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Physicochemical Characteristics and Pasting Properties of Modified Cassava Starch and Flour by Integrated Processing Technology

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Abstract A wide range of cassava derivative products, such as starch and flour, was applied in various food products. Therefore, this research investigated the processing techniques of cassava starch and flour, each with the aim of extracting the superior properties and characteristics for a specific end product. By modifying the existing procedures with integrated cassava processing technology, the production of both products could occur simultaneously. This was renewal processing as unified technology, which implied that one single processing could generate two products at a time. In addition to producing a superior characteristic, the integrated method also saved time and cost. In this research, two factors of Completely Randomized Design (CRD) were used in three replications. The first factor was soaking in the flowing water/continuous system (P1) and static water/batch system (P2). The second was the fermentation time (T) of 24 hours (T1), 48 hours (T2), and 72 hours (T3). Furthermore, the steps conducted include weighing, brown and white skin peeling, washing, size reduction, immersion in continuous and batch systems, fermentation for 24, 48, and 72 hours, refining/milling, and starch extraction, followed by the pressing process. The existing slurry was deposited for 8 hours, then the starch was extracted. The starch and flour were dried in the oven at 60°C until reaching a maximum moisture content of 13%. They were milled and sifted in a 100-mesh sieve. The results showed that the spontaneous fermentation process in the integrated cassava technology produces the superior characteristics of modified cassava starch and flour to the point of being recommended as a model. The yield whiteness value, and swelling power (g/g) of modified cassava starch and flour range from 9.0-12.5% and 30.58-35.44%, 91.34-94.04, and 90.41-91.56, as well as 13.28-14.35 and 14.43-17.44 (w/w), respectively. The amylograph characteristics of the starch paste included longer fermentation, increasing pasting temperature, increasing maximum viscosity (value > 600), decreasing breakdown, and increasing setback value. Meanwhile, for flour paste, it includes longer fermentation, increasing pasting temperature, decreasing peak viscosity (value > 500), decreasing breakdown, and increasing setback value.

Keywords Modified Cassava Starch And Flour, Integrated Technology, *Cassesart* Cassava

1. Introduction

Cassava is used by millions of people around the world due to its high carbohydrate content, which is 40% and 25% higher than rice and maize, respectively. In 2019, it was the sixth most important plant in the world after wheat, rice, corn, potatoes, and barley [1]. In Indonesia, cassava production reached 19.341.233 tons in 2018 (BPS, 2018), making the country the third largest producer in the world after Nigeria and Thailand [2].

Cassava derivatives products, such as starch and flour, are applied in various industries, including in the food industry. The high demand for these products creates various methods in the processing to obtain superior characteristics of cassava starch and flour. The greatest challenge being faced until now is the limitation of functional properties of native cassava starch, such as the lack of ability to form pastes and gels, as well as the low stability towards temperature, acid, or mechanical treatment [3]. There is an urgency for further engineering to modify and improve its functional properties [4] until it is widely used in the food industry. Modified starch and flour properties through spontaneous fermentation would increase its products' usage and economic value. The current evolving process is aimed at making a single product. Meanwhile, the two integrated products can be made simultaneously by modifying the existing process [5, 6]. Integrated can be defined as renewal processing in a unified whole such that a single processing can produce two products at a time. In addition to saving costs and time, integrated cassava processing is expected to produce a superior characteristic of modified starch and flour and can be applied primarily in the food industry.

Previous research reported that the fermentation process would increase solubility and swelling power [7], as well as viscosity and gelatinization temperature. Fermenting Onggok flour using *Saccharomyces cerevisiae* with fermentation time treatment could fix its characteristic by increasing the viscosity [8] Therefore, this research aims to determine the effect of the soaking method and fermentation time on the physicochemical and pasting amylograph characteristic of modified cassava starch and flour resulting from the development of integrated cassava processing technology.

2. Materials and Methods

Time and Place

This research was conducted from November 2021 to March 2022 at the Agroindustrial Waste Management Laboratory, Agriculture Faculty, Lampung University, Agricultural Products Technology Laboratory, Lampung State Polytechnic, and Laboratory of the Lampung StarchTechnology Center.

Materials

Cassava of the 9-10 month variety UJ-5 (Cassesart/kasesa) from local farmers in Central Lampung Regency and other materials for chemical analysis were utilized in this research. The continuous and batch system equipment was used to design the fermentation system, containers for batch fermentation, scales, electric grater, hammer mill grinder, sieve with 100 mesh filter size, pH meter, as well as other equipment that will be used for chemical analysis, color reader, centrifuge, *Viscograph* type Brabender GmbH & Co. KG, and Germany.

Experimental Design

The fermentation procedure was shown in Figure 1. A Completely Randomized Design (CRD) of two factors in three replications was used in this research. The first factor was soaking in a flowing water/continuous system (P1) and a steady water/batch system (P2). The second was the fermentation time (T) i.e., 24 hours (T1), 48 hours (T2), and 72 hours (T3).

Data were processed using ANOVA followed by the HSD test to determine the differences among the treatments. Statistical analysis was performed using the SPSS Statistics 25.0 program. The characteristics of starch and flour paste were analyzed descriptively.

