*THE EFFECT OF FER*MENTATION AND *VARIOUS OF* TEMPERATURE *PREGELATINIZED ON THE* PHYSICOCHEMICAL CHARACTERISTICS OF MODIFIED *CASSAVA FLOUR THE EFFECT OF FERMENTATION AND VARIOUS OF TEMPERATURE PREGELATINIZED ON THE PHYSICOCHEMICAL CHARACTERISTICS OF MODIFIED CASSAVA FLOUR*

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ABSTRACT

Modified cassava is cassava that has been treated biologically, physically or chemically so that it has physicochemical properties that are different from the original cassava. This study aims to determine the effect of fermentation method and pregelatinization temperature on the physicochemical and organoleptic characteristics of cassava flour. This study used a completely randomized design with two factors and two replications. Factor I is the type of cassava fermentation including no fermentation, spontaneous fermentation, and non-spontaneous fermentation. Factor II was pregelatinization temperature of 45°C, 50°C, 55°C, and 60°C. Observational data were analyzed using ANOVA, if there was an interaction or real effect on the two treatments then DMRT 5% further test was conducted. The results showed that the best treatment was fermented cassava with *Lactobacillus plantarum with a* heating temperature of **60°C**, which produced cassava flour with yield characteristics of 18.18 ± 0.348%, moisture content of 6.32 ± 0.011%, ash content of 0.31 ± 0.023%, starch content of 0.31 ± 0.023%, and starch content of 0.32 ± 0.011%.
78.96±0.121%, amylose content 17.28±0.146%, whiteness 84.14±0.325%, solubility 13.72±0.263%, *swelling* power 13.22±0.077g/g, water absorption 3.57±0.252ml/g, and oil absorption 1.99±0.129ml/g. The best treatment was tested microscopically using *Scanning Electrone Microscopy* (SEM) showing round-shaped starch granules with a hollow and swollen surface. Starch amylography properties using *Rapid Visco Analyzer* (RVA) showed fermented cassava flour with *Lactobacillus plantarum* at **60°C** pregelatinization temperature had high peak viscosity and final viscosity.

Keywords: fermentation, pregelatinization, cassava flour, physicochemical properties

INTRODUCTION

Praise the author's gratitude to Allah SWT, because thanks to His Grace and Guidance so that the author can complete the Research Proposal with the title **"Effect of Fermentation and Pregelatinization Temperature on Physicochemical Characteristics of Modified Cassava Flour"**.

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The author hopes that this writing can add insight and horizons in thinking to be more advanced and to be useful for those concerned. In addition, the author also realizes that this writing is far from perfection, so he expects constructive criticism and suggestions for further improvement.

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Author

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CHAPTER I
INTRODUCTION

A. Background Background

Cassava or cassava (*Manihot esculenta Crantz*) is one of Indonesia's local carbohydrate sources, ranking third largest after rice and corn. This plant is the most potential raw material to be processed into flour (Zarkasie *et al*., 2017). One of the industries that utilize cassava as a raw material for making cassava flour is PT Agung Bumi Agro. PT Agung Bumi Agro is a cassava flour producer and a *gluten free* food pioneer in Indonesia with the Ladang Lima *brand.*

Cassava flour produced by PT Agung Bumi Agro is modified by fermentation to produce characteristics that resemble wheat flour. The fermentation process is carried out spontaneously. According to Suprihatin (2010), spontaneous fermentation is the fermentation of food ingredients where microorganisms are not added in the form of stater or regi, but microorganisms that play an active role in the fermentation process develop spontaneously. However, the quality of the products produced by PT Agung Bumi Agro is still not good, including non-uniform products, low development rate, brownish color, and non-neutral odor, so it is necessary to find other fermentation methods that can produce cassava flour with better quality.

Improvements in the quality of *cassava flour* have been made through modification of the processing process by fermentation which produces *mocaf flour* (*modified cassava flour*) (Duryatmo 2009, Misgiyarta *et al*. 2009). In addition to spontaneous fermentation, there is a method of non-spontaneous fermentation, namely fermentation in which microorganisms are added in the form of stater where the microorganisms will grow and multiply actively (Suprihatin, 2010). The process of non-spontaneous fermentation in making mocaf flour uses species of lactic acid bacteria (LAB), some species that have been studied include Lactobacillus plantarum, Lactobacillus acidophilus, and Lactobacillus casei (Wulandari *et al*., 2021 and Darmawan *et al*., 2013).

Lactic acid bacteria have amylolytic properties, which are able to produce the enzyme amylase to degrade starch. Amylolytic lactic acid bacteria produce extracellular enzymes, namely amylase and pululanase, which can hydrolyze some natural starch into simple sugars and other oligosaccharides or dextrins. The α-amylase enzyme will cut carbohydrates at the endo-α 1,4 bond to produce maltose and dextrin. Pululanase will cut carbohydrates at the endo-α 1,6 bond to produce linear dextrin. Starch fermentation by LAB showed changes in microstructure, namely the formation of globular and lamellar structures. Changes in starch structure from crystalline to more porous (amorphous), increasing the ability to release amylose and lowering the starch gelatinization temperature (Nurhayati, 2011). In general, fermented cassava flour undergoes changes in its characteristics, including: an increase in the value of trough viscosity, breakdown, final viscosity, expandability, water binding capacity and morphological properties of *mocaf* starch granules (Putri *et al*., 2018; Widyatmoko *et al*., 2018).

Processed products from *mocaf* flour are very diverse including noodles, *cookies*, biscuits and so on. However, the characteristics of *mocaf flour are* not exactly the same as wheat flour and other flours so there are still shortcomings in this *mocaf flour*. According to Amri (2014) *mocaf flour* cannot replace wheat flour or rice perfectly because it still has a different taste and aroma so that in its use it still has to be mixed with wheat flour or rice with certain mixing levels. In the research of Subagio *et al*., (2008) showed that mocaf can substitute wheat flour up to 15% in instant noodle products and up to 25% for low-grade noodles. In *bakery* products that rely on gluten for volume development, such as fresh bread, wet pia and various other types of breads, the use of mocaf to replace wheat flour varies, ranging from 20% in fresh bread to 50% in wet pia. Swelling power and solubility properties can affect the characteristics of bakery products. Flour that has lower swelling power and solubility causes *bakery* products to not swell properly Kusumayanti *et al*., (2015) so further modification is needed to obtain cassava flour that has better characteristics.

In addition to the fermentation process, there are processes that can improve characteristics of cassava flour, namely with physical modifications that can be done

to improve the rise, solubility, water absorption and oil absorption of cassava flour. According to Collado *et al*. (2001), physical treatment for starch modification tends to be safer and more natural than chemical treatment. One of the physical modification methods to improve the characteristics of cassava flour is the pregelatinization process.

The pregelatinization process is a process of physically modifying starch by giving a boiling treatment at a certain temperature and time period (Miyazaki *et al.,* 2006). Flour produced after the pregelatinization process can improve the characteristics of cassava flour produced, especially the characteristics of viscosity, water absorption, and water solubility (Hidayat *et al*., 2009). Starch that undergoes the pregelatinization process is instant, which can dissolve in *cold water (cold water soluble*), remains stable after experiencing the *thawing* process (Waliszewski *et al*., 2002). In the research of Pratiwi *et al.* (2020), physical modification of cassava with the *blanching* method showed the results that the higher the temperature and the longer the heating can increase solubility and *swelling power*. One factor that affects pregelatinization is temperature (Palupi, 2011). According to Winarno (2004) the range of cassava gelatinization temperature is 52-64°C. If starch is not heated at the appropriate temperature, the degree of starch granule development is not correct and does not provide the desired properties (Imaningsih, 2012).

Based on research by Palupi *et al*. (2011) modification of cassava flour with pregelatinization at a temperature of 90^0 C for 10 minutes gives an influence on the characteristics of the degree of whiteness 71.3667%; maximum viscosity 1350.40 Cp; back viscosity 326.40 Cp. Recent research conducted by Hidayat *et al.* (2009), produced a water absorption value of 2.36 g/g and a water solubility value of 0.25 g/ml while cassava flour without pregelatinization had a water absorption value of 0.13 g/g and a water solubility value of 0.13 g/ml. However, the effect of fermentation process on *cassava* flour with physical modification of pregelatinization is not yet known. Therefore, in this research, modification was carried out on *cassava* flour with the factors of fermentation method and pregelatinization temperature to produce *cassava* flour with the best characteristics.

B. Research Objectives

1. To determine the effect of fermentation method and pregelatinization temperature on the physicochemical characteristics of *cassava* flour.
2. Determine the best treatment between fermentation method and pregelatinization temperature to produce *cassava* flour with the best physicochemical characteristics.

C. Benefits Research

1. Provide information to the public about the method of making *cassava* flour with fermentation and pregelatinization modification as an alternative to wheat flour.
2. Improve Science and Technology (IPTEK) about cassava flour with fermentation and pregelatinization modification.

CHAPTER II
LITERATURE REVIEW

A. Cassava

Cassava (*Manihot esculenta Crantz*) is the third staple food after rice and corn, while for the consumption of the world population, especially the population of tropical countries, about 300 million tons of cassava are produced annually. Cassava production in Indonesia is mostly produced in Java (56.6%), Lampung Province (20.5%) and other provinces in Indonesia (22.9%). In general, post-harvest processing of cassava is used to make tapioca flour, cassava flour, cakes, noodles, and others (Asnawi, 2008).

Cassava is usually traded in its skinned form. The tuber has a skin consisting of two layers, namely the outer skin and inner skin. Yam meat is usually white or yellow in the middle of the tuber meat there is a light composed of fibers and between the inner skin and tuber meat there is a layer of cambium. Fresh cassava contains a lot of water and starch (Muchtadi *et al*., 2011). The chemical composition of cassava can be seen in **Table 1.**

Table 1. Chemical composition of cassava (in 100 grams of material)

Composition	Nutritional Content
Water	62.50 g
Protein	1.2 g
Fat	0.3 g
Carbohydrates	34.00 g
Calcium	33.00 g
Phosphorus	40.00 mg
Vitamin B1	0.06 mg
Iron	0.70 mg
Vitamin C	30.00 mg
Calories	0.06146 kcal

Source: Salim (2011)

Generally the flesh of cassava tubers is white or yellowish, for sweet-tasting cassava produces at least 20 mg of HCN per kilogram of fresh root tubers and 50 times more in bitter-tasting tubers. In bitter cassava types, the cooking process is needed to reduce the toxicity (Roja, 2009).

One of the processing of *cassava* is cassava flour. *Cassava* flour can be used in making mixed flour, which is a mixture of wheat flour and *cassava* flour, because *cassava flour* has a color, texture, and aroma that resembles wheat flour. The mixed flour can be used in making bread, cakes, noodles, and other snack products (Ginting, 2002). The physical and nutritional characteristics of cassava flour can be seen in **Table 2.**

Table 2: Physical and nutritional characteristics of cassava flour

Parameters	Cassava Flour
Moisture content (%)	Max. 13
Starch (%)	82-85
Protein (%)	Max. 1.2
Fat (%)	0.4-0.8
Ash (%)	Max. 0.2
Fiber (%)	1.0-4.2
HCN (mg/kg)	Not detected
Grain Size (mesh)	Max. 80
Degree of vaginal discharge	85-87
Viscosity (mPa.s)	20-40 (2% pasta hot), 30-50 (2% cold paste)

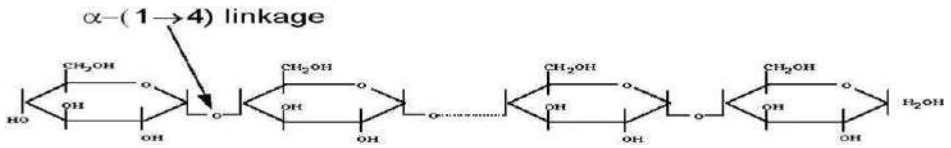
Source: Subagio (2008)

B. Modified Starch

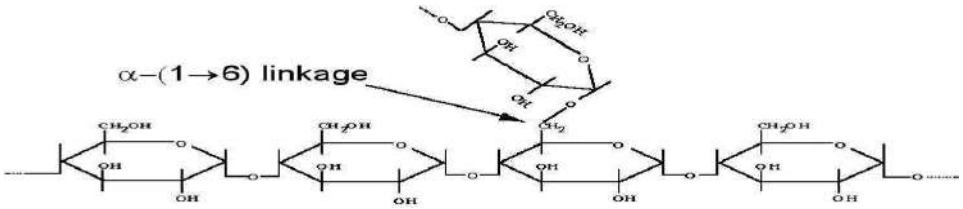
Starch is a polysaccharide composed of glucose units with α-glycosidic bonds. Starch granules have different structures and compositions depending on the starch source, but generally have two main components, namely amylose (20-30%) and amylopectin (70-80%). Both are α-D- glucose polymers. In their pure state, amylose and amylopectin molecules are organized in granules that are physically semicrystalline and amorphous (Cheng, 2006). Starch granules can be round, oblong, oval or irregular in shape. The size of starch granules also varies generally between 1-100 micrometers. These characteristics are influenced by the type of plant, environmental conditions, soil mineral content and plant maintenance (Putri and Zubaidah, 2017).

Starch consists of two fractions that can be separated with hot water. The soluble fraction is called amylose and the undissolved fraction is called amylopectin (Winarno, 2004). Amylose is one type of polymer constituent of granula

starch. Amylose consists of α-(1,4)-linked D-glucopyranose molecules in a straight chain structure. Amylose has a lighter molecular weight than amylopectin which is in the range of 1 x 10^5 to 1 x 10^6 . Amylose molecules can be composed of 3000 glucose monomers. Amylopectin is a starch polymer with a branched structure, its linear chain has the same bond as amylose, which is a glucose homopolymer with α-(1,4) bonds, while the branching point is α-(1,6) bonds. The molecular weight of amylopectin is about 1000 times the molecular weight of amylose and ranges from 1 x 10^7 to 5 x 10^8 g/mol (Putri and Zubaidah, 2017). The structure of amylose and amylopectin can be seen in **Figure 1.**



Amylose



Amylopectin

Structure of Amylose and Amylopectin (Chang, 2006) The starch content of cassava is 90.21 g/100 g of material (Permana, 2012). Cassava has an amylose proportion of 17%. However, in general, the ratio between amylose and amylopectin differs between starches, but for normal starch consists of 25% amylose and 75% amylopectin (Wulan *et al*., 2006). The ratio between amylose and amylopectin will affect the solubility and degree of gelatinization of starch. The gelatinization temperature range of cassava tepun is between 52-64^{o}C (Winarno, 2004).

Starch from cassava is used as a filler, thickener, film-forming gel and as a food stabilizing agent. However, natural starch derived from cassava has limited functions due to the nature of starch that is not resistant to heat, acidic conditions and is not resistant to stirring, so its function as a thickener or filler is not maximized. In natural starch, amylopectin and amylose contained in starch granules are connected by hydrogen bonds that are very susceptible to hydrogen bonds.

disconnection during the gelatinization process. This is why starch is not resistant to heating, low pH and stirring (Putri and Zubaidah, 2017). In its natural form, one type of starch cannot be applied to all types of processing. The causes of the limited application of starch in industry are the loss of viscosity at low pH, high temperature or mechanical treatment, and the occurrence of retrogradation that causes syneresis (Syamsir *et al*., 2012).

According to Munarso (2004), modified starch is defined as starch that is treated in such a way both physically and chemically that it has different rheological and functional properties from the original starch. Such modification aims to change the structure of starch, improve the stability of starch granules during the manufacturing process and expand the use of starch in various industrial fields (Bertolini, 2010; Cui, 2005). Putri *et al*. (2018) stated that starch modification is carried out because in its use, natural starch has several weaknesses as indicated by the appearance of undesirable characteristics under certain conditions of pH, temperature, and pressure. Starch modification can improve the resulting characteristics. flour characteristics determine its use in food products which are closely related to the quality of the product (Aini *et al.,* 2016).

Modified starch is starch that has undergone physical or chemical treatment in a controlled manner so as to change one or more of its original properties, such as the initial gelatinization temperature, characteristics during the gelatinization process, resistance by heating, acidification and stirring, as well as the tendency of retrodegration (Kusnandar, 2010). According to Herawati (2012), the process of starch modification can be influenced by several parameters, including particle size, temperature, reaction time, and substrate concentration.

One way to modify the characteristics of cassava starch is by modifying the functional properties of starch. Modification is defined as a change in molecular structure that can be done by several methods, either physically, chemically, or enzymatically (Koswara, 2013). Methods that are widely used to modify cassava starch are modification with acids, modification with enzymes, modification with oxidation and modification with crosslinking (An, 2005). Physical treatment for starch modification tends to be safer and more natural than chemical treatment (Collado, *et al*., 2001).

In food processing, starch products and starch derivatives have nutritional value and provide functional properties. Starch can function as a structure builder, increase product viscosity (thickener), gelling agent and other important functions in food products (Putri and Zubaidah, 2017). The types of starch and their utilization can be seen in **Table 3.**

Table 3. Types of starch and their utilization

No.	Starch Type	Nature	Utilization of
1	Pregelatinized Starch	Soluble in cold water, filling material	Instant soup, instant pudding, sauce mix bakery, frozen food
2	Acid Hydrolysis Starch	Low viscosity, high retrogradation, strong gel	Gum, candy, liquid food formulation
3	Dextrin	Binding agent, encapsulation	Candy, developer, flavors, spices and oil
4	Oxidized Starch	Stabilizer, adhesive, sealer, clarifier	Food formulation, gum, candy
5	Starch Ether	Stabilizer	Soup, , frozen food
6	Starch Ester	Stabilizers, fillers, ingredients purifier	Candy, emulsion
7	Starch Cross Reaction	Filler, stabilizer, texture determinant	Pie filler, bread, frozen food, bakery, pudding, instant food, soup, salad dressing, dressing

Source: (Hustiany, 2006)

C. Fermentation

Fermentation is a way of processing by utilizing the decomposition of compounds from complex materials. The complex compounds contained in the material are converted into simpler compounds with the help of enzymes derived from the material or from microorganisms and take place under controlled conditions (Adawyah, 2007). Biological processes involving microorganisms or metabolites produced by microorganisms can cause changes in starch characteristics. The types of microorganisms that are widely involved in the process of biological modification of starch are molds or lactic acid bacteria (LAB) (Putri and Zubaidah, 2017). Microbes that grow during fermentation will produce pectinolytic and cellulolytic enzymes that can destroy starch.

cassava cell walls in such a way that starch granule liberation occurs. The microbes also produce enzymes that hydrolyze starch into sugar and further convert it into organic acids, especially lactic acid. This process will cause changes in the characteristics of the flour produced in the form of increased gelation ability, rehydration power and solubility. Furthermore, the starch granules will undergo hydrolysis which produces monosaccharides as raw materials to produce organic acids. These acidic compounds will produce a distinctive aroma and flavor that can cover the aroma and flavor of cassava which tends to be unpleasant (Subagio, 2006).

According to (Suprihatin, 2010) based on the source of microorganisms, the fermentation process is divided into 2 (two), namely: a) Spontaneous fermentation, is the fermentation of food ingredients where in the manufacture is not added microorganisms in the form of starter or yeast, but microorganisms that play an active role in the fermentation process develop both spontaneously because the environment is made suitable for growth, where the activity and growth of lactic acid bacteria is stimulated due to the presence of salt, for example in the manufacture of salted vegetables.

b) Non-spontaneous fermentation is fermentation that occurs in foodstuffs in which microrganisms are added in the form of starters or yeast, where these microorganisms will grow and multiply actively changing the fermented material into the desired product.

Fermentation is divided into two, namely spontaneous and controlled fermentation (requires a stater). Spontaneous fermentation is fermentation without the addition of microorganism cultures that grow in a varied and uncontrolled environment (Hammes *et al*., 2003), while controlled fermentation is fermentation carried out with the addition of selected microorganism cultures along with selection media so that fermentation can take place faster (Rahayu, 2000).

Lactic acid bacteria have amylolytic properties, which are able to produce the enzyme amylase to degrade starch. Amylolytic lactic acid bacteria produce extracellular enzymes, namely amylase and pululanase, which can partially hydrolyze natural starch into simple sugars and other oligosaccharides or dextrins. The α-amylase enzyme will cut carbohydrates at the endo-α 1,4 bond and the pululanase enzyme will cut carbohydrates at the endo-α 1,4 bond.

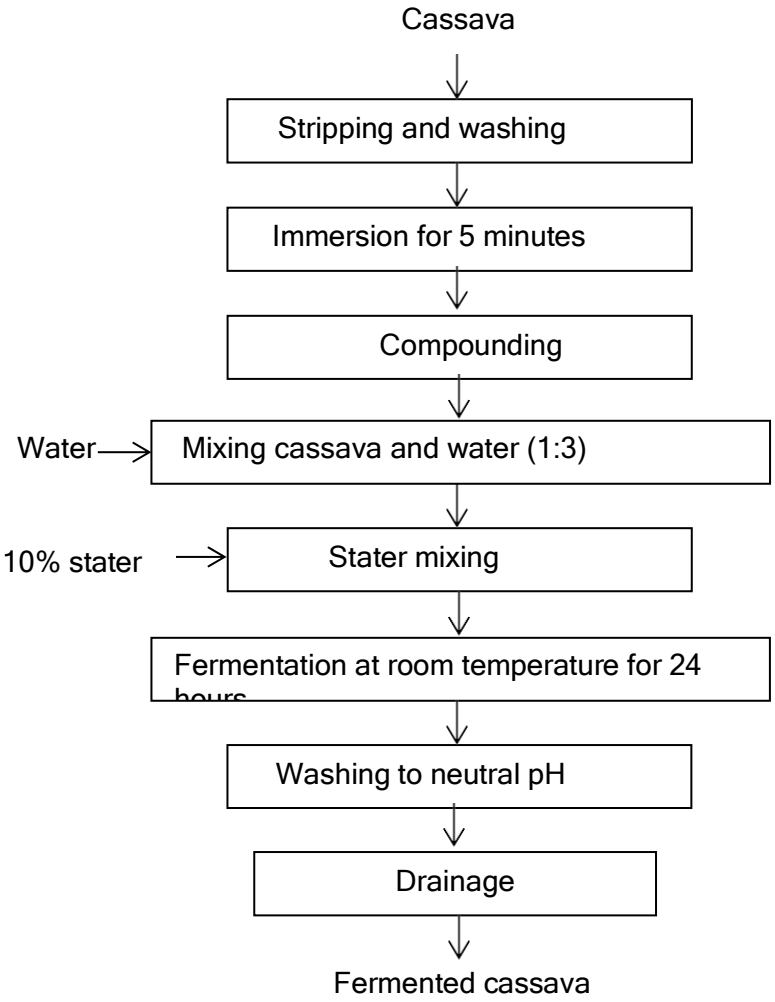
Starch fermentation by LAB showed changes in microstructure, namely the formation of globular and lamellar structures. Changes in starch structure from crystalline to more porous (amorphous), increasing the ability to release amylose and lowering the starch gelatinization temperature (Nurhayati, 2011).

Fermentation causes changes in starch characteristics due to the attack of starch granules by enzymes as well as acids released by the microorganisms involved. Starch degradation by LAB occurs because a carbon source is needed for its growth so the bacteria produce extracellular amylase enzymes. This enzyme breaks the polymeric bonds of starch into shorter, oligosaccharides or simple sugar molecules, so that the iodine test performed causes different color changes. Identification is strengthened by the results of using iodine to color amylose showing a dark blue color, which occurs due to complex formation. The complex occurs due to amylose forming a helical coil around the iodine molecule. If the amylose polymer is cut into shorter lengths, there is a change in the complex bond with iodine so that the color becomes lighter, red, or brown. Lactic acid can also cause starch degradation during fermentation by oxidizing the amorphous part and then simultaneously hydrolyzing amylose and amylopectin. The time required for lactic acid to degrade starch is longer than the breaking of bonds by enzymes (Putri *et al*., 2012).

Lactobacillus plantarum is one of the species of lactic acid bacteria (LAB). It is a lactic acid-producing bacteria and is widely used for MOCAF fermentation. *L. plantarum* is amylolytic which will directly convert starch into lactic acid. *L. plantarum* can be used as a starter in the fermentation process which plays a role in increasing lactic acid production (Reddy *et al*., 2003). The growth rate of *L. plantarum* when compared to other bacteria is higher. The bacteria can grow well on nutrient-rich substrates such as MRS-broth. *L. plantarum* has the ability to produce acid quickly and more than *L. brevis, L. fermentum, and L. acidophilus*. (Kurtman *et al*., 2009).

The cassava fermentation process in this study refers to the method of

Nurani (2013) modified. Cassava is peeled and washed with clean water. Next, cassava is soaked in boiling water for 5 minutes, then drained and shredded. Then, mix 500 grams of shredded cassava, 10% stater and water. The weight ratio of sawut cassava and soaking water is 1:3 w/v, then stirring is done using a sterile stirrer, then close the jar tightly. Fermentation was carried out for 24 hours at room temperature. Furthermore, the fermented cassava was washed until the pH was neutral and then drained. Flowchart of the process of making fermented cassava can be seen in **Figure 2.**



Flowchart of non-spontaneous fermentation cassava production (Nurani, 2013) as modified.

D. Pregelatinization

Pregelatinization is a method of physically modifying starch by giving a boiling treatment at a certain temperature and time period. Pregelatinized starch has the properties of dispersing and absorbing water more easily than unmodified starch (Miyazaki *et al*., 2006). According to Bindzus *et al*. (2002), pregelatinized starch is starch that is physically modified by using an appropriate temperature to achieve gelatinization conditions. Pregelatinized starch is divided into two categories, partial pregelatinsation and complete pregelatinization. Partially pregelatinized starch is a modified starch where most of the starch granules are still intact, while fully pregelatinized has no intact starch granules. The chemical composition of cassava starch with pregelatinization method can be seen in **Table 4.**

Table 4. Chemical composition of cassava flour by pregelatinization method (per 100 g of material)

No.	Component	Cassava flour
1	Water (g)	11,99
2	Ash (g)	0,13
3	Fiber (g)	1,74
4	Fat (g)	0,27
5	Protein (g)	0,79
6	Carbohydrate (g)	85,08
7	Starch content (g)	78,45

Source: Hidayat *et al*. (2009)

Hidayat, *et al*. (2009) reported that pregelatinized cassava flour has different characteristics from cassava flour without pregelatinization. Pregelatinized cassava flour has a higher gelatinization temperature, maximum viscosity, whiteness, water absorption, and solubility compared to flour without pregelatinization. Pregelatinized starch is instant, which is *cold water soluble*.

There are various methods of making pregelatinized flour. Pregelatinized flour can be made by high pressure steaming technique (Khomsatin, *et al*., 2012), and also using boiling technique (Palupi, *et al.,* 2011). In the boiling technique, pregelatinized flour is made by boiling the flour material at a temperature of 80-100 ºC for 10 minutes. After boiling the material is dried and crushed to obtain pregelatinized flour. This treatment gives a significant effect on amylose content, degree of whiteness and amylographic properties of cassava flour.

The pregelatinization process can increase the water binding capacity of the material or decrease the free water of the material, thereby decreasing the amount of evaporated water which is detected as low moisture content of the material. Flour that undergoes a gelatinization process by *parboiling* and then drying, thereby improving the quality, rheological properties and flour paste is called pregelatinized flour (Pratiwi *et al*., 2017).

