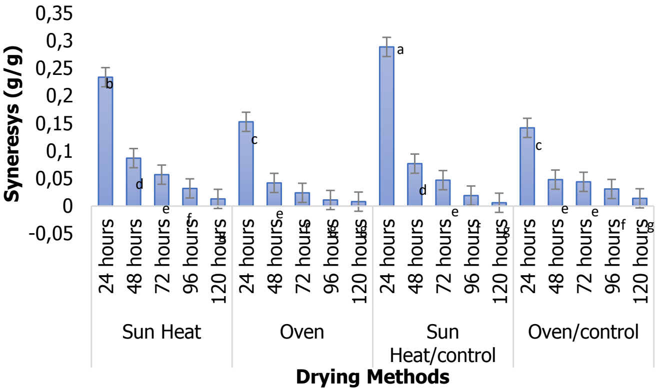
Syneresis of MOCAF

Syneresis is the release of water from food when the components of the ingredients are not closely bound to the water (Dipowaweso et al., 2018). Based on observation of MOCAF syneresis, the amount of water released during MOCAF production decreased with the duration of storage, as shown in Figure 3.



Notes: The same letters in the bar chart show values that are not significantly different with a significance level of 95% (α = 5%), after statistical testing with Duncan on SPSS 26.0

Figure 2. The effect of drying process on the solubility of MOCAF



Notes: The same letters in the bar chart show values that are not significantly different with a significance level of 95% (α = 5%), after statistical testing with Duncan on SPSS 26.0

Figure 3. The effect of drying process on the syneresis of MOCAF

The results are comparable to study conducted by (Putri et al., 2018), showing a decrease in syneresis value with prolonged storage. This suggested that a longer storage process led to a lower release of water from starch paste. Moreover, a higher syneresis value suggested greater starch retrogradation, capable of affecting the shelf life of food products.

Samples with the oven drying method had a lower syneresis value compared to sun drying method due to the amylose content in MOCAF. Moreover, high amylose content causes a higher possibility of retrogradation because amylose will bind again after gelatinization at low temperatures (cooling) (Winarno, 2004). This shows that when amylose binds strongly, the amount of water released is increased. In this study, starch syneresis value with the sun-drying method was higher than with the oven-drying method due to the amylose content (Putri et al., 2018). MOCAF tends to form stable gel and experience less retrogradation compared to native starch (tapioca) due to high amylose content (Zhu, 2015). Julianti et al. (2011) reported that amylose covering starch granules in MOCAF tended to inhibit changes in viscosity during the cooling process.

NIR MOCAF

NIR spectroscopy is a fast method for measuring the spectrum, without chemical waste. This method has been widely used in several sectors including food industry, particularly to support precision agriculture (Man and Moh, 1988; Pasquini, 2003). Büning-Pfaue and Kehraus (2001) stated that NIR spectroscopy method is reliable, inexpensive, fast, and capable of describing the fingerprint of food product compounds (Lengkey et al., 2013). The results of NIR test for MOCAF are shown in Table 2.

NIR analysis of MOCAF can determine the value of water, fat, protein, fiber, alanine, glycine, glutamic acid, and methionine. Based on the results, the value of moisture content in sun-dried and oven-dried samples ranged from 11.34% to 12.92%, while the control varied between 11.93% and 13.39%, as shown in Table 2. The moisture content obtained from the results meets the quality standards of MOCAF according to SNI 7622-2011, which is below 13%. Based on data from the Directorate of Nutrition, Ministry of Health of the Republic of Indonesia (2004), for every 100 g of cassava, there is 62.50 g of water and 60.00 g of yellow cassava (Yani & Akbar, 2018). Drying process on cassava slices caused free water to evaporate from within the raw material due to prolonged drying time. Therefore, faster drying process, resulted in reduced water evaporation and vice versa (Lubis 2008; Erni et al., (2018). The amount of water evaporated is influenced by the duration of material contact with heat, as longer contact time, resulted in greater evaporation (Wulan, 2018). A maximum moisture content of 13% is crucial for optimal quality of MOCAF, showing the significance of thorough drying to enhance shelf life (Yani & Akbar, 2018).

