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Effect of Fermentation on the Phsyco and Functional Properties of Red Sorghum Flour (*Sorghum bicolor* L.)

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Abstract: Modification of red sorghum flour by fermentation method can improve the physical, chemical, and functional properties of the resulting sorghum flour. The purpose of this study was to determine the fermentation time that can affect the physical and functional characteristics of red sorghum flour fermented spontaneous (TSS) and non-spontaneous (TTS). Results indicated that the best treatment was red sorghum flour fermented at 24 hours both spontaneous and non-spontaneous. TSS at 24 hours had a water absorption capacity of 1.04%, oil binding capacity of 1.04%, swelling volume of 7.47%, solubility of 7.57%, initial gelatinization temperature of 76.56°C, peak viscosity of 2855 cP, hot paste viscosity of 2214 cP, breakdown viscosity of 641 cP, cold paste viscosity of 3425 cP, and setback viscosity of 1211 cP. TTS at 24 hours had a water absorption capacity of 1.21%, oil binding capacity of 1.18%, swelling volume of 7.49%, solubility of 8.23%, initial gelatinization temperature of 75.81°C, peak viscosity of 3172 cP, hot paste viscosity of 2600 cP, breakdown viscosity of 572 cP, cold paste viscosity of 5107 cP, and setback viscosity of 2507 cP.

Keywords: red sorghum flour, fermentation, bread yeast, modified flour

Abstrak: *Modifikasi tepung sorgum merah dengan metode fermentasi dapat meningkatkan sifat fisik, kimia, dan fungsional dari tepung sorgum yang dihasilkan. Tujuan dari penelitian ini adalah untuk menentukan lama fermentasi yang dapat memengaruhi karaketristik fisik dan fungsional tepung sorgum merah yang difermentasi secara spontan (TSS) dan tidak spontan (TTS). Metode penelitian yang digunakan adalah metode eksperimen yang dilanjutkan dengan analisis deskriptif. Berdasarkan hasil penelitian perlakuan terbaik adalah tepung sorgum merah yang difermentasi pada jam ke-24. TSS jam ke-24 yang memiliki kapasitas penyerapan air 1,04%, kapasitas penyerapan minyak 1,04%, swelling volume 7,47%, kelarutan 7,57%, suhu awal gelatinisasi 76,56°C, viskositas puncak 2855 cP, viskositas pasta panas 2214 cP, viskositas breakdown 641 cP, viskositas pasta dingin 3425 cP, dan viskositas setback 1211 cP. TTS jam ke-24 memiliki kapasitas penyerapan air 1,21%, kapasitas penyerapan minyak 1,18%, swelling volume 7,49%, kelarutan 8,23%, suhu awal gelatinisasi 75,81°C, viskositas puncak 3172 cP, viskositas pasta panas 2600 cP, viskositas breakdown 572 cP, viskositas pasta dingin 5107 cP, dan viskositas setback 2507 cP.*

Kata kunci: *tepung sorgum merah, fermentasi, ragi roti, tepung modifikasi*

INTRODUCTION

Other cereals can be replaced with sorghum as an alternate cuisine. This is due to the high carbohydrate content of sorghum, which is 74.63 g/100 g, which is greater than wheat's 71.97 g/100 g and lower than corn's 76.85 g/100 g (Winarti *et al*. 2023). The processing of red seeds sorghum has been carried out hereditary by many people on Selayar Island, South Sulawesi, because sorghum is beneficial for health (Tan *et al*. 2024). Red sorghum can be used to make sorghum tape, sorghum rice, and a variety of cakes, however the high amounts of tannins give the final products a harsh flavor. Typically, red sorghum seeds have more tannins than white seeds (Khoddami *et al*. 2023).

Sorghum flour has a low degree of whiteness, swelling volume, breakdown viscosity, and peak viscosity, according to Adzqia *et al*. (2023). This is an issue with numerous food applications. Therefore, adjustments are required to change these qualities. In order to change the molecular structure of sorghum flour, various physical (heat moisture treatment), chemical (cross-linking), and biological (fermentation and enzymatic) processes are used (Batariuc *et al*. 2023). Fermentation modification of starches can enhance functional qualities and reduce amounts of tannins and phytic acid by about 50%

(Sharma *et al*. 2020). Fermentation with the assistance of microbes that produce the amylase enzyme, such as various yeasts, most notably *Saccharomyces cerevisiae*. Starches can be broken down by *S. cerevisiae* into simple sugars and alcohol. *S.cerevisiae* can be obtained from bread yeast. Bread yeast is easily obtained commercially and does not require specific treatment (Parapouli *et al*. 2020).