Procedures

Making Modified Cassava Starch and Flour

Modified cassava starch and flour were processed by integrated technology with some modifications from "beras aruk" technology [9] and "garri" processing [10]. The steps included weighing 10 kg cassava, peeling the brown and white skin, washing until clean from mucus, slicing into 5 cm cassava chips, then 8 kg were soaked in 10 L flowing water/continuous (P1), the same number as the batch system (P2). Fermentation times of 24, 48, and 72 hours were then applied in each container. In the end, the cassava pieces were removed and drained for further grating in an electrical grater. Furthermore, the starch extraction process was performed by adding water to the cassava pulp at a ratio of 1:10, followed by being pressed. The existing slurry was deposited for 8 hours to extract the starch, while the pulp/fiber was dried in an oven at 60^{o}C until it reached 13% maximum water content. The same stage was also conducted after the precipitation of cassava starch. Subsequently, the resulting modified starch and flour were ground and sieved using a 100-mesh sieve. The complete integrated modified cassava starch and flour processing technology can be seen in Figure 1.

Observations

The yield, whiteness degree [11] swelling power value (Gravimetric Method), water content (Gravimetric Method, AOAC, 1984), and pasting characteristics of starch and cassava flour were observed.

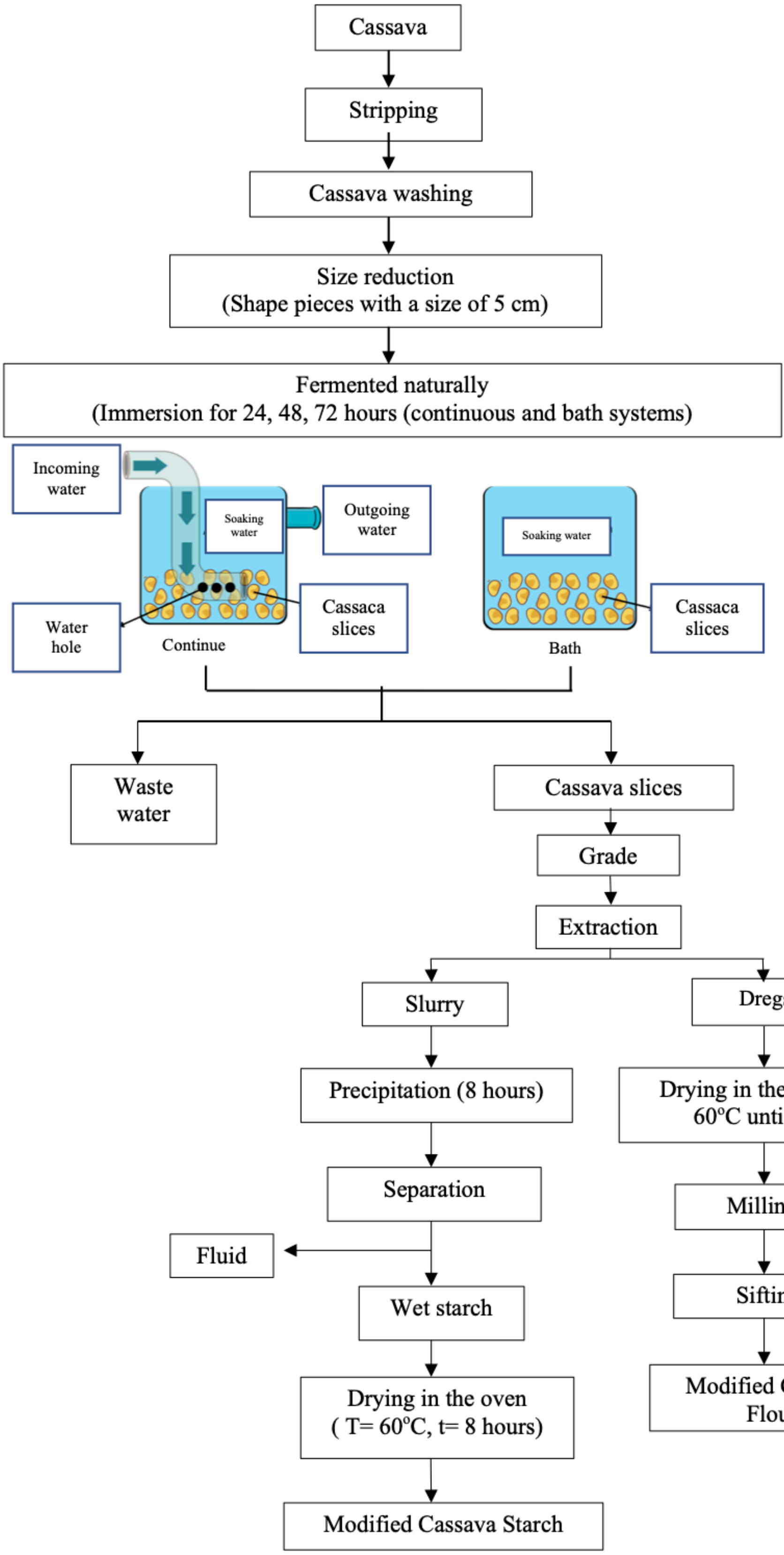
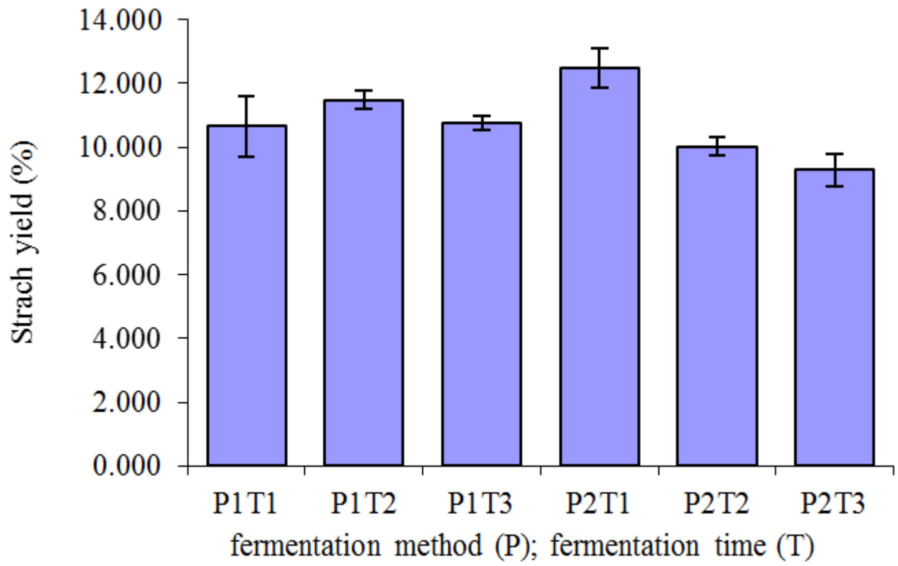