The fat content in the sun-dried and oven-dried MOCAF samples had an average value of 1.66% and 1.73%, while the control had an average value of 1.69% and 1.88%. Furthermore, the lowest fat content in the sun-dried MOCAF sample was 1.66%. However, these values did not meet the chemical composition of MOCAF ranging from 0.4-0.8% according to Codex Stan 176-1989, as reported by Julianti et al. (2011). The variation in results is attributed to several factors, including the high content of fatty acids in cassava caused by the secretion of microbes. Oyewole and Odunfa (1988) reported that most of the constituent mass of microbial cells is protein, although there is a small number of phospholipids. According to Aisah et al. (2021), a long soaking time makes the cell tissue more damaged and perforated, facilitating the diffusion of fat in the cell.

The protein content value in sun-dried and oven-dried MOCAF samples was 4.24% and 3.72%, while the control was 4.1% and 3.58%, respectively. Based on the results, the highest protein content in the sun-dried MOCAF sample was 4.24%, while the lowest in oven drying method was 3.58%. Julianti et al. (2011) reported that 1.36 g of protein in 100 g of cassava decreased due to a prolonged drying process. According to Diaz et al. (2018), a significant increase in drying time and temperature would degrade amino acids contained in protein. This condition causes the protein analysis results detected in flour small (Emannuel et al., 2012).

Fiber content in sun-dried and oven-dried MOCAF samples had an average value of 2.46% and 2.12%, while the control had 2.46% and 2.4%, respectively. However,

Table 2. The effect of drying method on the NIR test

Parameter (% dry base)	Drying method			
	Sun heat	Oven	Control (sun heat)	Control (oven)
Moisture content (%)	12,92±0.12^{a}	11,34±0.10^{a}	13,39±0.15^{a}	11,93±0.09^{a}
Fat (%)	1,66±0.07^{c}	1,73±0.14^{c}	3,72±0.21^{a}	2,12±0.15^{b}
Protein (%)	4,24±0.17^{a}	3,72±0.23^{b}	4,10±0.18^{a}	3,58±0.20^{b}
Alanin (%)	0,10±0.01^{a}	0,9±0.03^{a}	0,07±0.01^{a}	-
Glisin (%)	0,12±0.08^{a}	-	-	-
Glutamic acid (%)	0,54±0.05^{a}	-	0,32±0.03^{b}	-
Methionine (%)	0,14±0.02^{a}	-	0,16±0.01^{a}	-
Fibre (%)	2,47±0.12^{a}	2,12±0.10^{a}	2,46±0.12^{a}	2,40±0.15^{a}
Phosphor (%)	0,21±0.04^{a}	-	-	-

Note: - (not identified)
Notes: The same letters in the row of table show values that are not significantly different with a significance level of 95% (α = 5%), after statistical testing with Duncan on SPSS 26.0

fiber content obtained in all samples meets the chemical composition of MOCAF according to Codex Stan 176-1989 in Julianti et al. (2011), which ranged from 1.9 to 3.4%. Yani & Akbar (2018) reported that fiber in cassava would experience lysis (decomposed) into glucose by lactic acid bacteria (LAB) naturally, causing a significant decrease with increasing fermentation time. Prayitno et al. (2018) stated that the amount of crude fiber increased due to a rise in the concentration of MOCAF.

During fermentation, protein breakdown showed the presence of amino acids such as alanine, glycine, glutamic acid, and melatonin, as identified through NIR test results in Table 2. Analysis of the alanine content of MOCAF in fermentation using a starter ranged from 0.10% to 0.9%, while sun-dried control showed a value of 0.07. Furthermore, glycine and phosphorus content was only identified in sun-dried sample at 0.12% and 0.14%, respectively. Analysis of methionine content which was only identified using sun-dried and control samples was 0.14 and 0.16%, respectively.