Fermentation modification can be done spontaneous or non-spontaneous. The two treatments can change the characteristics of food, especially the starch component. In the modification of red sorghum flour, yeast acts as a natural biocatalyst, breaking down starch and proteins, enhancing nutritional content, and improving functional and sensory properties. This makes the modified flour more versatile for various food applications, particularly gluten-free products. Therefore, it is necessary to do further research on spontaneous and non-spontaneous fermentation using yeast on red sorghum flour to determine the characteristics of its functional, amylographic properties, increase the solubility and water capacity that can be absorbed by the flour (Gómez *et a*l. 2020). Starch is one of several compounds degraded during fermentation. The solubility and other biochemical characteristics of flour will alter as a result of the breakdown of starch components.

Both spontaneous and non-spontaneous fermentation can be modified. Food qualities can be altered by the two procedures, especially the starch content. In order to ascertain the characteristics of the functional and amylographic qualities of red sorghum flour, additional study on spontaneous and non-spontaneous fermentation using yeast is required. Gómez *et al*. (2020) claim that fermentation can improve the amount of solubility and water that flour can absorb. During the fermentation process, substances like starch are degraded. The solubility of flour will alter as a result of the breakdown of the starch components. The fermenting procedure, according to Nkhata *et al*. (2018), can also decrease anti-nutritional elements, specifically the quantities of tannins and phytic acid in sorghum flour. According to research by Setiarto & Widhyastuti (2016), the fermentation method was able to lower the phytic acid and tannin content of sorghum flour by 13.36 to 44.65% and by 29.13 to 33.69 percent, respectively. The process of degradation will take longer if the flour has a higher tannin content. This is so that the tannase enzyme, which is produced by Lactic Acid Bacteria (LAB), may grow more in order to break down the increased amounts of tannins into simpler chemicals (Biswas *et al*. 2024).

In this work, fermentation was conducted both spontaneous and non-spontaneous. The 57 bacterial isolates that contained proteolytic acid were produced by spontaneous fermentation in sorghum for 24 hours after isolation. The isolate with the highest level of proteolytic activity was identified as LAB type Lactobacillus plantarum S4512 (Yudianti *et al*. 2020). According to Wahyuni *et al*. (2021)'s research, fermentation of sorghum for 24-36 hours can boost the LAB population. Yeast is one of the microorganisms that can be used to carry out the non-spontaneous fermentation process. Some yeasts contain amylase enzymes, which cause the amylolytic starch structure to be broken down and changed. *S. cerevisiae* was the type of yeast employed. By adding yeast, sorghum flour's protein level can rise by 10% (Dube *et al*. 2020).

Numerous factors affect the qualities of fermented flour. One of the key elements that affect fermentation's timing and temperature in addition to microorganisms. S. cerevisiae quickly adapted to the environment of the fermenter (lag phase) within 24 hours. During this phase, S. cerevisiae produced enzymes that were compatible with the substrate and at 24 hours produced the most yeast cells, 22,107 cells/mL (Parapouli *et al*. 2020).

The purpose of this study was to compare the physical and functional properties of spontaneous and non-spontaneous fermented red sorghum flour (with the addition of 1% bread yeast) at various fermentation durations, specifically at 0, 24, 48, and 72 hours.

MATERIALS AND METHOD

Materials

The raw materials used in this experiment were Bandung Local Cultivar red sorghum flour, bread yeast (Saf-instant), cooking oil (Tropical). The equipment that used in this study such as an incubator, Memert oven cabinet, RVA, Hermle z 306 centrifuge, Hwashin technology co 250 VM vortex, and Clifton waterbath.

The research method used is an experimental method followed by descriptive analysis. Observations were carried out for 72 hours in a 24-hour analysis time interval, resulting in 4 observation points for each treatment. The treatments to be performed are as follows:

A1 (TSS1) = Fermented Spontaneous 0 hour
A2 (TSS2) = Fermented Spontaneous 24 hours
A3 (TSS3) = Fermented Spontaneous 48 hours
A4 (TSS4) = Fermented Spontaneous 72 hours
B1 (TTS1) = Fermented Non-Spontaneous 0 hour
B2 (TTS2) = Fermented Non-Spontaneous 24 hours
B3 (TTS3) = Fermented Non-Spontaneous 48 hours
B4 (TTS4) = Fermented Non-Spontaneous 72 hours

This research process is based on the research conducted by (Alka *et al*. 2012). Sorghum flour was dissolved in distilled water with a ratio of 1:2 (w/v) to increase the water content to 20-30% in a plastic container with a lid. The plastic container was not tightly closed so that air could enter, then the container was placed in an incubator at a temperature of 35 ± 2°C for the fermentation process. The addition of yeast was carried out at 1% of the weight of the red sorghum flour used as a fermentation inoculum (w/w). Fermentation was carried out at a temperature of 35±2^{o}C and samples were taken every 24 hours at the 0, 24, 48 and 72 fermentation hours to see changes in its characteristics. The fermented flour was then dried at a temperature of 50^{o}C for 16 hours. Drying was carried out to reduce the water content so that it could prevent the growth of microbes and inhibit enzymatic reactions. The flour was considered to have been dried when it had reached a maximum water content of 13% or had the characteristics of not sticking to the baking sheet. After drying, the modified flour is then ground and sieved with an 80 mesh sieve, so that fine flour is obtained.