Pregelatinized flour undergoes hydrolysis by heat from constantly increasing temperatures resulting in hydrogen bonds being broken so that the starch fraction breaks into shorter chains. With a smaller molecular size, it is easy to dissolve in water. Continued heating will cause starch granules to break so that the water contained in the starch granules and water-soluble starch molecules easily escape and enter the solution system (Baah, 2009). Flour that is pregelatinized by boiling or *parboiling* has undergone changes in the bond structure and shape of the granule. Hydrogen bonds between amylose and amylopectin are weakened due to preheating. Gelatinization results in dehydration and conversion of the *amorphous* form of amylose to the helical form. The helical form becomes the weak part of the starch granule crystal (Palupi *et al.,* 2011).

The flour has undergone pregelatinization due to heating in the pregelatinization treatment or coupled with drying treatment using a *cabinet*. Starch granules can absorb water and swell, but cannot return to their original state (retrogradation). Water absorbed in the molecules causes the granules to expand. In the gelatinization process, intramolecular hydrogen bonds are destroyed. Hydrogen bonds play a role in maintaining the structural integrity of the granule. The presence of free hydroxyl groups will absorb water, resulting in swelling of the starch granules. Thus, the more the number of hydroxyl groups of starch molecules, the higher the ability to absorb water (Hariyadi, 2012).

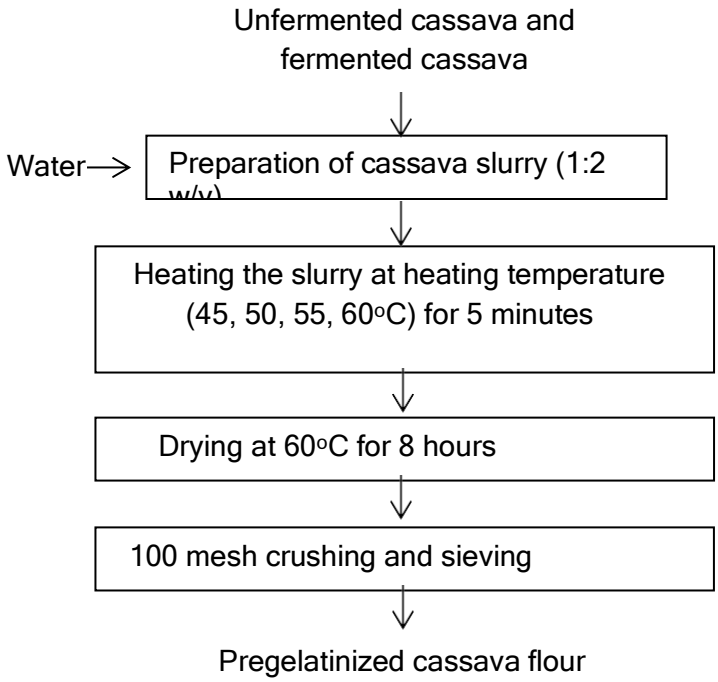
According to Palupi, *et al*. (2011) pregelatinized flour made through *parboiling* process has better paste characteristics than natural flour. Pregelatinization temperature and time are important factors that affect the characteristics of the resulting product. If heating is not done at the appropriate temperature and time, the degree of development of the pregelatinized flour will be reduced.

The resulting flour granules are not precise and do not provide the desired properties. The gelatinization temperature of various cassava varieties can be seen in **Table 5.**

Table 5. Starch gelatinization temperature of different cassava varieties

Cassava Variety	Gelatinization Temperature	Source
Adira	71,1°C	Kartikasari *et al*., (2016)
UJ	67,4-90,3°C	Palupi *et al*., (2011)
Adira I	68,5-95°C	Hidayat *et al*. (2009)
Kaspro	67,95°C	Widyamotko *et al.,* (2018)
-	69-87°C	Polnaya *et al*., (2015)

According to Ariyantoro *et al*. (2020) the pregelatinization temperature used can affect moisture content and water absorption. The higher the temperature used, the more water absorption increases. Heating the pregelatinized flour causes the starch granules to swell and causes weak hydrogen bonds in the granules. Granules that have swelled have a larger size. So that with a larger granule size, flour will absorb more water. Heating temperature can also increase the solubility of pregelatinized flour. In the research of Putra *et al*. (2017), pregelatinization temperature had a significant effect on *swelling power* and water absorption of pregelatinized chimp flour. In addition, the initial gelatinization temperature and initial gelatinization time were also significantly affected by the pregelatinization temperature. Increasing the pregelatinization temperature can reduce the initial gelatinization temperature. The process in making pregelatinized flour is to make *slurry* from unfermented and spontaneously and non-spontaneously fermented cassava with a ratio of cassava and water (1: 2) w/v and heating the *slurry* using a *hotplate* at temperatures (45^{o}C, 50^{o}C, 55^{o}C, and 60^{o}C) for 5 minutes. Next, it was dried at 60^{o}C for 8 hours. Then crushing and sieving with a 100 mesh sieve was carried out. The process of making pregelatinized flour can be seen in **Figure 3.**



Flowchart of the preparation of pregelatinized cassava flour (Adedokun and Itiola, 2010) as modified.

E. Functional Properties Starch

Functional properties are physicochemical properties beyond nutritional properties that enable an ingredient to contribute desirable characteristics to a food based on the properties of its components when interacting with other components in a complex food system. Functional properties are strongly influenced by various physical or chemical factors and also play an important role in food processing, storage, and presentation that affect the desired characteristics, food quality, and consumer acceptance (such as appearance, color, texture, and taste). The functional properties of starch-containing flour can be related to water absorption, oil, solubility, texture, and stickiness (Alam, 2008).

Syafutri (2015) added several characteristics of starch paste properties including initial gelatinization temperature, maximum gelatinization temperature, time and maximum viscosity or peak viscosity, falling viscosity, reverse viscosity,

and cold viscosity. The paste properties of flour or starch are usually referred to as the amylographic properties of flour or starch.

1. Swelling Power

Swelling power is the maximum increase in volume and weight of starch during development in water. When a certain amount of starch is heated in excessive amounts of water, its crystalline structure is disrupted, causing damage to the hydrogen bonds and hydrogen molecules to escape from the hydroxyl groups of amylose and amylopectin. This causes an increase in swelling and solubility of the granule (Ratnayake *et al*., 2002). Starch with high swelling power has high digestibility and indicates the ability of starch to improve food properties and the use of starch in various food applications. Starch with high *swelling power* is best used for bakery products that require high development, while starch with low *swelling power* is suitable for products that do not require high development, such as noodles (Kaur *et al.*, 2011).

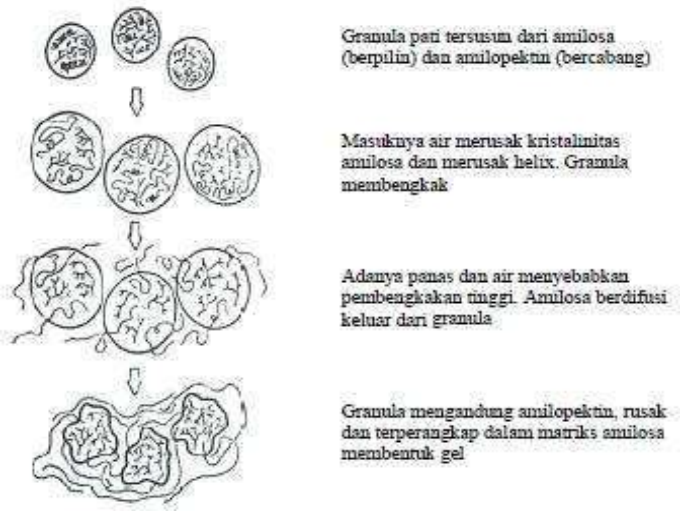
2. *Solubility*

Solubility indicates the ease with which a flour can dissolve in water. High *solubility* indicates that the flour is more soluble in water and vice versa. This is because less water-insoluble particles will be dispersed. The higher the *sollubility*, the better the quality of the flour (Janathan, 2007). According to Pomeranz (1991), starch solubility increases with increasing temperature. The higher the heating temperature causes the degradation of starch so that the starch chain is reduced and tends to be shorter, increasing the hydrophilic properties of starch. An increase in solubility is always followed by an increase in starch viscosity. This is due to the increase in the number of hydroxy groups which causes the solubility in water to increase and results in water that was previously free to move outside the granule becoming trapped and unable to move freely anymore.

3. Gelatinization

Starch gelatinization is a complex *phenomenon* that occurs in the crystalline structure of starch granules that is lost due to heating and the presence of water (Batey and Curtin, 2000). Gelatinization is a process where starch granules *irreversibly* lose their molecular so-called *birefringence*, as a result of a series of events when starch granules are heated to excessive water. The gelatinization process begins with the swelling of the granules as a result of hydrogen bonds in the amorphous part being disrupted. Subsequently, water acting as a *plasticizer* is absorbed and excessive hydration and swelling occurs in the amorphous region as the temperature increases causing the crystals to break and then hydrate and liquefy. Finally, the primary molecules especially amylose decays from the granules and increases the viscosity (Manaois, 2009).

According to Swinkels (1985), the mechanism of gelanitization basically occurs in three stages, namely: (1) absorption of water by starch granules to a limit that will expand slowly where water slowly and alternately imbibes into the granule, resulting in the breaking of hydrogen bonds between granule molecules, (2) rapid development of the granule as it absorbs water rapidly until it loses *its birefriengence* properties, and (3) granule rupture if enough water and temperature continue to rise so that amylose molecules come out of the granule. The mechanism of gelatinization can be seen in **Figure 4.**



Gelatinization Mechanism (Harper, 1981)

Gelatinization is affected by heating, stirring, and starch concentration. Heating with stirring can accelerate gelatinization. The thicker the solution, the slower the gelatinization temperature is reached. Even at certain temperatures, the viscosity of the starch solution does not increase and sometimes even decreases. The optimum concentration of starch solution is 20% (Winarno 2008).

4. Starch Retrogadation and Syneresis

Retrogradation is a change in the state of starch solution from dissociated to associated during the cooling process which causes a decrease in the solubility of starch molecules. The process of re-crystallization of gelatinized starch is called retrogadation. There are two processes that occur during retrogadation, the first is rigidity and crystallinity gel that develops rapidly to form crystals again, this happens to amylose molecules. Secondly, the gel that develops slowly and occurs in amylopectin molecules. Starch retrogadation is caused by the re-formation of hydrogen bonds between amylose and amylopectin molecules, especially in amylose molecules because the formation of hydrogen bonds between amylose molecules is easy to form. The more amylose molecules that come out of the granule during the gelatinization process, the more retrogadated starch is formed in the retrogadation process (Srichuwong, 2006).

Starch retrogadation can cause several changes in the gel properties of starch. The changes that occur are an increase in the resistance of amylose and amylopectin molecules to hydrolysis by amylolytic enzymes, a decrease in light transmission ability and the loss of the ability to form blue complexes when iodine is added. In addition, starch retrogradation can also increase gel strength, causing the starch gel to lose its ability to bind water, and the re-formation of crystallinity with a large size (Putri and Zubaidah, 2017).

5. Amylographic Properties of Flour

Amylographic properties are related to the measurement of the viscosity of starch with a certain concentration during heating and stirring (singh *et al*., 2006). Continuous heating of excess water in the presence of stirring causes the granules to swell, amylose to break down more.

many, and the granules break resulting in the material becoming viscous, which is called baking. Glazing occurs simultaneously after gelatinization. Amylographic properties are important as an indicator of how starch behaves (changes in starch) during processing and measurement using RVA (*Rapid Visco Analyzer*) (BeMiller, 2007). The parameters of amylography analysis consist of three things. First is the initial gelatinization temperature, which is the temperature at which the curve starts to rise. Then the temperature at the peak of gelatinization, which is the temperature at which the maximum value of viscosity can be achieved. Third, the maximum viscosity at the peak of gelatinization expressed in *Brabender units* (Argasasmita, 2008).

F. Flour Quality Parameters Cassava

1. Yield

Yield is an important parameter to determine the economic value and effectiveness of a product or material process. The calculation of yield is based on the percentage ratio between the final weight and the initial weight of the process. The greater the yield, the higher the economic value of the product, as well as the effectiveness of the product (Cucikodana *et al.,* 2012). According to Widya (2003), low yield is caused by the shrinkage of material weight due to water lost during drying, so this causes the yield of cassava flour to be low.

According to Suprapti (2005) factors that affect the amount of yield include: a) the age of cassava harvest; b) the machine or grater is not good so that the results of the grater are not smooth; c) less perfect squeezing process; d) a lot of starch is wasted in the process of separating tapioca with water; and e) low quality of raw materials.

2. Water Content

Moisture content is the percentage of water bound by a material to its oven dry weight. Determination of moisture content is done to determine the amount of water bound by the solid component of the material. The water content in a material can determine the appearance, texture and ability to survive the material against the attack of microorganisms expressed in aw, which is the amount of free water that is bound by the solid component of the material.

can be utilized by microorganisms for their growth (Sudarmadji *et al*., 1997).

3. Ash Content

Ash content is a mixture of inorganic or mineral components found in food ingredients (Astuti, 2012). Minerals in the fermentation process can increase the availability of carbon and nitrogen that can be used by microbes as an energy source (Safitri *et al*., 2016). The function of minerals such as Calcium (Ca) as a source of calcium in the growth medium of microorganisms so as to increase the microbial population (Irawati, 2017). Phosphorus (P) is needed by microbes as part of the formation of nucleic acids, phospholipids and coenzymes. Potassium functions as an inorganic cation in cells and as a cofactor for several enzymes. Magnesium sulfate will decompose into magnesium and sulfur. Magnesium functions as an important cell cation as a cofactor for protease enzymes, while sulfur is needed in the formation of the amino acids cysteine and methionine. Manganese (Mn) is required by microbes as an enzyme cofactor. These minerals are needed by microorganisms as electron acceptors for the metabolism of glucose and other carbohydrates (Malaka *et al*., 2013).

4. Degree of Whiteness

The degree of whiteness is the ability of a material to reflect light that hits the surface of the material. During the fermentation process there is degradation of complex compounds by microorganisms so that the pigmented material contained in the material also breaks down and dissolves in water (Iswari *et al*., 2016). The heating process can cause cell damage so that the solution in the cell will come out to interact with air and then react with oxygen to form color components (Palupi *et al*., 2011).

5. Starch Content

Starch is a polysaccharide composed of glucose units with α-glycosidic bonds. Starch granules have different structures and compositions depending on the starch source, but generally have two main components, namely amylose (20-30%) and amylopectin (70-80%). Both are α-D- glucose polymers. In its pure state, the molecule

amylose and amylopectin are organized in granules that are physically semicrystalline and amorphous (Cheng, 2006).

6. Amylose Content

Amylose is the main component of starch which acts as the structural framework of starch. Both molecules are composed of several glucose units that are bonded together. Amylose is a linear polysaccharide molecule with α-1,4 bonds with a degree of polymerization (DP) of several hundred glucose units (Whistler *et al*. 1984). Increasing the heating temperature results in a decrease in amylose content and clarity of the paste but increases solubility and expandability. The increase in expandability due to heating at higher temperatures is due to lower amylose or higher amylopectin levels (Jading *et al*., 2011).

7. Swelling Power

Swelling power is a property that characterizes the *swelling power* of a material. The swelling power is influenced by the heating temperature of the flour suspense, the duration of heating, the flour suspense and the amylose content in the starch, the heating temperature of the flour suspense affects the amylose content and the swelling power. According to Li and Yeh (2001), there is a negative correlation between swelling power and amylose content, where the swelling power value decreases as the amylose content increases. Hydrogen bonds connecting amylose and amylopectin molecules are disrupted and weakened, which will disrupt the cohesiveness of starch granules. Water molecules will bond with hydroxyl groups on amylose and amylopectin, causing the starch granules to enlarge and the swelling power value to increase (Indrastuti, 2012).

8. Solubility

Based on Sulieman *et al*. (2014), solubility is the ability of a product to form a solution, precipitate or emulsion when mixed with water. Solubility is an important property in assessing the physical characteristics of granule or powder products (Yuliawaty & Susanto, 2015). Marcon *et al.* (2009) stated that fermented cassava starch granules have higher solubility compared to unfermented starch. This is due to the amylose molecules in the starch granules.

fermented cassava starch is partially hydrolyzed. The release of amylose from starch granules will increase its solubility and reduce its density.

9. Water Absorbency

Water absorption is one of the various factors that affect flour quality. Water absorption in flour is the ability of flour to absorb water. According to Kartika (2010), prolonged heating treatment can cause macromolecules that are initially relatively compact to become somewhat porous because they break down into simple molecules with a small mass weight so that they are rather tenuous and more easily absorb water. The high water absorption is related to the amylose content in flour. The lower the amylose content, the higher the absorbency (Suarni, 2009).

10. Oil Absorbency

Oil absorbency indicates the amount of oil that can be absorbed by the food matrix. Oil absorption is the ability of starch to physically absorb and retain oil by capillary attraction into the material and this is very important, as oil acts as a flavor preserver and also improves *mouthfeel* in food (Ali *et al*., 2016).

11. *Rapid Visco Analyzer* (RVA)

Amylographic properties are concerned with measuring the viscosity of starch of a certain concentration during heating and stirring. Amylographic properties include initial gelatinization temperature, maximum gelatinization temperature, maximum viscosity, balk viscosity and cold viscosity (50^{o}C). The amylographic properties of flour can be analyzed using the *Rapid Visco Analyzer* (RVA) (Singh *et al*., 2003). RVA is a viscometer equipped with a heating and cooling system to measure sample resistance to controlled stirring (Collado and Corke, 2001).

This amylography test is used to determine the gelatinization temperature of flour suspensions. The parameters of amylography analysis consist of three things. First is the initial temperature of gelatinization, which is the temperature at which the curve begins to rise. Then the temperature at the peak of gelatinization, which is the temperature at which the maximum value of viscosity can be achieved. Third, the maximum viscosity at the peak of gelatinization expressed in *Brabender Units* (Argasasmita, 2008). RVA

can simulate the food processing process and be used to determine the effect of the process on the structural functional characteristics of the mixture (Copeland, *et al*., 2009).

12. *Scanning Electrone Microscopy* (SEM)

SEM (*Scanning Electron Microscope*) is a type of electron microscope that uses electron beams to describe the surface shape of the material being analyzed. The beam that falls on the sample will be reflected and diffracted. The presence of diffracted electrons can be observed in the form of diffraction patterns. The diffraction patterns that appear depend on the shape and size of the unit cell of the sample. SEM can also be used to summarize crsitalography data, so that it can be developed to determine elements or compounds (Frost, 2009).

13. **Organoleptic Test *Scoring***

The scoring test is a type of scalar test in sensory evaluation. In the scalar test, panelists are asked to state the magnitude of the impression they get. This quantity can be expressed in the form of a scalar quantity or in the form of a numerical scale. Scalar quantities are depicted as straight, directional lines with equally spaced scale divisions or scalar bands. Numerical scales are expressed by numbers that indicate the cores of the quality attributes being tested. Thus the scoring test is a type of scalar test expressed on a numerical scale (Susiwi, 2009). The more panelists, the smaller the differences between panelists, and the better the indication of observations and responses from a wider population (Carpenter, 2000).

G. Analysis Decision

A decision is an action to choose one alternative choice or solution to realize a desire. Decision analysis is the basis for choosing the best alternative determination. Each alternative that is estimated is determined to have the predicted results. The decision made is by numerical evaluation, this evaluation is generally expressed through financial values, so what is done is to compare aspects of quality, quantity, and financial aspects (Dermawan, 2005).

One method for decision making is the effectiveness test (Zeleny *et al*., 1982) which determines the best treatment by determining the ideal value of each parameter, followed by calculating the density degree (dk) and density distance. The best treatment is chosen from the treatment that has the maximum L1, L2, and L∞ values.

I. Theoretical Foundation

Cassava flour is made from pieces of cassava that have been dried and then mashed. So far, cassava flour is still limited in use, because it is generally limited by its physical and chemical properties (Palupi *et al*., 2011). The development of fermented cassava flour processing technology as reported by Subagio (2008) produced *Mocaf* (*Modified Cassava Flour*) flour. *MOCAF (Modified cassava flour)* is a flour product from cassava processed using the principle of modifying *cassava* cells by fermentation. In general, the process of making *mocaf* includes the stages of weighing, peeling, cutting, soaking (fermentation), and drying (Rahayu, 2010).

Lactic acid bacteria have amylolytic properties, which are able to produce the enzyme amylase to degrade starch. Amylolytic lactic acid bacteria produce extracellular enzymes, namely amylase and pululanase, which can partially hydrolyze natural starch into simple sugars and other oligosaccharides or dextrins. The α-amylase enzyme will cut carbohydrates at the endo-α 1,4 bond and the pululanase enzyme will cut carbohydrates at the end-α 1,6 bond to produce short-chain oligosaccharides. Starch fermentation by LAB shows changes in microstructure, namely the formation of globular and lamellar structures. Changes in starch structure from crystalline to more porous (amorphous), increasing the ability to release amylose and lowering the starch gelatinization temperature (Nurhayati, 2011).

According to Subagio *et al*. (2008), the fermentation process in *MOCAF* results in changes in flour characteristics such as increased viscosity, gelation ability, rehydration power, and solubility. A recent study by Diniyah *et al*. (2018) showed that the fermentation process on cassava flour of Kaspro variety for 24 hours has the highest value of *swelling power* 7.4516 ± 0.1185 (g/g), *solubility* 1.9294 ± 0.2456 (%), *water content* 1.9294 ± 0.2456 (%), and *water content* 1.9294 ± 0.2456 (%).

absorption capacity (WAC) 12.0000±1.0000 (mL/g) and *oil absorption capacity* (OAC) 17.6667±0.5774 (mL/g), while the *swelling power* and *solubility* values of unfermented cassava flour were 5.89±0.0750 (g/g) and 1.31±0.3905 (%).

Based on the research of Wulandari *et al*. (2021), showed that the type of LAB affects the physical, chemical, and microbiological quality of *mocaf* flour. The best treatment was obtained in the type of *L. plantarum* with a fermentation time of 48 hours with a protein content of 2.06%, pH value of 5.44, and total LAB 6.2 CFU/g. Research by Diniyah *et al*. (2018) showed that the 24-hour fermentation of cassava variety Kaspro had the highest value of *swelling* power 7.4516 g/g, *sollubility* 1.9294%, water absorption 12 ml/g, oil absorption 17.67 ml/g and degree of whiteness 85.9113%. Based on the amylographic characteristics of starch fermented for 24 hours, the highest peak viscosity and heat viscosity values were 4896 cP and 2859 cP, respectively, with the lowest setback value of 646 cP and low peak temperature and time values of 3.7 minutes and 71.5°C (Kartikasari *et al*., 2016).

In addition to modification by fermentation method, there is physical modification, namely pregelatinization. Pregelatinization is a method of physically modifying flour by giving boiling treatment at a certain temperature and time period (Miyazaki *et al.*, 2006). According to Bindzus *et al*. (2002), pregelatinized starch is divided into two categories, partial pregelatinization and complete pregelatinization. Partially pregelatinized starch is a modified starch where most of the starch granules are still intact, while perfectly pregelatinized has no intact starch granules. Flour that undergoes pregelatinization undergoes changes in bond structure and granule shape. Hydrogen bonds between amylose are weakened by heating (Palupi *et al.,* 2009). Pregelatinized flour undergoes hydrolysis by heat from an ever-increasing temperature resulting in weakened hydrogen bonds until broken so that the starch fraction is broken into shorter chains (Baah, 2009).

In the research of Pratiwi *et al*., (2020) physical modification using heat with a temperature of 50-60 ° C and a time range of 5-7.5 minutes showed the results of the higher the temperature and the longer the heating caused a decrease in water content, ash content, amylose content, increased solubility and *swelling power*, and caused changes in granule morphology.

starch. Research by Adedokun and Itiola (2010) showed that 4 types of starch prelatinized at 55°C for 10 minutes produced starch that had higher *swelling power*, solubility and water absorption values than natural starch. Research by Muchlisyiyah *et al*. (2016) conducted pragelatinization of red glutinous rice flour by heating at 60°C for 10 minutes to produce characteristics of water absorption of 2.45 g/g, oil absorption of 2.02 g/g, *swelling power of 2*.39 g/g, solubility index of 0.0050%.

In Sari's (2019) research, a combination of fermentation and pregelatinization methods was carried out in modifying corn flour and aimed to determine the effect of modified corn flour substitution on the quality of the bread produced. The combination of these two methods produced the best treatment with the *Aspergillus sp* - LAB fermentation method (1:3) followed by pregelatinization. Pregelatinized flour has starch content with a higher ability to absorb water than ordinary starch and is easily soluble in cold water (Rogol 1986) and quickly forms a paste in cold water. Hidayat *et al*. (2006) stated that efforts to improve flour characteristics can be done through improving the characteristics of the starch. According to Yuliana (2011), starch pregelatinization is made through a process involving water and heat. Water absorption by starch granules occurs at a certain time and temperature so that the starch granules swell. Partial pregelatinization process on cassava flour with a *rotary drum* at 90^{o}C in the research of Hidayat *et al*. (2009) resulted in a water absorption value of 2.36 g/g and a water solubility value of 0.25 g/ml while cassava flour without pregelatinization had a water absorption value of 0.13 g/g and a water solubility value of 0.13 g/ml.

J. Hypothesis

The treatment of different types of fermentation and pregelatinization temperature is thought to affect the physicochemical characteristics of cassava flour.

CHAPTER III
RESEARCH MATERIALS AND METHODS

A. Time and Place Research

The research was conducted in the Food Microbiology laboratory, Food Analysis laboratory, Food Processing Technology laboratory of the Food Technology Study Program of UPN "Veteran" East Java, Central Laboratory of Advanced Minerals & Materials FMIPA State University of Malang and Chemical Engineering Laboratory and PAU Food and Nutrition of IPB which was carried out in March 2021 – June 2021.

B. Materials Used

The raw materials used in this research were 9-12 months old Daplang cassava varieties obtained from PT Agung Bumi Agro. Additional materials used include *Lactobacillus plantarum* FNCC 0027 culture obtained from the Center for Food and Nutrition Studies UGM, and distilled water. Materials used for analysis were distilled water, HCL, NaOH, KI, and $AgNO_3$.

C. Tools Used

The tools used were SEM (Scanning Electron Microscope) (Hitachi Science Systems type M 300, Ltd, Hitachinaka, Japan) for starch granule morphology analysis, RVA (Rapid Visco Analyzer) (Techmaster type Parten) for starch amlography profile analysis, centrifuge, *hotplate*, incubator, *cabinet dryer*, *vortex*, desiccator, analytical balance, digital balance, *waterbath*, *blender*, thermometer, measuring cup, beaker cup, erlenmeyer flask, centrifuge tube, 100 mesh sieve, baking pan, plastic jar, pipette, stirrer, cutting board, and knife.

D. Methods Research

This study used a completely randomized design (CRD) factorial pattern of 2 factors with 2 replicates (Kusriningrum, 2008). The data obtained were processed using *Analysis of Variance* (ANOVA) at the 5% confidence level, if there were significant differences, further tests were carried out using the DMRT (*Duncan't Multiple Range Test)* 5% method. Organoleptic test using the scoring method with 20 trained panelists, the data obtained were processed using *Analysis Of Variance (*ANOVA) at the 5% confidence level. If there is a significant difference, a further test with the DMRT method is carried out.