MOCAF Proximate Test

The results of proximate test on MOCAF samples showed the values for dry matter, moisture content, ash, crude protein, crude fat, and crude fiber. Table 3 shows the dry matter values in each sample, which range from 89.13% to 92.84%. In MOCAF sample, the highest dry matter value of 92.84% value was obtained using oven drying method. Based on the control sample, oven drying method had a higher value of 92.1% compared to the sun drying at 89.13%. In comparison, sun-dried sample and control have values of 89.81% and 89.13%, while oven drying had 92.84% and 92.1%, respectively, as shown in Table 3. Drying process on cassava slices caused free water to evaporate from the raw material. Diniyah et al., (2018) stated that the high moisture content of MOCAF starch produced a low dry matter due to significantly high evaporation of water, causing lower yield. The difference between the results of proximate and NIR analysis on the nutritional characteristics of MOCAF was due to variations in the working principles of both methods. Consequently, variation and diversity of data could be obtained from the results of the nutritional analysis of MOCAF.

Proximate analysis results showed that the moisture content in MOCAF sample ranged from 7.9% to 10.87%, with the highest and lowest value obtained using sun drying and oven drying method, respectively, as shown in Table 3. Yerizam et al. (2019) reported that drying rate significantly influenced the decrease in moisture content of MOCAF. Moreover, the difference in results was caused by the magnitude of drying rate that occurred during the process. Westby and Cereda, (1994) reported that a greater drying rate would result in a higher decrease in moisture content in cassava. According to SNI standard (SNI 7622-2011), a value of 12% moisture content is allowed in cassava, In this study, a different value was obtained in MOCAF sample but still met the standard limit, showing suitability for storage and processing into various food products (SNI, 2011).

Proximate analysis showed that the ash content in MOCAF samples ranged from 0.65% to 0.89%. Based on the results, the highest and lowest value was obtained using oven drying and sun drying methods, respectively. In comparison, control sample in oven drying had a higher value of 0.73% compared to 0.65% obtained using sun drying method. Diaz et al., (2018) reported that the increase in ash content occurred because longer drying time and temperature, resulted in more water evaporation. According to (Aisah et al., 2021), drying process resulted in the decomposition of water molecule bonds (H_2O), causing a significant increase in sugar, fat, minerals, and ash content. Although the ash content of MOCAF samples was different, the value obtained was still within the standard limits of SNI (0.17-0.74%) (Lopulalan et al., 2016).

Protein content in proximate analysis of food is the amount of nitrogen (N) in the material (Priandono