With the minor adjustment, water holding capacity was carried out using the methodology of (American Association of Cereal Chemists 2000)

Before being weighed, a 2 g sample was placed into a centrifuge tube. Mix in 9 millilitres of distilled water and give it a good vortexing. The mixture was centrifuged at 1000 rpm for 15 minutes after being let to stand for 10 minutes. After weighing and decanting (which involves putting dissolved ingredients into a solvent to separate the liquid from the particles), the following formula is used for calculation:

$$KPA = \left(\% \frac{b}{k}\right) = \frac{b - a}{a} x\ 100\%$$

Description:
a = weight before centrifugation (g)
b = weight after centrifugation

With the minor adjustment, oil holding capacity was carried out using the methodology of Alka *et al.* (2012).

Enter 1 g of the sample by adding 10 mL of oil. Stir for 30 seconds using a vortex. Allow the mixture to sit for half an hour at room temperature. After adding the solution, spin the centrifuge at 5,000 revolutions per minute for 30 minutes.

Perform the calculation of oil absorption capacity with the formula:

$$KPM = \left(\% \frac{b}{k}\right) = \frac{b-a}{a} x\ 100\%$$

Description:
a = weight before centrifugation (g)
b = weight after centrifugation (g)

With the minor adjustment, solubility dan swelling volume was carried out using the methodology of Collado & Corke (1999) with modification.

To get the swelling volume, we used a centrifuge tube, 0.35 grammes of flour, and 12.5 millilitres of water. Then, before being immersed in water up to a temperature of 92.5 degrees Celsius, the substance is packed with salt. For the next 10 minutes, the fabric will be bent every 5 minutes. According to the instructions, after 1 minute of waiting in the drying air. Afterwards, brush for 15 minutes with a 25°C washcloth. The next step is to spin the solution for 15 minutes at 3600 rpm to dissolve it. A known container is used to collect supernatants, and its properties are determined by heating it to 110 C in the dark. One way to determine solubility is using the formula:

Swelling volume :

$$Swelling\ volume = \frac{W2}{Wdm} x\ 100\%$$

Solubility :

$$Solubility = \frac{W1}{Wdm} x\ 100\%$$

Description:
Wdm = ws (1-ka) (g)
W1 = weight of the supernatant (g)
W2 = weight of gel formed (g)
Ws = weight of sample (g)
ka = water content (decimal) in wet basis

With the minor adjustment, gelatinization profile analysis using the RVA Tool (Rapid Visco Analyzer) was carried out using the methodology of AACC 22-12 method in Hung & Morita (2005).

A measuring cup was used to measure 450 millilitres of distilled water. To create a suspension, 45 g of the material was added to a beaker and mixed with distilled water. The amylograph bowl was filled with the suspension, and the leftover water was used to rinse the beaker before being added to the bowl. The amyloid head is lowered into the bowl, and the sensor arm is connected and inserted. The temperature is first regulated at 30 degrees Celsius using a thermoregulator. After the water temperature is set at below 97 degrees Celsius, the amilograph is used to measure the pH of the water at a rate of 75 parts per minute, increasing the pH by 1.5 degrees Celsius each minute. After the pasta had been heated to 95°C for 10 minutes, the amyloid machine was shut off. Then, a fan was put on to bring the temperature down to 60°C at a rate of 1.5°C per minute. Finally, the machine was started up again. After 10 minutes of temperatures over 50 degrees Celsius, the engine is again shut off. Amylography software allows computers to automatically record changes in paste viscosity. A direct printout of the graph showing the change in viscosity is possible. The following formula is used to calculate amylograph analysis:

The point at which the rising curve starts to represent the starting temperature of gelatinization. The temperature at which the gel becomes its thickest (the point when the curve is at its steepest) is called the gelatinisation peak.

Calculation of gelatinization temperature = initial temperature + [time (minutes) x 1.5°C/min] before reaching the holding temperature 95°C

Viscosity maximum = paste viscosity in *peak viscosity* expressed in *Brabender Unit* (BU)

Breakdown viscosity = viscosity maximum – viscosity in 95ºC after 10 minutes.

With the minor adjustment, starch granule shape and size was carried out using the methodology of Operating Introduction Manual (2006).

Using Electron Microscopy (SEM), the size and shape of starch granules were examined under a microscope. According to Bertoft (2017), starch granule size in the range of 5-7 m is a small granule size, 8-40 m is a medium granule size, and 110 m is a large granule size. The starch sample is stored in the specimen holder. The sample is cleaned with a hand blower to keep it free of dust. The sample was given a thin layer (coating) with gold-palladium. The sample is inserted into the specimen chamber. Observations were made on the SEM machine JSM-35: JSM 6300 LA with shooting.

