Journal of Sustainability Science and Management
Volume 19 Number 6, June 2024: 154-168
eISSN: 2672-7226

DEVELOPING COMBINED PROCESSING OF CASSAVA INTO MODIFIED CASSAVA FLOUR AND TAPIOCA (MOCAFTAP) AND PHYSICOCHEMICAL PROPERTIES OF THE MOCAFTAP PRODUCTS

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http://doi.org/10.46754/jssm.2024.06.012
Submitted final draft: 14 March 2024 *Accepted: 20 March 2024* *Published: 15 June 2024*

Abstract: Modified cassava flour (Mocaf) processing by fermentation produces liquid waste, which is expected to be a potential starch source. This study aims to show starch yield and physicochemical characteristics by advancing the waste from a single mocaf processing flow used in a small-scale industry using cassava var. Gajah to a new double processing flow called MocafTap (mocaf tapioca). Mocaf and starch yields were 18.15% and 4.20%, respectively. The starch yield is insignificantly different ($p > 0.05$) from the starch processed from fermented cassava. The starch meets the National Indonesian Standard for water content and carbohydrates but not ash and fibre content, which are significantly higher ($p < 0.05$). The physical characteristics of starch are insignificantly different ($p > 0.05$) from the starch of fermented cassava, i.e., bulk density 0.49 g/mL, wettability 10.39 second, water absorption capacity 0.87 g/g, oil absorption capacity 2.82 g/g, swelling power 23.41 g/g, solubility 23.33% db, and gelatinisation temperature 72.10 C. The cassava var. Gajah is unsuitable for mocaf production due to its low yield; however, considering the large yield (120 tonnes/ha) and the possibility of introducing a new processing line (MocafTap), the cassava var. Gajah still has potential as a candidate for mocaf production.

Keywords: Gajah Cassava, mocaf, modified starch, tapioca.

Introduction

Cassava is a starchy, easy-to-grow tropical crop used as a staple food in some tropical countries. For example, in West African countries, cassava is consumed as gari, fufu, lafun, akyeke, or agbelima (Twum *et al.*, 2021; Zannou *et al.*, 2022; Sama *et al.*, 2023; Otoo *et al.*, 2024), and also very popular cuisine in Brazil (Gonçalves *et al.*, 2024) up to date, research on the consumption of the root and its derived products has not been reported in Brazil. Thus, it is important to estimate the frequency of consumption of this root and its products, as well as to understand which products are not yet consumed and for what reasons. Therefore, the aim was to identify the consumption and culinary uses of cassava and its derived products. This was an exploratory study, through the answers obtained from an online self-completed questionnaire. Among the 1,487 participants, the most used nomenclature to refer to cassava is aipim and the consumption of white cassava is higher (71.8%). Currently, in Indonesia, cassava processing is dominated by the production of semi-finished ingredients, such as tapioca (Kurniawan *et al.*, 2019) and modified cassava flour (Meutia *et al.*, 2020), which will later be processed into various food products (Sefrienda *et al.*, 2020; Amaliah *et al.*, 2021; Tavares & Suseno, 2022; Indrianingsih *et al.*, 2024).

Cassava var. Gajah, a cassava-type breed in East Kalimantan, shows superior productivity, reaching 40 kg per tree or 120 tonnes per ha

[Research Center for Pea and Tuber Plants (BALITKABI), 2017]. Cassava is currently the primary source for a host of semi-finished products. However, to date, there has not been any information on this cassava variant's physical and sensory properties. Knowledge of the physical and chemical properties of cassava flour or the starch of the Cassava var. Gajah will increase its value as a priority ingredient in food product processing and as a buffer for food security (Rozi *et al.*, 2023). In addition, mocaf processing technology needs to be developed to increase industry revenue by converting waste into products (Andareswari *et al.*, 2019; Weligama Thuppahige *et al.*, 2023).

This study aimed to explore the potential of single mocaf processing into tapioca combination processing (MocafTap processing), namely mocaf processing carried out inline by utilising the waste liquid into tapioca. This research also explores the physicochemical characteristics of the resulting mocaf and tapioca. This research is expected to help business actors develop the mocaf industry into the MocafTap industry.

Materials and Methods

The flow processing design conducted in this study is shown in Figure 1. This research was conducted based on the mocaf processing flow (E), carried out in small-scale industries in Kota Bangun District, Kutai Kartanegara Regency, which was engaged in developing Cassava var. Gajah processing facilities (Figure 1). The process flow is similar to the process introduced by Subagio (Subagio *et al.*, 2008).

Mocaf processing covers several stages: Peeling and washing cassava, chopping (chip making), fermenting chips, pressing chips, drying fermented chips in an oven, and flourishing. In this research, a combination process for mocaf and tapioca was developed by running processing flows E and F, while processing flows D and G were conducted to study the physicochemical properties of tapioca.