Figure 1. Integrated modified starch and cassava flour production processing (modified by "beras aruk" technology [9] and "gari" processing [10])

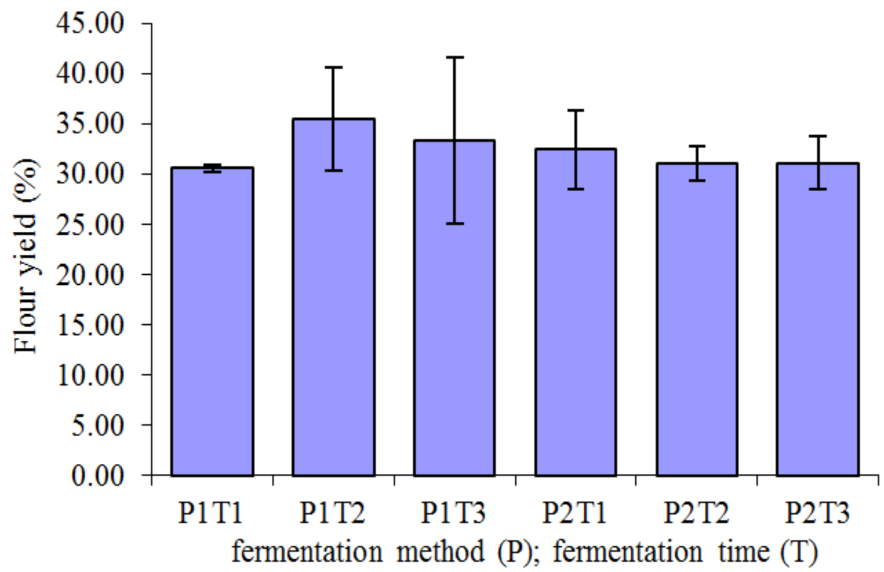
3. Result and Discussion

Modified Cassava Starch and Flour Yield

Modified cassava starch and flour yield was significantly influenced by fermentation time and its interaction with the soaking method. However, modified cassava flour was not influenced by the soaking method, fermentation time, and their interactions, as shown in Figure 2.



(a)



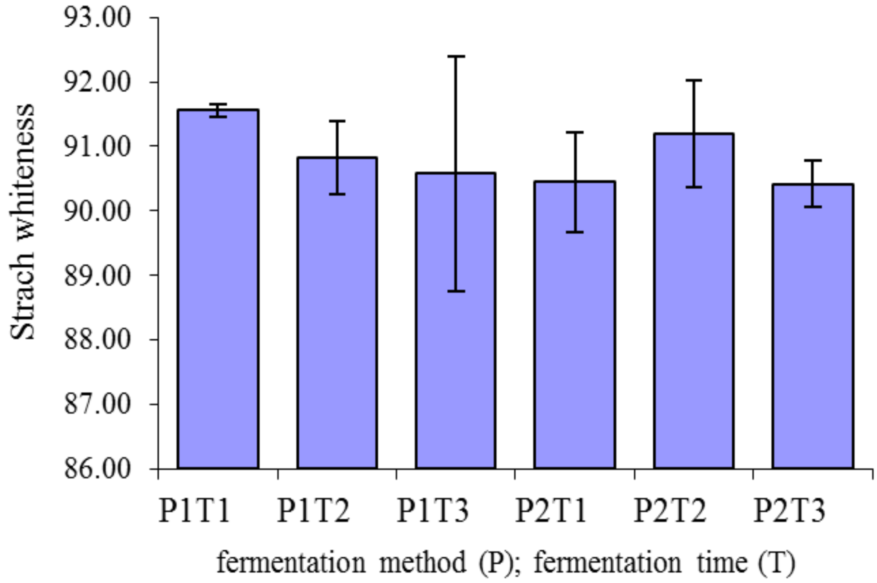
(b)