RESULT AND DISSCUSION

Water Holding Capacity (WHC) and Oil Holding Capacity (OHC)

The water holding capacity of the spontaneous fermentation treatment ranged from 0.9923 - 1.1448 (g/g), while the treatment fermentation non spontaneous ranged from 1.0815 - 1.2371 (g/g). The oil holding capacity of the spontaneous fermentation treatment ranged from 1.0074 - 1.1603 (g/g), while the treatment fermentation non spontaneous ranged from 1.0273 - 1.205 (g/g) (Figure 1).

According to Figure 1, flour that has undergone spontaneous fermentation has a lower water absorption capacity than flour that has not undergone spontaneous fermentation. The ability of non-spontaneous fermented flour to absorb water is greater than that of spontaneous fermented flour may be due to *S. cerevisiae* yeast's hydrolytic activity,

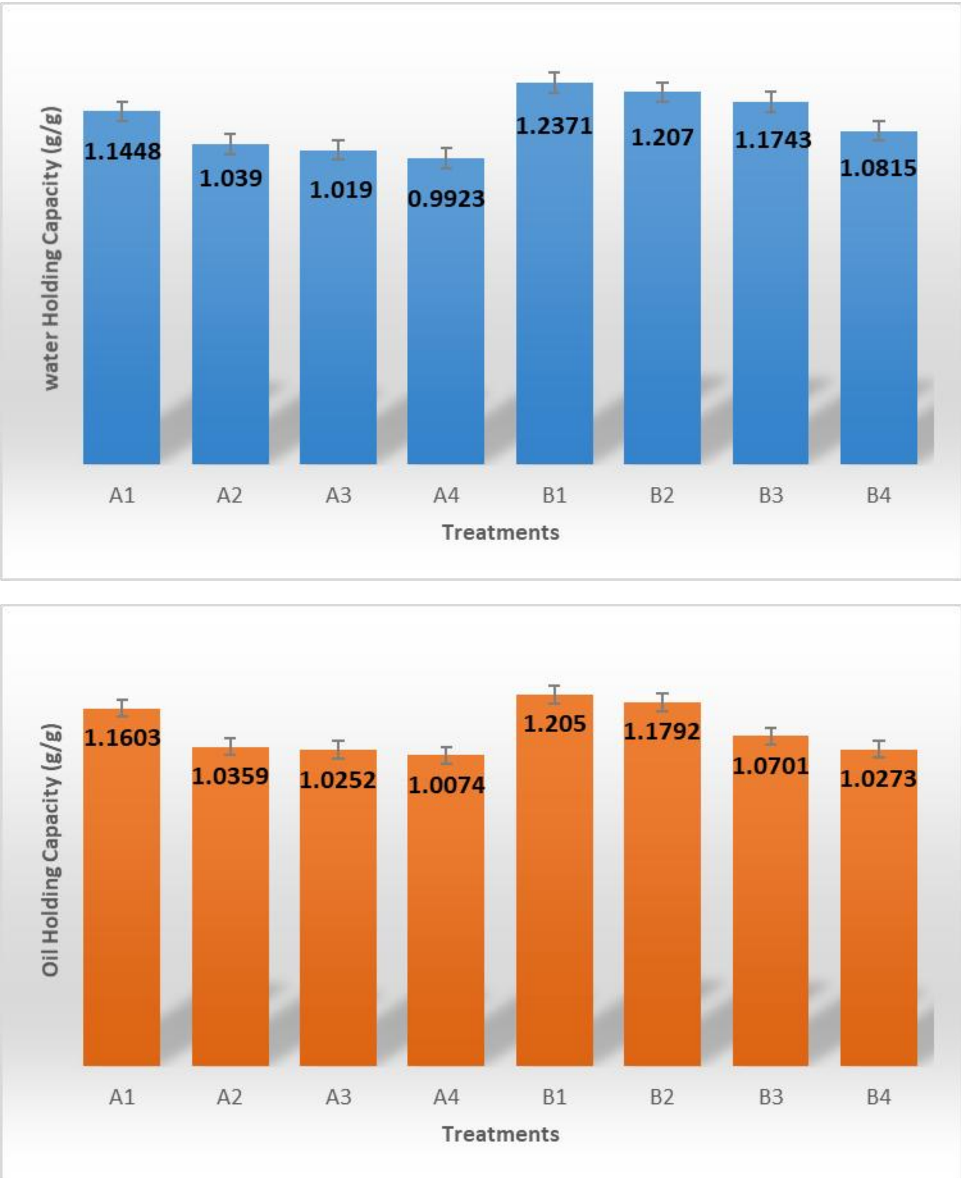


Figure 1. Water holding capacity and oil holding capacity of fermented sorghum flour

which can produce water from its metabolic process (Parapouli *et al*. 2020).The lower water absorption capacity of spontaneous fermented flour results from the extensive hydrolytic breakdown of starch (amylose and amylopectin), which diminishes its ability to retain water. Additionally, the formation of soluble sugars and altered interactions among flour components further contribute to the reduction in WHC.