Materials

Cassava var. Gajah root crops between 9 and 12 months of age were obtained from farmers in Kota Bangun District, Kutai Kartanegara Regency. The compounds used in the fermentation process of mocaf processing (A, B, and C compounds) were obtained from the mocaf small-scale industry. The A, B, and C compounds are components that serve as pH regulators, Lactic Acid Bacteria (LAB) starter, and washing salt (pH neutraliser), respectively. The chemicals used in this study were obtained from Sigma.

Experimental Design

The main product in this experiment was mocaf, while the waste produced was cassava peel and pressed, fermented cassava chip filtrate (TPFCF). In this experiment, the physicochemical properties of mocaf and starch obtained from TPFCF were observed. In addition, starch extraction from fresh cassava and fermented cassava chips (TFC) was also used as a comparison. The processing was replicated six times using three kilogrammes of cassava chips per batch/replication.

Parameters observed were yield, physical properties (swelling power, solubility, bulk density, wettability, wetting time, water absorption capacity, oil absorption capacity, and gelatinisation temperature), and chemical properties (moisture, ash, protein, fat, carbohydrate, and crude fibre content). The data was presented in the form of 95% CI.

Statistical Analysis

Data was subjected to one-way ANOVA, which was continued by the Tukey test for the normally distributed data, while ANOVA on Rank was applied for the not normally distributed data, which was then continued by the Dunn test. The statistical analysis was performed using Sigma Plot v.12.

Experimental Procedure

Preparation

Cassava roots were sorted, peeled and washed with clean water, and stored in a container filled with water. Cassava chips were prepared from 3 kg cassava var. Gajah. Cassava roots were then sliced with a manual slicer to produce chips with a thickness of between 2 mm and 3 mm. The cassava chips were then used as raw material for making mocaf, which starts from the cassava chips' fermentation process, pressing, drying, and flourishing (Figure 1).

Fermentation of Cassava Chips

The cassava root chips fermentation condition was semi anaerobic (carried out in open bath without stirring) at room temperature (28^{o}C). The fermentation was carried out in two steps. First, initial fermentation was carried out in mixture solutions A and B for 12 h. Cassava chips were fermented in immersion solution, i.e., clean water of one m^3 added by one tablespoon of A compound (Subagio *et al.*, 2008). Then, B solution was added when