P1T1: continuous system, 24 hours fermentation time; P1T2 continuous system, 48 hours fermentation; P1T3: continuous system, 72 hours fermentation; P2T1: Batch system, 24-hour fermentation; P2T2: Batch system, 8 hours fermentation; P2T3: Batch system, 72 hours fermentation. Numbers followed by the same letter in the same column are not significantly different (α=5%)

Figure 2. Modified cassava starch (a) and flour (b) yield

The Whiteness of Modified Cassava Starch and Flour

ANOVA test showed that the whiteness of modified starch and flour was not affected by the soaking method and fermentation time, as shown in Figure 3. The whiteness of cassava starch was in the range of 91.46-94.04, while the modified flour was 90.41-91.56.



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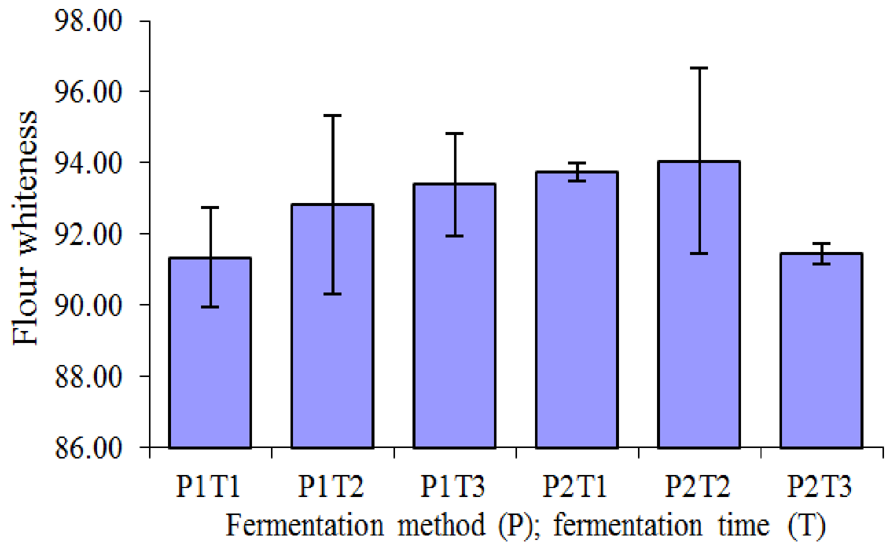
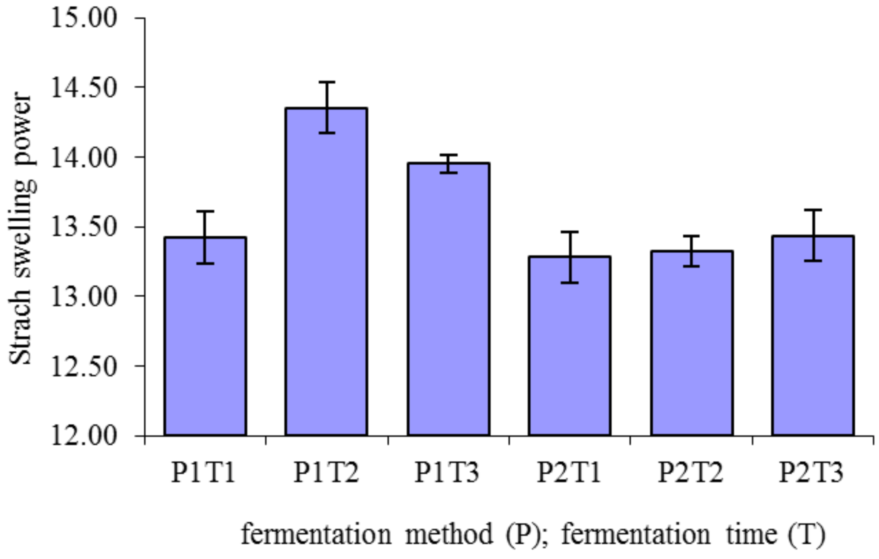


(b)