The complex chemicals included in red sorghum flour are assumed to be the cause of the decline in the value of water absorption capacity and oil absorption capacity at the 24th hour, making it harder for water and oil to be absorbed by flour (Saeed Omer *et al*. 2023). According to Ann Bock & Flores (2011), the amount of fat found in flour is what causes the decrease in water absorption ability in the 48th and 72nd hours. The fat will accumulate as a coating on the granules' surface, preventing them from combining with water and causing a reduction in their ability to absorb oil from 24 to the following hour. The reason for 72 hours is that during the fermentation process, lipolytic microbial activity results in fat degradation, which lowers the amount of non-polar poles in fat.

Swelling Volume and Solubility

The swelling volume of the spontaneous fermentation treatment ranged from 7.0958 - 7.8748 (%), while the treatment fermentation non spontaneous ranged from 1.0815 - 1.2371 (%). The solubility of the spontaneous fermentation treatment ranged from 7.0958 - 7.8748 (%), while the treatment fermentation non spontaneous ranged from 6.9052 - 7.9469 (%) (Figure 2).

Figure 2. Swelling volume and solubility of fermented sorghum flour

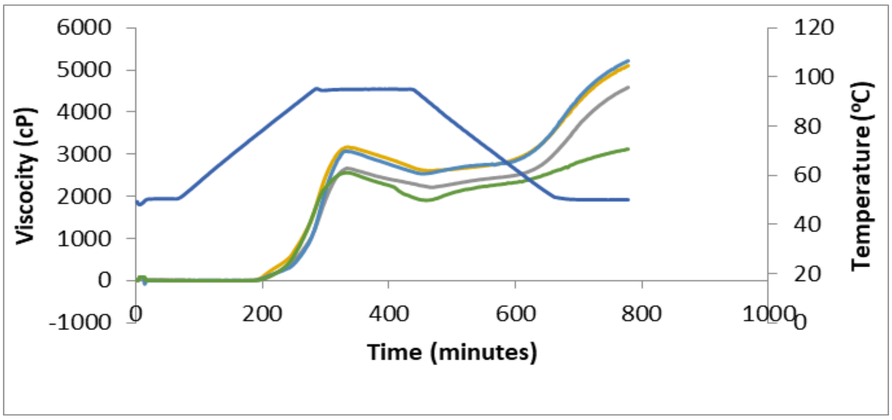
Based on Figure 2, the difference in swelling volumes reflects the extent of starch hydrolysis during fermentation. Spontaneous fermentation involves diverse microbial activity and higher enzymatic hydrolysis, leading to lower swelling volumes due to disrupted starch granules. In contrast, non-spontaneous fermentation preserves starch structure better, resulting in higher swelling capacity. Lactic acid bacteria create the acetyl group (Dillon 2014). Subroto *et al*. (2023) claim that as more hydroxyl groups are replaced by the acetyl group, the amylose content of starch drops and the levels of amylopectin rise, which results in an expansion in swelling volume. By breaking down and becoming more easily soluble in water, components that are difficult to dissolve in water such starch, fat, and protein are changed by amylase, lipase, and protease enzymes produced by microbes, which results in an increase in solubility from 0 to 72 hours (Sharma *et al*. 2020).

The gelatinization profile of Spontaneous Fermented Sorghum flour (TSS) and Non-Spontaneous Fermented Sorghum flour (TTS) can be seen in Figure 3.

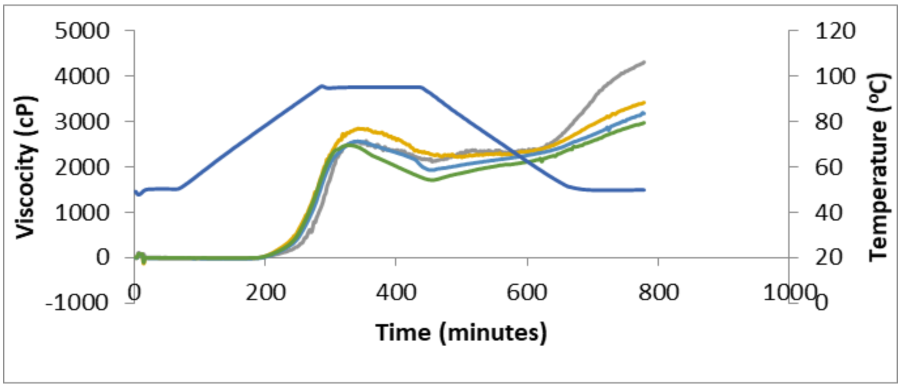
Based on the research conducted by Dwiani, Yunianta and Estiasih (2014), spontaneous fermented winged bean flour at pH 5 for 32 hours resulted in flour with a water absorption capacity of 1.6% and oil absorption capacity of 1.37%, a cold viscosity value of 18 mPas, and a hot paste viscosity value of 25 mPas. According to Ntsamo *et al*. (2020), spontaneous fermentation dominated by LAB plantararum A6 in sorghum flour fermented for 72h/37°C significantly affected peak viscosity, breakdown viscosity, and water and oil absorption capacity.