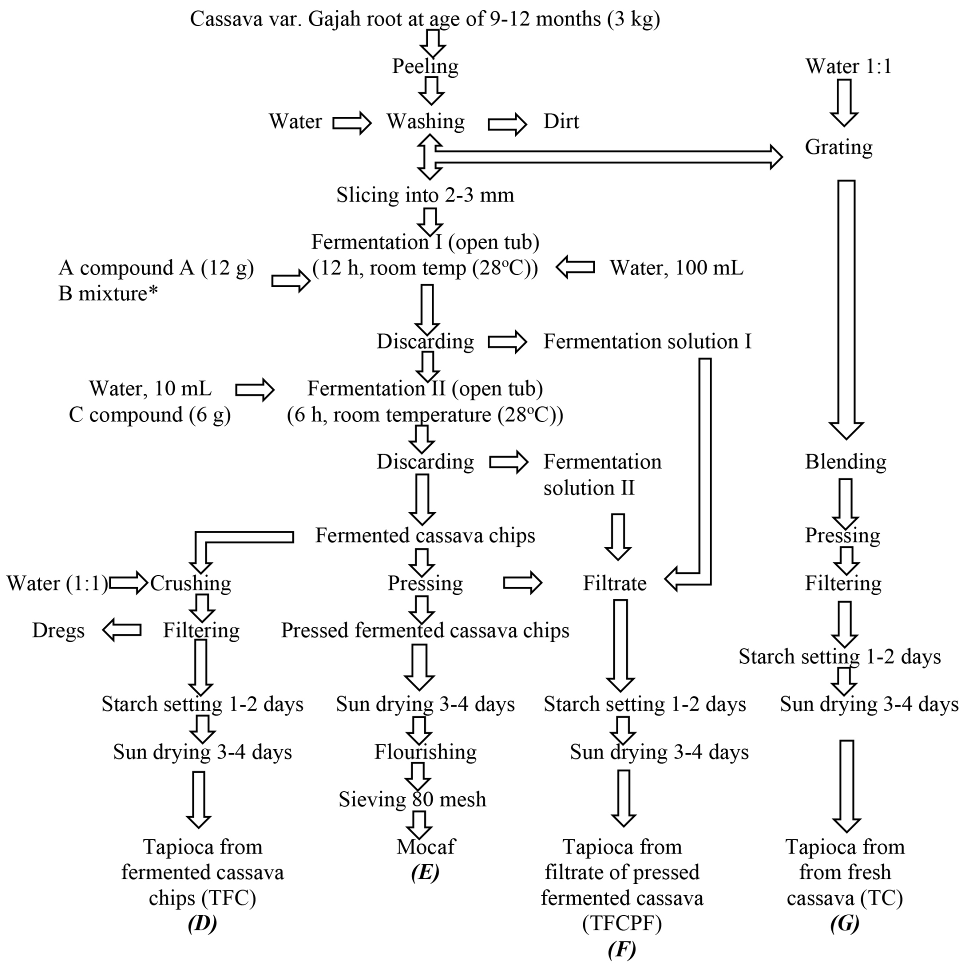


Figure 1: The processing flow of mocaf and tapioca in this study. E is the mocaf derived from the small-scale mocaf processing industry in Kota Bangun, Kutai Kartanegara Regency. E and F proposed MocafTap processing in this study. D and G are the processing conducted in this study to explore the physical properties of tapioca. A, B, and C are the compounds applied in the fermentation process

the chips were completely immersed. The B solution was prepared priorly by immersing 15 g of cassava chips in one L water, mixed with 0.50 g of enzyme-substrate powder and 1.20 g of microbe culture in powder form, then let at room temperature (28^{o}C) for 24 hours.

After 12 hours, the initial fermentation solution was replaced by the second fermentation using solution C, prepared by adding 3 g of a C compound in 50 mL water (Subagio *et al.*, 2008). The second fermentation was carried out for 6 h. Cassava chips had to be submerged in the solution, which was carried out by stirring the chips periodically. The results of successful fermentation are marked by the appearance of foam on the solution's surface.

Downstream Process of the Fermented Cassava Chips into Mocaf

The fermented cassava chips were pressed, resulting in pressed, fermented cassava chips and filtrate. The pressed cassava chips then dried while the filtrate was collected, which became part of this research. In the actual process, the filtrate is discarded as liquid waste.

The dried fermented cassava root chips were floured using an 80-mesh sieve for Mocaf. The filtrate from the pressing process was transferred into a tub and then added to the discarded fermentation solutions I and II, and the process continued by letting the starch decant at room temperature for 1-2 days. The water was removed by draining until only starch remained, then the starch was dried under sunlight and continued by flourishing the starch using an 80-mesh sieve, obtaining starch from the filtrate (TPFCF).

Tapioca Processing from the Fermented Cassava Chips

This process was conducted to explore the physicochemical properties of fermented cassava. The process designed in this research is different from the mocaf processing by small-scale industry. 600 grams of fermented cassava chips were mashed in a blender after having added to 600 mL of water to it. The mashed, fermented cassava chips were pressed, and the filtrate was collected. The filtrate was then decanted for the starch at room temperature for 1-2 days. Next, the water was removed by draining until only starch remained, then drying it in the sun continued by flourishing the starch using an 80-mesh sieve, obtaining starch from the fermented cassava (TFC).

Analysis

Yield

The yield was analysed using the comparison method between product and base material weight expressed in percent (%) referring to Nusa *et al.* (2012).

Chemical Properties

Moisture, ash, protein, fat, and crude fibre content refer to the method of Sudarmadji *et al.* (2010). The carbohydrate content is calculated using a 'by the difference method'.

Physical Properties

The bulk density was analysed by measuring the weight of the sample, which was put into a 50 mL measuring cup, according to Oladele and Aina (2007). Wettability was measured by placing a sample of 0.4 g into 40 mL of distilled water in a 50 mL measuring cup. The dispersion was carried out at room temperature without stirring. The time was recorded using a stopwatch (Park *et al.*, 2001) and green tea powder was attached to the surface of the glucose particles. The formulated green tea powder was instantly dispersed in cold (4°C).

Water Absorption Capacity (WAC) and Oil Absorption Capacity (OAC) were analysed according to Oladele and Aina (2007). First, the WAC was performed by decanting the starch/flour mixture, and then WAC was expressed as a percentage of the weight of water absorbed by 1 g of starch/flour. Next, the OAC was analysed by decanting the starch/flour mixture, and then OAC was expressed as a percentage by weight of oil absorbed by 1 g of flour.

Swelling power and solubility were measured using the method referred to by Collado *et al.* (2001) with a minor modification, i.e., the heating process of the starch or flour mixture was conducted at 90°C. The starch gelatinisation temperature profile was analysed from Rapid Visco Analyser Tech Master Newport Scientific Pty Ltd., Warriewood, Australia (Zaidul *et al.*, 2007).

Results and Discussion

The yield and chemical properties of the semi-finished product from the MocafTap processing are presented in Table 1. In addition, data from fresh cassava properties are offered for comparison.