(*Duncan't Multiple Range Test)* 5%

1. Research Design

The mathematical model that applies to the Randomized Complete Factorial Design design (Kusriningrum, 2008) is as follows:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

Where,

Y_{ijk} = the observation result in the i-th treatment j-th replication μ = common mean value

α_i = the effect of the i-th level of factor A

β_j = effect of the jth level of factor B

$(\alpha\beta)_{ij}$ = interaction effect of level i of factor A and level j of factor B

ε_{ij} = residual effect (experimental error) of the i-th level of factor A and the jth level of factor B in the kth replication.

2. Research Variables

a. Changeable Variables

Factor I. Cassava fermentation method

A1 = Unfermented cassava A2 = Spontaneous fermented cassava

A3 = Non-spontaneously fermented cassava

Factor II. Pregelatinization temperature B1 = 45°C

B2 = 50°C B3 = 55°C

B4 = 60°C

From the results of the combination of the two factors, ten treatments were obtained, namely:

A \ B	B1	B2	B3	B4
A1	A1B1	A1B2	A1B3	A1B4
A2	A2B1	A2B2	A2B3	A2B4
A3	A3B1	A3B2	A3B3	A3B4

Description:

A1B1 = Cassava without fermentation; pregelatinization temperature 45°C A1B2 = Cassava without fermentation; pregelatinization temperature 50°C A1B3 = Cassava without fermentation; pregelatinization temperature 55° C A1B4 = Cassava without fermentation; pregelatinization temperature 60° C A2B1 = Cassava spontaneous fermentation; pregelatinization temperature 45°C A2B2 = Spontaneous fermentation cassava; pregelatinization temperature 50°C A2B3 = Spontaneous fermentation cassava; pregelatinization temperature 55°C A2B4 = Spontaneous fermentation cassava; pregelatinization temperature 60°C

A3B1 = Fermented cassava with *Lactobacillus plantarum*; pregelatinization temperature 45°C

A3B2 = Fermented cassava with *Lactobacillus plantarum*; pregelatinization temperature 50°C

A3B3 = Fermented cassava with *Lactobacillus plantarum*; pregelatinization temperature 55°C

A3B4 = Fermented cassava with *Lactobacillus plantarum*; pregelatinization temperature 60°C

b. Fixed Variable

- eight of unfermentedcassava 100 grams
- Weight of fermented cassavaspontaneous grams
- Weight of cassava fermented with *L* plantarum = 100 grams
- Volume ofwater 200 ml
- Fermentation time 24 hours
- Concentration of addingstater 10%
- Ratio of cassava and watersoaking 1:3 (w/v)

- Length ofwarm-up 5minutes
- Drying time 8 hours
- Dryingtemperature 60 C°
- Sizesieve 100 mesh

E. Parameters Observed

The parameters observed in this study are:

I. Natural Cassava

a. Moisture content (AOAC, 2012 925.10).
b. Ash content (AOAC, 2012 923.03).
c. Starch content (AOAC, 2005).
d. Amylose content (AOAC, 2005).

II. Modified Cassava Flour

a. Yield (AOAC, 2005).
b. Moisture content (AOAC, 2012 925.10).
c. Ash content (AOAC, 2012 923.03).
d. Starch content (AOAC, 2005).
e. Amylose content (AOAC, 2005).
f. *Swelling power* (Kaur *et al*., 2011).
g. Solubility (Kaur *et al*., 2011).
h. Water absorption (Subagio, 2006).
i. Oil absorbency (Subagio, 2006).
j. Degree of whiteness (Whiteness Meter)
k. Sensory Evaluation scoring test of texture, aroma, and color (Susiwi, 2009).

III. Best Treatment of Cassava Flour

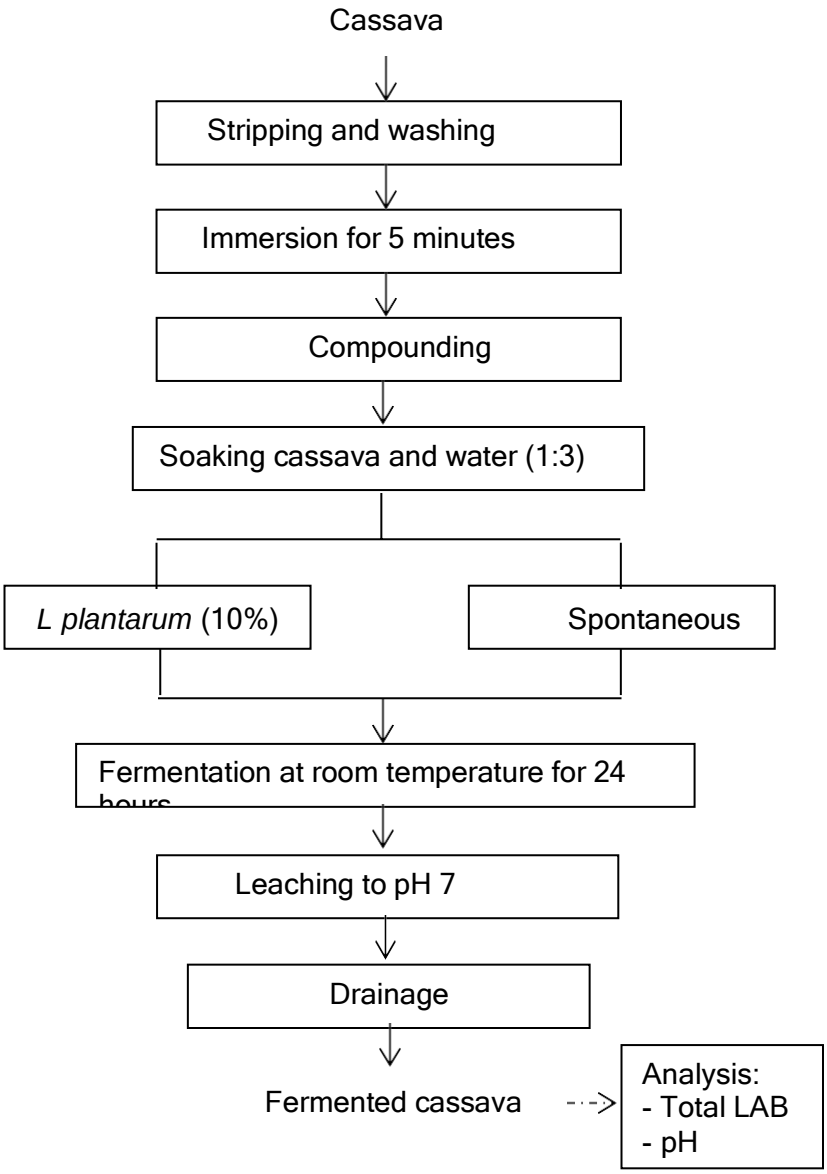
a. Starch amylography profile (AACC, 2000).
b. Morphology of starch granules (Srichuwong, 2006).

F. Research Procedure

1. Manufacture of Fermented Cassava (Nurani *et al*., 2013 and PT. Agung Bumi Agro, 2019 with modifications).

Making fermented cassava begins with peeling and washing the cassava with clean water. Next, the cassava is soaked

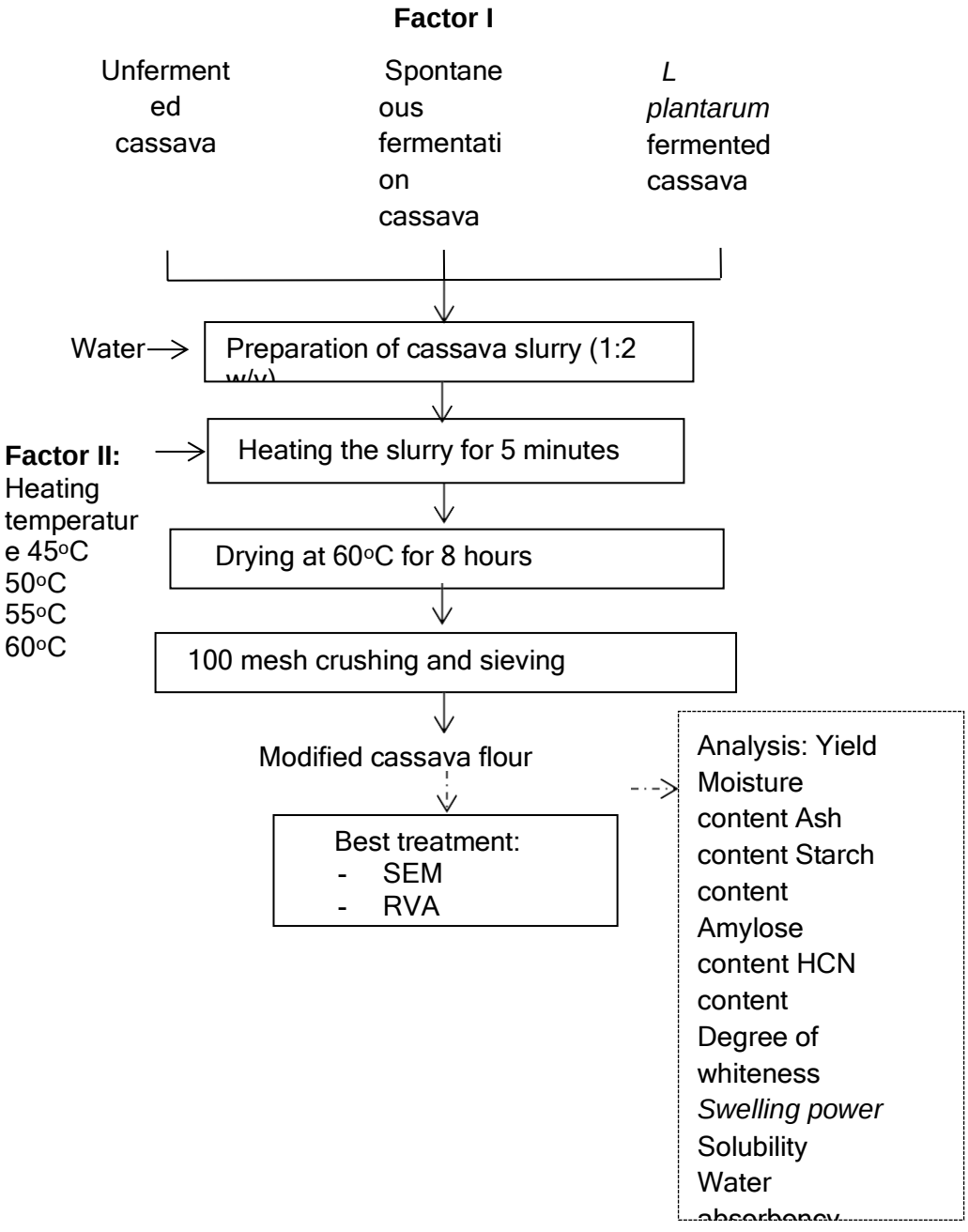
in boiling water for 5 minutes, then drained and shredded. Then, spontaneous soaking and soaking using *L plantarum* were carried out by mixing 500 grams of shredded cassava, 10% stater and water. The weight ratio of shredded cassava and soaking water was 1:3 w/v, then stirred using a sterile stirrer, then closed the jar tightly. Fermentation was carried out for 24 hours at room temperature. Furthermore, the fermented cassava was washed until the pH was neutral and then drained.



Flowchart of fermented cassava production (Nurani *et al*., 2013 and PT. Agung Bumi Agro, 2019) as modified.

2. Preparation of Pregelatinized Flour (Adedokun and Itiola, 2010 with modifications)

The pregelatinization process was carried out by making *slurry* from unfermented and spontaneously fermented cassava and fermented with *L plantarum* with a ratio of cassava and water (1: 2) w/v and heating the *slurry* using a *hotplate* at temperatures (45°C, 50°C, 55°C, and 60°C) for 5 minutes. Next, it was dried at 60°C for 8 hours. Then crushing and sieving with 100 mesh sieve.



Flow chart of modified cassava flour preparation (Adedokun and Itiola, 2010) modified

CHAPTER IV

RESULTS AND DISCUSSION

A. Raw Material Analysis

The manufacture of cassava flour products needs to consider the quality of the raw materials, namely by conducting several analyses that can support the quality of flour products. Analysis of raw materials aims to determine the initial state of raw materials before the fermentation and pregelatinization process. Analysis of raw materials in this study includes: 1) Water content, 2) Ash content, 3) Starch content and 4) Amylose content. In addition, the total lactic acid bacteria and pH of spontaneously fermented cassava and non-spontaneously fermented cassava were analyzed.

1. Cassava Raw Materials

The results of the chemical composition analysis of sigkong raw materials can be seen in

Table 6.

Table 6: Results of chemical composition analysis of cassava raw materials

Parameters	Analysis Result	Literature
Water Content (%)	64,33±0,521	67,79*
Ash Content (%)	0,75±0,002	1,21*
Starch Content (%)	28,45±0,357	24,11*
Amylose Content (%)	22,16±0,686	21,73*

Source: * Hidayat *et al*. (2009)

The results of the analysis in **Table 6** show that cassava raw materials have a moisture content of 64.33%, ash content of 0.75%, starch content of 28.45%, and amylose content of %, while in the research of Hidayat *et al*. (2009) fresh cassava has 67.79% moisture content, 1.21% ash content, 24.11% starch content, and 21.73% amylose content.

Based on the analysis results in **Table 6.** obtained, there are differences in the results of the analysis of raw materials with the literature. Differences can be caused by differences in varieties, places to grow, climate, environmental or soil conditions, age at harvest and cultivation methods. Research by Ariani *et al*. (2017) showed that there were differences in the physical and chemical characteristics of the three cassava varieties. In general, differences in content can be caused by differences in varieties, harvest age, and environmental factors, such as cropping factors (Aldana and Quintero, 2013; Oladayo *et al*., 2016).

2. Total Lactic Acid Bacteria and pH of Fermented Cassava

Total lactic acid bacteria analysis of fermented cassava was conducted to determine the initial number of lactic acid bacteria. Fermented cassava consists of spontaneous fermentation and non-spontaneous fermentation using *Lactobacillus plantarum* culture. The results of the analysis of total lactic acid bacteria of fermented cassava can be seen in **Table 7.**

Table 7. Total Lactic Acid Bacteria and pH of Fermented Cassava

Fermentation Method	Total LAB (log CFU/ml)	pH
Spontaneous fermentation cassava	6,92 ± 0,034	5,00
Cassava fermentation with culture *lactobacillus plantarum*	8,74 ± 0,044	3,90

Based on **Table 7.** shows that fermented cassava with *lactobacillus plantarum* produces a higher total LAB than spontaneously fermented cassava. Fermented cassava with *lactobacillus plantarum* produced a total LAB of 8.74 ± 0.034 log cfu/ml, while spontaneous fermented cassava produced a total LAB of 8.74 ± 0.044 log cfu/ml. This is because fermented cassava is done by adding *lactobacillus plantarum* bacterial stater, while spontaneous fermentation only utilizes microbes from the environment. In the research of Kimaryo *et al.* (2000) showed that cassava with fermentation method using *lactobacillus plantarum* for 24 hours produced total lactic acid bacteria of 8.2 log cfu/ml, this value was higher than spontaneous fermentation which produced total lactic acid bacteria of 4.4 log cfu/ml. According to Tortora *et al.* (2004) spontaneous fermentation occurs without the addition of microbes so that the fermentation process depends on the microbes found in the raw materials which causes the quality of the product to be not uniform.

Table 7 shows that the pH of fermented cassava ranged from 3.90-5.00. Spontaneous fermented cassava produces a higher pH than fermented cassava with *lactobacillus plantarum* culture. Spontaneous fermented cassava produced a pH of 5.00, while fermented cassava with *lactobacillus plantarum* culture produced a pH of 3.90. The difference in pH value is due to

Spontaneous fermentation cassava is done by soaking cassava in water for 24 hours by utilizing microorganisms from the environment. LAB activity that grows during fermentation produces enzymes that hydrolyze starch into sugar and then convert it into organic acids, especially lactic acid (Subagio, 2006). Therefore, LAB that grows during the spontaneous fermentation process has a smaller amount compared to fermentation with *Lactobacillus plantarum* culture so that less lactic acid is produced which causes spontaneous fermented cassava to be less sour and the resulting pH value is high. While fermented cassava using *lactobacillus plantarum culture* can produce lactic acid as the only final product. This is in accordance with the statement of Handayani (2012) which says that *L. plantarum* can grow either with oxygen or without oxygen, and these bacteria can live in even very acidic environments, such as at pH 4-5 or below and these bacteria are homofermentative bacteria, namely bacteria that produce lactic acid as the only final product. In fermented cassava with *lactobacillus plantarum* culture*, the* microbes that play a role can utilize starch in cassava for metabolic processes so that more microbes produce lactic acid. This is further stated by Schnurer and Magnusson (2005) that lactic acid is the main LAB metabolite that causes a decrease in pH and inhibits many microorganisms. An increase in lactic acid can be measured by a decrease in pH.

B. Cassava Flour Product Analysis Results

1. Yield

Yield is the percentage of the product obtained from comparing the initial weight with the final weight. In this research, the calculation of yield is based on the weight of whole cassava and the final weight of flour after sieving 100 mesh. Based on the analysis of variance (Appendix 2), it can be seen that there is a significant interaction ($p \leq 0.05$) between the type of fermentation and pregelatinization temperature on flour yield.

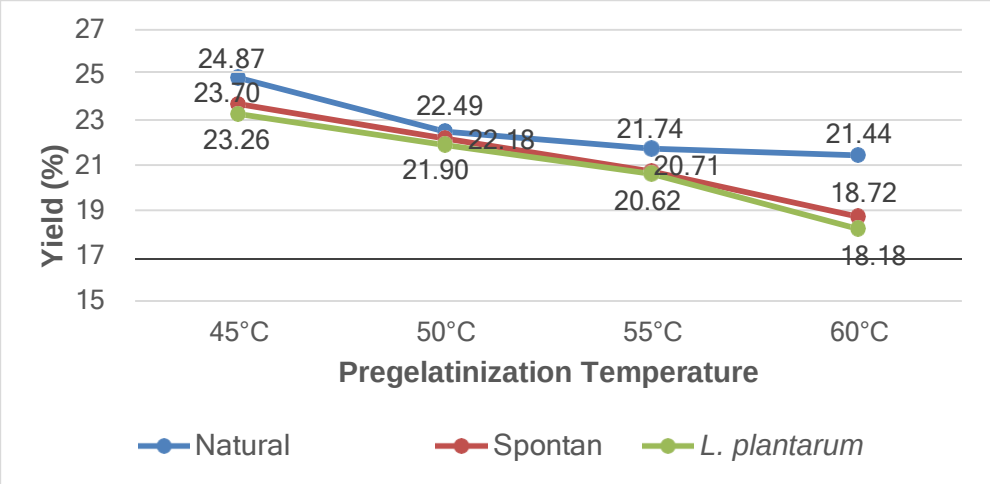
cassava. The average value of cassava flour yield with fermentation method treatment and pregelatinization temperature can be seen in **Table 8.**

Table 8. Mean yield value of cassava flour treated with fermentation method and pregelatinization temperature

Treatment		Yield (%)	DMRT	Notation
Methods Fermentation	**Temperature** Pregelatinization			
Without fermentation	45°C	24,87 ± 0,125	0,710	g
	50°C	22,49 ± 0,153	0,705	e
	55°C	21,74 ± 0,402	0,692	cd
	60°C	21,44 ± 0,194	0,684	c
Fermentation spontaneous	45°C	23,70 ± 0,028	0,709	f
	50°C	22,18 ± 0,113	0,702	de
	55°C	20,71 ± 0,189	0,673	b
	60°C	18,72 ± 0,287	0,626	a
Fermentation with *lactobacillus* culture *plantarum*	45°C	23,26 ± 0,376	0,707	f
	50°C	21,90 ± 0,557	0,698	cde
	55°C	20,62 ± 0,217	0,661	b
	60°C	18,18 ± 0,348	-	a

Notes: Mean values accompanied by the same letter mean not significantly different at p ≥ 0.05.

The average yield of cassava flour in **Table 8** ranged from 18.18-24.87%. The treatment of fermentation method with *L plantarum* with pregelatinization temperature of 60°C produced the lowest yield of 18.18%, while the treatment of unfermented cassava with pregelatinization temperature of 45°C produced the highest yield of 24.87%. The graph of the relationship between fermentation method treatment and pregelatinization temperature on cassava flour yield can be observed in **Figure 7.**



Yield of cassava flour treated with fermentation method and pregelatinization temperature

Figure 7 shows that fermentation method and pregelatinization temperature significantly affected the yield of cassava flour. The treatment of fermentation method with *L plantarum* gave the lowest yield compared to the type of spontaneous fermentation and without fermentation. This is because in the fermentation process there is soaking treatment that causes the components contained in cassava to dissolve in water. This is in accordance with Wulandari *et al.* (2020) that during the fermentation process, growing microorganisms will produce pectinolytic and cellulolytic enzymes that can destroy the cassava cell wall so that the cell wall dissolves into water which results in a decrease in cassava flour yield. The cellulose component in cassava will be destroyed, causing the texture to become soft and perforations in the starch granules, the more cellulose that breaks and dissolves into water, resulting in a decrease in yield.

The use of a low pregelatinization temperature resulted in a higher yield compared to using a high pregelatinization temperature. This is related to the water content which decreases with increasing temperature, causing a decrease in yield. This is in accordance with Rahmawati (2008) in Yuniarti *et al.* (2013), the smaller the water content produced causes a decrease in the water weight of the material, because water in the material is the main component that affects the weight of the material. If water is removed, the material will be lighter so that it will affect the yield of the final product.

2. Water Content

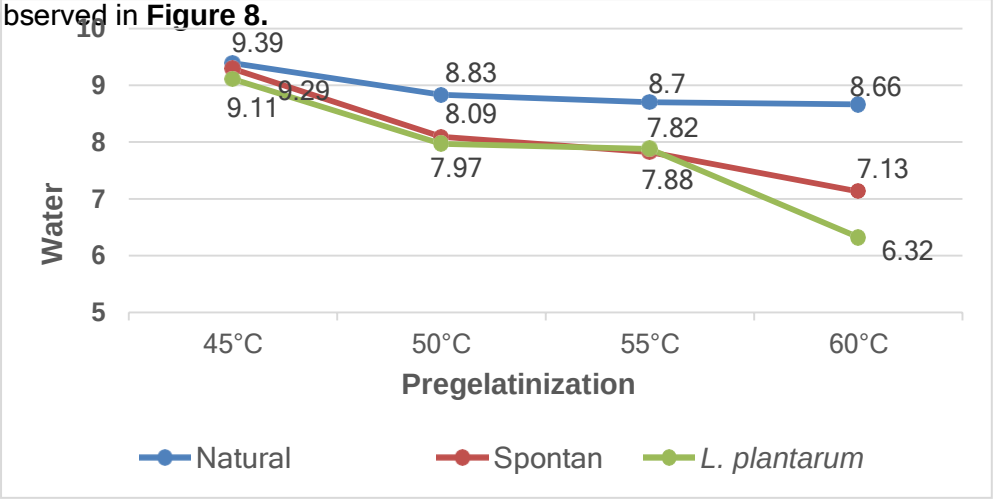
Based on the analysis of variance (Appendix 3), it can be seen that there is a significant interaction ($p \leq 0.05$) between fermentation method and pregelatinization temperature. Each treatment had a significant effect on the moisture content of the cassava flour produced. The average value of moisture content of cassava flour with the treatment of fermentation method and pregelatinization temperature can be seen in **Table 9.**

Average value of moisture content of cassava flour treated with fermentation method and pregelatinization temperature

Treatment		Water Content (%)	DMRT	Notation
Fermentation Method	**Pregelatinization Temperature**			
Without fermentation	45°C	9,39 ± 0,013	0,205	g
	50°C	8,83 ± 0,002	0,204	e
	55°C	8,70 ± 0,061	0,203	e
	60°C	8,66 ± 0,091	0,202	e
Spontaneous fermentation	45°C	9,29 ± 0,058	0,205	fg
	50°C	8,09 ± 0,012	0,200	d
	55°C	7,82 ± 0,069	0,191	c
	60°C	7,13 ± 0,058	0,181	b
Fermentation with *Lactobacillus plantarum* culture	45°C	9,11 ± 0,081	0,204	f
	50°C	7,97 ± 0,210	0,198	cd
	55°C	7,88 ± 0,088	0,194	c
	60°C	6,32 ± 0,011	-	a

Notes: Mean values accompanied by the same letter mean not significantly different at p ≥ 0.05.

The average moisture content of cassava flour in **Table 9** ranged from 6.32 to 9.39%. The treatment of fermentation method with *L plantarum* with pregelatinization temperature of 60°C produced the lowest moisture content of 6.32%, while the treatment of unfermented cassava with pregelatinization temperature of 45°C produced the highest moisture content of 9.39%. The graph of the relationship between fermentation method treatment and pregelatinization temperature on the moisture content of cassava flour can be observed in **Figure 8.**



Water content of cassava flour treated with fermentation type and pregelatinization temperature

Figure 8 shows that cassava flour treated with fermentation method and pregelatinization temperature produces different water content. The fermentation method with *L plantarum* produces lower water content compared to the treatment of cassava without fermentation and spontaneous fermentation cassava. This is due to the porous structure of starch granules which makes it easier for water to evaporate. The porosity of starch granules is caused by the fermentation process where microorganisms produce extracellular amylolytic enzymes that can hydrolyze some of the starch which results in hollow starch granules (shafts) making it easier for water to evaporate during the drying process. This is in accordance with the statement of Subagio (2006) that the activity of extracellular amylolytic enzymes, starch granules are partially hydrolyzed on the surface of the granules as a result of hollow granules. In addition, the fermentation process causes lactic acid bacteria to produce amylolytic enzymes that can attack the amorph region of starch granules, causing the starch granules to become more porous (Marcon *et al*., 2009). According to Kartikasari *et al*. (2016), the more starch granules that are porous, the easier water is evaporated. Treatment with heating temperature also produces low water content, the higher the heating temperature, the lower the water content produced. This is because during the heating process the starch granules expand which results in wider cavities in the material and easily absorbs water so that during the drying process the water is easier to evaporate. According to Palupi *et al*. (2011) heating causes weak hydrogen bonds in granules, so that granules that have swelled have a large size and are *irreversible*. The decrease in water content along with the increase in heating temperature is due to the increasing temperature that can cause greater granule development. This is because amylose and amylopectin molecules are physically maintained only by weak hydrogen bonds. Increasing suspension temperature will cause hydrogen bonds to weaken, while water molecules have higher kinetic energy so that they easily penetrate into the granule Some amylose molecules come out of the granule so that the granule is more porous or density in the granule.

reduced so that when dried more water is evaporated (Putri and Zubaidah, 2017).