Amylographic Profile

The pasting temperature of the spontaneous fermentation treatment ranged from 76.95-77.79 (°C), while the treatment fermentation non spontaneous ranged from 75.81-77.03 (°C). The peak viscosity, the through viscosity, the breakdown viscosity, the final viscocity and the setback viscocity of the spontaneous fermentation range from 2470 - 2855 (cP); 1702 - 2214 (cP); 461 - 768 (cP); 2963 - 4309 (cP) and 1261 - 2197 (cP) respectively. The peak viscosity, the through viscosity, the breakdown viscosity, the final viscocity and the setback viscocity of the non spontaneous fermentation range from 2572 - 3172 (cP); 1911 - 2600 (cP); 453 - 661 (cP); 3135 - 5213 (cP) and 1224 - 2684 (cP) respectively (Table 1).



(a)



(b)

Figure 3. RVA (a) spontaneous fermented sorghum flour (TSS) (b) non-spontaneous fermented sorghum flour (TTS)

Table 1: Spontaneous and non-spontaneous fermented flour amylography

Fermentation Time	**Pasting Temperature (°C)**		**Peak Viscosity (cP)**		**Trough Viscosity (cP)**		**Breakdown Viscosity (cP)**		**Final Viscosity (cP)**		**Setback Viscosity (cP)**	
	TSS	TTS	TSS	TTS	TSS	TTS	TSS	TTS	TSS	TTS	TSS	TTS
The 0th hour	77.79	77.03	2573	2670	2112	2217	461	453	4309	4597	2197	2380
The 24th hour	76.56	75.81	2855	3172	2214	2600	641	572	3425	5107	1211	2507
The 48th hour	76.95	76.23	2572	3068	1940	2529	632	539	3185	5213	1245	2684
The 72nd hour	76.95	77.03	2470	2572	1702	1911	768	661	2963	3135	1261	1224

Based on Table 1, non-spontaneous fermented flour often has a greater amylographic value than spontaneous fermented flour, with the exception of the breakdown and setback viscosities at 72 hours and the initial temperature of gelatinization at 0 to 48 hours. This is most likely a result of the microflora's more controlled growth in non-spontaneous fermented flour compared to the uncontrolled growth of the microflora on spontaneous fermented flour, which results in a wide range of microflora growth. This is consistent with study by Wang *et al*. (2021), who found that distinct LAB, specifically Lactobacillus plantarum, Lactobacillus delbrueckii, and Lactococcus lactis, contributed to the microflora engaged in a 4 day spontaneous fermentation.

Although there was no discernible difference between the two treatments' starting gelatinization temperatures, both of them exhibited a drop in temperature by the 24 hours mark. Due to the increased hydration capacity of starch molecules during the 24 hours, less energy is needed to complete the gelatinization process (Yan *et al*. 2021). In a study by Altay & Gunasekaran (2006) on fermented modified corn flour, a decrease in the first gelatinization temperature at the 24 hours also occurred, with the starting gelatinization temperature at the 0th hour dropping from 76.50 to 71.50.

High quantities of protein that can form complexes with amylose, resulting in insoluble sediment and inhibiting the release of amylose from the granules, were the cause of the increase in the initial temperature of gelatinization at the 48 and 72 hours. Due to this, amylose needs more energy to leave, increasing the temperature at which gelatinization occurs (Cornejo-Ramírez *et al*. 2018).

The decrease in the initial temperature of gelatinization at the 24^{th} hour increased the peak viscosity of the spontaneous and non-spontaneous fermented flour. Xu *et al*. (2021) suggest that because the initial gelatinization temperature is dropping, starch granules may gelatinize more quickly. Microbes produce more amylase enzymes as the fermentation process goes on, which speeds up the process of breaking down the components of starch. According to research by Wulandari *et al*. (2019), the hydrolysis reaction rate increases with amylase enzyme content. Since the amylase enzyme prefers to break 1,4 bonds more easily than 1,6, this results in a drop in amylose content and an increase in amylopectin content. High peak viscosity is caused by high amylopectin concentration (Mauro *et al*. 2023). In a study by Sukainah *et al*. (2017), fermented modified maize flour saw an increase in peak viscosity from the 0th hour of 840 BU to 970 BU at 24 hours, demonstrating the same trend in peak viscosity at 24 hours.

The ability of starch to absorb water will be decreased by the hydrolysis reaction of the amylose and amylopectin chains, resulting in a drop in the value of peak viscosity at the 48 and 72 hours (Wulandari *et al*. 2019). This is consistent with studies by Hellemans *et al*. (2020), which found that the reduced viscosity is consistent with the decline in flour starch concentration. Increasing quantities of hydrophilic protein can also contribute to the decline in peak viscosity since they will compete with carbohydrates for water. The gelatinization process may be hampered by starch that hasn't absorbed enough water (Donmez *et al*. 2021).