Yield

The yield of tapioca from fermented cassava (TFC), tapioca from pressed fermented cassava filtrate (TPFCF), and mocaf from Cassava var. Gajah were significantly different ($p < 0.05$) (Table 1). In this experiment, the TFC is an outliner process of mocaf production to determine the starch yield from fermented cassava, i.e., 5.82% starch. This value shows that the Cassava var. Gajah has a meagre starch yield. However, this determination should be repeated using more extraction water to confirm the low starch yield from Cassava var. Gajah. Armanto and Nurasih (2008) reported that a starch yield of 19.6% could be achieved using a volume of extracted water to the grated cassava of 4:1. The cassava starch content, however, depends on the planting and harvesting windows (Enesi *et al.*, 2022) aside from the type of cassava (Sikkin & Candra, 2015; Subekti *et al.*, 2018).

In the mocaf process, waste liquid from the pressing step of fermented cassava chips was discarded. This experiment demonstrated that a yield of 4.20% could be achieved as tapioca from the pressed, fermented filtrate (TPFCF) from the waste liquid, equal to 72.15% of TFC. This finding provides information that mocaf processing using the fermentation method could be improved into MocafTap processing, a combined process of parallel producing mocaf and tapioca, by utilising pressed fermented chips (the liquid waste) as starch sources. It will increase the revenue in the industry based on cassava processing.

The yield of mocaf from the Cassava var. Gajah, i.e., 18.15%, is lower than the yield of mocaf by fermentation using indigenous bacteria from cassava on sticky rice cassava type with a yield of 35.85% (Kamsina *et al.*, 2019). Amanu and Susanto (2014) reported a higher mocaf yield from cassava var. Mentega and var. Karet of 47.47% and 42.66%, respectively. This finding tells that the cassava var. Gajah is only partially suitable for mocaf production—however, the high on-farm productivity of cassava var. Gajah may replace the low yield of mocaf produced. In this condition, the introduction of MocafTap processing will be precious.

Chemical Properties

Water Content

The water content of the products in this study meets the requirements of the Indonesian National Standard for tapioca, SNI 3451:2011 (BSN, 2011a) of a maximum of 14% or mocaf SNI 7622:2011 (BSN, 2011b) of a maximum of 13% (Table 1). The water content of products (tapioca and mocaf) from the MocafTap process (9.93-10.27%) was significantly lower than tapioca from a single process of fresh and fermented product (tapioca, 12.25-12.28%) ($p < 0.05$). The low water content of tapioca and mocaf from the MocafTap process is an advantage of this process as it could extend the shelf life of the products.

Ash Content

Ash content of products from fermented Cassava var. Gajah was significantly ($p < 0.05$) higher than the product from the unfermented cassava (Table 1). Only tapioca from the fresh cassava root meets the requirements of the Indonesian National Standard for ash content, SNI 3451:2011 (BSN, 2011a) of maximal 0.5%, while the two other tapioca from the fermented

Table 1: Yield and chemical properties of tapioca and mocaf from Cassava var. Gajah (*Manihot esculenta*)

Yield and Chemical Properties (%)	TC	TFC	TPFCF	Mocaf	SNI for Tapioca*	SNI for Mocaf**
Yield §	nc	5.82 ± 0.13ab	4.20 ± 0.35a	18.15 ± 0.70b		
Water content ‡	12.28 ± 0.16c	13.07 ± 0.29d	10.27 ± 0.17b	9.93 ± 0.22a	Max 14%	Max 13%
Ash §	0.34 ± 0.02a	0.83 ± 0.13ab	0.85 ± 0.10ab	1.20 ± 0.21b	Max 0.5%	Max 1.5%
Protein ‡	2.71 ± 0.16c	0.38 ± 0.11a	2.13 ± 0.25b	2.89 ± 0.34c		
Lipid §	0.64 ± 0.03	1.00 ± 0.47	1.42 ± 0.52	1.08 ± 0.52		
Carbohydrate ‡	84.03 ± 0.23b	82.97 ± 1.13a	84.42 ± 0.68b	83.15 ± 0.70ab	Min 75%	
Fibre ‡	0.09 ± 0.00a	2.83 ± 0.72c	0.92 ± 0.61ab	1.75 ± 0.55b	Max 0.4%	Max 2.0%