3. Ash Content

Based on the analysis of variance (Appendix 4), it can be seen that there is no significant interaction ($p \geq 0.05$) between the treatment of fermentation method and pregelatinization temperature on the ash content of cassava flour. The fermentation method treatment gave a significant effect on the ash content, but the pregelatinization temperature increased the ash content of cassava flour. The average value of ash content of cassava flour with fermentation method treatment can be seen in **Table 10.**

Table 10: Average value of ash content of cassava flour treated with fermentation method

Fermentation Type	Ash Content (%)	DMRT	Notation
Without fermentation	1.30 ± 0,130	0,219	b
Spontaneous fermentation	1,14 ± 0,109	0,207	b
Fermentation with culture *Lactobacillus plantarum*	0,29 ± 0,014	-	a

Notes: Mean values accompanied by the same letter mean not significantly different at p≥0.05

Table 10 shows that the average ash content of cassava flour in the fermentation method treatments ranged from 0.29-1.30%. The treatment of fermentation method with *Lactobacillus plantarum* culture produced the lowest ash content of 0.29%, while the treatment of cassava without fermentation produced the highest ash content of 1.30%. With the fermentation process, the ash content decreased. Safitri *et al*. (2016) stated that minerals in the fermentation process can increase the availability of carbon and nitrogen that can be used by microbes as an energy source. Mineral functions such as phosphorus (P) are needed by microbes as part of the formation of nucleic acids, phospholipids and coenzymes. Potassium functions as an inorganic cation in cells and as a cofactor for several enzymes. Manganese (Mn) is needed by microbes as an enzyme cofactor. These minerals are needed by microorganisms as electron acceptors for the metabolism of glucose and other carbohydrates (Malaka *et al*., 2013).

The pregelatinization temperature treatment did not give a significant effect on the ash content of cassava flour. The average value of cassava flour ash content in pregelatinization temperature treatment can be seen in **Table 11.**

Average value of ash content of cassava flour pregelatinization temperature treatment

Pregelatinization Temperature	Ash Content (%)	DMRT	Notation
45°C	0.81,± 0,473	0,207	a
50°C	0,86 ± 0,492	-	ab
55°C	0,94 ± 0,563	0,219	ab
60°C	1.03 ± 0,629	0,223	b

Notes: Mean values accompanied by the same letter mean not significantly different at p≥0.05

Table 11 shows that the average ash content of cassava flour in the pregelatinization temperature treatment ranged from 0.81-1.03%. The 45°C pregelatinization temperature treatment produced the lowest ash content of 0.81%, while the 60°C pregelatinization temperature produced the highest ash content of 1.03%. An increase in pregelatinization temperature causes the ash content to increase. The increase in ash content is related to the moisture content. Low moisture content indicates that more residue is left in cassava flour so that this affects the increasing ash content. This is in accordance with Susanto and Saneto (1994) that the water content of dried foodstuffs will experience a higher decrease and cause the concentration of materials left behind, one of which is minerals. Minerals that are classified as inorganic nutrients are referred to as ash elements in food, because it turns out that if food is burned, organic elements will disappear and the remaining organic material (ash) consists of minerals. Sudarmadji *et al.* (1994) said that the ash component easily decomposes or even evaporates at high temperatures. However, pregelatinization temperature did not significantly affect the increase in ash content. This is because in the heating process the temperature used is not high so the difference is not significant. This is in accordance with the statement of Marta *et al*. (2017) that the ash content will not change in the modification process because the heat given in the modification process is not able to burn the ash and the hydrolysis reaction does not reach the minerals contained in the material.

4. Levels Starch

Based on the analysis of variance (Appendix 5), it can be seen that there is no significant interaction ($p \geq 0.05$) between the treatment of fermentation method and pregelatinization temperature on the starch content of cassava flour. However, each treatment of fermentation method and pregelatinization temperature gave a significant effect on the starch content of cassava flour. The average value of cassava starch content with the treatment of fermentation method and pregelatinization temperature can be seen in **Table 12.**

Table 12: Average value of starch content of cassava flour treated with fermentation method

Fermentation Method	Starch Content (%)	DMRT	Notation
Without fermentation	75,09 ± 0,725	-	a
Spontaneous fermentation	75,99 ± 0,772	0,906	a
Fermentation with culture *Lactobacillus plantarum*	77,95 ± 0,812	0,956	b

Notes: Mean values accompanied by the same letter mean not significantly different at p≥0.05

Table 12 shows that the average starch content of cassava flour in the fermentation method treatment ranged from 75.09-77.28%. The treatment of cassava without fermentation produced the lowest starch content of 75.09% while fermented cassava with *Lactobacillus plantarum* culture produced the highest starch content of 77.28%. Cassava flour with fermentation treatment has a higher starch content compared to cassava flour without fermentation. This is related to the decrease in water content of cassava flour. During fermentation, microorganisms produce extracellular amylolytic enzymes that can hydrolyze some of the starch resulting in starch granule shafts that cause water to evaporate easily. Water that is easily evaporated causes the water content of cassava tepug processed by the fermentation method to decrease. In the research of Erni *et al.,* (2018) showed the results of increased starch content because more water is evaporated so that the content of ingredients such as carbohydrates will be more concentrated.

Pregelatinization temperature treatment gave a significant effect on the starch content of cassava flour. The average value of cassava starch content in heating temperature treatment can be seen in **Table 13.**

Average value of starch content of cassava flour pregelatinization temperature treatment

Pregelatinization Temperature	Starch Content (%)	DMRT	Notation
45°C	75,49 ± 1,174	-	a
50°C	76,02 ± 1,157	0,906	ab
55°C	76,59 ± 1,189	0,956	bc
60°C	77,28 ± 1,250	0,973	c

Notes: Mean values accompanied by the same letter mean not significantly different at p≥0.05

Table 13 shows that the average starch content of cassava flour in the pregelatinization temperature treatment ranged from 75.49-77.28%. The 45°C pregelatinization temperature treatment produced the lowest starch content of 75.49%, while the 60°C pregelatinization temperature produced the highest starch content of 77.28%. The higher the heating temperature, the higher the starch content. This is due to the water content which is closely related to the starch content. According to Winarno (2004), carbohydrate (starch) is one of the important components in determining the value of water absorption. Starch is a compound that is hydrophyric. Starch granules have a very large ability to absorb water due to the large number of starch hydroxyl groups, therefore the smaller the water content, the higher the starch content. The presence of heating and increasing the heating temperature, the greater the heat received by the material, resulting in the expansion and development of the starch granule structure. The development of the material structure causes the cavity in the material to become wider and easier to absorb water, but it is easy to release water during the drying process (Pratiwi *et al*., 2020).

5. Levels Amylose

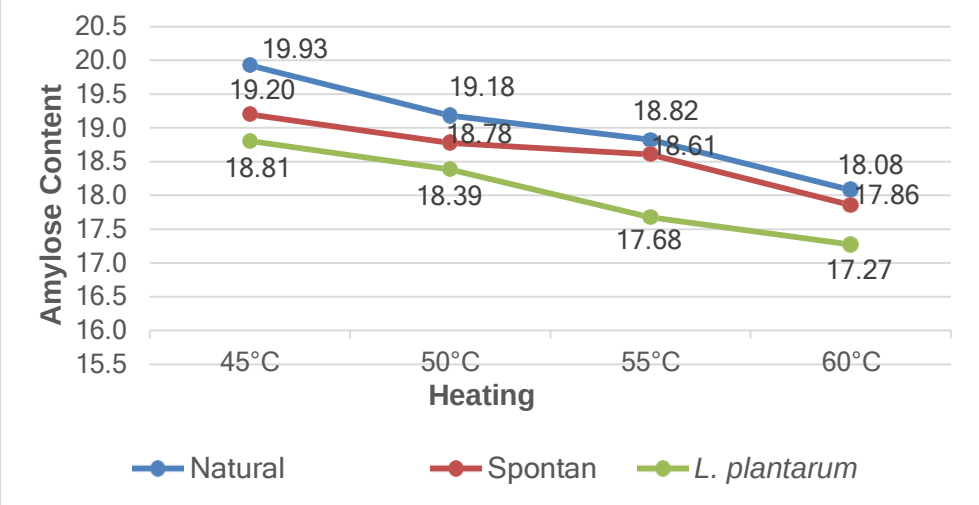
Based on the analysis of variance (Appendix 6), it can be seen that there is a significant interaction (p ≥ 0.05) between the treatment of fermentation method and pregelatinization temperature on the amylose content of cassava flour. Each treatment had a significant effect on the amylose content of cassava flour produced. The average value of amylose content of cassava flour with the treatment of fermentation method and pregelatinization temperature can be seen in **Table 14.**

Average value of amylose content of cassava flour treated with fermentation method and pregelatinization temperature

Treatment		Amylose Content (%)	DMRT	Notation
Fermentation Method	**Pregelatinization Temperature**			
Without fermentation	45°C	19,93 ± 0,105	0,321	h
	50°C	19,18 ± 0,137	0,320	g
	55°C	18,82 ± 0,135	0,319	f
	60°C	18,08 ± 0,113	0,304	cd
Spontaneous fermentation	45°C	19,20 ± 0,146	0,321	g
	50°C	18,78 ± 0,114	0,316	f
	55°C	18,61 ± 0,139	0,313	ef
	60°C	17,86 ± 0,130	0,299	bc
Fermentation with *L plantarum*	45°C	18,81 ± 0,139	0,318	ef
	50°C	18,39 ± 0,122	0,306	d
	55°C	17,68 ± 0,126	0,283	b
	60°C	17,27 ± 0,146	-	a

Notes: Mean values accompanied by the same letter mean not significantly different at p ≥ 0.05.

Table 14 shows that the average amylose content of cassava flour ranged from 19.93-17.27%. The treatment of fermentation method with *L plantarum* and pregelatinization temperature of 60°C produced the lowest amylose content of 17.27%, while unfermented cassava produced the highest amylose content and pregelatinization temperature of 45, 19.93%. The graph of the relationship between the treatment of fermentation method and pregelatinization temperature on the amylose content of cassava flour can be observed in **Figure 9.**



Amylose content of cassava flour treated with fermentation method and pregelatinization temperature.

Figure 9 shows that fermentation can cause a decrease in amylose content. This is because the microbial fermentation process produces extracellular amylolytic enzymes that cause amylose to hydrolyze into simpler compounds. The enzyme will cut carbohydrates at the endo-1,4 bond and the pululanase enzyme will cut carbohydrates at the endo-1,6 bond to produce short-chain oligosaccharides or simple sugar molecules (Nurhayati, 2011). Furthermore, microbes will utilize the monosaccharides from hydrolysis as raw materials to produce organic acids, especially lactic acid (Subagio, 2006). The higher the pregelatinization temperature, the lower the amylose content. This is because an increase in temperature causes the hydrogen bonds of starch to become weak, which makes it easier for water to enter the granule, resulting in amylose coming out of the granule. This is in accordance with Pratiwi *et al*. (2020) that heat energy causes starch hydrogen bonds to weaken. Weak bonds make it easier for water to enter the granule, causing the granule to expand and facilitating amylose to leave the granule. Some amylose is soluble and some is insoluble. Furthermore, research (Haryanti *et al*., 2014) showed that amylose levels decreased due to an increase in temperature, which can result in the starch constituent component being amylose with a low molecular weight. Amylose that has been formed is depolymerized at high temperature heating so that amylose has a low molecular weight. Amylose in starch tends to limit gelatinization because amylose diffuses out during development and forms a continuous network outside the granule while amylopectin has greater development ability (Odenigbo *et al*., 2013).

6. Degrees White

Based on the analysis of variance (Appendix 7), it can be seen that there is a significant interaction ($p \leq 0.05$) between fermentation method and pregelatinization temperature. Each treatment significantly affects the degree of whiteness of the cassava flour produced. The average value of white degree of cassava flour with the treatment of fermentation method and pregelatinization temperature can be seen in **Table 15.**

Table 15: Mean white degree of cassava flour treated with fermentation method and pregelatinization temperature.

Treatment		Degree of Whiteness (%)	DMRT	Notation
Fermentation Method	**Pregelatinization Temperature**			
Without fermentation	45°C	82,77 ± 0,255	0,881	d
	50°C	82,67 ± 0,283	0,876	d
	55°C	82,16 ± 0,481	0,868	cd
	60°C	81,70 ± 0,580	0,858	c
Spontaneous fermentation	45°C	79,92 ± 0,410	0,844	b
	50°C	79,74 ± 0,240	0,829	b
	55°C	79,64 ± 0,113	0,785	b
	60°C	78,79 ± 0,396	-	a
Fermentation with *L plantarum*	45°C	87,08 ± 0,368	0,890	g
	50°C	86,56 ± 0,396	0,889	g
	55°C	85,49 ± 0,226	0,887	f
	60°C	84,14 ± 0,325	0,885	e

Notes: Mean values accompanied by the same letter mean not significantly different at p ≥ 0.05.

Based on **Table 15.** states that the degree of whiteness of cassava flour ranges from 78.79-87.08%. The treatment of spontaneous fermentation with pregelatinization temperature of 60°C produced the lowest whiteness of 78.79%, while the treatment of fermentation method with *Lactobacillus plantarum with* pregelatinization temperature of 45°C produced the highest whiteness of 87.08%. The graph of the relationship between fermentation method treatment and pregelatinization temperature on the degree of whiteness of cassava flour can be observed in **Figure 10.**

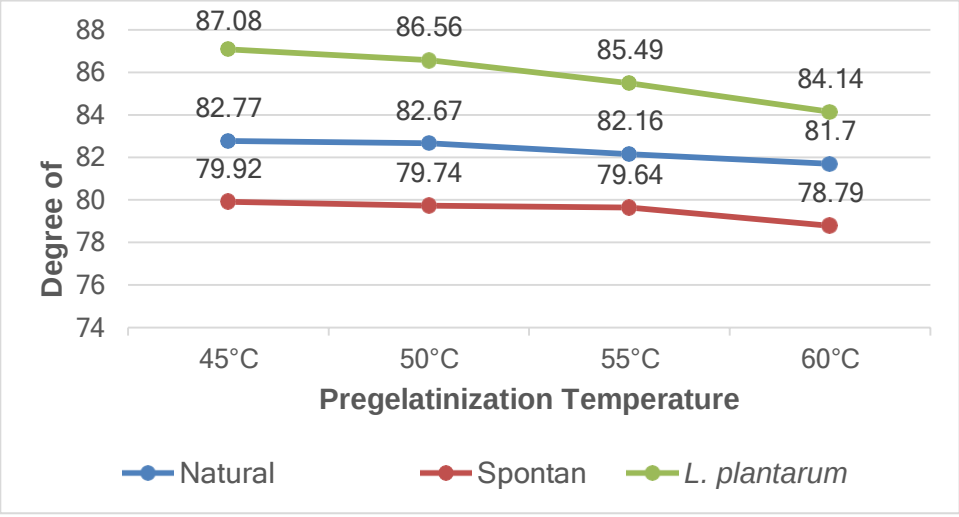


Figure 10. Degree of whiteness of cassava flour treated with fermentation method and heating temperature

Figure 10 shows that fermentation using *Lactobacillus plantarum* produces a higher degree of whiteness compared to cassava without fermentation and cassava with spontaneous fermentation. This is because in the fermentation process microbes can degrade pigmented compounds. This is in accordance with Iswari *et al.* (2016) that the fermentation process produces MOCAF with an increasingly white color caused by the degradation of complex compounds by microorganisms so that the pigmented material contained in the material also breaks down and dissolves in water. However, the heating temperature treatment causes a decrease in the degree of whiteness, the higher the heating temperature used, the lower the degree of whiteness produced. The presence of heating causes the chemical components in the cells to dissolve so that the higher the heating temperature, the more it dissolves the chemical components. According to Palupi *et al*. (2011) the process of cell destruction causes the solution in the cell to come out to interact with air and then react with oxygen to form color components. This is in accordance with Belitz and Groszh (1987) the interaction of amino components and monosaccharides, followed by the release of water, will form *intermediary imine* compounds or N glycosides. N glycoside is an initial product that can then form *Amadori* compounds *(Amadori rearrangement).* This compound is an intermediate product, which in turn is a series of *Maillard* reactions, namely reactions that cause brown color in foodstuffs.

7. Solubility

Based on the analysis of variance (Appendix 8), it can be seen that there is a significant interaction ($p \leq 0.05$) between fermentation method and pregelatinization temperature. Each treatment significantly affected the solubility of cassava flour produced. The average value of solubility of cassava flour with the treatment of fermentation method and pregelatinization temperature can be seen in **Table 16.**

Average value of solubility of cassava flour treated with fermentation method and pregelatinization temperature**.**

Treatment		Solubility (%)	DMRT	Notation
Fermentation Method	**Pregelatinization Temperature**			
Without fermentation	45°C	4,66 ± 0,023	-	a
	50°C	5,05 ± 0,087	0,290	b
	55°C	5,83 ± 0,032	0,306	c
	60°C	8,23 ± 0,104	0,317	e
Spontaneous fermentation	45°C	7,60 ± 0,079	0,311	d
	50°C	8,67 ± 0,061	0,323	f
	55°C	9,17 ± 0,085	0,325	g
	60°C	10,61± 0,154	0,327	i
Fermentation with *L plantarum*	45°C	8,35 ± 0,107	0,320	ef
	50°C	9,82 ± 0,006	0,326	h
	55°C	11,93± 0,266	0,328	j
	60°C	13,72± 0,263	0,329	k

Notes: Mean values accompanied by the same letter mean not significantly different at p ≥ 0.05.

Based on **Table 16.** shows that the average solubility of cassava flour in the treatment of fermentation method and pregelatinization temperature ranged from 4.66-13.72%. The treatment of cassava without fermentation and pregelatinization temperature of 45°C produced the lowest solubility of 4.66%, while the treatment of fermented cassava with *Lactobacillus plantarum* and pregelatinization temperature of 60°C produced the highest solubility of 13.72%. The graph of the relationship between fermentation method treatment and pregelatinization temperature on the solubility of cassava flour can be observed in **Figure 11.**

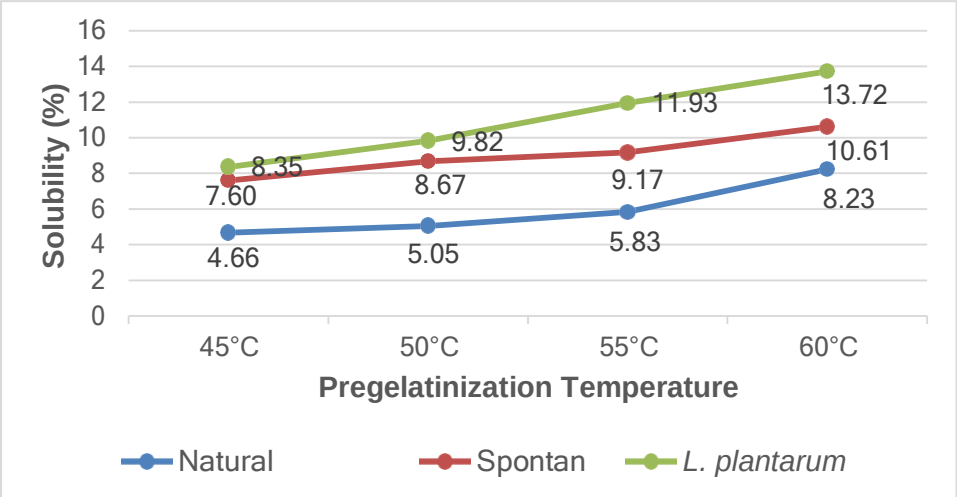


Figure 11: Solubility of cassava flour in fermentation method and pregelatinization temperature

Figure 11. shows that the presence of fermentation and increasing pregelatinization temperature increased the solubility. The fermentation treatment produced cassava flour with higher solubility compared to the cassava treatment without fermentation. This is due to the liberation of starch granules during fermentation, thus increasing starch solubility. This is in accordance with Subagio (2007) that microbes that grow during the fermentation process will produce cellulolytic and pectinolytic enzymes that can cause liberation of starch granules. The more enzymes produced, the more starch granule liberation that can increase s t a r c h solubility. Marcon *et al.* (2009) further explained that fermented cassava starch granules have higher solubility compared to starch without fermentation. This is due to the amylose molecules in fermented cassava starch being partially hydrolyzed. The release of amylose from starch granules will increase its solubility and reduce its density.

The fermentation process followed by pregelatinization with increasing temperature can cause hydrogen bonds to break so that the starch fraction is partially broken into shorter chains, with a smaller molecular size, it is easy to dissolve in water (Baah, 2009). In addition, the increase in solubility is related to the moisture content of cassava flour. According to Prabasini *et al.* (2013), the lower the moisture content, the higher the solubility. Low flour moisture content causes flour to disperse more easily in water, resulting in higher solubility.

8. Swelling Power

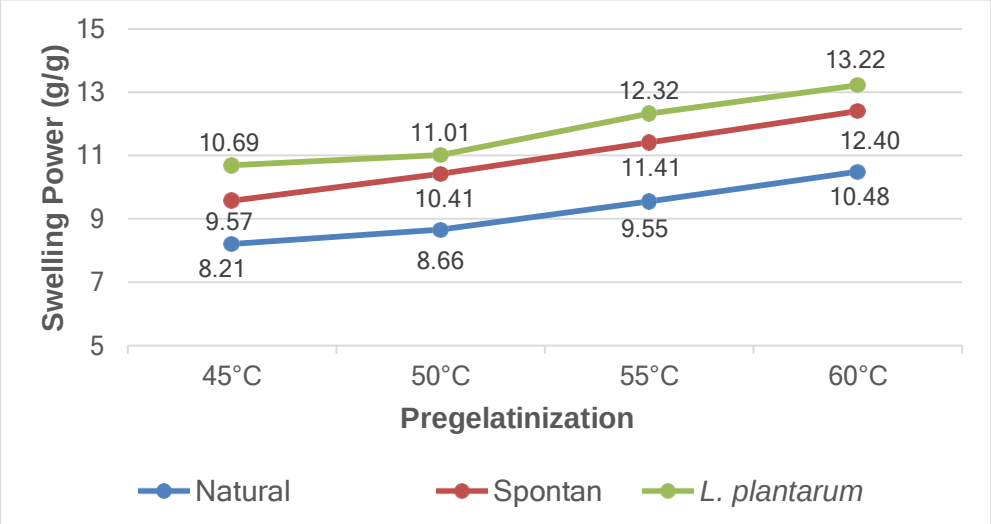
Based on the analysis of variance (Appendix 9), it can be seen that there is a significant interaction ($p \leq 0.05$) between fermentation method and pregelatinization temperature. Each treatment significantly affected the *swelling power of* cassava flour produced. High *swelling power* value is good for *bakery* products that require large development (Kaur *et al*., 2011). The average value of *swelling power of* cassava flour with the treatment of fermentation method and pregelatinization temperature can be seen in **Table 17.**

Table 17: Average value of *swelling power of* cassava flour treated with fermentation method and pregelatinization temperature.

Treatment		*Swelling Power* (g/g)	DMRT	Notation
Fermentation Method	**Pregelatinization Temperature**			
Without fermentation	45°C	8,21 ± 0,173	-	a
	50°C	8,66 ± 0,092	0,202	b
	55°C	9,55 ± 0,087	0,213	c
	60°C	10,48± 0,076	0,223	de
Spontaneous fermentation	45°C	9,57 ± 0,029	0,217	c
	50°C	10,41 ± 0,124	0,221	d
	55°C	11,41 ± 0,115	0,227	g
	60°C	12,40 ± 0,076	0,228	h
Fermentation with *L plantarum*	45°C	10,69 ± 0,044	0,225	e
	50°C	11,01 ± 0,088	0,226	f
	55°C	12,32 ± 0,006	0,228	h
	60°C	13,22 ± 0,077	0,229	i

Notes: Mean values accompanied by the same letter mean not significantly different at p ≥ 0.05.

The average swelling power of cassava flour in **Table 17** ranged from 8.21-13.22 g/g. The treatment of unfermented cassava with pregelatinization temperature of 45°C resulted in the lowest swelling power of 8.21 g/g, while the treatment of fermented cassava with *Lactobacillus plantarum* and pregelatinization temperature of 60°C resulted in the highest swelling power of 13.22 g/g. The graph of the relationship between the treatment of fermentation method and pregelatinization temperature on the *swelling power of* cassava flour can be observed in **Figure 12.**



Swelling power of cassava flour treated with fermentation method and pregelatinization temperature

Figure 12 shows that the fermentation method and pregelatinization temperature had a significant effect on *swelling power*. The fermentation treatment and the higher pregelatinization temperature can increase the *swelling power* value of cassava flour. The fermentation treatment produced cassava flour with higher *swelling power* compared to cassava without fermentation. This is due to the activity of extracellular amylase enzymes produced by LAB during fermentation that can cut the straight bonds of amylose which will be degraded into simpler compounds, so that the amylose content decreases. According to Li and Yeh (2001), there is a negative correlation between *swelling power* and amylose content, where the *swelling power* value decreases with increasing amylose content.

The fermentation process followed by pregelatinization with increasing temperature can accelerate the release of amylose in the granule caused by the weakening of hydrogen bonds, thus increasing the *swelling power* value. An increase in pregelatinization temperature results in higher *swelling power*. In **Figure 12, it is** known that the higher the pregelatinization temperature, the higher the *swelling power of the* cassava flour produced. This is caused by hydrogen bonds that connect amylose and amylopectin are weakened so that some amylose comes out of the granule which causes the proportion of amylopectin to increase. This is in accordance with the statement of Jading *et al.* (2011), that the increase in expandability due to heating at higher temperatures is due to lower amylose or higher amylopectin levels. In addition, hydrogen bonds connecting amylose and amylopectin molecules are disrupted and weakened, which will disrupt the cohesiveness of starch granules. Water molecules will bond with hydroxyl groups on amylose and amylopectin, causing the starch granules to enlarge and the *swelling power* value to increase (Indrastuti, 2012). The swelling power value is also influenced by differences in the amount or composition of amylose and amylopectin. According to Putri and Zubaidah (2017), the ability of granules to expand during gelatinization has a negative correlation with amylose content (because the carrier of *swelling* properties is amylopectin).

9. Absorbability Water

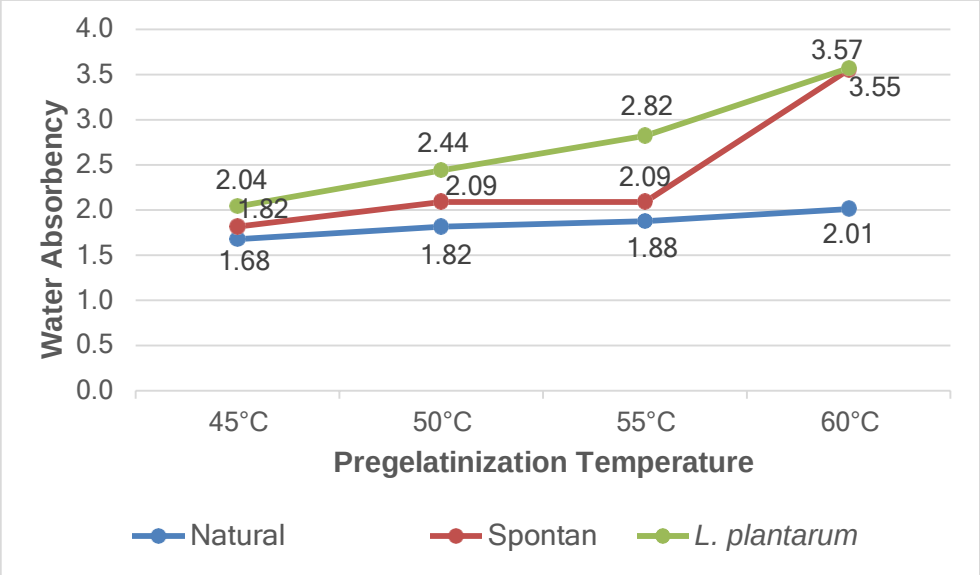
Based on the analysis of variance (Appendix 10), it can be seen that there is a significant interaction ($p \leq 0.05$) between the type of fermentation and pregelatinization temperature. Each treatment had a significant effect on the water absorption of cassava flour produced. Water absorption is a parameter that shows the amount of ability to attract water around it to bind to material particles or retained in the pores between material particles (Trisyulianti *et al*., 2001). The average value of water absorption of cassava flour with the treatment of fermentation type and pregelatinization temperature can be seen in **Table 18.**

Table 18: Average value of water absorption of cassava flour treated with fermentation type and pregelatinization temperature.