Table 3. The effect of drying method on proximate test

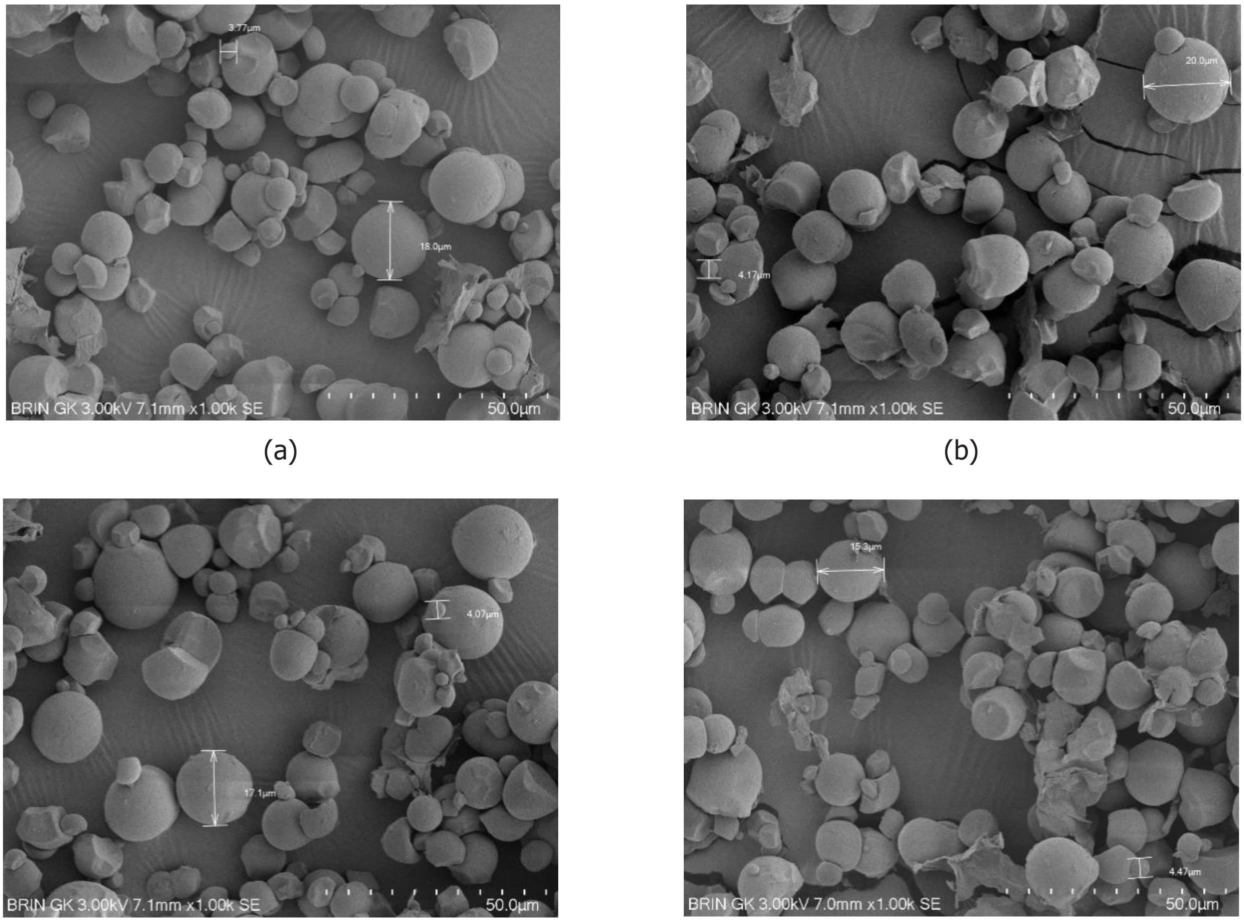
Treatment	Drying method	Proximate characteristics (% dry base)					
		Dry material (%)	Moisture content (%)	Ash content (%)	Total protein (%)	Total fat (%)	Crude fiber (%)
1	Solar heat	89,81±0.64^{b}	10,18±0.17^{a}	0,65±0.09^{c}	0,86±0.12^{b}	0,79±0.13^{a}	1,50±0.04^{c}
2	Oven	92,84±0.38^{a}	7,15±0.29^{b}	0,89±0.13^{a}	1,04±0.15^{a}	0,51±0.09^{b}	1,75±0.08^{b}
Control	Solar heat	89,13±0.27^{b}	10,87±0.35^{a}	0,65±0.08^{c}	0,94±0.07^{b}	0,72±0.10^{a}	1,35±0.12^{c}
Control	Oven	92,10±0.25^{a}	7,90±0.73^{b}	0,73±0.04^{b}	0,89±0.05^{b}	0,78±0.06^{a}	2,53±0.06^{a}

Notes: The same letters in the column table show values that are not significantly different with a significance level of 95% (α = 5%), after statistical testing with Duncan on SPSS 26.0

et al., 2018). In this study, proximate analysis results showed that the protein content in MOCAF sample ranged from 0.86% to 1.04%, with the highest and lowest values obtained in oven drying and sun drying methods, respectively. Meanwhile, the control in sun drying method had a higher value of 0.94% compared to 0.89% obtained in oven drying sample. The difference in results was caused by heating during drying, as high temperatures resulted in denaturation and protein degradation, leading to a reduction in the function of essential amino acids (Diaz et al., 2018). Priandono et al. (2018) reported that heating caused the protein to denature, thereby reducing the functional properties. Heating can damage the amino acids, as the resistance of protein to heat is closely related to the amino acids content (Diaz et al., 2018). This phenomenon causes protein content to decrease with the increasing length of drying process (Diaz et al., 2018).