Note: Data (mean ± CI at 95%) was calculated from six replications. ‡) Data analysed by ANOVA, data within the same row followed by different letters show significantly different (Tukey, $p < 0.05$). *§)* Data analysed by ANOVA on ranks, data within the same row followed by different letters show significantly different (Dunn, $p < 0.05$). TC = Tapioca from fresh cassava, TFC = Tapioca from fermented cassava, TPFCF = tapioca from pressed fermented cassava filtrate, Mocaf = Modified cassava flour. *) Indonesian National Standard for tapioca SNI 3451:2011, **) Indonesian National Standard for mocaf SNI 7622:2011, nc = not calculated

cassava were out of the standard. The mocaf processed from Cassava var. Gajah meets the requirement of the Indonesian National Standard, SNI 7622:2011 (BSN, 2011b), which is a maximum of 1.5%. Kurniati *et al.* (2012) reported that different mocaf produced by fermentation method using three other starters, i.e., *Saccharomyces cerevisiae*, *Rhizopus oryzae,* and *Lactobacillus plantarum*, has an ash content of 0.4-0.6% following five days of fermentation. Amanu and Susanto (2014) reported that the ash content of mocaf is around 1.26-1.96%, depending on the type of cassava and planting location.

Protein Content

TSS, TCF, TFP, and mocaf protein content ranged between 0.38 and 2.89%. Mocaf showed a higher protein value than the other samples, which may be that the mocaf used all parts of the cassava chips, which still contained protein. In contrast, the fresh tapioca and fermented tapioca only used extracted starch. Tandrianto *et al.* (2014) showed that fermentation using *L. plantarum* could increase protein content in mocaf, which may cause the lactic acid bacteria to produce protease enzymes during fermentation. In addition, the length of fermentation time made the population of *L. plantarum* increase to 3.4% compared with the protein content of unfermented cassava flour, which was 2.78% at 72 hours. Kustyawati *et al.* (2013) also showed that the addition of *S. cerevisiae* in the manufacture of tapioca could increase the protein content (2.17%) compared to natural tapioca (0.28%). The best protein content in this study was found in mocaf flour of 2.89 ± 0.34%. The higher protein content of mocaf flour than tapioca allows the mocaf to mimic the characteristics of wheat flour.

Lipid Content

Mocaf, TC, TCF, and TPFCF fat content ranged between 0.64 and 1.42%. This result is lower than the research conducted by Kurniati *et al.* (2012), which produced the highest fat content in mocaf, 3.75%, by fermentation using *R. oryzae*. The duration of fermentation has a significant effect on the fat content produced. The longer the fermentation time, the higher the product's fat content because the weight of the material decreases the water so that the concentration of other components increases (Yenrina *et al.*, 2015).

The decreased fat content during the fermentation process could be due to the activity of the extra-cellular amylase enzyme, which breaks down starch cells so that components such as fat will participate in the fermented water. Therefore, the fat content in modified starch is decreasing (Kartikasari *et al.*, 2016).

Carbohydrate and Fibre Content

Carbohydrate levels of TC, TFC, TPFCF, and mocaf ranged between 84.03 and 85.79%. The starch content in TCF was higher than in the other samples, which caused the process of making tapioca to be carried out by extraction and deposition to obtain starch. In contrast, in mocaf processing, it is directly floured so that the non-starch content is still in large enough quantities.

Other factors affecting the starch content in mocaf and tapioca flour are differences in variety, planting location, and harvest age (Feliana *et al.*, 2014). In addition, according to Nusa *et al.* (2012), the length of time fermentation using *Acetobacter xylinum* can increase the value of carbohydrates in mocaf flour, which showed that the longer the fermentation time, the greater the number of starter bacteria.

The decrease in starch content in the starch filtrate may be due to several things, including starch being dissolved in the immersion water and some starch still bound to the cassava (Haryanti *et al.*, 2014).

This study showed that the crude fibre content of starch from fresh cassava roots (TFC), starch from pressed, fermented cassava roots chips filtrate (TPFCF), and mocaf ranged between 0.09 and 2.83%. TPFCF has the highest fibre content, which might be due to microorganisms that produce cellulose in the fermentation process.

The fibre content of mocaf flour obtained is 1.75%, fulfilling the National Indonesian Standard, SNI 7622:2011 (BSN, 2011b) of a maximum of 2.0%. On the other hand, the product of gari, a naturally fermented cassava flour, has a fibre content of 3.10% (Irtwange & Achimba, 2009). The fibre content of starch processed by the fermentation process is higher than that of starch products processed without the fermentation process.

Physical Properties

The physical properties of the semi-finished product in this experiment (fermented process: Mocaf, TPFCF, and TFC) are presented in Table 2. The chemical characteristics of the fresh cassava tapioca (TC) are also presented as a comparison.