Treatment		Water Absorbency (ml/g)	DMRT	Notation
Methods Fermentation	**Temperature Pregelatinization**			
Without fermentation	45°C	1,68 ± 0,141	-	a
	50°C	1,82 ± 0,113	0,491	a
	55°C	1,88 ± 0,154	0,528	a
	60°C	2,01 ± 0,043	0,537	a
Spontaneous fermentation	45°C	1,82 ± 0,392	0,518	a
	50°C	2,09 ± 0,008	0,548	a
	55°C	2,09 ± 0,282	0,551	ab
	60°C	3,55 ± 0,294	0,556	d
Fermentation with *L plantarum*	45°C	2,04 ± 0,344	0,543	a
	50°C	2,44 ± 0,213	0,553	bc
	55°C	2,82 ± 0,059	0,555	c
	60°C	3,57 ± 0,252	0,557	e

Notes: Mean values accompanied by the same letter mean not significantly different at $p \geq 0.05$.

Based on **Table 18.** shows that the average water absorption of cassava flour in the treatment of fermentation method and pregelatinization temperature ranged from 1.68-3.57 ml/g. The treatment of unfermented cassava with pregelatinization temperature of 45°C produced the lowest water absorption of 1.68 ml/g, while the treatment of fermented cassava with *Lactobacillus plantarum* and pregelatinization temperature of 60°C produced the highest water absorption of 3.57 ml/g. The graph of the relationship between the treatment of fermentation method and pregelatinization temperature on the water absorption of cassava flour can be observed in **Figure 13.**



Water absorption of cassava flour in the treatment of fermentation method and pregelatinization temperature

Figure 13 states that the fermentation treatment of cassava can increase the water absorption capacity of cassava flour. This is because during fermentation, the starch structure changes from crystalline to amorphous and porous. Granules that have many pores cause the ability to trap water that enters the shaft to increase. Wronkowska *et al*. (2006) explained that fermentation of wheat starch, potato starch and pea starch by lactic acid bacteria for 24 hours showed changes in microstructure, namely the formation of globular and lamellar structures. The change in starch structure to be more porous (amorphous) increases the ability to release amylose (Sajilata *et al*., 2006). This is in accordance with Dayad (2009) who stated that the porous starch structure makes it easier for water to seep into the material, and the high water absorption is related to the amylose content in flour. The lower the amylose content, the higher the absorbency (Suarni, 2009).

The fermentation process followed by pregelatinization with increasing temperature can cause starch granules to become more porous, thus increasing water absorption. The water absorption capacity of cassava flour increases as the pregelatinization temperature increases. This is due to the presence of heat which causes hydrogen bonds between starch granules.

Starch molecules are weakened so that water easily enters into the starch granules. According to Kartika (2010), heating treatment that is too long can cause macromolecules that are initially relatively compact to become somewhat porous because they break down into simple molecules with a small mass weight so that they are rather tenuous and more easily absorb water. This is in accordance with the statement of Puspitaningtyas (2004) in Susanti (2015) which explains that flour treated with *blanching* will have a greater porosity so that it can make it easier for flour to absorb water.

10. Absorbability Oil

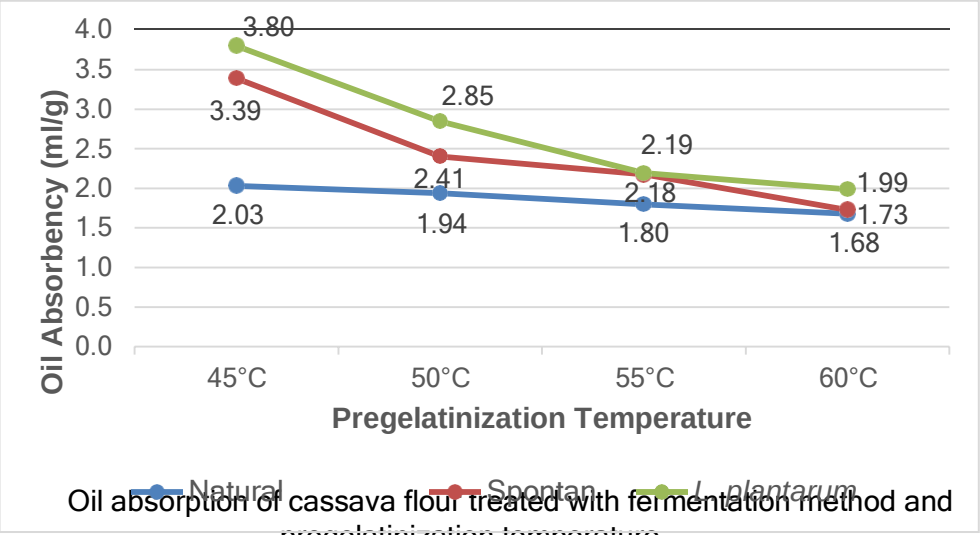
Based on the analysis of variance (Appendix 11), it can be seen that there is a significant interaction ($p \leq 0.05$) between the type of fermentation and pregelatinization temperature. Each treatment had a significant effect on the oil absorption of cassava flour produced. The ability to absorb oil in flour indicates that flour has lipophilic parts in its constituent components (Falade *et al*., 2014). The average value of oil absorption of cassava flour with the treatment of fermentation type and pregelatinization temperature can be seen in **Table 19.**

Table 19: Average value of oil absorption of cassava flour treated with fermentation method and pregelatinization temperature.

Treatment		Oil Absorbency (ml/g)	DMRT	Notation
Methods Fermentation	**Temperature Pregelatinization**			
Without fermentation	45°C	2,03 ± 0,078	0,288	cd
	50°C	1,94 ± 0,057	0,282	bcd
	55°C	1,80 ± 0,001	0,278	abc
	60°C	1,68 ± 0,133	0,258	a
Spontaneous fermentation	45°C	3,39 ± 0,008	0,292	g
	50°C	2,41 ± 0,197	0,292	e
	55°C	2,18 ± 0,140	0,290	de
	60°C	1,73 ± 0,203	0,273	ab
Fermentation with *L plantarum*	45°C	3,80 ± 0,039	0,293	h
	50°C	2,85 ± 0,075	0,292	f
	55°C	2,19 ± 0,134	0,291	de
	60°C	1,99 ± 0,129	0,286	bcd

Notes: Mean values accompanied by the same letter mean not significantly different at $p \geq 0.05$.

Based on **Table 19, the** oil absorption ranged from 1.68-3.80 ml/g. The treatment of unfermented cassava with pregelatinization temperature of 45°C produced the lowest oil absorption of 1.68 ml/g, while the treatment of fermentation with *Lactobacillus plantarum* with pregelatinization temperature of 45°C produced the highest oil absorption of 3.80 ml/g. The graph of the relationship between fermentation type and pregelatinization temperature on the oil absorption capacity of cassava flour can be observed in **Figure 14.**



Oil absorption of cassava flour treated with fermentation method and pregelatinization temperature

Figure 14 shows that fermentation method and pregelatinization temperature had a significant effect on oil absorption. Spontaneous fermentation and fermentation with *Lactobacillus plantarum* produced cassava flour with higher oil absorption compared to unfermented cassava. This is because during fermentation there is liberation of starch granules which causes changes in starch structure. According to Diniyah *et al*. (2018), the rupture of starch granules will make the hydrophobic structure of the granules that were originally on the inside open out so that starch has the ability to bind oil. In addition, oil absorption is also influenced by protein in cassava. Gunawan *et al*. (2015) explained that cassava that underwent a fermentation process for 24 hours using *L. plantarum* culture increased protein levels from 1.93% to 2.94%. This is in accordance with Wulandari *et al.*

al., (2021) which states that the increase in protein content is obtained from the activity of proteinase enzymes produced by microbes and during the fermentation process the protein is also able to increase as the number of microorganisms that act as *single protein cells* (SPC) increases. However, the higher the pregelatinization temperature can reduce the oil absorption of pregelatinized cassava flour. The decrease in oil absorption is in line with the decrease in amylose because amylose has the ability to form complexes with oil (lipids) in the form of amylose-lipids. Further explained by Qin *et al.* (2016), that the higher the amylose content, the higher the oil absorption. According to Birt *et al.*, (2013) amylose is able to form single helix complexes with fatty acids and fatty alcohols. The linear chain of starch (amylose) in the helical structure will form a complex with fatty acids in the helical cavity. According to Mohamed *et al*. (1994), the addition of pragelatinized rice flour (13.78% amylose) to high amylopectin *rice dough* does not significantly affect oil absorption while oil absorption in low amylopectin *rice dough* will increase.

11. Organoleptic

Quality assessment of a food product encompasses a complex range of sensory properties. Sometimes the quality of the product is based on the intensity of specific sensory properties including taste, aroma, and color. One of the tests of the intensity of specific sensory properties is the scoring test referring to Susiwi (2009) which is based in the form of a scalar quantity or in the form of a numerical scale.

a. Color

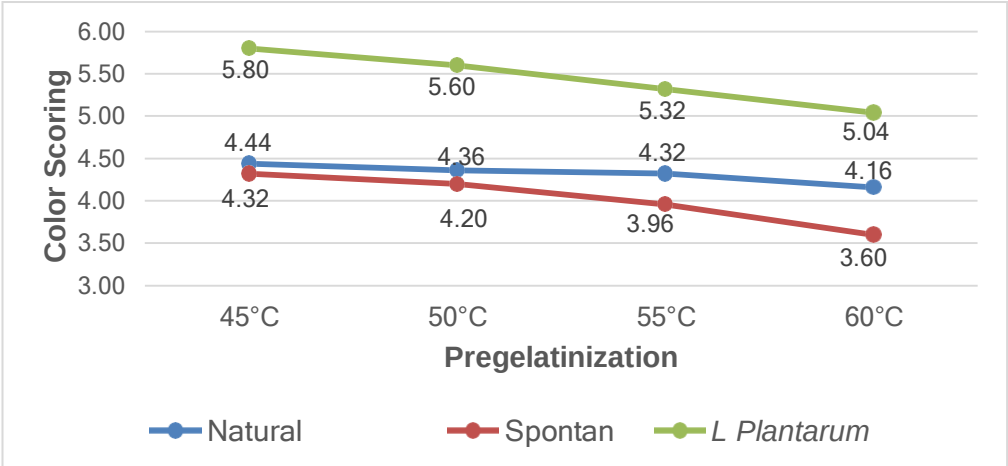
Based on the analysis of variance (Appendix 12), it can be seen that the treatment of fermentation method and pregelatinization temperature has a significant effect on the color of cassava flour. The average value of organoleptic color of cassava flour with the treatment of fermentation method and pregelatinization temperature can be seen in **Table 20**.

Table 20: Mean organoleptic value of color of cassava flour treated with fermentation method and pregelatinization temperature.

Treatment		Average	DMRT	Notation
Fermentation Method	**Pregelatinization Temperature**			
Without fermentation	45°C	4,44 ± 0,651	0,399	g
	50°C	4,36 ± 0,757	0,394	f
	55°C	4,32 ± 0,802	0,388	e
	60°C	4,16 ± 0,850	0,360	c
Spontaneous fermentation	45°C	4,32 ± 0,748	0,381	e
	50°C	4,20 ± 0,866	0,373	d
	55°C	3,96 ± 0,841	0,342	b
	60°C	3,60 ± 0,816	-	a
Fermentation with *Lactobacillus plantarum*	45°C	5,80 ± 0,408	0,413	k
	50°C	5,60 ± 0,707	0,412	j
	55°C	5,32 ± 0,852	0,407	i
	60°C	5,04 ± 0,889	0,403	h

Notes: Mean values accompanied by the same letter mean not significantly different at p ≥ 0.05

Table 20 shows that the average value of color *scoring of* cassava flour ranged from 3.60 to 5.80. The treatment of spontaneous fermentation method with pregelatinization temperature of 60°C produces the lowest color score of 3.60 which means white, while the treatment of fermentation method with *Lactobacillus plantarum* with pregelatinization temperature of 45°C produces the highest color score of 5.80 which means it has a very white color. The graph of the relationship between the treatment of fermentation type and pregelatinization temperature on the color value of cassava flour can be seen in **Figure 15.**



Organoleptic color of cassava flour treated with fermentation method and pregelatinization temperature**.**

Figure 15 shows that the fermentation method and pregelatinization temperature significantly affected the color value of cassava flour. The treatment of fermentation method with *Lactobacillus plantarum* produced a higher color value than cassava without fermentation and cassava with spontaneous fermentation. During fermentation, there is a decrease in pH caused by the increase in lactic acid so that the media conditions become acidic which allows the enzymatic browning reaction to be lower, causing the flour color to become whiter. This is in accordance with Porres *et al*., 2003; Winarno, 2004) that acidic conditions will block *maillard* reactions and reduce levels of browning-inducing compounds such as tannin, phytic acid, phenols, and trypsin inhibitors. In addition, during fermentation there is degradation of complex compounds by microorganisms which causes the pigmented material contained in the material to break down and dissolve in water, resulting in increasingly white *mocaf* flour (Iswari *et al.*, 2016).

The higher pregelatinization temperature treatment resulted in higher scores. The relatively yellowish color is due to the presence of chemical components in soluble granules that allow sugar and protein to react to produce brown pigments as a result of the *maillard* reaction. This is in accordance with Palupi *et al.* (2011) that the drying process in pregelatinized products allows soluble compounds such as sugar, amylose and protein to react to produce brown pigments which are the result of the *maillard* reaction.

b. Aroma

Based on the analysis of variance (Appendix 12), it can be seen that the treatment of fermentation method and pregelatinization temperature has a significant effect on the aroma of cassava flour. The average value of organoleptic aroma of cassava flour with the treatment of fermentation method and pregelatinization temperature can be seen in **Table 21**.

Table 21: Mean value of aroma organoleptic of cassava flour treated with fermentation method and pregelatinization temperature.

Treatment		Average	DMRT	Notation
Fermentation Method	**Pregelatinization Temperature**			
Without fermentation	45°C	4,16 ± 0,943	0,443	f
	50°C	4,04 ± 0,841	0,437	e
	55°C	3,68 ± 0,852	0,413	b
	60°C	3,56 ± 0,821	-	a
Spontaneous fermentation	45°C	3,88 ± 0,881	0,431	d
	50°C	3,84 ± 0,746	0,423	c
	55°C	3,56 ± 0,712	0,380	a
	60°C	3,56 ± 0,651	0,400	a
Fermentation with *Lactobacillus plantarum*	45°C	4,60 ± 0,707	0,458	g
	50°C	4,52 ± 0,872	0,457	h
	55°C	4,40 ± 0,707	0,451	i
	60°C	4,20 ± 0,866	0,447	j

Notes: Mean values accompanied by the same letter mean not significantly different at p ≥ 0.05

Table 21 shows that the average value of cassava flour aroma ranges from 3.56-4.60. The fermentation type treatment with *Lactobacillus plantarum* with a pregelatinization temperature of 45°C produces the highest aroma value of 4.60 which means it does not smell of cassava. Meanwhile, the treatment of no fermentation and spontaneous fermentation with heating temperatures of 55°C and 60°C produced the lowest aroma value of 3.56, which means a slight smell of cassava. The graph of the relationship between fermentation method treatment and pregelatinization temperature on the aroma value of cassava flour can be seen in **Figure 16.**

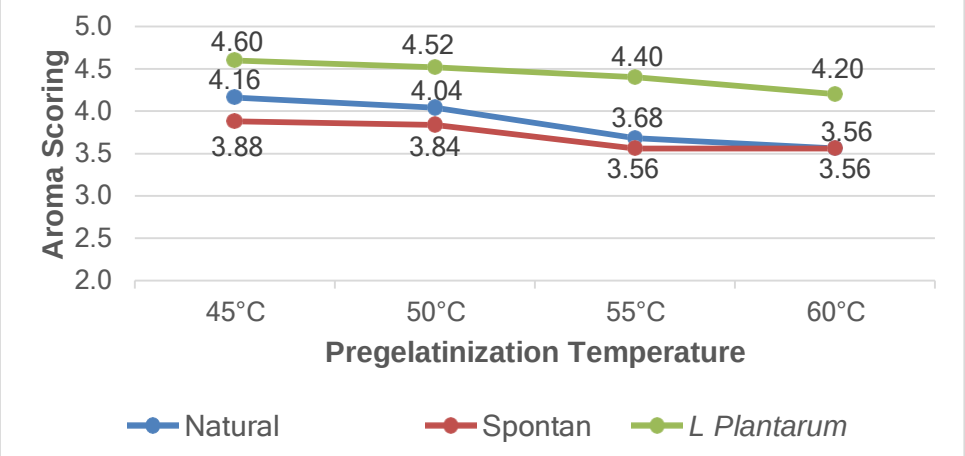


Figure 16: Organoleptic aroma of cassava flour treated with fermentation method and pregelatinization temperature.

Figure 16 shows that fermentation method and pregelatinization temperature significantly influenced the aroma value of cassava flour. The treatment of fermentation method with *Lactobacillus plantarum* has a high aroma value that does not smell of cassava compared to the treatment of cassava without fermentation and cassava with spontaneous fermentation which produces an average aroma value of slightly smelling cassava. The fermentation process produces lactic acid as a result of hydrolysis of starch and monosaccharides by microbial lactic acid bacteria. According to Wulandari *et al.* (2021) the aroma of cassava flour that undergoes a fermentation process can eliminate the aroma of raw materials because lactic acid bacteria produce organic acids formed from the hydrolysis of starch and monosaccharides.

The treatment with increasing pregelatinization temperature resulted in a decrease in aroma value. The decrease in aroma value is caused by heating with increasing temperature. This is in accordance with the research of Apriana *et al*. (2016) that the higher the heating temperature can cause a reduction in the aroma of the sweet potato produced. According to Fubar (2011) the excessive *blanching* process can cause the product to overcook and lose flavor and nutritional components because these components are dissolved into the heating medium.

c. Texture

Based on the analysis of variance (Appendix 12), it can be seen that the treatment of fermentation method and pregelatinization temperature has a significant effect on the texture of cassava flour. The average value of organoleptic texture of cassava flour with the treatment of fermentation method and pregelatinization temperature can be seen in **Table 22**.

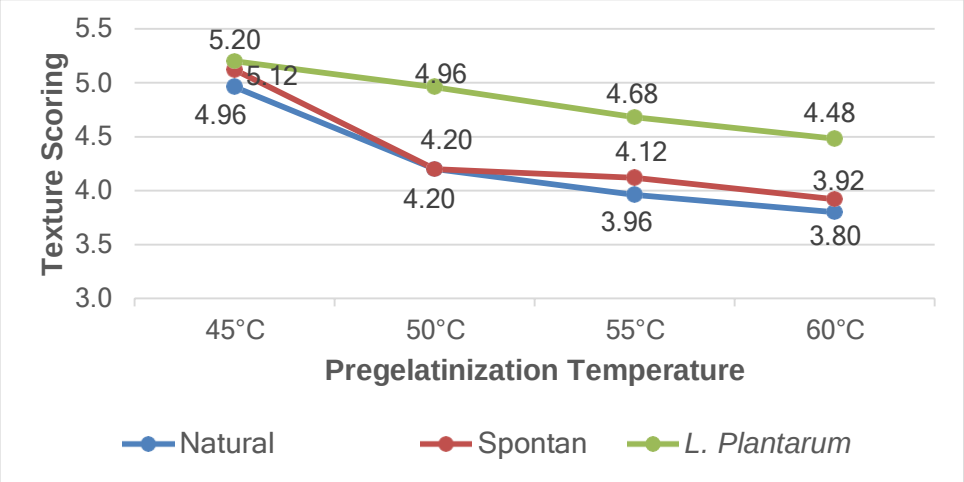
Table 22: Mean value of organoleptic texture of cassava flour treated with fermentation method and gelatinization temperature.

Treatment		Average	DMRT	Notation
Fermentation Method	**Pregelatinization Temperature**			
Without fermentation	45°C	4,96 ± 0,889	0,458	h
	50°C	4,20 ± 0,866	0,441	e
	55°C	3,96 ± 0,841	0,409	c
	60°C	3,80 ± 0,707	-	a
Spontaneous fermentation	45°C	5,12 ± 0,781	0,468	i
	50°C	4,20 ± 0,816	0,433	e
	55°C	4,12 ± 0,781	0,423	d
	60°C	3,92 ± 0,812	0,389	b
Fermentation with *Lactobacillus plantarum*	45°C	5,20 ± 0,816	0,469	j
	50°C	4,96 ± 0,935	0,462	h
	55°C	4,68 ± 0,852	0,453	g
	60°C	4,48 ± 0,918	0,448	f

Notes: Mean values accompanied by the same letter mean not significantly different at p ≥ 0.05

Table 22 shows that the average color value of cassava flour ranges from 3.80 to 5.20. The treatment without fermentation with a pregelatinization temperature of 60°C produced the lowest texture value of 3.80 which means smooth, while the treatment of the non-spontaneous fermentation method with a pregelatinization temperature of 45°C produced the highest texture value of 5.20 which means it has a very smooth texture.

The graph of the relationship between fermentation method treatment and pregelatinization temperature on the texture value of cassava flour can be seen in **Figure 17.**



Organoleptic texture of cassava flour treated with fermentation method and pregelatinization temperature

Figure 17 shows that the fermentation method and pregelatinization temperature significantly affect the texture value of cassava flour. The treatment of cassava that undergoes a fermentation process produces a high texture value (very smooth) compared to cassava without fermentation which produces an average smooth texture value. This is because during the fermentation process microbes produce cellulolytic and peknolytic enzymes that can degrade cellulose cell walls resulting in damaged cassava cell tissue and soft cassava. This is in accordance with Nusa *et al*. (2012) that the fermentation process produces pectinolytic enzymes and cellulolytic enzymes, with so many of these two enzymes, the breakdown of starch and cellulose into fine granules will be higher, causing the texture of the mocaf to be smoother. Increasing pregelatinization temperature treatment results in a decreasing texture value. This is due to heat treatment which causes changes in the structure and size of the granules. According to Palupi *et al*. (2011), the pregelatinization process causes starch granules to expand, and change shape even though they remain in a layer or fragment that surrounds them.

C. Decision Analysis

Selection of the best treatment of cassava flour is based on analysis using the *Multiple Attribute* Method of Zeleny (1982). The best treatment selection assessment procedure was carried out by determining the ideal value of each parameter followed by calculating the density degree (dk) and density distance (Lp). The best treatment was selected from treatments that had minimal L1, L2, and L values. This method is determined based on the parameters analyzed. These parameters include: yield, moisture content, ash content, starch content, amylose content, degree of whiteness, solubility, *swelling* power, water absorption, oil absorption, and organoleptic *scoring* (including color, aroma and texture). The analysis table for determining the best treatment for organoleptic characteristics of cassava flour can be seen in **Table 23.**

Table 23: Results of the analysis of determining the best treatment for organoleptic characteristics of cassava flour

Treatment		L1	L2	Max L	Best Treatment
Fermentation Method	**Pregelatinization Temperature**				
Without fermentation	45°C	0,1254	0,0074	0,0782	0,2110
	50°C	0,1874	0,0126	0,0828	0,2828
	55°C	0,2312	0,0180	0,0851	0,3343
	60°C	0,2594	0,0226	0,0943	0,3762
Spontaneous fermentation	45°C	0,1424	0,0100	0,0851	0,2374
	50°C	0,2111	0,0156	0,0920	0,3187
	55°C	0,2503	0,0217	0,1057	0,3777
	60°C	0,2839	0,0284	0,1264	0,4387
Fermentation with *Lactobacillus plantarum*	45°C	0,0000	0,0000	0,0000	0,0000*
	50°C	0,0327	0,0004	0,0154	0,0485
	55°C	0,0754	0,0021	0,0333	0,1108
	60°C	0,1188	0,0049	0,0462	0,1698

Description: *=best treatment

Based on **Table 23, the** fermentation treatment with *Lactobacillus plantarum* and pregelatinization temperature of 45°C had the lowest total L1, L2, and L Max values on organoleptic parameters. This indicates that the treatment is the best treatment for organoleptic properties. The results of organoleptic testing of cassava flour on color, aroma and texture parameters show that the smaller the pregelatinization temperature used, the more it increases. It is suspected that the smaller the pregelatinization temperature used, the lower the dissolution of several chemical components in flour and starch cells such as sugar, amylose, and protein. In addition, heating can cause starch granules to expand and change shape (Palupi *et al*., 2011). Meanwhile, the fermentation process can produce flour with a smooth texture. This is caused by pectinolytic enzymes and cellulolytic enzymes that can break down starch and cellulose, causing a smoother flour texture (Nusa *et al.*, 2012).

The best treatment of physicochemical characteristics (Appendix 13) of cassava flour is also important and closely related to its functional properties and applications. The analysis table for determining the best treatment of physicochemical characteristics of cassava flour can be seen in **Table 24.**

Table 24: Analysis results of determining the best treatment for physicochemical characteristics of cassava flour

Treatment		L1	L2	Max L	Best Treatment
Fermentation Method	**Pregelatinization Temperature**				
Without fermentation	45°C	0,3402	0,0180	0,3402	0,6983
	50°C	0,3344	0,0171	0,3344	0,6859
	55°C	0,3233	0,0164	0,3233	0,6630
	60°C	0,2980	0,0147	0,2980	0,6107
Spontaneous fermentation	45°C	0,2699	0,0122	0,2699	0,5520
	50°C	0,2637	0,0109	0,2637	0,5383
	55°C	0,2628	0,0116	0,2628	0,5371
	60°C	0,2138	0,0105	0,2138	0,4382
Fermentation with *Lactobacillus plantarum*	45°C	0,1531	0,0048	0,1531	0,3111
	50°C	0,1533	0,0034	0,1533	0,3100
	55°C	0,1471	0,0040	0,1471	0,2981
	60°C	0,0905	0,0032	0,0905	0,1841*

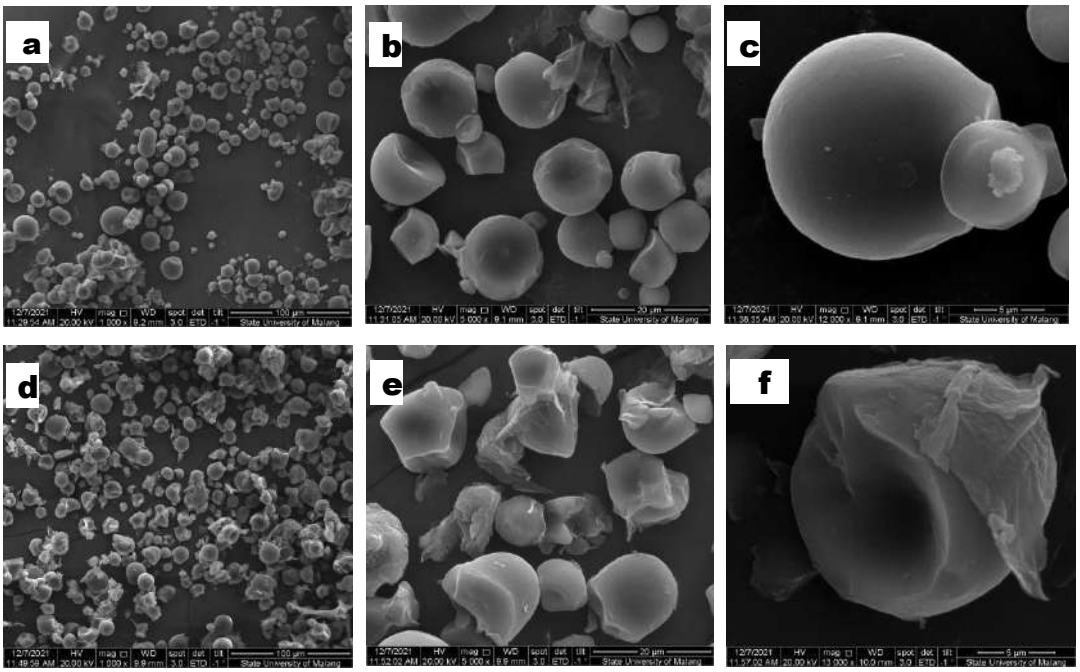
Description: *=best treatment

Based on **Table 24,** the best treatment of physicochemical properties of cassava flour with the *Multiple Atribrute* method shows that the treatment of fermented cassava with *Lactobacillus plantarum* and pregelatinization temperature of 60°C with the smallest total value. The results of testing the physicochemical properties of ash content and moisture content parameters show that the fermentation process and the higher the pregelatinization temperature can cause a decrease in moisture content and ash content and reduce yield, amylose content, and oil absorption capacity of cassava flour, while the higher the heating temperature and the presence of the fermentation process can increase starch content, *swelling power*, solubility and water absorption.