In addition to being connected with peak viscosity, the low beginning temperature of gelatinization was also correlated with heat viscosity. Low initial gelatinization temperatures for starch will result in fluffier, more heat-resistant starch granules (Aini *et al*. 2016).It is obvious that the hot paste viscosity values that were observed at 24 hours are higher than those at 48 and 72 hours. This is also in line with studies done by Muhandri & Subarna (2009), which found that the viscosity of heated paste increased from 720 BU to 910 BU from 0 to 24 hours, then fell from 48 to 9 hours to 825 BU and 780 BU.

The breakdown viscosity value can be decreased by the hydrolysis reaction, which can lower the amylose concentration and increase the stability to heating. Since the acetyl group formed by BAL replaces the hydroxyl group, lowering the amylose content of starch, the lower viscosity value for non-spontaneous fermented breakdown should be consistent with the large swelling value of the spontaneous fermented volume (Saputro *et al*. 2012).

The breakdown viscosity value also has a direct relationship with how sticky the gel is the less sticky the gel, the more stable the paste is generated. The starch granule structure is fragile and readily shatters, as seen by the rise in breakdown viscosity after 24 and 72 hours. This happens when the starch granules expand and are heated while being stirred. The starch then decomposes, causing the viscosity to drop, indicating that the starch has broken down (Kartikasari *et al*. 2016). According to Wahyuni *et al*. (2021) research, fermented sorghum flour with a fermentation time of 1 day and 3 days witnessed an increase in breakdown from 666 RVU (non-fermented natural sorghum flour) to 1386 RVU and 1358 RVU, and declined in 2 days of fermentation, precisely equating to 1315 RVU.

The setback viscosity is inversely correlated with the breakdown viscosity. Non-spontaneous fermented flour has a greater setback viscosity value than spontaneous fermented flour. This is in line with the low swelling volume value found in flour that spontaneous ferments. The setback viscosity value is stable against retrogradation the lower it is. This is because an amylose-lipid combination will form and prevent the growth of starch granules. Amylose leaves the starch granule during gelatinization and creates an amylose-fatty inclusion complex. As a result of this complex development, amylose propensity to gel up and connect less readily, slowing down how quickly it hardens when heated (Chumsri *et al*. 2022). Conversely, a syneresis process will take place if the value becomes more negative since a higher setback viscosity will result in a stronger retrogradation process (Aini *et al*. 2016). Because it would result in hardness after cold products, a high setback viscosity is not anticipated for cake products or rerotian (Wahyuni *et al*. 2021).

The cold paste viscosity and setback viscosity in the spontaneous fermented flour treatment declined from 0 to 72 hours, while they increased at 0 to 48 and reduced at 72 hours in the non-spontaneous fermented flour treatment. In a study by Wahyuni *et al*. (2021), the setback viscosity increased from 2507 RVU (non-fermented sorghum flour) to 2905 RVU on fermentation for one day, 3043 RVU for two days, and throughout fermentation. This increase in setback and cold paste viscosities also happened in that study. While the viscosity setback increased by 1303 RVU of fermentation for one day, 1316 RVU for two days, and 1329 RVU for three days, the duration of the experiment was 3057 RVU.

The decrease that occurs is due to the breakdown of amylose and protein which can reduce the binding power of water, causing water to easily be released again. Likewise, the increase in viscosity of cold paste is directly proportional to the increase in amylose and protein, so that water absorption increases. The higher the viscosity value of cold paste shows the material is more resistant to the friction forces that occur during stirring (Kartikasari *et al*. 2016). The higher the thickness of a material, the more suitable the material is used as a thickening agent or thickener (Garcia & Chambers 2019).

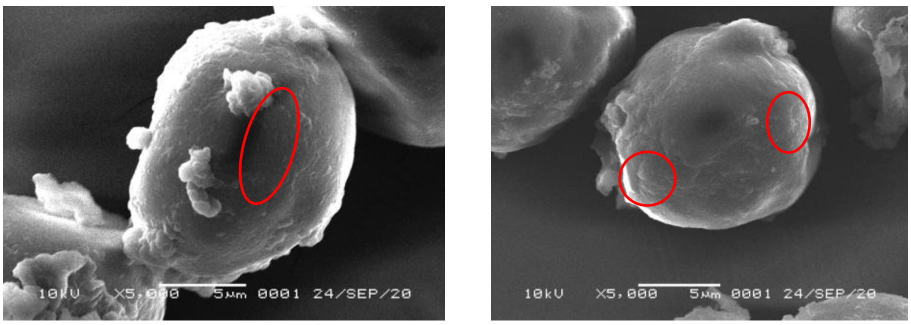
Based on Figure 4 (b), the surface of the granules which is marked with a red circle in the non-spontaneous fermented sorghum flour has a rougher surface (the number of holes on the granule surface) compared to spontaneous fermented sorghum flour. This rough granule surface is thought to be due to the activity of extracellular amylolytic enzymes produced by microbes (*S.cerevisiae*) during the fermentation process, where the starch granules undergo decomposition and then partially hydrolyzed on the surface of the granules, as a result the starch granules are perforated (Kartikasar *et al*. 2016) .