Proximate analysis results showed that crude fat in MOCAF samples ranged from 0.51% to 0.79%, with the highest and lowest values obtained in sun drying and oven drying methods, respectively. In comparison, control sample in oven drying method had a higher value of 0.78% compared to 0.72% obtained using sun drying. Oyewole and Afolami, (2001) reported that the major cause of food spoilage is oxygen, accelerating the breakdown of fat through the occurrence of oxidative rancidity. Oyeyinka et al. (2019) stated that a long soaking time made the cell tissue more damaged and perforated, resulting in higher diffusion of fat content in the cell. In this study, a significant decrease was observed in fat content during the fermentation process. Aisah et al. (2021) reported that a decrease in fat content was possible during the fermentation process, as microbes required energy obtained from fat. Based on the results, MOCAF sample's fat content met the SNI 7622-2011 required quality standards, with a maximum value of 0.806% (Iswari et al., 2016).

The results of proximate analysis showed that crude fiber yield in MOCAF sample ranged from 1.35%



(a) (b)

(c) (d)

Figure 4. The shape of MOCAF granules in the sun drying method (A), oven (B), sun drying control (C), and oven drying control (D)

to 2.53%, with the highest and lowest value obtained using oven drying and sun drying methods, respectively. In comparison, the control samples for both methods had a highest and lowest value of 1.75% and 1.5%, respectively. The decrease in crude fiber content was caused by the lysis of the lignocellulosic and ligno-hemicellulose bonds due to the presence of cellulolytic bacteria (Yani & Akbar, 2018). Based on the results, fat content of MOCAF sample met quality standards of 2% as required by SNI 7622-20111.

SEM Analysis on MOCAF

SEM is a reliable method for testing and analyzing morphology of matrices at the micro/nanoscale. This method is an electron microscope that uses an electron beam reflected with high energy to describe the surface shape of the analyzed material (Julianti et al., 2011). The results of the observations made in this study are shown in Figure 4.

The results of SEM analysis of MOCAF samples showed that the largest starch granule sizes ranged from 15.3μm – 20.0μm, while the smallest varied between 3.77μm and 4.47μm. The morphology of MOCAF sample obtained the structure of large irregular round granules. In MOCAF samples A and B, the granules were irregularly rounded, and some parts had holes. Meanwhile, in the control samples C and D, the granules were irregularly round, the size was more non-uniform, and some parts were observed to have holes. Samples A and B presented in Figure 4 appeared coarser and unified due to the process of MOCAF production using a modified fermentation process, where enzymes used degraded the cell wall cellulose. This phenomenon resulted in the liberation of starch granules, which led to the separation of starch granules.

Lopulalan et al. (2016) reported that the morphological structure of starch changed after modification. Based on the results, the morphology of ozone-modified starch had a rougher and more fibrous surface, showing breakage of starch crystals due to the high influence of water concentration absorbed. Additionally, the application of microwave heating affected changes in the morphological structure of MOCAF (Budiarti & Sulistiawati, 2019). The grain structure of MOCAF, rich in beta-carotene, appeared rounded, with some parts crumbling into flakes. The grinding and sifting processes resulted in irregular morphology, potentially causing damage to starch granules (Sefrienda et al., 2020). Zhang et al. (2018) reported that the morphological structure of starch granules would be damaged with increasing temperatures above 60 °C.

CONCLUSION

In conclusion, this study showed that drying methods significantly affected the physicochemical properties of MOCAF, causing differences in viscosity, solubility, and decreased syneresis. Based on the results, a decrease was observed in water, ash, protein, and fat content, followed by an increase in fiber, crude, and dry matter content. MOCAF microstructure with various drying methods resulted in the reformation of starch granules due to changes in morphology and structure, which were separated into irregular round and hollow shapes.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding this study.

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