Based on the analysis of determining the best treatment for organoleptic and physicochemical characteristics, the best treatment was obtained, namely cassava flour with fermentation treatment with *Lactobacillus plantarum* and pregelatinization temperature of 60 ° C which has the characteristics of color 5.04, aroma 4.20, texture 4.68, yield 18.18%, moisture content 6.32%, ash content 0.31%, starch content 5.04, aroma 4.20, texture 4.68, and yield 18.18%. 74.26%, amylose content 17.24%, whiteness 84.14%, solubility 13.72%, *swelling power* 13.22 g/g, water absorption 3.57 ml/g, and oil absorption 1.99 ml/g.

D. Microscopic Structure

Changes in the shape and size of cassava starch granules can be seen using SEM (*Scanning Electrone Microscope*). Observations were made on cassava flour with spontaneous fermentation treatment (Ladang Lima) and the best treatment cassava flour, namely fermentation treatment using *Lactobacillus plantarum* and pregelatinization temperature of 60°C. The results of microscopic structure observation can be seen in **Figure 18.**



Microscopic form of (a) Spontaneously fermented cassava flour 1000x magnification, (b) Spontaneously fermented cassava flour 5000x magnification**.**
(c) Spontaneous fermentation cassava flour 13000x magnification, (d) Best treatment cassava flour 1000x magnification, (e) Best treatment cassava flour 5000x magnification, (f) Best treatment cassava flour 13000x magnification.

SEM results were carried out at primary electron beam acceleration energy from a 20kV (*High Voltage*) wolfram wire source using magnifications of 1000x, 5000x, and 12000x. According to research by Srichuwong et al (2005), flour that has not undergone a physical modification process has a smoother and more intact surface than flour that has been modified. It is also reinforced by Rohaya's research (2013) which shows that theanan treatment causes starch granules to swell and then absorb more water.

Figure 18 (a) to (c) shows fermented cassava flour

spontaneous without pregelatinization temperature treatment (Ladang Lima), while Figure 25 (d) to (f) shows cassava flour treated with fermentation with *Lactobacillus plantarum* and pregelatinization temperature of 60°C. In **Figure 18** (a) spontaneous fermentation cassava flour (Ladang Lima) shows that the appearance of some starch granules is regular round and some do not have a regular shape with a slightly hollow surface. This is due to the spontaneous fermentation treatment which can produce amylase and cellulolytic enzymes so that there is amylase and cellulolytic enzyme activity that can damage cell walls. However, in spontaneous fermentation cassava flour there is no contact with heat so it does not cause starch granules to expand, while **Figure 18** (d) shows observations of cassava flour granules fermented with *Lactobacillus plantarum* and pregelatinization temperature of 60°C showing granules in the form of *polygonal* (containing many) with more starch granules that are hollow, causing an increasingly irregular shape and larger granule size.

Fermented cassava flour treatment with *Lactobacillus plantarum* and pregelatinization temperature of 60°C shown in Figure 25 has many starch granules with holes so that most of the granule shapes are not uniform compared to spontaneously fermented cassava flour. This is because cassava is fermented by adding *Lactobacillus plantarum* stater*. The* addition of this stater causes microorganisms to grow and multiply actively compared to spontaneous fermentation which breeds naturally due to its living environment. This is indicated by the pH value of cassava fementation with *Lactobacillus plantarum* which is smaller than the pH value of spontaneously fermented cassava. According to Kartikasari *et al*. (2016), an increase in the number of acid-producing microbes causes a decrease in pH during fermentation. With an increase in the number of microbes, there are more amylolytic enzymes that can hydrolyze starch so that starch granules are hollow. According to Subagio (2006), changes in starch granules are caused by the activity of cellulolytic enzymes that begin to intensify in degrading cell wall cellulose, so that the cell wall is damaged and starch granules are liberated. Due to the presence of extracellular amylolytic enzymes, the liberated granules are then partially hydrolyzed on the surface.

granules resulting in starch granules with holes. Furthermore, the heating also causes changes in the starch granules. With the addition of pregelatinization treatment, the starch granules appear to expand with an increasingly irregular shape. The irregular granule shape is caused by more starch granules with holes. In the research of Pratiwi *et al*. (2020), heating resulted in more cell wall components that expanded and almost separated from the starch granules. This is because during heating, water is absorbed into the starch granules so that the strength of hydrogen bonds is weakened, resulting in increased *swelling power*. According to research by Srichuwong *et al.,* (2005) flour that has not undergone a physical modification process has a smoother and more intact surface than modified flour. Heating can cause many hydrogen bonds to be broken so that water can be absorbed into the starch granules which results in the structure of the starch granules becoming more open and absorbing more water so that the granules swell. This is reinforced by the research of Rohaya (2013) which shows that heat treatment causes starch granules to swell and then absorb more water.

E. Amylographic Properties

The amylographic properties of flour were analyzed using a *Rapid Visco Analyzer* (RVA). Analysis of amylographic properties was carried out on spontaneously fermented cassava flour samples (Ladang Lima) and the best treatment cassava flour, namely fermentation treatment with *Lactobacillus plantarum* and pregelatinization temperature of 60°C. Based on amylographic properties, the values of gelatinization peak temperature, gelatinization peak time, peak viscosity, hot viscosity, final viscosity, *breakdown viscosity* and *setback viscosity* can be known. The results of the analysis of amylographic properties of flour can be seen in **Table 25** and **Figure 19.**

Table 25: Characteristics of amylographic properties of spontaneously fermented cassava flour (Ladang Lima) and cassava flour fermented with *Lactobacillus plantarum* and pregelatinization temperature of 60°C.

No.	Test Type	Unit	Analysis Result	
			A2	A3B4
1.	Peak Viscosity (PV)	Cp	4286	6825
2.	Hot Viscosity (HPV)	Cp	1447	1743
3.	Viscosity decrease due to Cooking (BD)	Cp	2839	5082
4.	Final Viscosity (FV)	Cp	2268	2923
5.	Increased Viscosity due to Cooling (SB)	Cp	821	1180
6.	Peak Time	Minutes	6.53	6.33
7.	Thickening Temperature (PT)	°C	72.80	72.05

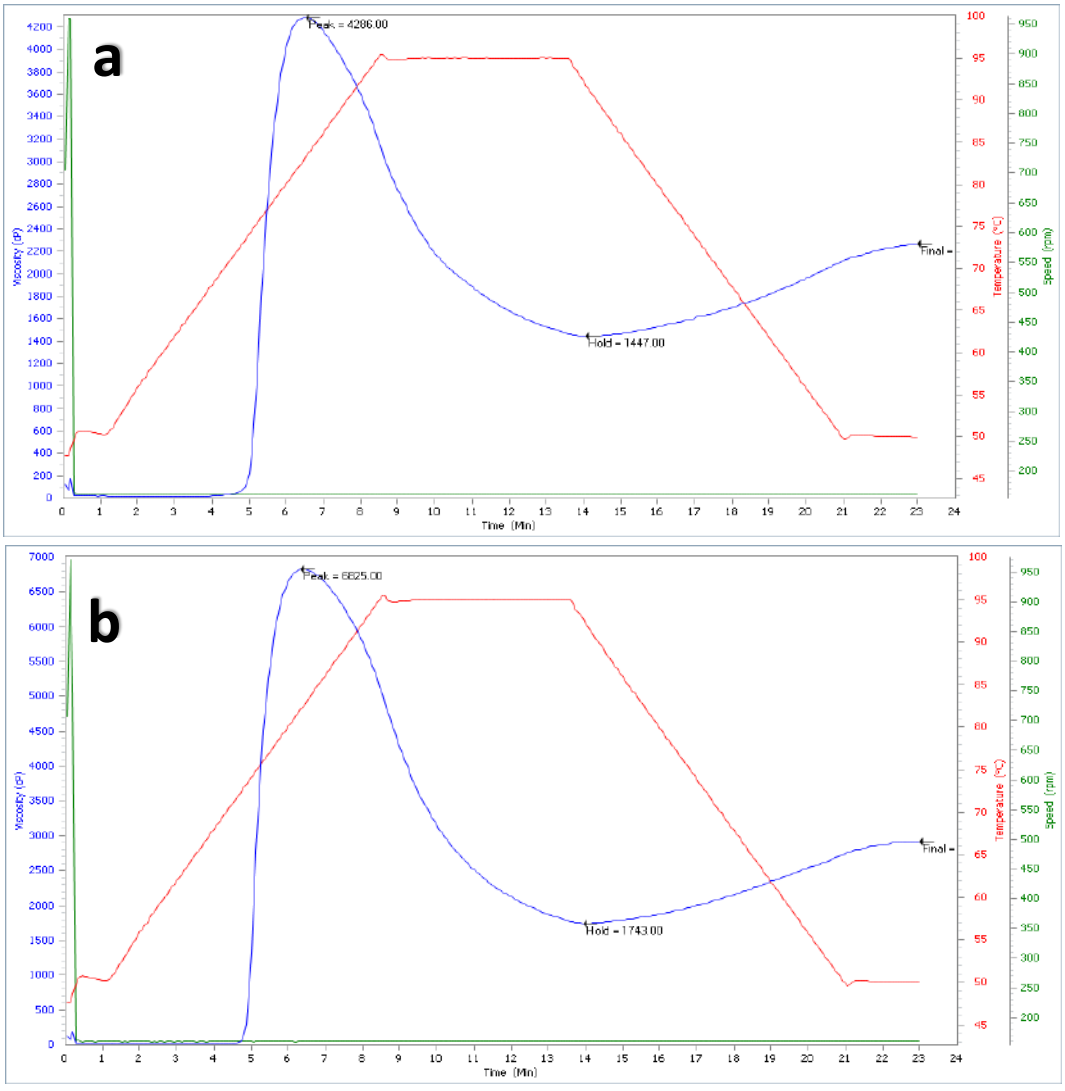


Figure 19. (a) RVA analysis graph of spontaneously fermented cassava flour (Ladang Lima), (b) RVA analysis graph of fermented cassava flour with *Lactobacillus plantarum* and pregelatinization temperature of 60°C.

1. Initial Gelatinization Temperature

The initial gelatinization temperature is the temperature at which viscosity first rises due to *irreversible* swelling of starch granules or cannot return to its original form. Based on the results of RVA analysis in **Table 25, it** shows that the value of the initial gelatinization temperature of cassava flour fermented with *Lactobacillus plantarum* and pregelatinization temperature of 60°C is lower than that of spontaneously fermented cassava flour. Cassava flour treated with fermentation with *Lactobacillus plantarum* and pregelatinization temperature of 60°C has an initial gelatinization temperature of 72.05°C while spontaneous fermentation cassava flour is 72.80°C. This shows that cassava flour with the treatment is easier to cook and will shorten the processing process. The decrease in the initial gelatinization temperature in cassava flour treated with fermentation with *Lactobacillus plantarum* and pregelatinization temperature of 60°C is due to changes in the bond structure where hydrogen bonds between amylose and amylopectin are weakened due to heating. According to Singh-Sodhi and Singh (2005), the stronger the bonds between starch molecules, the higher the amount of heat required to break the bonds between molecules and therefore, the higher the gel temperature. Furthermore, according to Murtiningrum *et al*. (2012), gelatinization temperature besides depending on granule size is also closely related to amylose content. Cassava flour with heating treatment can cause bonds to weaken, making it easier for water to enter the starch granules which causes the granules to expand and facilitates amylose out of the granules (Pratiwi *et al*., 2020). Research conducted by Honestin (2007) showed that sweet potato flour without pre-cooking treatment has a higher initial gelatinization temperature compared to flour with pre-cooking treatment.

2. Gelatinization Peak Time

The peak gelatinization time is the time required to reach the peak viscosity value or the occurrence of peak gelatinization (Syafutri, 2015). In Table 25, cassava flour with fermentation treatment using *Lactobacillus plantarum* and pregelatinization temperature of 60°C has a shorter gelatinization peak time of 6.33 minutes, while cassava flour with spontaneous fermentation (Ladang Lima) has a gelatinization peak time.

which is longer at 6.53 minutes. The decrease in gelatinization time indicates that the gelatinization process in fermented cassava flour with *Lactobacillus plantarum* and a pregelatinization temperature of 60°C is shorter than spontaneously fermented flour. The decrease in gelatinization time can be caused by weak hydrogen bonds between starch molecules due to heating. This is in accordance with Singh-Sodhi and Singh (2005) that the stronger the bonds between starch molecules, the higher the amount of heat required to break the bonds between molecules, therefore the higher the gelatinization temperature. According to Bunga *et al*. (2017), amylose-amylopectin levels affect the starch gelatinization process when associated with the gelatinization temperature. High levels of amylopectin in starch can facilitate the gelatinization process (Setiani *et al*., 2013).

3. Peak Viscosity

Peak viscosity represents high viscosity. The peak viscosity value shows the initial condition of gelatinized starch granules or reaches maximum development until it breaks. Based on the results of RVA analysis in **Table 26, it** shows that the peak viscosity value of cassava flour fermented with *Lactobacillus plantarum* and pregelatinization temperature of 60°C is higher than that of spontaneously fermented cassava flour. Fermented cassava flour with *Lactobacillus plantarum* and pregelatinization temperature of 60°C has a peak viscosity of 6825 cP while spontaneous fermented cassava flour is 4286 cP. The fermentation process using microbes that are able to produce pectinolytic enzymes and cellulolytic enzymes that can destroy the cassava cell wall which results in starch consisting of amylose and amylopectin coming out of the granule. In addition, heating can cause hydrogen bonds that maintain amylose and amylopectin molecules to weaken so that the higher kinetic energy of water can enter the starch granules which causes the granules to swell. According to Deetae *et al*. (2008), peak viscosity describes the fragility of the expanding starch granule, which is when it first expands until it breaks due to the stirring process. Peak viscosity is influenced by various factors including amylose content, protein,

fat, and granule size. Peak viscosity values reflect the ability of the granule to bind water and maintain swelling during heating (Syamsir *et al*., 2011).

4. Hot Viscosity

Hot viscosity is the minimum viscosity during the holding period at 95°C (Winarsa *et al*., 2013). **Table 25** shows that the hot viscosity value of cassava flour fermented with *Lactobacillus plantarum* and pregelatinization temperature of 60°C has a higher value of 1743 cP, while cassava flour with spontaneous fermentation (Ladang Lima) has a lower hot viscosity value of 1447 cP. Heating treatment can weaken starch granules by the interaction between amylose molecules located in amorphous regions and amylopectin located in crystalline regions. According to Sun *et al*. (2007), the higher the temperature used, it will increase the crystallability of starch due to changes in the structure of starch granules and increase the partial transition of amorphous to crystalline regions. Furthermore, Hormdok *et al*. (2007) stated that the increase resulted in more stable starch during heating.

5. Viscosity Drop due to Cooking (*Breakdown*)

Breakdown is a measurement of the condition where the swollen starch granules begin to subside and stabilize during cooking (Adebowale and Lawal, 2003). **Table 25** shows that the *breakdown* value of cassava flour fermented with *Lactobacillus plantarum* and pregelatinization temperature of 60°C has a higher value of 5082 cP, while spontaneously fermented cassava flour (Ladang Lima) has a lower value of 2839 cP. The heating process can weaken hydrogen bonds and there are even some hydrogen bonds that are broken. This causes water to be absorbed or enter the granule which can cause amylose to be released into the water phase that envelops the granule, so that the granule will swell. According to Imam *et al*. (2014), a high breakdown value during the heating process indicates that starch granules that have completely swollen have fragile properties and are not resistant to heat.

6. Viscosity Increase due to Cooling (*Setback*)

Setback or viscosity change during cooling is a measurement of recrystallization of gelatinized starch during cooling (Beta and Corke, 2011). **Table 25** shows that the *setback* value of cassava flour fermented with *Lactobacillus plantarum* and pregelatinization temperature of 60°C has a higher value of 1180 cP, while spontaneously fermented cassava flour (Ladang Lima) has a lower value of 821 cP. The heating process can cause amylose to come out of the granule so that it has a tendency to increase retrogradation. This shows that the fermentation treatment with *Lactobacillus plantarum* and pregelatinization temperature of 60°C experienced faster retrogradation compared to spontaneously fermented flour (Ladang Lima). The high *setback* value indicates a high tendency for retrogradation to occur. The higher *setback* value indicates a high tendency to gel (increase viscosity) during cooling (Marta, 2016). According to Aprianita *et al.,* (2010) a low viscosity setback value is important for frozen or chilled products.

7. Final Viscosity

Final viscosity is a parameter that shows the ability of starch to form a thick paste or gel after the heating and cooling process and the resistance of the paste to shear forces that occur during stirring (Budiyanto and Yuliyanti, 2012). **Table 25** shows that the final viscosity value of cassava flour with fermentation treatment using *Lactobacillus plantarum* and pregelatinization temperature of 60°C is higher than that of cassava flour with spontaneous fermentation (Ladang Lima) with values of 2923 and 2268 cP, respectively. The increase in viscosity occurs due to heating which can cause hydrogen bonds between amylose and amylopectin to weaken or even break. The weakening of starch granule bonds will cause the soluble amylose fraction to escape from the granule. This can cause the proportion of amylopectin to increase. Increased

This amylopectin can cause higher viscosity. This is in accordance with Imaningsih (2012) that when starch is heated with excess water above its gelatinisation temperature, starch granules with higher amylopectin content will swell more than those with lower content. According to Hegenbart (1996), the higher the amylopectin content, the higher the viscosity.

CHAPTER V
CONCLUSION AND SUGGESTIONS

A. Conclusion

1. The results of the analysis of variance showed that there was a significant interaction between the type of fermentation and pregelatinization temperature on yield, moisture content, degree of whiteness, solubility, *swelling* power, water absorption, oil absorption and organoleptic tests (color, aroma and texture) of cassava flour. However, there was no significant interaction on ash content, starch content, and amylose content of cassava flour.
2. The results of this study obtained the best treatment, namely cassava flour with fermentation treatment with *Lactobacillus plantarum* culture and pregelatinization temperature of 60 ° C. It has the characteristics of color 5.04, aroma 4.20, texture 4.48, yield 18.18%, moisture content 6.32%, ash content 0.31%, starch content 78.96%, amylose content 17.24%, whiteness 84.14%, solubility 13.72%, *swelling power* 13.22 g/g, water absorption 3.57 ml/g, and oil absorption 1.99 ml/g; microscopic structure of starch granules of flour fermented with *Lactobacillus plantarum* culture and pregelatinization temperature 60 ° C, the surface shape is porous and swollen compared to spontaneously fermented cassava flour (Ladang Lima); and amylographic properties of flour include gelatinization temperature 72.05°C; gelatinization peak time 6.33 minutes; peak viscosity 6825 cP; hot viscosity 1743 cP; viscosity decrease due to cooking 5082 cP; final viscosity 2923 cP; and viscosity increase due to cooling 1180 cP.

B. Advice

1. Further research needs to be done on the application of products related to cassava flour.
2. Further research is needed to determine the shelf life of cassava flour.

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Appendix 1. Analysis Procedure

A. Moisture Content (AOAC, 2012 925.10)

1. The dish was oven dried at 1300C for 15 minutes, then cooled in a desiccator for 10 minutes. The dried dishes were weighed before use.
2. About 2 g of sample was weighed into the cup.
3. The dish was placed in an oven at 130°C for 1 hour.
4. The cup was cooled in a desiccator and weighed until the weight was constant. Moisture content was calculated using the following formula:

$$\text{Moisture content (\%bk)} = a\text{-}(b\text{-}c) \text{ x } 100 \text{ \%}$$

Description:

a: initial sample weight (g)

b: weight of sample and cup after drying (g) c:

weight of empty cup (g)

B. Ash Content (AOAC, 2012 923.03)

1. The porcelain cup was dried in a 1050C oven for 15 minutes and cooled in a desiccator.
2. The dry porcelain cup was weighed and recorded the weight before use.
3. Samples of 3.0-5.0 g were weighed in the porcelain cup and placed in an electric furnace at 5500C until complete ashing.
4. After the ashing is complete, the sample cup is cooled in a desiccator, and weighed. Weighing is repeated until a fixed weight is obtained. Calculation of ash content is done using the following formula:

$$\text{Ash content (\%)} = \frac{C - A}{B - A} \, x \, 100\%$$

Description:

a: weight of empty cup (g)

b: weight of cup + initial sample (g)

c: weight of cup + dry sample (g)

C. Starch content by *Direct Acid Hydrolysis* method (AOAC, 2005)

1. A 5 gram sample was dissolved with 50 ml of distilled water in a glass cup.
2. The resulting suspension was then filtered with filter paper and washed with distilled water until the filtrate volume was 250 ml.
3. The suspension was filtered again with filter paper. The residue contained in the filter paper was then transferred into an erlenmeyer by washing with 200 ml of distilled water and adding 20 ml of 25% HCl.
4. The Erlenmeyer was covered with a counter cooler and simmered on a water bath for 2.5 hours.
5. The erlenmeyer was then cooled at room temperature. The sample in the erlenmeyer was neutralized with 45% NaOH and diluted to a volume of 500 ml.
6. Then the sample is filtered again with filter paper. The sugar content calculated as glucose is determined from the filtrate obtained. The weight of glucose was multiplied by a conversion factor of 0.9.

Starch content (%bk) = X x fp x 100 x 0.9/mg sampleWhere X = table number

fp = dilution factor

D. Yield (AOAC, 2005)

The yield is obtained from the number of kilograms of product formed from each kilogram of material processed.

$$\text{Yield } (\%) = \frac{Berat\ produk\ yang\ dihasilkan\ (gr)}{Berat\ bahan\ baku\ (g)} x\ 100\%$$

E. Amylose Content (AOAC, 2005)

1. 100 mg of starch was put into a 100 ml volumetric flask and then 95% ethanol and 9 ml of 1 N NaOH were added.
2. The solution was left for 23 hours at room temperature or heated in a 100˚C water bath for 10 minutes and cooled for 1 hour.

3. The solution was then diluted with distilled water to 100 ml, pipetted as much as 5 ml, put into a 100 ml volumetric flask containing 60 ml of water.
4. The solution in the volumetric flask was added 1 ml of 1N acetic acid and 2 ml of 2% I2 and diluted to a volume of 100 ml.
5. The solution was shaken and allowed to stand for 20 minutes, then the absorbance was measured at a wavelength of 620 nm. Amylose content was calculated with the following formula:

Amylose content (%) = $\frac{A620 \times fk \times 100}{100\text{-}k.a}$ X 100%

Where fk =1X abs 1 ppm $\frac{1000 \times 20}{1000000}$

F. Swelling Power (Kaur *et al*., 2011)

1. A modified starch sample of 0.1 g was put into a test tube then 10 ml of distilled water was added and mixed until homogeneous.
2. The suspension was then heated in a water bath at 60°C for 30 minutes.
3. Furthermore, the suspension was cooled, then the supernatant was separated from the solution by centrifuge at 2500 rpm for 15 minutes, after which it was decanted.
4. The paste is then taken out and weighed. Swelling power is calculated based on the equation below.

$$Swelling\ Power\ (g/g) = \frac{berat\ pasta\ pati\ (g)}{berat\ sampel\ kering\ (g)}$$

G. Solubility (Kaur *et al*., 2011)

1. A modified starch sample of 0.1 g was put into a test tube then 10 ml of distilled water was added and mixed until homogeneous.
2. The suspension was then heated in a *water bath* at 60°C for 30 minutes.

3. Next, the suspension was cooled, then the supernatant was separated from the solution by centrifuge at 2500 rpm for 15 minutes.
4. Then the supernatant was decanted and dried in an oven to 105°C until the weight was constant. Solubility can be calculated based on the equation below:

$$Kelarutan\ (\%) = \frac{berat\ padatan\ terlarut\ disupernatan(g)}{berat\ sampel\ kering\ (g)} x100$$

H. Water Absorbency (Subagio, 2006)

1. A total of 10 ml of distilled water was added to 1 gram *(dry basis) of* starch *MOCAF*.
2. The suspension was then stirred for 5 min and transferred into a centrifuge tube and centrifuged at 3,500 rpm for 30 min at 25°C.
3. The supernatant obtained was measured using a 10 ml measuring cup.
4. The water absorption value is calculated based on the water absorbed by the material after centrifugation per volume of initial water added.
5. The result is expressed as the percentage of water absorbed by starch in g/mL.

I. Oil Absorbency (Subagio, 2006)

1. 1 g of sample was put into a centrifuge tube and added with 10 ml of vegetable oil, then stirred with a spatula for 5 minutes.
2. The suspension was then centrifuged at 3500 rpm for 30 minutes.
3. After that, the oil is separated as a supernatant measured using a 10 ml measuring cup. The oil absorption value was calculated based on the amount of oil absorbed by the sample per volume of initial oil used. The percentage of oil absorption is expressed as g/mL of oil absorbed in starch.

J. Scoring Test (Susiwi, 2009)

SCORING TEST QUESTIONNAIRE

Name :

Date :

Product :Modified cassava flour

Instructions :You are presented with 12 samples ofmodified cassava flour. Evaluate the samples based on color, aroma and texture. Use the scale provided below to indicate your assessment of the quality attributes of each sample by giving your score.

Comparison Scale			Score
Color	**Aroma**	**Texture**	
Very white	Very not smelly cassava	Very fine	6
Very white	No cassava odor	Very smooth	5
White	Slight odor cassava	Smooth	4
Slightly white	Smells of cassava	Slightly smooth	3
Not white	Very smelly cassava	Not smooth	2
Not very white	Very smelly cassava	Not very smooth	1

Code	**Parameters**		
	Color	**Aroma**	**Texture**
127			
992			
841			
945			
256			
653			
117			
294			
479			
628			
279			
165			

The work steps of the scoring test with the acquisition of moderately trained panelists whose members are 25 people, scoring testing is carried out where panelists are asked to give scores on 12 cassava flour samples that have been coded.

randomly with 3 numbers. The parameters measured from the cassava flour are texture, aroma and color. The scale used is 1-6.