The more perforated granules, the smaller the granule size. The smaller the granule size, the faster the gelatinization process and the lower the gelatinization temperature. The smaller the granule size, the larger the surface area so that the water absorption will be greater and the peak viscosity will also be higher, besides that it is also correlated with the hot paste viscosity and breakdown viscosity, where the more water absorption into the granule, the stronger the material. retain water during the cooking process and make the dough more stable to heating (Aini *et al*. 2016). This is by following Table 1 where the decreased initial gelatinization temperature at 24 hours increased the peak viscosity, the viscosity of the hot paste.

Aini *et al*. (2016) found that the likelihood of retrogradation increased with decreasing starch granule size at cold paste viscosity and setback viscosity. The reason for this is that smaller granules have higher surface area, increasing the amylose leaching of starch granules. The retrogradation will rise with the amount of amylose that is leached, causing the product to harden more upon cooling. This is done in accordance with the study's findings, which are shown in Table 1, which showed an increase in hot paste and setback viscosity with longer fermentation times in the non-spontaneous fermented treatment.

The five different ways that enzymes can decompose a granule surface include eroding the granules surface, creating tiny pores, eroding sponge-like pores, creating medium-sized pores, and creating transparent pores in the internal granules (Jung *et al*. 2017).

According to Yusra & Putri (2023), fermented modified sorghum flour produced the greatest effectiveness index at 0 hours (control) and 12 hours. The water absorption capacity, oil absorption capacity, swelling volume, and solubility of modified sorghum flour at 0 hours were 14.21%, 5.89%, and 10.26%, respectively. However, at hours, the



(a) **(b)**

Figure 4. Starch granules of fermented sorghum flour (a) spontaneous and (b) non-spontaneous magnification 5,000 times

modified sorghum flour did not spontaneous fermented. On the 12th, we got a solubility of 9.47%, a swelling volume of 6.06%, a water absorption capacity of 14.51%, and an oil absorption capacity of 6.85%.

According to Armanda & Putri (2016) , Research on whole brown sorghum flour fermented with different yeast concentrations revealed that longer fermentation times and higher yeast concentrations resulted in lower water, starch, and tannin content, but higher swelling volume, solubility, and viscosity values. Additionally, Adegunwa *et al*. (2011) found that the temperature and time of peak viscosity were impacted by the duration of fermentation of sweet potato and bread, with higher values indicating longer fermentation times. This is likely due to a decrease in amylose and an increase in amylopectin and other minor components (such as ash, protein, and fibre). It is believed that the ratio of ammonia to amylopectin, a very small component, affects the viscosity of the punch at both the time and water levels. Time and temperature required to reach maximal viscosity are proportional to minor content and amylose/amylopectin ratio.

Based on research conducted by Akbar & Yunianta (2014) cornflour that has been soaked with $Na_2S_2O_5$ 36 hours, after which 1% yeast was introduced and left to ferment for 12 hours, the results were as follows: The percentages of water, starch, protein, amylose, yield, water absorption, swelling power, viscosity d.Pas, and total are 7.11%, 72.17%, 24.03%, and 92.71%, respectively. Angelina *et al.* (2013) found that white asparagus with a 1% rootstock had a water content of 12.85%, a protein content of 1.79%, and a protein content of 3.10%, fiber content 0.56%, protein content 5.87 % and carbohydrates 75.82%. The use of *S. cerevisiae* as much as 1 gram of yeast from the weight of cassava can increase protein from 1.92% to 2.29% (Gunawan *et al*. 2015).

CONCLUSION

After 24 hours, both spontaneous and non-spontaneous fermentation of red sorghum flour have the best functional propertis results. After 24 hours fermentation, red sorghum flour that had spontaneous fermented showed a low initial gelatinisation temperature, high peak viscosity, high hot paste viscosity, a slightly increased breakdown viscosity, a reduced setback, and high cold paste viscosity. The solubility, swelling volume, and water and oil absorption capability change their term were not affected by fermentation after 24 hours. Unseasonably fermented red sorghum flour exhibited a number of undesirable properties, including a low starting gelatinisation temperature, high peak and hot paste viscosities, slightly elevated breakdown and cold paste viscosities, and an increased setback after 24 hours. Modified red sorghum flour, particularly through fermentation, offers unique advantages that make it highly suitable for specific food applications, that are Gluten-free bread, cereal flakes, gluten-free crackers, chips and snacks.

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