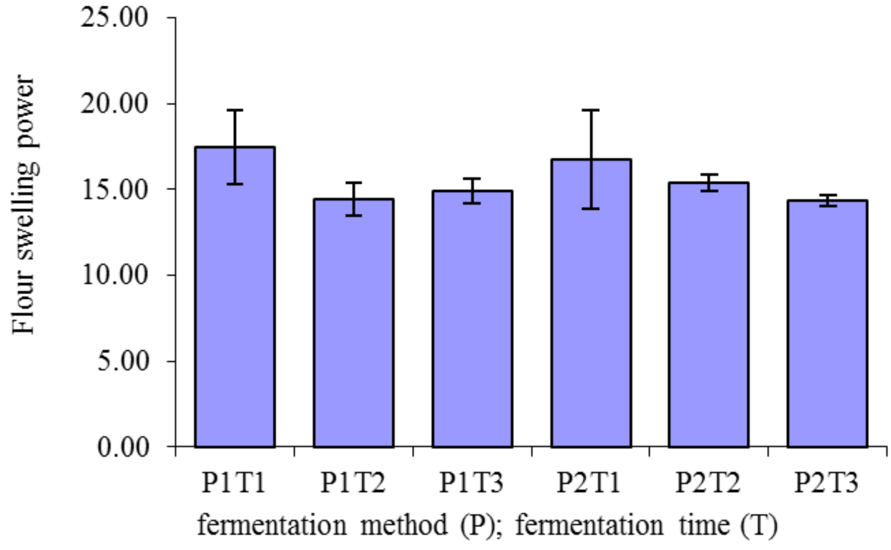
P1T1: continuous system, 24 hours fermentation time; P1T2 continuous system, 48 hours fermentation; P1T3: continuous system, 72 hours fermentation; P2T1: Batch system, 24-hour fermentation; P2T2: Batch system, 8 hours fermentation; P2T3: Batch system, 72 hours fermentation. Numbers followed by the same letter in the same column are not significantly different (α=5%)

Figure 3. Whiteness of modified cassava starch (a) and flour (b)

Modified Cassava Starch and Flour Swelling Power



(a)

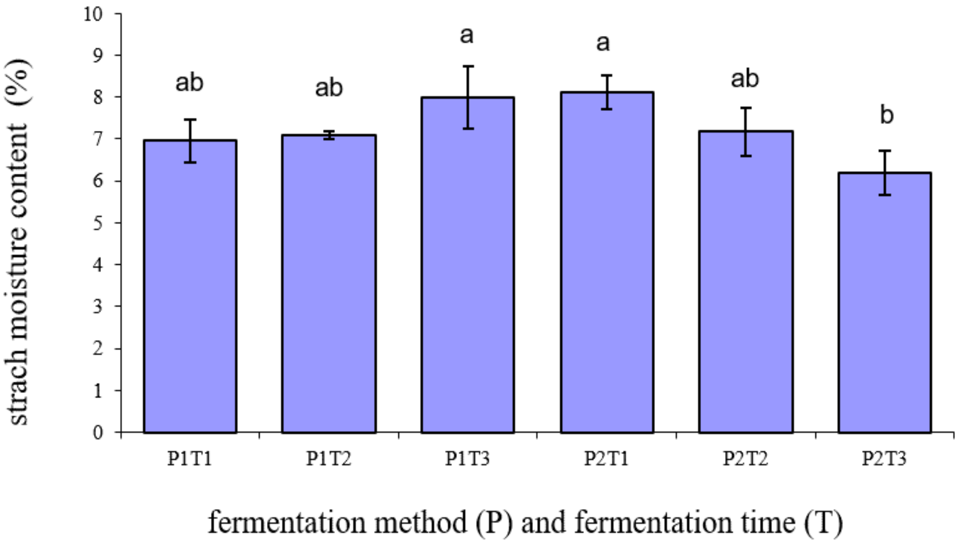


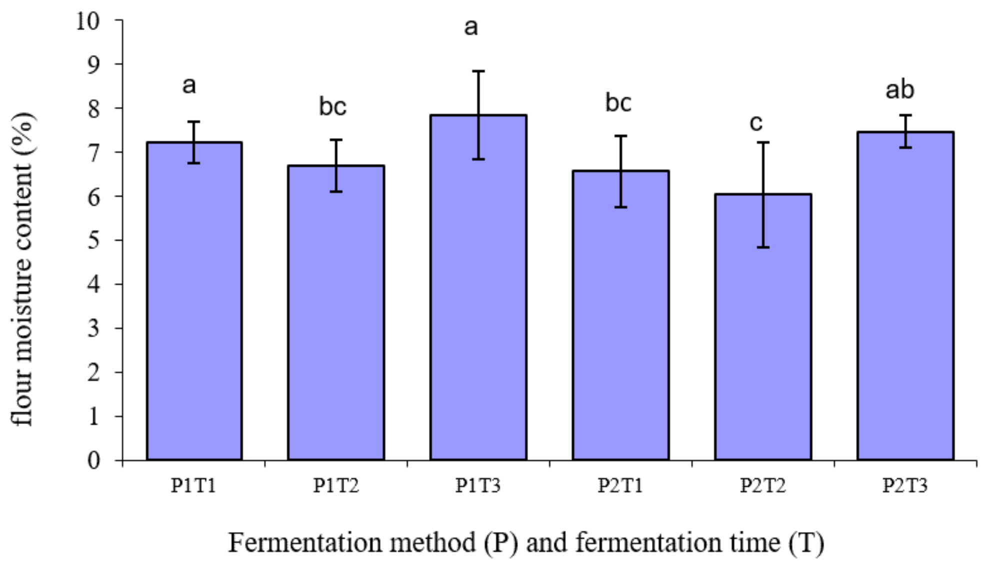
(b)

P1T1: continuous system, 24 hours fermentation time; P1T2 continuous system, 48 hours fermentation; P1T3: continuous system, 72 hours fermentation; P2T1: Batch system, 24-hour fermentation; P2T2: Batch system, 8 hours fermentation; P2T3: Batch system, 72 hours fermentation. Numbers followed by the same letter in the same column are not significantly different (α=5%)