Bulk Density

The bulk density of TFC, TPFCF, mocaf, and TC ranged between 0.35 and 0.57 g/mL. The processing type may cause a difference in the bulk density of the sample. It decreases in line with the water content succession of the sample, namely fresh cassava tapioca (TC), fresh cassava roots tapioca (TFC), fermented cassava roots chips filtrate (TFCPF), and mocaf. This fact is in line with Prabowo (2010), who reported that millet flour with high water content causes the weight of the material to be measured to be more significant in the volume of the same container. Besides, the fermentation process also causes the liberation of starch granules so that the resulting flour has an irregular grain shape (particles), affecting the bulk density. Particles with irregular shapes tend to have large porosity due to the cavities between particles filled with air, so the bulk density becomes smaller (Jufri *et al.*, 2006). In this study, the TC showed the highest bulk density. Diniyah *et al.* (2018) reported mocaf produced from fermented Cassava var. Cimanggu and var. Craspo has a bulk density of 0.58 and 0.75 g/mL, respectively.

Wettability

Wettability is used to determine how quickly the flour reaches a wet condition. This number is essential as it affects the speed of dough formation, which is essential in determining the

Table 2: Physical characteristics of modified cassava flour (mocaf) and tapioca of Cassava var. Gajah (*Manihot esculenta*)

Physical Properties	TC	TFC	TPFCF	Mocaf
Bulk density (g/mL) ‡	0.57 ± 0.03c	0.50 ± 0.02b	0.49 ± 0.27b	0.35 ± 0.03a
Wettability (second) §	15.43 ± 6.69b	8.95 ± 0.93a	10.39 ± 0.78a	10.15 ± 1.05a
Water absorption capacity (g/g) §	2.20 ± 0.29c	0.82 ± 0.09a	0.87 ± 0.06ab	1.44 ± 0.03bc
Oil absorption capacity (g/g) ‡	nc	2.90 ± 0.32	2.82 ± 0.25	3.08 ± 0.10
Swelling power (g/g) §	21.81 ± 1.27	23.15 ± 1.94	23.41 ± 1.59	25.00 ± 1.60
Solubility (% db) ‡	21.98 ± 3.52	21.67 ± 4.28	23.33 ± 8.57	26.67 ± 5.42
Gelatinisation temperature (ºC)*	70.14 ± 1.11	72.05	72.10	74.30

Note: Data (mean ± CI at 95%) was calculated from six replications. ‡) Data analysed by ANOVA, data within the same row followed by different letters show significantly different (Tukey, $p < 0.05$). §) Data analysed by ANOVA on ranks, data within the same row followed by different letters show significantly different (Dunn, $p < 0.05$). *Determined from chosen replicate (the exact replication for each treatment), except tapioca from fresh cassava (TC) was from 4 replications. nc = not calculated. TC = Tapioca from fresh cassava, TFC = Tapioca from fermented cassava, TFCPF = tapioca from fermented cassava pressed filtrate, Mocaf = Modified cassava flour, nc = not calculated

optimal processing time (Hartoyo & Sunandar, 2006). The wettability numbers of TC, TFC, TFCPF, and mocaf ranged from 8.95-15.43 seconds, with the TC showing the highest number. It is suspected that the fermentation process changes the starch structure, such as a decrease in starch polymerisation, thus making it easier to attract water.

Water Absorption Capacity

Water absorption capacity (WAC) is essential in flour product testing. WAC is closely related to the ability of the material to attract the surrounding water to bind to the material particles or survive in the pores between other particles. In other words, WAC provides an overview of how much water solid objects can absorb.

This study used the WAC of TC, TFC, TPFCF, and mocaf from cassava var. Gajah ranged between 0.82 and 2.20 g/g (Table 1). The TC (tapioca from fresh cassava) showed the highest WAC among the products. Tapioca from fresh cassava (TC) analysed for its WAC value produced the best value compared to fermented products. Efendi (2010) found that the WAC of mocaf of cassava planted in Solo, Center Java, i.e., Cassava var. Malang-1 and Cassava var. Mentega ranged between 1.52 and 1.76 mL/g. On the other hand, the WAC of starch of Cassava var. Kuning, var. Pacar and var. Buton, cassava originated and was planted in Samarinda, East Kalimantan, Indonesia, and ranged between 5.75 and 6.11 g/g (Raselli, 2015).

The WAC of a product is related to the ability of the protein to bind water so that the higher protein content of the product will lead to more water absorption (Sihotang *et al.*, 2015). The water absorption capacity determines the amount of water available for the starch gelatinisation process during cooking. If the amount of water is less, the gel formation does not reach the optimum condition (Aini *et al.*, 2016).

Oil Absorption Capacity

Oil absorption is an essential property in food formulations because it can improve the flavour and mouthfeel of food (Aini *et al.*, 2016). The value of the oil absorption capacity of TC, TFC, TPFCF, and mocaf ranged between 12.82 and 3.08 g/g. Testing the oil absorption capacity of mocaf shows that it is higher than TFC and TPFCF, which causes the protein content (Table 3.) in mocaf to be higher than in the other two samples. The value of OAC in flour is closely related to protein and fat content. Rohmah (2012) reported that the greater the protein or fat content, the greater the oil absorption capacity of banana flour.