K. Amylography Profile with RVA (AACC, 2000)

1. A total of 3.0 g of sample (dry weight) was weighed in an RVA container, then 25 g of distilled water was added.
2. Measurements with the RVA include the heating and cooling process phases at constant stirring (160 rpm).
3. In the heating phase, the starch suspension is heated from 50° C to 95° C at a speed of 6° C/min, then maintained at that temperature (holding) for 5 minutes.
4. After the heating phase is completed, the starch paste is passed through the cooling phase, where the temperature is reduced from 95° C to 50° C at a rate of 6° C/min, then maintained at that temperature for 2 minutes.
5. The RVA instrument plots the gelatinization profile curve as the relationship of the viscosity value (cP) on the y-axis with the change in temperature (o C) during the heating and marinating phases on the x-axis.
6. Changes in the crystalline and amorphous regions of the starch structure were observed by X-ray diffraction. A small amount of sample is placed in a sample container, then inserted into the X-ray diffraction apparatus.
7. The analysis was performed at 40kV and 40 mA and scanned at 2 tetra 2-30° at room temperature in 0.02° increments. The data obtained is a curve of the relationship between 2 tetra° on the x-axis and the intensity (a.u.) on the y-axis

L. Morphology of Starch Granules (Srichuwong, 2006)

1. The starch powder is placed on top of the sample holder using double-side tape.
2. The sample is then coated with gold, and then inserted into the SEM instrument.
3. The starch structure was observed on a monitor screen using a magnification scale of 500 and 800 times. The observation results were then photographed using a digital camera.

Cassava Flour Yield Yield Analysis Data

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	24.782	24.959	49.741	24.870	0.125
A1B2	22.385	22.601	44.986	22.493	0.153
A1B3	21.451	22.019	43.470	21.735	0.402
A1B4	21.305	21.579	42.884	21.442	0.194
A2B1	23.724	23.684	47.408	23.704	0.028
A2B2	22.103	22.263	44.366	22.183	0.113
A2B3	20.578	20.845	41.423	20.711	0.189
A2B4	18.512	18.918	37.430	18.715	0.287
A3B1	23.529	22.997	46.526	23.263	0.376
A3B2	22.294	21.507	43.801	21.901	0.557
A3B3	20.778	20.471	41.250	20.625	0.217
A3B4	18.424	17.932	36.356	18.178	0.348
Total	191.246	190.197	519.640		
Average	21.250	21.133			

Two-way Table

A	B				Total	Average
	B1	B2	B3	B4		
A1	49.741	44.986	43.470	42.884	181.081	43.780
A2	47.408	44.366	41.423	37.430	170.627	41.073
A3	46.526	43.801	41.250	36.356	167.932	40.469
Total	143.674	133.154	126.143	116.669	519.640	
Average	47.891	44.385	42.048			

ANOVA Table

SK	DB	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	81.80	7.44	90.22*	2.72
A	2	12.06	6.03	73.16*	3.89
B	3	64.91	21.64	262.52*	3.49
AB	6	4.83	0.80	9.76*	3.00
Error	12	0.99	0.08		
Total	23	82.79			

Notes: *) significant effect or interaction (Fhitung>Ftabel)

DMRT Table

Sample Code	Average	A3B4	A2B4	A3B3	A2B3	A1B4	A1B3	A3B2	A2B2	A1B2	A3B1	A2B1	A1B1	P	SSR	LSR
		18.18	18.72	20.62	20.71	21.44	21.74	21.9	22.18	22.49	23.26	23.7	24.87			
A3B4	18.180															
A2B4	18.720	0.540												2	3.082	0.626
A3B3	20.620	2.440	1.900											3	3.255	0.661
A2B3	20.710	2.530	1.990	0.090										4	3.313	0.673
A1B4	21.440	3.260	2.720	0.820	0.730									5	3.370	0.684
A1B3	21.740	3.560	3.020	1.120	1.030	0.300								6	3.410	0.692
A3B2	21.900	3.720	3.180	1.280	1.190	0.460	0.160							7	3.439	0.698
A2B2	22.180	4.000	3.460	1.560	1.470	0.740	0.440	0.280						8	3.459	0.702
A1B2	22.490	4.310	3.770	1.870	1.780	1.050	0.750	0.590	0.310					9	3.474	0.705
A3B1	23.260	5.080	4.540	2.640	2.550	1.820	1.520	1.360	1.080	0.770				10	3.484	0.707
A2B1	23.700	5.520	4.980	3.080	2.990	2.260	1.960	1.800	1.520	1.210	0.440			11	3.490	0.709
A1B1	24.870	6.690	6.150	4.250	4.160	3.430	3.130	2.970	2.690	2.380	1.610	1.170	-	12	3.496	0.710
NOTATION		a	a	b	b	c	cd	cde	de	e	f	f	g	s.e		0.203

Water content of cassava flour Water content analysis data

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	9.398	9.379	18.777	9.389	0.013
A1B2	8.832	8.829	17.661	8.831	0.002
A1B3	8.744	8.658	17.402	8.701	0.061
A1B4	8.719	8.591	17.310	8.655	0.091
A2B1	9.246	9.328	18.574	9.287	0.058
A2B2	8.085	8.102	16.186	8.093	0.012
A2B3	7.767	7.864	15.630	7.815	0.069
A2B4	7.169	7.087	14.256	7.128	0.058
A3B1	9.170	9.056	18.227	9.113	0.081
A3B2	8.121	7.824	15.945	7.972	0.210
A3B3	7.814	7.939	15.754	7.877	0.088
A3B4	6.312	6.328	12.640	6.320	0.011
Total	99.377	98.984	198.361		
Average	8.281	8.249			

Two-way Table

	B				Total	Average
A	**B1**	**B2**	**B3**	**B4**		
A1	18.777	17.661	17.402	17.310	71.151	17.458
A2	18.574	16.186	15.630	14.256	64.646	15.357
A3	18.227	15.945	15.754	12.640	62.565	14.779
Total	55.577	49.792	48.786	44.206	198.361	
Average	18.526	16.597	16.262			

ANOVA Table

SK	DB	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	18.47	1.68	244.09	2.72
A	2	5.01	2.51	364.61	3.89
B	3	10.92	3.64	529.30	3.49
AB	6	2.53	0.42	61.31	3.00
Error	12	0.08	0.00688		
Total	23	18.55			

Notes: *) significant effect or interaction (Fhitung>Ftabel)

DMRT Table

Sample Code	Average	A3B4	A2B4	A2B3	A3B3	A3B2	A2B2	A1B4	A1B3	A1B2	A3B1	A2B1	A1B1	P	SSR	LSR
		6.320	7.128	7.815	7.877	7.972	8.093	8.655	8.701	8.831	9.113	9.287	9.389			
A3B4	6.320															
A2B4	7.128	0.808												2	3.082	0.181
A2B3	7.815	1.495	0.687											3	3.255	0.191
A3B3	7.877	1.557	0.749	0.062										4	3.313	0.194
A3B2	7.972	1.653	0.844	0.157	0.096									5	3.370	0.198
A2B2	8.093	1.773	0.965	0.278	0.216	0.121								6	3.410	0.200
A1B4	8.655	2.335	1.527	0.840	0.778	0.683	0.562							7	3.439	0.202
A1B3	8.701	2.381	1.573	0.886	0.824	0.729	0.608	0.046						8	3.459	0.203
A1B2	8.831	2.511	1.703	1.016	0.954	0.858	0.738	0.176	0.130					9	3.474	0.204
A3B1	9.113	2.793	1.985	1.298	1.237	1.141	1.020	0.458	0.412	0.283				10	3.484	0.204
A2B1	9.287	2.967	2.159	1.472	1.410	1.314	1.194	0.632	0.586	0.456	0.173			11	3.490	0.205
A1B1	9.389	3.069	2.261	1.574	1.512	1.416	1.296	0.734	0.688	0.558	0.275	0.102	-	12	3.496	0.205
NOTATION		**a**	**b**	**c**	**c**	**cd**	**d**	**e**	**e**	**e**	**f**	**fg**	**g**		**s.e**	**0.058**

Ash content Ash

content analysis data

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	1.238	1.095	2.334	1.167	0.101
A1B2	1.240	1.161	2.400	1.200	0.056
A1B3	1.341	1.317	2.659	1.329	0.017
A1B4	1.573	1.424	2.997	1.498	0.106
A2B1	1.109	0.865	1.973	0.987	0.172
A2B2	1.225	0.944	2.169	1.085	0.199
A2B3	1.262	1.143	2.405	1.203	0.084
A2B4	1.328	1.213	2.542	1.271	0.081
A3B1	0.257	0.289	0.546	0.273	0.023
A3B2	0.288	0.303	0.591	0.296	0.011
A3B3	0.295	0.298	0.593	0.297	0.002
A3B4	0.296	0.328	0.625	0.312	0.023
Total	11.452	10.382	21.834		
Average	0.954	0.865			

Two-way Table

	B					Average
A	**B1**	**B2**	**B3**	**B4**	**Total**	
A1	2.334	2.400	2.659	2.997	10.389	2.685
A2	1.973	2.169	2.405	2.542	9.089	2.307
A3	0.546	0.591	0.593	0.625	2.355	0.603
Total	4.853	5.161	5.657	6.163	21.834	
Average	1.618	1.720	1.886			

ANOVA Table

SK	DB	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	4.88	0.44	49.05	2.72
A	2	4.65	2.32	256.91	3.89
B	3	0.16	0.05	5.81	3.49
AB	6	0.07	0.01	1.38	3.00
Error	12	0.11	0.01		
Total	23	4.99			

Notes: *) significant effect or interaction (Fhitung>Ftabel)

DMRT Table Variable A

Sample Code	Average	A3	A2	A1	P	SSR	LSR
		0.294	**1.136**	**1.299**			
A3	0.294						
A2	1.136	0.842			2	3.082	0.207
A1	1.299	1.004	0.162	-	3	3.255	0.219
NOTATION		**a**	**b**	**b**	**s.e**		**0.067**

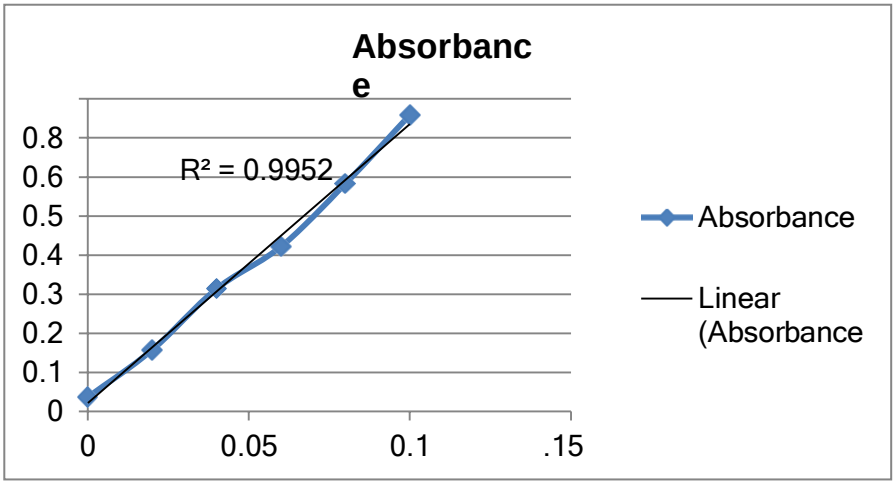
DMRT Table Variable B

Sample Code	Average	B1	B2	B3	B4	P	SSR	LSR
		0.809	**0.860**	**0.943**	**1.027**			
B1	0.809							
B2	0.860	0.051				2	3.082	0.207
B3	0.943	0.134	0.083			3	3.255	0.219
B4	1.027	0.218	0.167	0.084	-	3	3.313	0.223
NOTATION		**a**	**ab**	**ab**	**b**	**s.e**		**0.067**

Starch content of cassava flour Glucose

Standard Curve

Glucose Concentration	Absorbance
0	0.0365
0,02	0.1575
0,04	0.314
0,06	0.422
0,08	0.583
0,1	0.7585



Starch Content Analysis Data

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	74.111	74.418	148.529	74.265	0.217
A1B2	75.142	74.466	149.608	74.804	0.478
A1B3	75.876	74.821	150.697	75.348	0.746
A1B4	76.420	75.486	151.906	75.953	0.661
A2B1	74.995	75.286	150.281	75.141	0.206
A2B2	75.821	75.519	151.340	75.670	0.214
A2B3	76.320	76.127	152.447	76.223	0.136
A2B4	76.492	77.394	153.886	76.943	0.638
A3B1	77.032	77.119	154.151	77.076	0.061
A3B2	77.788	77.361	155.149	77.575	0.301
A3B3	77.892	78.493	156.385	78.193	0.426
A3B4	78.871	79.042	157.914	78.957	0.121
Total	916.760	915.534	1,832.2		
Average	76.397	76.294			

Two-way Table

A	B				Total	Aver age
	B1	B2	B3	B4		
A1	148.529	149.608	150.697	151.906	600.741	150.737
A2	150.281	151.340	152.447	153.886	607.954	152.558
A3	154.151	155.149	156.385	157.914	623.599	156.483
Total	452.962	456.097	459.529	463.706	1832.294	
Average	150.987	152.032	153.176			

ANOVA Table

SK	db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	44.82	4.07	23.60	2.72
A	2	34.14	17.07	98.86	3.89
B	3	10.65	3.55	20.55	3.49
AB	6	0.03	0.01	0.03	3.00
Error	12	2.07	0.17		
Total	23	46.89			

DMRT Table Variable A

Sampl e Code	Aver age	A1	A2	A3	P	SSR	LSR
		75.0926	75.9942	77.9499			
A1	75.0926						
A2	75.9942	0.9017			2	3.082	0.9056
A3	77.9499	2.8573	1.9557	-	3	3.255	0.9564
NOTATION		a	a	b	s.e		0.2938

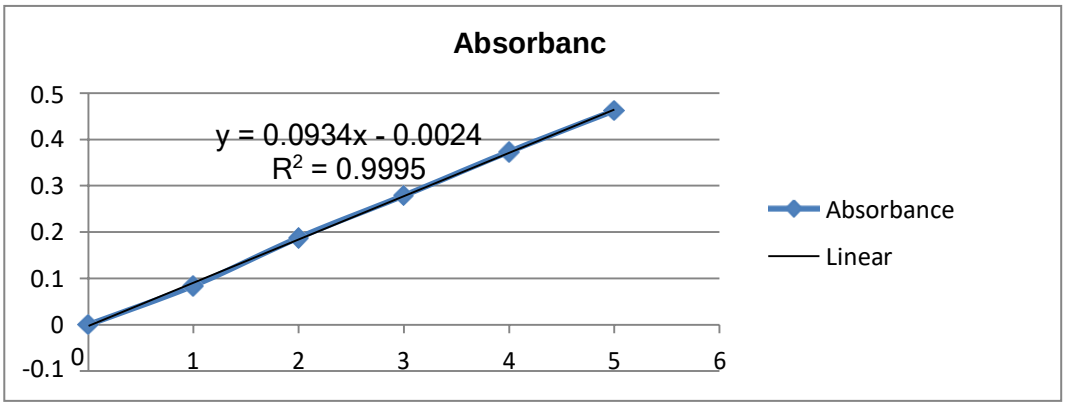
DMRT Table Variable B

Sampl e Code	Aver age	B1	B2	B3	B4	P	SSR	LSR
		75.49	76.02	76.59	77.28			
B1	75.4936							
B2	76.0162	0.522567				2	3.082	0.9056
B3	76.5881	1.094467	0.5719			3	3.255	0.9564
B4	77.2844	1.7907	1.2682	0.6963	-	4	3.313	0.973
NOTATION		a	ab	bc	c	s.e		0.2938

Amylose content of cassava flour Amylose

Standard Curve

Amylose Concentration	Absorbance
0	0.0007
1	0.0845
2	0.188
3	0.279
4	0.3735
5	0.0.4625



Amylose Content Analysis Data

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	19.851	19.996	39.850	19.93	0.105
A1B2	19.086	19.280	38.365	19.18	0.137
A1B3	18.729	18.920	37.649	18.82	0.135
A1B4	18.162	18.002	36.164	18.08	0.113
A2B1	19.098	19.305	38.403	19.20	0.146
A2B2	18.859	18.698	37.558	18.78	0.114
A2B3	18.707	18.511	37.218	18.61	0.139
A2B4	17.949	17.765	35.713	17.86	0.130
A3B1	18.707	18.903	37.610	18.81	0.139
A3B2	18.472	18.300	36.772	18.39	0.122
A3B3	17.767	17.588	35.355	17.68	0.126
A3B4	17.378	17.172	34.549	17.27	0.146
Total	222.766	222.444	445.209		
Average	18.564	18.537			

Two-way Table

A	B				Total	Average
	B1	B2	B3	B4		
A1	39.8504	38.3655	37.6493	36.1639	152.029	37.392
A2	38.4034	37.5575	37.2183	35.7134	148.892	36.829
A3	37.6105	36.7724	35.3551	34.5495	144.287	35.559
Total	115.36	112.501	109.830	106.427	445.209	
Average	38.6214	37.5613	36.7409			

ANOVA Table

SK	db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	12.05	1.10	64.94	2.72
A	2	3.79	1.90	112.33	3.89
B	3	7.95	2.65	157.01	3.49
AB	6	0.31	0.05	3.11	3.00
Error	12	0.20	0.02		
Total	23	12.26			

DMRT Table

Sample Code	Average	A3B4	A3B3	A2B4	A1B4	A3B2	A2B3	A2B2	A3B1	A1B3	A1B2	A2B1	A1B1	P	SSR	LSR
		17.27	**17.68**	**17.86**	**18.08**	**18.39**	**18.61**	**18.78**	**18.81**	**18.82**	**19.18**	**19.20**	**19.93**			
A3B4	17.27															
A3B3	17.68	0.40												2	3.082	0.2831
A2B4	17.86	0.58	0.18											3	3.255	0.2990
A1B4	18.08	0.81	0.40	0.23										4	3.313	0.3043
A3B2	18.39	1.11	0.71	0.53	0.30									5	3.37	0.3095
A2B3	18.61	1.33	0.93	0.75	0.53	0.22								6	3.41	0.3132
A2B2	18.78	1.50	1.10	0.92	0.70	0.39	0.17							7	3.439	0.3159
A3B1	18.81	1.53	1.13	0.95	0.72	0.42	0.20	0.03						8	3.459	0.3177
A1B3	18.82	1.55	1.15	0.97	0.74	0.44	0.22	0.05	0.02					9	3.474	0.3191
A1B2	19.18	1.91	1.51	1.33	1.10	0.80	0.57	0.40	0.38	0.36				10	3.484	0.3200
A2B1	19.20	1.93	1.52	1.34	1.12	0.82	0.59	0.42	0.40	0.38	0.02			11	3.49	0.3206
A1B1	19.93	2.65	2.25	2.07	1.84	1.54	1.32	1.15	1.12	1.10	0.74	0.72	-	12	3.496	0.3211
NOTATION		**a**	**a**	**b**	**c**	**d**	**d**	**e**	**f**	**g**	**g**	**h**	**i**	**s.e**		**0.0919**

White degree of cassava flour White degree analysis data

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	82.59	82.95	165.54	82.77	0.255
A1B2	82.47	82.87	165.34	82.67	0.283
A1B3	81.82	82.50	164.32	82.16	0.481
A1B4	81.29	82.11	163.40	81.70	0.580
A2B1	79.63	80.21	159.84	79.92	0.410
A2B2	79.57	79.91	159.48	79.74	0.240
A2B3	79.56	79.72	159.28	79.64	0.113
A2B4	78.51	79.07	157.58	78.79	0.396
A3B1	86.82	87.34	174.16	87.08	0.368
A3B2	86.28	86.84	173.12	86.56	0.396
A3B3	85.33	85.65	170.98	85.49	0.226
A3B4	83.91	84.37	168.28	84.14	0.325
Total	987.78	745.22	1981.32		
Average	82.32	82.80			

Two-way Table

	B					Average
A	**B1**	**B2**	**B3**	**B4**	**Total**	
A1	165.54	165.34	164.32	163.40	658.60	164.35
A2	159.84	159.48	159.28	157.58	636.18	158.78
A3	174.16	173.12	170.98	168.28	686.54	170.79
Total	499.54	497.94	494.58	489.26	1981.32	
Average	166.51	165.98	164.86			

ANOVA Table

SK	Db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	172.26	15.66	120.71	2.72
A	2	159.14	79.57	613.35	3.89
B	3	10.32	3.44	26.53	3.49
AB	6	2.79	0.47	3.58	3.00
Error	12	1.56	0.13		
Total	23	173.81			

DMRT Table

Sample Code	Average	A2B4	A2B3	A2B2	A2B1	A1B4	A1B3	A1B2	A1B1	A3B4	A3B3	A3B2	A3B1	P	SSR	LSR
		78.79	79.64	79.74	79.92	81.7	82.16	82.67	82.77	84.14	85.49	86.56	87.08			
A2B4	78.79															
A2B3	79.64	0.85												2	3.082	0.785
A2B2	79.74	0.95	0.1											3	3.255	0.829
A2B1	79.92	1.13	0.28	0.18										4	3.313	0.844
A1B4	81.7	2.91	2.06	1.96	1.78									5	3.37	0.858
A1B3	82.16	3.37	2.52	2.42	2.24	0.46								6	3.41	0.868
A1B2	82.67	3.88	3.03	2.93	2.75	0.97	0.51							7	3.439	0.876
A1B1	82.77	3.98	3.13	3.03	2.85	1.07	0.61	0.1						8	3.459	0.881
A3B4	84.14	5.35	4.5	4.4	4.22	2.44	1.98	1.47	1.37					9	3.474	0.885
A3B3	85.49	6.7	5.85	5.75	5.57	3.79	3.33	2.82	2.72	1.35				10	3.484	0.887
A3B2	86.56	7.77	6.92	6.82	6.64	4.86	4.4	3.89	3.79	2.42	1.07			11	3.49	0.889
A3B1	87.08	8.29	7.44	7.34	7.16	5.38	4.92	4.41	4.31	2.94	1.59	0.52	-	12	3.496	0.890
NOTATION		**a**	**b**	**b**	**b**	**c**	**cd**	**d**	**d**	**e**	**f**	**g**	**g**	**s.e**		**0.254689**

Solubility of cassava flour Solubility

Analysis Data

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	4.648	4.681	9.328	4.664	0.023
A1B2	4.989	5.112	10.100	5.050	0.087
A1B3	5.849	5.804	11.654	5.827	0.032
A1B4	8.158	8.304	16.462	8.231	0.104
A2B1	7.542	7.654	15.196	7.598	0.079
A2B2	8.717	8.630	17.346	8.673	0.061
A2B3	9.230	9.110	18.340	9.170	0.085
A2B4	10.715	10.498	21.213	10.606	0.154
A3B1	8.427	8.276	16.703	8.351	0.107
A3B2	9.818	9.826	19.644	9.822	0.006
A3B3	12.122	11.746	23.869	11.934	0.266
A3B4	13.907	13.535	27.442	13.721	0.263
Total	88.635	87.579	207.296		
Average	9.848	9.731			

Two-way Table

	B					Average
A	**B1**	**B2**	**B3**	**B4**	**Total**	
A1	9.328	10.100	11.654	16.462	47.544	12.738
A2	15.196	17.346	18.340	21.213	72.096	18.966
A3	16.703	19.644	23.869	27.442	87.657	23.651
Total	41.228	47.090	53.863	65.116	207.296	
Average	13.743	15.697	17.954			

ANOVA Table

SK	db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	160.32	14.57	825.22	2.72
A	2	102.25	51.13	2894.87	3.89
B	3	52.59	17.53	992.53	3.49
AB	6	5.48	0.91	51.69	3.00
Error	12	0.21	0.02		
Total	23	160.53			

DMRT Table

Sample Code	Average	A1B1	A1B2	A1B3	A2B1	A1B4	A3B1	A2B2	A2B3	A3B2	A2B4	A3B3	A3B4	P	SSR	LSR
		4.66	**5.05**	**5.83**	**7.6**	**8.23**	**8.35**	**8.67**	**9.17**	**9.82**	**10.61**	**11.93**	**13.72**			
A1B1	4.66															
A1B2	5.05	0.39												2	3.082	0.290
A1B3	5.83	1.17	0.78											3	3.255	0.306
A2B1	7.6	2.94	2.55	1.77										4	3.313	0.311
A1B4	8.23	3.57	3.18	2.4	0.63									5	3.37	0.317
A3B1	8.35	3.69	3.3	2.52	0.75	0.12								6	3.41	0.320
A2B2	8.67	4.01	3.62	2.84	1.07	0.44	0.32							7	3.439	0.323
A2B3	9.17	4.51	4.12	3.34	1.57	0.94	0.82	0.5						8	3.459	0.325
A3B2	9.82	5.16	4.77	3.99	2.22	1.59	1.47	1.15	0.65					9	3.474	0.326
A2B4	10.61	5.95	5.56	4.78	3.01	2.38	2.26	1.94	1.44	0.79				10	3.484	0.327
A3B3	11.93	7.27	6.88	6.1	4.33	3.7	3.58	3.26	2.76	2.11	1.32			11	3.49	0.328
A3B4	13.72	9.06	8.67	7.89	6.12	5.49	5.37	5.05	4.55	3.9	3.11	1.79	-	12	3.496	0.329
NOTATION		**a**	**b**	**c**	**d**	**e**	**ef**	**f**	**g**	**h**	**i**	**j**	**k**	**s.e**		**0.093971**

Swelling Power of* Cassava Flour *Swelling

***Power* Analysis Data**

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	8.083	8.329	16.412	8.206	0.173
A1B2	8.721	8.591	17.312	8.656	0.092
A1B3	9.608	9.485	19.093	9.547	0.087
A1B4	10.538	10.431	20.969	10.485	0.076
A2B1	9.590	9.548	19.138	9.569	0.029
A2B2	10.326	10.502	20.828	10.414	0.124
A2B3	11.325	11.487	22.813	11.406	0.115
A2B4	12.454	12.346	24.800	12.400	0.076
A3B1	10.720	10.658	21.377	10.689	0.044
A3B2	10.949	11.074	22.024	11.012	0.088
A3B3	12.318	12.326	24.644	12.322	0.006
A3B4	13.273	13.164	26.437	13.218	0.077
Total	101.493	101.536	255.846		
Average	11.277	11.282			

Two-way Table

A	B				Total	Average
	B1	B2	B3	B4		
A1	16.412	17.312	19.093	20.969	73.787	19.125
A2	19.138	20.828	22.813	24.800	87.578	22.813
A3	21.377	22.024	24.644	26.437	94.481	24.368
Total	56.927	60.164	66.550	72.206	255.846	
Average	18.976	20.055	22.183			

ANOVA Table

SK	Db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	51.15	4.65	542.78	2.72
A	2	27.76	13.88	1619.91	3.89
B	3	23.09	7.70	898.61	3.49
AB	6	0.30	0.05	5.82	3.00
Error	12	0.10	0.01		
Total	23	51.25			