Figure 4. Modified cassava starch (a) and flour (b) swelling power

The Moisture Content of Modified Cassava Starch and Flour





P1T1: continuous system, 24 hours fermentation time; P1T2 continuous system, 48 hours fermentation; P1T3: continuous system, 72 hours fermentation; P2T1: Batch system, 24-hour fermentation; P2T2: Batch system, 8 hours fermentation; P2T3: Batch system, 72 hours fermentation. Numbers followed by the same letter in the same column are not significantly different (α=5%)

Figure 5. Modified cassava starch (a) and flour (b) moisture content

Modified Cassava Starch and Flour Pasting Characteristic

The pasting characteristics of modified starch and cassava flour can be seen in Tables 1 and 2 as well as in Figure 5 and Figure 6. The continuous and batch systems showed an increase in the gelatinization temperature (SG). This is the temperature at which the maximum (SVT), and the setback viscosity, were reached, while the retrogradation (breakdown) viscosity decreased.

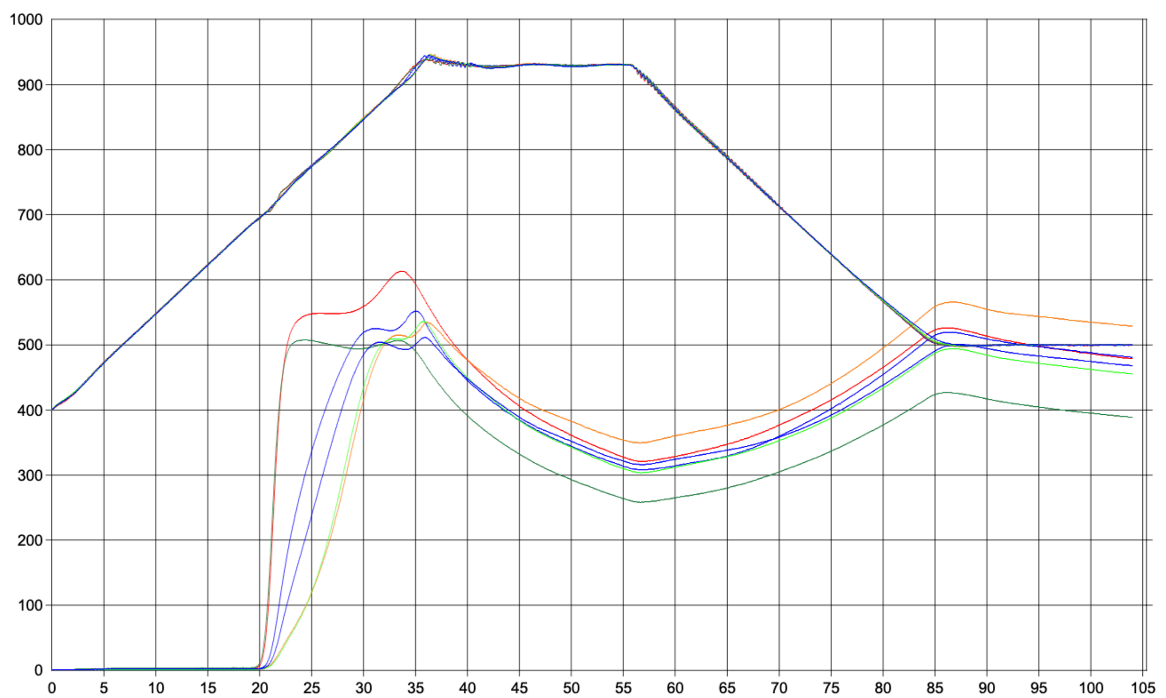
Table 1. Pasting characteristics of modified cassava starch in various soaking methods and fermentation time

Treatment	*Pasting temperature* (^{0}C)	SVT(^{0}C)	*Peak viscosity* (BU)	VawP (BU)	VaKP (BU)	*Breakdown*	*Setback* (BU)