The ability of foodstuffs to bind water and oil cannot be separated from the involvement of proteins caused by the presence of hydrophilic and lipophilic groups (Astawan & Hazmi, 2016). For example, the OAC of Bambara groundnut flour is more significant than Bambara groundnut starch due to the higher protein and fat content in flour, which can trap more oil (Sirivongpaisal, 2008).

The fermentation process in mocaf processing affects the ability of mocaf to absorb oil. According to Chelule *et al.* (2010), the longer the fermentation time, the greater the degradation of macromolecules into simpler molecules. As a result, previously relatively compact macromolecules become somewhat porous because they are broken up into simple molecules with a small mass. As a result, they are slightly loose and more able to absorb oil. The best value for oil absorption capacity is found in mocaf flour at 3.08 g/g, supported by the high protein content in mocaf.

Swelling Power and Solubility

The swelling power and solubility of TC, TCF, TPFCF, and mocaf are not significantly different (p > 0,05). They ranged between 21.81 g/g and 25.00 g/g and between 21.67% and 26.67% db for swelling power and solubility, respectively. However, the starch from fermented cassava (TFC and TPFCF) and mocaf show higher swelling power, and the mocaf is the highest among the products (Table 2). In contrast, Oyeyinka *et al.* (2020) reported that the swelling power of extracted starch from fermented cassava (24-72 h) insignificantly reduced, which the slightly lower amylose may cause compared to starch extracted from unfermented cassava roots.

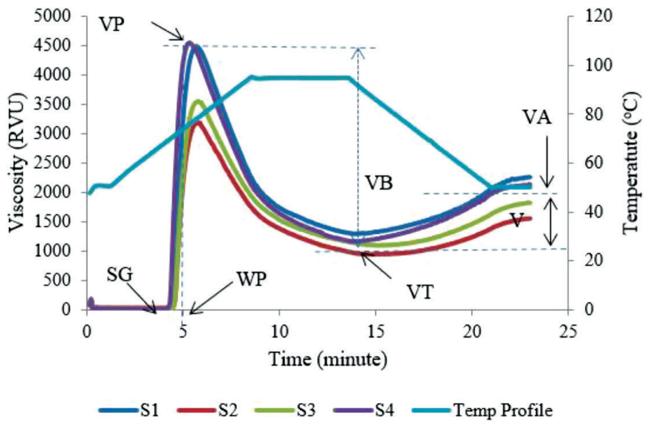
The difference in solubility values in flour and tapioca products is also thought to be due to differences in water content. The lower the water content of a material, the higher the solubility, which causes the low water content in the material causes the material to spread quickly in water so that a wide surface area is formed. As a result, the material can absorb large amounts of water. In addition, the fermentation process can also increase the solubility and capacity of water that can be absorbed (Etudaiye *et al.*, 2009).

Gelatinisation Profile

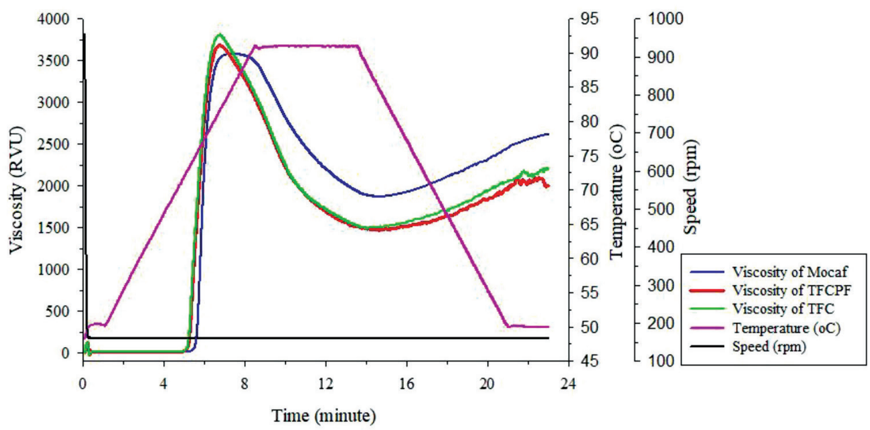
The gelatinisation profile was carried out to determine the character of tapioca from fresh cassava (TC) is shown in Figure 2 (A), while the gelatinisation profiles of tapioca from fermented cassava (TFC), tapioca from pressed, fermented cassava filtrate (TPFCF) and mocaf are presented in Figure 2 (B). Parameters observed include Peak Viscosity (highest viscosity), trough viscosity, breakdown viscosity, final viscosity, setback viscosity, and peak time (highest time), presented in Table 3.