DMRT Table

Sample Code	Average	A1B1	A1B2	A1B3	A2B1	A2B2	A1B4	A3B1	A3B2	A2B3	A3B3	A2B4	A3B4	P	SSR	LSR
		8.21	8.66	9.55	9.57	10.41	10.48	10.69	11.01	11.41	12.32	12.4	13.22			
A1B1	8.21															
A1B2	8.66	0.45												2	3.08	0.20
A1B3	9.55	1.34	0.89											3	3.26	0.21
A2B1	9.57	1.36	0.91	0.02										4	3.31	0.22
A2B2	10.41	2.20	1.75	0.86	0.84									5	3.37	0.22
A1B4	10.48	2.27	1.82	0.93	0.91	0.07								6	3.41	0.22
A3B1	10.69	2.48	2.03	1.14	1.12	0.28	0.21							7	3.44	0.23
A3B2	11.01	2.80	2.35	1.46	1.44	0.60	0.53	0.32						8	3.46	0.23
A2B3	11.41	3.20	2.75	1.86	1.84	1.00	0.93	0.72	0.40					9	3.47	0.23
A3B3	12.32	4.11	3.66	2.77	2.75	1.91	1.84	1.63	1.31	0.91				10	3.48	0.23
A2B4	12.40	4.19	3.74	2.85	2.83	1.99	1.92	1.71	1.39	0.99	0.08			11	3.49	0.23
A3B4	13.22	5.01	4.56	3.67	3.65	2.81	2.74	2.53	2.21	1.81	0.90	0.82	-	12	3.50	0.23
NOTATION		**a**	**b**	**c**	**c**	**d**	**de**	**e**	**f**	**g**	**h**	**h**	**i**	**s.e**		**0.065448**

Water absorption of cassava flour Water absorption analysis data

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	1.579	1.778	3.357	1.678	0.141
A1B2	1.895	1.735	3.630	1.815	0.113
A1B3	1.767	1.986	3.753	1.877	0.154
A1B4	2.042	1.981	4.023	2.012	0.043
A2B1	2.093	1.539	3.632	1.816	0.392
A2B2	2.096	2.085	4.181	2.091	0.008
A2B3	1.891	2.290	4.181	2.091	0.282
A2B4	3.760	3.345	7.105	3.552	0.294
A3B1	1.798	2.284	4.081	2.041	0.344
A3B2	2.288	2.590	4.878	2.439	0.213
A3B3	2.865	2.782	5.647	2.823	0.059
A3B4	3.747	3.391	7.138	3.569	0.252
Total	22.581	22.286	55.607		
Average	2.509	2.476			

Two-way Table

	B					Average
A	**B1**	**B2**	**B3**	**B4**	**Total**	
A1	3.357	3.630	3.753	4.023	14.764	3.802
A2	3.632	4.181	4.181	7.105	19.100	5.156
A3	4.081	4.878	5.647	7.138	21.744	5.888
Total	11.070	12.690	13.582	18.266	55.607	
Average	3.690	4.230	4.527			

ANOVA Table

SK	Db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	9.48	0.86	16.99	2.72
A	2	3.10	1.55	30.59	3.89
B	3	4.74	1.58	31.15	3.49
AB	6	1.64	0.27	5.27	3.00
Error	12	0.61	0.05		
Total	23	10.09			

DMRT Table

Sample Code	Average	A1B1	A1B2	A2B1	A1B3	A1B4	A3B1	A2B2	A2B3	A3B2	A3B3	A2B4	A3B4	P	SSR	LSR
		1.68	1.82	1.82	1.88	2.01	2.04	2.09	2.09	2.44	2.82	3.55	3.57			
A1B1	1.68															
A1B2	1.82	0.14												2	3.082	0.491
A2B1	1.82	0.14	0.00											3	3.255	0.518
A1B3	1.88	0.20	0.06	0.06										4	3.313	0.528
A1B4	2.01	0.33	0.19	0.19	0.13									5	3.37	0.537
A3B1	2.04	0.36	0.22	0.22	0.16	0.03								6	3.41	0.543
A2B2	2.09	0.41	0.27	0.27	0.21	0.08	0.05							7	3.439	0.548
A2B3	2.09	0.41	0.27	0.27	0.21	0.08	0.05	0.00						8	3.459	0.551
A3B2	2.44	0.76	0.62	0.62	0.56	0.43	0.40	0.35	0.35					9	3.474	0.553
A3B3	2.82	1.14	1.00	1.00	0.94	0.81	0.78	0.73	0.73	0.38				10	3.484	0.555
A2B4	3.55	1.87	1.73	1.73	1.67	1.54	1.51	1.46	1.46	1.11	0.73			11	3.49	0.556
A3B4	3.57	1.89	1.75	1.75	1.69	1.56	1.53	1.48	1.48	1.13	0.75	0.02	-	12	3.496	0.557
NOTATION		**a**	**a**	**a**	**a**	**a**	**a**	**a**	**ab**	**bc**	**c**	**d**	**e**	**s.e**		**0.1593**

Oil Absorbency of Cassava Flour Oil Absorbency

Analysis Data

Treatment	Test I	Test II	Total	Average	STDEV
A1B1	2.089	1.979	4.068	2.034	0.078
A1B2	1.899	1.979	3.878	1.939	0.057
A1B3	1.797	1.799	3.596	1.798	0.001
A1B4	1.585	1.774	3.360	1.680	0.133
A2B1	3.396	3.385	6.782	3.391	0.008
A2B2	2.266	2.545	4.811	2.406	0.197
A2B3	2.078	2.277	4.355	2.177	0.140
A2B4	1.873	1.586	3.459	1.729	0.203
A3B1	3.775	3.830	7.605	3.802	0.039
A3B2	2.899	2.793	5.693	2.846	0.075
A3B3	2.288	2.098	4.386	2.193	0.134
A3B4	1.898	2.080	3.979	1.989	0.129
Total	22.059	22.369	55.969		
Average	2.451	2.485			

Two-way Table

A	B				Total	Average
	B1	B2	B3	B4		
A1	4.068	3.878	3.596	3.360	14.901	3.611
A2	6.782	4.811	4.355	3.459	19.406	4.208
A3	7.605	5.693	4.386	3.979	21.661	4.686
Total	18.454	14.382	12.336	10.797	55.969	
Average	6.151	4.794	4.112			

ANOVA Table

SK	db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	10.06	0.91	65.11	2.72
A	2	2.96	1.48	105.41	3.89
B	3	5.50	1.83	130.56	3.49
AB	6	1.60	0.27	18.95	3.00
Error	12	0.17	0.0140		
Total	23	10.23			

DMRT Table

Sample Code	Average	A1B4	A2B4	A1B3	A1B2	A3B4	A1B1	A2B3	A3B3	A2B2	A3B2	A2B1	A3B1	P	SSR	LSR
		1.68	1.73	1.8	1.94	1.99	2.03	2.18	2.19	2.41	2.85	3.39	3.8			
A1B4	1.68															
A2B4	1.73	0.05												2	3.082	0.258
A1B3	1.8	0.12	0.07											3	3.255	0.273
A1B2	1.94	0.26	0.21	0.14										4	3.313	0.278
A3B4	1.99	0.31	0.26	0.19	0.05									5	3.37	0.282
A1B1	2.03	0.35	0.3	0.23	0.09	0.04								6	3.41	0.286
A2B3	2.18	0.5	0.45	0.38	0.24	0.19	0.15							7	3.439	0.288
A3B3	2.19	0.51	0.46	0.39	0.25	0.2	0.16	0.01						8	3.459	0.290
A2B2	2.41	0.73	0.68	0.61	0.47	0.42	0.38	0.23	0.22					9	3.474	0.291
A3B2	2.85	1.17	1.12	1.05	0.91	0.86	0.82	0.67	0.66	0.44				10	3.484	0.292
A2B1	3.39	1.71	1.66	1.59	1.45	1.4	1.36	1.21	1.2	0.98	0.54			11	3.49	0.292
A3B1	3.8	2.12	2.07	2	1.86	1.81	1.77	1.62	1.61	1.39	0.95	0.41	-	12	3.496	0.293
NOTATION		**a**	**ab**	**abc**	**bcd**	**bcd**	**cd**	**de**	**de**	**e**	**f**	**g**	**h**	**s.e**		**0.083809**

Organoleptic Test Scoring of Cassava Flour

A. Color

Panelists	Sample Code												Total	Average
	A1B1	A1B2	A1B3	A1B4	A2B1	A2B2	A2B3	A2B4	A3B1	A3B2	A3B3	A3B4		
P1	4	4	4	3	4	4	2	3	6	6	6	5	51	4.25
P2	4	4	4	5	4	4	4	3	6	6	5	4	53	4.42
P3	5	5	4	4	5	5	4	4	5	6	6	5	58	4.83
P4	4	3	4	4	4	4	4	3	6	4	5	4	49	4.08
P5	4	4	4	4	4	4	4	3	6	6	5	5	53	4.42
P6	6	5	6	6	6	5	6	5	6	6	6	6	69	5.75
P7	4	5	4	4	4	6	4	4	6	6	6	6	59	4.92
P8	4	5	4	4	5	4	5	4	6	5	6	5	57	4.75
P9	4	5	5	5	5	4	4	3	6	6	5	6	58	4.83
P10	5	5	6	4	5	5	5	3	6	6	6	6	62	5.17
P11	4	6	5	4	4	5	5	3	6	6	6	6	60	5.00
P12	4	4	4	4	4	4	4	4	5	4	5	5	51	4.25
P13	4	4	4	4	4	4	3	3	6	5	5	4	50	4.17
P14	4	4	5	4	4	6	4	3	6	6	6	3	55	4.58
P15	5	5	5	5	5	5	4	5	6	6	6	6	63	5.25
P16	4	4	4	4	4	4	4	4	6	6	6	5	55	4.58
P17	4	4	3	4	3	3	3	3	6	5	4	4	46	3.83
P18	5	5	4	4	4	4	3	5	6	6	6	5	57	4.75
P19	5	3	5	2	5	3	3	4	6	6	3	6	51	4.25
P20	4	4	3	3	3	3	4	3	5	5	5	4	46	3.83
P21	5	5	5	5	5	5	5	5	6	6	5	5	62	5.17
P22	6	5	5	6	5	4	4	4	6	6	6	6	63	5.25
P23	4	3	4	4	3	4	4	4	5	6	4	5	50	4.17
P24	5	4	3	4	4	3	3	3	5	4	4	4	46	3.83
P25	4	4	4	4	5	3	4	2	6	6	6	6	54	4.50
Total	111	109	108	104	108	105	99	90	145	140	133	126	1378	
Average	4.44	4.36	4.32	4.16	4.32	4.20	3.96	3.60	5.80	5.60	5.32	5.04		
STDEV	0.651	0.757	0.802	0.850	0.748	0.866	0.841	0.816	0.408	0.707	0.852	0.889		

ANOVA Table

SK	db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	128.87	11.72	30.73	1.83
Panelists	24	72.89	3.04	7.97	1.56
Error	264	100.63	0.38		
Total	299	302.39			

DMRT Table

Code Sample	Average-flat	A2B4	A2B3	A1B4	A2B2	A2B1	A1B3	A1B2	A1B1	A3B4	A3B3	A3B2	A3B1	P	SSR	LSR
		90	99	104	105	108	108	109	111	126	133	140	145			
A2B4	90															
A2B3	99	9												2	2.772	0.342
A1B4	104	14	5											3	2.918	0.360
A2B2	105	15	6	1										4	3.017	0.373
A2B1	108	18	9	4	3									5	3.089	0.381
A1B3	108	18	9	4	3	0								6	3.146	0.388
A1B2	109	19	10	5	4	1	1							7	3.193	0.394
A1B1	111	21	12	7	6	3	3	2						8	3.232	0.399
A3B4	126	36	27	22	21	18	18	17	15					9	3.265	0.403
A3B3	133	43	34	29	28	25	25	24	22	7				10	3.294	0.407
A3B2	140	50	41	36	35	32	32	31	29	14	7			11	3.34	0.412
A3B1	145	55	46	41	40	37	37	36	34	19	12	5	-	12	3.343	0.413
NOTATION		**a**	**b**	**c**	**d**	**e**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**s.e**		**0.123**

B. Aroma

Panelists	Sample Code												Total	Average
	A1B1	A1B2	A1B3	A1B4	A2B1	A2B2	A2B3	A2B4	A3B1	A3B2	A3B3	A3B4		
P1	6	4	3	3	4	2	3	2	5	5	3	5	45	3.75
P2	4	5	3	3	3	5	3	4	4	5	5	5	49	4.08
P3	4	4	5	6	5	4	5	3	4	5	5	6	56	4.67
P4	5	5	4	4	4	4	4	4	5	5	4	5	53	4.42
P5	5	6	5	4	5	5	5	5	4	6	5	4	59	4.92
P6	3	2	3	4	2	4	3	3	4	5	5	3	41	3.42
P7	4	4	3	4	6	4	4	4	6	6	4	4	53	4.42
P8	3	4	4	3	3	3	3	3	5	4	5	4	44	3.67
P9	4	4	5	3	4	5	4	3	4	4	5	4	49	4.08
P10	6	3	4	4	4	4	3	4	5	5	5	5	52	4.33
P11	6	3	3	4	4	4	3	3	5	4	5	4	48	4.00
P12	3	4	4	3	4	4	4	3	4	4	4	4	45	3.75
P13	4	4	4	3	3	3	3	4	4	4	4	4	44	3.67
P14	4	4	4	4	4	4	3	4	6	6	3	5	51	4.25
P15	4	5	3	3	5	4	4	4	5	5	5	4	51	4.25
P16	4	4	5	3	4	3	4	4	4	4	5	5	49	4.08
P17	3	4	3	3	4	3	3	4	4	4	4	3	42	3.50
P18	4	3	3	4	5	4	4	4	6	4	4	3	48	4.00
P19	4	3	2	2	3	3	3	3	4	3	3	3	36	3.00
P20	3	4	3	3	3	3	2	3	4	4	4	3	39	3.25
P21	4	5	4	5	4	4	4	4	5	5	5	5	54	4.50
P22	5	5	4	3	4	5	4	3	5	5	5	5	53	4.42
P23	3	4	3	4	3	4	4	4	4	5	4	5	47	3.92
P24	5	4	5	4	4	4	4	4	5	3	5	4	51	4.25
P25	4	4	3	3	3	4	3	3	4	3	4	3	41	3.42
Total	104	101	92	89	97	96	89	89	115	113	110	105	1200	
Average	4.16	4.04	3.68	3.56	3.88	3.84	3.56	3.56	4.6	4.52	4.4	4.2		
STDEV	0.943	0.841	0.852	0.821	0.881	0.746	0.712	0.651	0.707	0.872	0.707	0.866		

ANOVA Table

SK	db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	39.52	3.59	7.66	1.83
Panelists	24	62.67	2.61	5.57	1.56
Error	264	123.81	0.47		
Total	299	226.00			

DMRT Table

Code Sample	Average-flat	A1B4	A2B3	A2B4	A1B3	A2B2	A2B1	A1B2	A1B1	A3B4	A3B3	A3B2	A3B1	P	SSR	LSR
		89	89	89	92	96	97	101	104	105	110	113	115			
A1B4	89															
A2B3	89	0												2	2.772	0.380
A2B4	89	0	0											3	2.918	0.400
A1B3	92	3	3	3										4	3.017	0.413
A2B2	96	7	7	7	4									5	3.089	0.423
A2B1	97	8	8	8	5	1								6	3.146	0.431
A1B2	101	12	12	12	9	5	4							7	3.193	0.437
A1B1	104	15	15	15	12	8	7	3						8	3.232	0.443
A3B4	105	16	16	16	13	9	8	4	1					9	3.265	0.447
A3B3	110	21	21	21	18	14	13	9	6	5				10	3.294	0.451
A3B2	113	24	24	24	21	17	16	12	9	8	3			11	3.34	0.457
A3B1	115	26	26	26	23	19	18	14	11	10	5	2	-	12	3.343	0.458
NOTATION		**a**	**a**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**s.e**		**0.1369**

C. Texture

Panelists	Sample Code												Total	Average
	A1B1	A1B2	A1B3	A1B4	A2B1	A2B2	A2B3	A2B4	A3B1	A3B2	A3B3	A3B4		
P1	6	4	3	4	6	4	4	3	4	6	4	5	53	4.42
P2	6	4	3	3	6	3	5	4	6	6	6	4	56	4.67
P3	4	3	3	3	5	4	3	3	6	6	4	4	48	4.00
P4	4	4	3	4	4	3	4	3	5	5	4	4	47	3.92
P5	5	4	4	5	6	4	4	5	6	5	6	4	58	4.83
P6	5	5	5	5	5	5	5	5	6	6	6	5	63	5.25
P7	4	3	4	4	4	3	4	4	6	4	4	6	50	4.17
P8	6	5	4	4	5	5	4	4	6	6	5	5	59	4.92
P9	4	4	3	4	4	5	4	4	5	4	4	3	48	4.00
P10	6	3	3	4	6	3	3	3	5	6	4	3	49	4.08
P11	5	3	5	3	6	4	3	3	5	5	4	4	50	4.17
P12	4	4	4	3	4	5	5	5	5	4	5	5	53	4.42
P13	5	5	4	3	5	5	4	4	6	5	4	4	54	4.50
P14	6	5	5	4	6	6	6	5	6	6	6	5	66	5.50
P15	6	5	5	4	6	5	4	4	6	6	5	5	61	5.08
P16	5	4	3	3	5	4	3	3	4	5	5	3	47	3.92
P17	5	4	4	4	5	4	4	3	5	5	6	5	54	4.50
P18	6	4	4	3	5	3	4	3	6	3	4	5	50	4.17
P19	5	4	3	3	6	4	5	4	4	5	4	5	52	4.33
P20	4	3	4	3	4	4	4	3	4	3	3	3	42	3.50
P21	5	4	4	4	4	4	3	4	4	4	4	4	48	4.00
P22	5	4	5	5	5	4	5	5	5	5	5	5	58	4.83
P23	4	6	4	4	5	5	5	4	4	4	5	6	56	4.67
P24	3	5	4	4	6	4	4	5	5	5	5	4	54	4.50
P25	6	6	6	5	5	5	4	5	6	5	5	6	64	5.33
Total	124	105	99	95	128	105	103	98	130	124	117	112	1340	
Average	4.96	4.2	3.96	3.8	5.12	4.2	4.12	3.92	5.2	4.96	4.68	4.48		
STDEV	0.889	0.866	0.841	0.707	0.781	0.816	0.781	0.812	0.816	0.935	0.852	0.918		

ANOVA Table

SK	db	JK	KT	Fhit	Ftab (0.05%)
Treatment	11	68.99	6.27	12.77	1.83
Panelists	24	72.00	3.00	6.11	1.56
Error	264	129.68	0.49		
Total	299	270.67			

DMRT Table

Sample Code	Average	A1B4	A2B4	A1B3	A2B3	A2B2	A1B2	A3B4	A3B3	A1B1	A3B2	A2B1	A3B1	P	SSR	LSR
		95	**98**	**99**	**103**	**105**	**105**	**112**	**117**	**124**	**124**	**128**	**130**			
A1B4	95															
A2B4	98	3												2	2.772	0.389
A1B3	99	4	1											3	2.918	0.409
A2B3	103	8	5	4										4	3.017	0.423
A2B2	105	10	7	6	2									5	3.089	0.433
A1B2	105	10	7	6	2	0								6	3.146	0.441
A3B4	112	17	14	13	9	7	7							7	3.193	0.448
A3B3	117	22	19	18	14	12	12	5						8	3.232	0.453
A1B1	124	29	26	25	21	19	19	12	7					9	3.265	0.458
A3B2	124	29	26	25	21	19	19	12	7	0				10	3.294	0.462
A2B1	128	33	30	29	25	23	23	16	11	4	4			11	3.34	0.468
A3B1	130	35	32	31	27	25	25	18	13	6	6	2	-	12	3.343	0.469
NOTATION		**a**	**b**	**c**	**d**	**e**	**e**	**f**	**g**	**h**	**h**	**i**	**j**	**s.e**		**0.1401**

Appendix 13. *Multiple Attribute* Method Best Treatment Determination Test (Zeleny 1982)

A. Organoleptic

Parameters	Alternative											
	A1B1	**A1B2**	**A1B3**	**A1B4**	**A2B1**	**A2B2**	**A2B3**	**A2B4**	**A3B1**	**A3B2**	**A3B3**	**A3B4**
Color	4.44	4.36	4.32	4.16	4.32	4.2	3.96	3.6	5.8	5.6	5.32	5.04
Aroma	4.16	4.04	3.68	3.56	3.88	3.84	3.56	3.56	4.6	4.52	4.4	4.2
Texture	4.96	4.2	3.96	3.8	5.12	4.2	4.12	3.92	5.2	4.96	4.68	4.48
dk Color	0.7655	0.7517	0.7448	0.7172	0.7448	0.7241	0.6828	0.6207	1.0000	0.9655	0.9172	0.8690
dk Aroma	0.9043	0.8783	0.8000	0.7739	0.8435	0.8348	0.7739	0.7739	1.0000	0.9826	0.9565	0.9130
dk Texture	0.9538	0.8077	0.7615	0.7308	0.9846	0.8077	0.7923	0.7538	1.0000	0.9538	0.9000	0.8615
^	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333
L1	0.1254	0.1874	0.2312	0.2594	0.1424	0.2111	0.2503	0.2839	0.0000	0.0327	0.0754	0.1188
L2	0.0074	0.0126	0.0180	0.0226	0.0100	0.0156	0.0217	0.0284	0.0000	0.0004	0.0021	0.0049
Max L	0.0782	0.0828	0.0851	0.0943	0.0851	0.0920	0.1057	0.1264	0.0000	0.0154	0.0333	0.0462
Treatment Best	0.2110	0.2828	0.3343	0.3762	0.2374	0.3187	0.3777	0.4387	0.0000*	0.0485	0.1108	0.1698

Note: * = best treatment

B. Physicochemistry

Parameters	Alternative											
	A1B1	A1B2	A1B3	A1B4	A2B1	A2B2	A2B3	A2B4	A3B1	A3B2	A3B3	A3B4
Yield	24.87	22.49	21.74	21.44	23.7	22.18	20.71	18.72	23.26	21.9	20.62	18.18
Water Content	9.390	8.830	8.700	8.660	9.290	8.090	7.820	7.130	9.110	7.970	7.880	6.320
Ash Content	1.167	1.200	1.329	1.498	1.085	0.987	1.203	1.271	0.273	0.296	0.297	0.312
Starch	71.175	72.036	75.348	75.953	72.252	74.120	75.971	76.943	73.567	75.524	78.193	78.957
Amylose	19.776	19.086	18.825	18.242	19.098	18.779	18.413	17.857	18.805	18.386	17.678	17.275
Degree of Whiteness	82.770	82.670	82.160	81.700	79.920	79.740	79.640	78.790	87.080	86.560	85.490	84.140
Swelling Power	8.206	8.656	9.547	10.485	9.569	10.414	11.406	12.400	10.689	11.012	12.322	13.218
Solubility	4.664	5.050	5.827	8.231	7.598	8.673	9.170	10.606	8.351	9.822	11.934	13.721
DSA	1.678	1.815	1.877	2.012	1.816	2.091	2.091	3.552	2.041	2.439	2.323	3.569
DSM	2.034	1.939	1.798	1.680	3.391	2.406	2.177	1.729	3.802	2.846	2.193	1.989
dk Yield	1.0000	0.9043	0.8741	0.8621	0.9530	0.8918	0.8327	0.7527	0.9353	0.8806	0.8291	0.7310
dk Water Content	0.6731	0.7157	0.7264	0.7298	0.6803	0.7812	0.8082	0.8864	0.6937	0.7930	0.8020	1.0000
dk Ash Content	0.2339	0.2275	0.2054	0.1822	0.2516	0.2766	0.2269	0.2148	1.0000	0.9223	0.9192	0.8750
dk Pati	0.9014	0.9123	0.9543	0.9620	0.9151	0.9387	0.9622	0.9745	0.9317	0.9565	0.9903	1.0000
dk Amylose	0.8735	0.9051	0.9177	0.9470	0.9045	0.9199	0.9382	0.9674	0.9186	0.9396	0.9772	1.0000
dk Degree of Whiteness	0.9505	0.9494	0.9435	0.9382	0.9178	0.9157	0.9146	0.9048	1.0000	0.9940	0.9817	0.9662
dk Swelling Power	0.6208	0.6549	0.7223	0.7932	0.7239	0.7879	0.8629	0.9381	0.8087	0.8331	0.9322	1.0000
dk Solubility	0.3399	0.3680	0.4247	0.5999	0.5537	0.6321	0.6683	0.7730	0.6086	0.7158	0.8698	1.0000
dk DSA	0.4702	0.5085	0.5259	0.5637	0.5088	0.5859	0.5859	0.9952	0.5719	0.6834	0.6509	1.0000
dk DSM	0.5350	0.5100	0.4729	0.4419	0.8919	0.6328	0.5726	0.4548	1.0000	0.7486	0.5768	0.5231
Λ	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000

L1	0.3402	0.3344	0.3233	0.2980	0.2699	0.2637	0.2628	0.2138	0.1531	0.1533	0.1471	0.0905
L2	0.0180	0.0171	0.0164	0.0147	0.0122	0.0109	0.0116	0.0105	0.0048	0.0034	0.0040	0.0032
LMaks	0.0766	0.0773	0.0795	0.0818	0.0748	0.0723	0.0773	0.0785	0.0428	0.0317	0.0423	0.0477
Best Treatment	0.4348	0.4287	0.4192	0.3945	0.3569	0.3469	0.3516	0.3029	0.2008	0.1884	0.1934	0.1413*

Description: * = best fit

Picture of Cassava Flour

Untreated Cassava Flour

Cassava Flour with Treatment of Fermentation Type and Pregelatinization Temperature

Picture of the Process of Making Fermented and Pregelatinized Cassava Flour

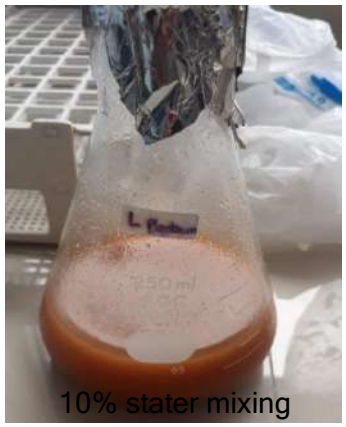
1. Picture of the Process of Making Fermented Cassava with *Lactobcillus plantarum*

Cassava weighing

Stripping

Cassava shredding

Mixing cassava and water



10% stater mixing

Fermentation for 24 hours

Washing to neutral pH

Drainage

Preparation of cassava slurry

Heating the slurry at heating temperature (45, 50,
55, 60°C)

Drying for 4 hours

100 mesh crushing and sieving

Appendix 16. Figure Analysis Flour Fermentation and Pregelatinization

Yield Test

Moisture Content Test

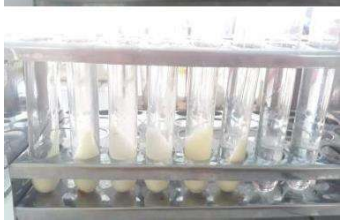
Ash Content

Starch Content

Amylose Content

Solubility

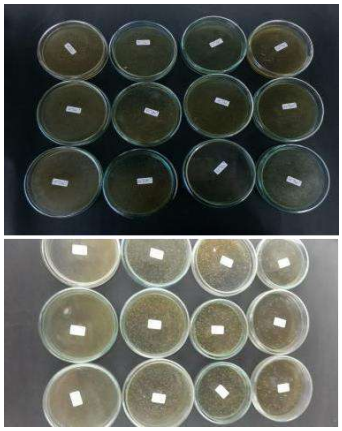
Swelling Power



Water Absorbency

Oil Absorbency

pH



Total LAB

Organoleptic