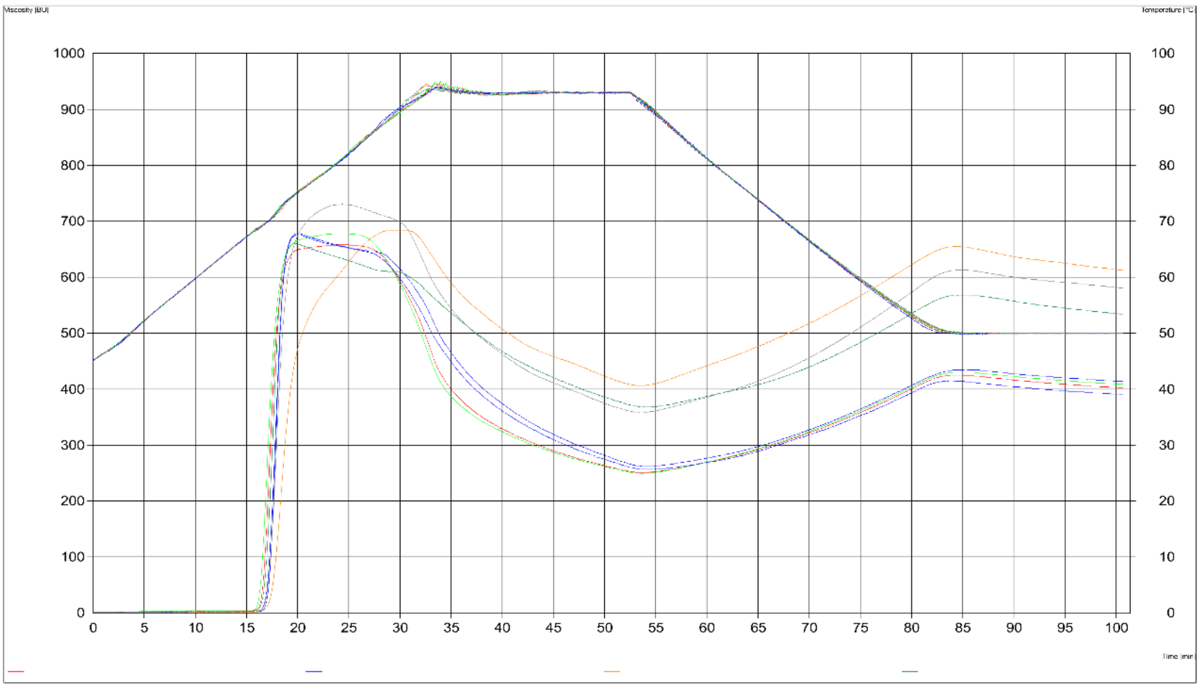
						(BU)	
P1T1	68,9	77,1	681,5	257,5	406,0	424,0	148,5
P1T2	69,5	77,4	691,0	263,5	402,0	419,0	146,5
P1T3	69,7	84,3	621,5	223,0	463,5	329,5	172,0
P2T1	68,7	80,6	684,5	260,5	416,5	424,0	156,0
P2T2	69,4	81,0	668,5	268,5	432,0	390,0	153,5
P2T3	70,5	90,6	686,0	430,0	668,5	256,0	238,5

Table 2. Pasting characteristics of modified cassava flour in various soaking methods and fermentation time

Treatment	***Pasting temperature*** **(^{0}C)**	**SVT(^{0}C)**	***Peak viscosity*** **(BU)**	**VawP (BU)**	**VaKP (BU)**	***Breakdown*** **(BU)**	***Setback*** **(BU)**
P1T1	69,4	76,4	508,0	262,0	415,0	246,0	153,0
P1T2	71,5	93,3	536,0	308,0	477,0	228,0	169,0
P1T3	70,9	93,7	512,0	320,0	480,0	192,0	160,0
P2T1	69,6	90,6	614,0	326,0	513,0	288,0	187,0
P2T2	70,6	92,5	552,0	312,0	504,0	240,0	192,0
P2T3	71,5	94,1	535,0	353,0	547,0	182,0	194,0



(a)



(b)

Information:

= Continuous system at 24 hours fermentation
= Continuous system at 48 hours fermentation
= Continuous system at 72 hours fermentation
= Batch system at 24 hours fermentation
= Batch system at 48 hours fermentation
= Batch system at 72 hours fermentation

Figure 6. Pasting amilograph of modified cassava starch (a) and flour (b)

Figure 2 shows that modified cassava starch yield from a continuous system at 48 hours was different from the 24 and 72 hours fermentation treatments. In contrast, the 24 hours treatment was not significantly different from the 72 hours. The yield of modified cassava starch (w/w) ranges from 9.29 to 12.48%, while that of the flour is between 28.25 and 39.60%. This is the value of the ratio between the starch weight or dried refined tapioca to the wet peeled cassava (w/w). Furthermore, the starch yield is closely related to its content in cassava. The production of modified casava starch tends to decline after 48 hours (in continuous system) and 24 hours (in batch system) fermentations. The decrease in starch yield was caused by several factors, including the starch loss during the separation of slurry and starch particles in the extraction stage [12], the starch being dissolved in soaking water, and those bound in the cassava flour. [13] stated that the occurrence of degradation is accompanied by the formation of simple sugars due to microbial activity during the fermentation process [14]. The results of [15] showed that the yield of modified cassava starch fermented by *Saccharomyces cerevisiae* ranged from 11% to 14%. It is indicated by a decrease after 36 hours of fermentation. In contrast, there was no reduction in yield in both continuous and batch systems during fermentation time.

The whiteness of cassava starch (Figure 3) stands in the range between 91.46 and 94.04, while it is between 90.41 and 91.56 for modified cassava flour. The whiteness value of modified cassava starch and flour remains within the National Indonesian Standard (SNI) number 3451-2011 and SNI number 7622-2011, which are at 91 and 87, respectively. The degree of whiteness indicated the ability of a material to reflect light on its surface. The consumer relies on color acceptability, hence, this result showed high quality in product whiteness. Several factors, including drying, heating temperature, and the fermentation process, influence the whiteness of modified cassava flour. Some research results showed that the range of cassava flour was between 96.8-97.2 [16] and 86.69-96.77 [17].