The gelatinisation profile is closely related to the starch content in the sample. The higher the starch content in the sample, the higher the viscosity value with faster time and lower gelatinisation temperature than materials with less starch content. According to Faridah *et al.* (2010), starch with a gelatinisation profile with a reasonably high peak viscosity followed by a sharp decrease in viscosity (breakdown viscosity) during heating indicates that the starch is less resistant or less stable in the heating process.

In this experiment, the gelatinisation profile of each sample tends to be stable because it does not experience a sharp decrease in viscosity. Mocaf has a low breakdown viscosity value, which indicates that mocaf is stable in hot conditions. A significant breakdown viscosity value suggests that the swollen flour granules are brittle and cannot withstand heating (Aini *et al.*, 2016). In addition, mocaf also has a final viscosity with a higher value, which was also reported by Subagio *et al.* (2008), who reported that the fermentation process could increase the viscosity value of the product.



(A)



(B)

Figure 2: Gelatinisation profile chart of tapioca from fresh cassava var. Gajah (TC) by Rapid Visco Analyser (A). Gelatinisation profile chart of mocaf, tapioca from pressed fermented cassava filtrate and tapioca from fermented cassava (B). VP = peak viscosity, SG = gelatinisation temperature, WP = peak time, VT = trough viscosity, VB = breakdown viscosity, VS = setback viscosity, VA = end viscosity. S1-S4 = replication 1-4

Gelatinisation temperature is the temperature at which the starch granules break. In this phase, the gelatinisation is characterised by the viscosity increase suspension during heating, which decreases after passing the gelatinisation temperature and will rise again when cooled. The difference in the gelatinisation profile is related to the starch water content. The greater the water content, the lower the starch gelatinisation temperature in each type of cassava. Conversely, the greater moisture content causes the granules to swell more quickly and rupture. Maaruf *et al.* (2001) reported that gelatinisation is a breakdown of the molecular sequence in starch granules, depending on temperature and water content. It is immutable and starts from an increase in the size of starch granulation, causing an increase in the viscosity of the solution or suspension, varying depending on ripening conditions and the grain type of the plant source. Mocaf flour has the lowest moisture content (Table 3), so it has the highest gelatinisation temperature compared to modified and fresh starch without fermentation. Several factors influencing gelatinisation, water content, and temperature are pH, starch concentration, granule type, and granule heterogeneity. The gelatinisation temperature is different for each

Table 3: Gelatinisation profile of tapioca from fresh cassava, tapioca from fermented cassava, tapioca from pressed fermented cassava filtrate, and mocaf of cassava (*Manihot esculenta*) var. Gajah

Parameter (unit)	TC	TFC	TPFCF	Mocaf
Peak viscosity (RVU)	3,942	3,805	3,681	3,582
Trough viscosity (RVU)	1,123	1,493	1,470	1,873
Breakdown viscosity (RVU)	2,819	2,312	2,211	1,709
Final viscosity (RVU)	1,942	2,193	2,001	2,610
Setback viscosity (RVU)	819	700	531	737
Peak time (minute)	4.39	6.67	6.67	7.40
Gelatinisation temperature (^{o}C)	70.13	72.05	72.10	74.30

Note: TC = Tapioca from fresh cassava, TFC = Tapioca from fermented cassava, TFCPF = tapioca from pressed fermented cassava filtrate, Mocaf = Modified cassava flour

type of material and is a range, for example, corn starch is between 62°C and 80°C, potato starch is between 58°C and 65°C, tapioca starch is between 52°C and 65°C, and wheat starch is between 52°C and 85°C (BeMiller & Huber, 2008).

Several chemical characteristics of flour, mainly fat and amylose content, affect flour stability during heating and cooling. Singh *et al.* (2009) reported that the formation of the amylose-lipid complex would inhibit the development of starch granules.

During gelatinisation, amylose leaves the starch granules, inhibiting the setting during heating. The gelatinisation forms a fatty amylose inclusion complex, reducing the binding tendency, gel-forming, and retrogradation.

Conclusions

The combined flow applied on the MocafTap processing deserves consideration to replace the single flow of the mocaf processing. The filtrate of pressing fermented cassava chips step in the mocaf processing (classified as waste in the single flow mocaf processing) is very feasible for tapioca products (TPFCF). The yield of TPFCF reached 4.20%, only slightly lower than the yield of tapioca from fermented cassava chips (TFC, 5.82%) instead of being processed into mocaf. The TPFCF shows different physicochemical properties than tapioca from fresh cassava roots. The physicochemical properties of TPFCF are closer to the physicochemical properties of mocaf.

Acknowledgements

The authors extend their gratitude to with PT Bintang Kaltim Perkasa, a small-scale industry for Mocaf production based in Samarinda, East Kalimantan, Indonesia, for collaborating on this research.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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