Figure 3 shows that the swelling power of modified cassava starch was influenced by the soaking method, fermentation duration, and their interaction. In contrast, modified cassava flour was only affected by the length of fermentation. Swelling power is the maximum increase in volume and weight experienced by starch when allowed to swell freely in water [18]. There were strong interactions among the granules that influence changes in swelling power value until it reduces the number of free OH groups which is available for hydration and decreased water migration [19]. The difference in swelling power characteristics in each treatment indicates a variation in the binding force of the starch granules [20]. The results of this research supported [7], which stated that the swelling power value increased at 12 and 24 hours and reached the best conditions for cassava palm fermentation after 48 hours. Finally, a higher value indicated a greater ability of starch to expand in water.

The moisture content of modified cassava starch was influenced by the soaking method and fermentation time, but the interaction between the two was not significantly different (Figure 4). Meanwhile, these did not affect the water content of modified cassava flour. The results of the development of integrated cassava processing and the moisture content of modified flour are in the range of 6.04-7.84% and 6.99-8.12%, respectively. This indicated that the starch and modified cassava flour produced had a relatively low moisture content and could be stored for a specific time with good quality. According to SNI for tapioca, the water content of cassava starch and flour is at a maximum value of 13%. Finally, the small changes in water content with increasing fermentation time are due to microbial activity [14].

Characteristic of the starch paste is the phenomenon of gelatinization, which shows the viscosity behavior that occurs during the heating and cooling process equipped by controlled stirring [21]. Also, it is one of the essential functional properties that measure the ability of starch and flour to form a paste [22]. Functional properties also provide information on how food ingredients behave in a food system during processing [18]. It can also be used to predict the application of starch and flour to processed food products by observing the pasting characteristics [23] and determining the texture integrity of the product [22]. The ability of starch to swell and give a thick paste when the suspension is heated in an aqueous environment will undergo a series of gelatinization and pasting processes [24]. Table 2 shows that fermentation can change the properties of the cassava starch paste, including the maximum viscosity value, the retrogradation (breakdown), the setback, and the final cooling viscosities.

Peak viscosity is a measure of the highest level that paste can achieve during a heating cycle (25-95^{0}C). Also, it reflects the ability of starch to swell freely before being damaged [25] [26]. The peak viscosity of cassava starch was highest in the continuous immersion method during 48 hours fermentation. This value describes the ability of the granules to bind water and maintain swelling during heating. Cassava starch has pasting characteristics of reasonably high peak viscosity followed by rapid dilution during heating [27]. The continuous and batch immersion methods did not significantly differ in all fermentation times, except for the continuous system immersion approach after 72 hours. The treatments had peak viscosity values of more than 600 BU. Peak viscosity is often correlated with the quality of the final product [24] and high peak viscosity (>500) is an indication of optimal starch content, which is also associated with water binding capacity [18].

The pasting temperature is the level at which irreversible swelling of the starch granules occurs, which leads to the formation of a thick paste and is characterized by an initial change in viscosity [18]. It ranged from 68.7-70.5^{o}C and 69.4-71.5^{o}C for cassava starch and flour, respectively. The soaking method and fermentation time did not affect the pasting temperature of modified cassava starch and flour resulting from the development of integrated cassava processing technology. The pasting temperature has been reported to indicate the minimum degree of celsius required to cook starchy ingredients. Meanwhile, food with lower pasting temperatures is generally considered easier to cook [28]. This is usually undesirable because it has low paste stability [18].

Retrogradation viscosity indicates how easily starch granules break or crack [29]. The longer the fermentation in continuous and batch immersion systems, the lower the retrogradation viscosity. Its higher value is undesirable because it will cause uniform viscosity and produce cohesive properties in starch paste [13]. However, the lower retrogradation viscosity determines the ductility of the paste against thermal and shear disturbances, which are very essential in determining stability [22]. Starch and flour samples with low retrogradation viscosity can withstand high heat treatment and shear stress and will be more appropriate to be grouped into products that require high-temperature treatment [22].

Another thing related to the viscosity of the starch paste produced is the setback viscosity (VB). It is a parameter used to see the tendency of retrogradation and syneresis of pasta [30]. A high reverse viscosity indicates a lower susceptibility to retrogradation during cooling and forms a gel quickly during the cooling process (Rahmiati et al., 2016). Meanwhile, a low reverse viscosity can be used for edibles that do not require viscosity, such as complementary foods for infants [31]; [22].

This study showed that integrated modified starch and cassava flour production processing was proven to improve overall quality. In addition, a continuous system combined with 48h fermentation time (P1T2) was found to be the most potential for application in various food products due to high swelling power and peak viscosity, and low setback viscosity.

4. Conclusion

This research showed that integrated cassava processing technology through a spontaneous fermentation process (continuous and batch methods) can be developed as a model for modified cassava starch and flour. Modified cassava starch produced from the integrated processing technology had a yield, whiteness index, and swelling power values of 9.0%-12.5%, 92, 13-14 (w/w). The amylograph characteristics of its paste included longer fermentation, increasing pasting temperature, increasing maximum viscosity (value > 600), decreasing breakdown, and increasing setback value. Modified cassava flour produced from the integrated processing technology has a yield, whiteness index, and swelling power, HCN residue values of 30.0-39.5, 92, 14-17, and 17.4-27.1 ppm, respectively. The amylograph characteristics of its paste included longer fermentation, increasing pasting temperature, decreasing peak viscosity (value > 500), decreasing breakdown, and increasing setback value.

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