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The physicochemical properties of white sorghum (*Sorghum bicolor* L.) flour in various particle sizes by soaking the seeds before and after dehulling

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Abstract

Sorghum seeds have good nutrition for human health. Therefore, preparation for food needs to be done by various methods. This study aimed to investigate the physicochemical properties of sorghum flour at various particle sizes obtained from soaked seeds in water before and after dehulling. This study used white sorghum seeds (KD-4 variety), and the experiment involved three factors: seeds soaking in water before and after dehulling, the soaking duration of the seeds (0, 12, 24, 36, 48 hrs), and the particle size of the flour passed through 40, 60, 80, 100 mesh sieves. This result showed, was chosen method of making white sorghum flour that was to soak the seeds in water for 24 hrs after dehulling. Followed by drying, milling, and sieving on various particle fractions will be adjusted according to their use. The physicochemical properties of sorghum flour were whiteness: 66.85±0.85–73.44±0.99%; bulk density: 514.35±0.95–584.10±1.00 g/L; initial temperature of gelatinization: 87.80±1.20 – 92.25±1.45°C; gelatinization time: 16.00±0.01 –18.00±1.00 mins; viscosity at temperature 50°C: 1250.1±46.7–3568.3±230.9 Cp; setback viscosity: 1250.6±46.7–3568.3±230.9 Cp; moisture content: 8.26±0.14 - 9.56±0.30% wet basis; ash content: 0.14±0.01–0.35±0.02% dry basis; protein content: 5.30±0.05–6.77±0.38% dry basis; fat content: 1.02±0.01–2.40±0.01% dry basis; carbohydrate content: 81.66±0.60–84.33±0.18% dry basis; and amylose content: 12.43±0.28–24.35±0.06% dry basis. The method for making white sorghum flour can be used to produce applied technology in home industries and suitable for cake and extrusion products.

1. Introduction

Sorghum seeds (*Sorghum bicolor* L. Moench) have many advantages, including their nutritional characteristics and protein digestibility (Austin *et al.,* 2012), food fiber content (Dicko *et al.,* 2006), bioactive compound content (Khan *et al.,* 2013), antioxidant content (Cardoso *et al.,* 2014), resistant starch content (Niba and Hoffman, 2003), and an ability to decrease the levels of cholesterol (Brites *et al.,* 2011). According to Dicko *et al*. (2006), β-glucan dietary fiber in sorghum seeds is anti-hyper cholesterol, anti-radiation, anti-inflammatory, and anti-diabetic. The phenolic components have anti-tumorigenic, antioxidant, and antimicrobial properties (Chandra *et al.,* 2016). However, some of these beneficial properties are reduced by inhibiting compounds, including tannins in the pericarp and testa layers, which cover the endosperm of sorghum seeds. These inhibiting compounds cause low digestibility of starch and protein and constipation (Cheng *et al*., 2009; Mkandawire, 2013). These inhibiting compounds need to be eliminated through various preliminary treatments before sorghum seeds are used as food products.

Sorghum seeds and flour are still limited in their use as food because they provide dry, sandy, and crumb fast and hard so that preliminary treatment is needed to improve products characteristics (Gallagher *et al.*, 2003). The palatability of sorghum seeds and flour is low, as it feels dry, is easily destroyed, and certain varieties have a dark color. In the milling process, the seeds are difficult to grind due to the high fiber and bran content of the endosperm (Alvarenga *et al*., 2018) and phenolic

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compounds on the surface of the seeds (Rooney and Waniska, 2000; Awika and Rooney, 2004). These phenolic compounds are bioactive, affecting the pericarp's color and thickness (Dykes and Rooney, 2007; Svensson *et al*., 2010). The δ-tocopherol content correlates highly with physical characteristics such as color (L*, a*, and b*) and the weight of 100 sorghum seeds (Chung *et al*., 2013).

Flour is an intermediate product that lasts longer (making it suitable for storage), is easy to mix, is enriched with nutrients, and can be easily processed into a variety of end products. The separation of the pericarp and testa is a significant problem in producing sorghum flour acceptable to the food industry. Generally, this separation uses an abrasive seeding machine (Yoon *et al*., 2017). Besides dehulling, good quality sorghum flour is obtained by additional treatments, such as soaking the seeds in water or certain solvents or fermenting lactic acid bacteria. Soaking in water can minimize damage due to oxidation of the material, and it also changes the physicochemical characteristics of flour (Haros *et al*., 2004),

Kajihausa *et al.* (2014) reported that soaking seeds in water for 12 to 14 hrs can improve the nutritional composition of sesame seeds and sesame flour and improve the flour's functional properties. Chiang and Yeh (2002) found that rice flours texture was smoother if the rice seeds were first soaked in water. After soaking, the moisture content of the seeds seemed to be a critical factor in loosening the structure of the rice seeds, resulting in fine flour particles. Corn flour made using spontaneous fermentation has a higher gel strength. Sensory evaluation of corn flour has shown that spontaneous fermentation significantly improves the quality of noodles made from corn flour that was fermented for 19 days. This study also used a toxin test to show that spontaneous fermentation was safe (Yuan *et al*., 2008). The fermentation process can improve sorghum flour's texture by reducing crumbs, the gritty texture of cookies and cakes, dryness, and hardness (Schober *et al*., 2007).

Sorghum contains high levels of crude fiber. Milling produces coarse flour, which is not suitable for bakery products. Trappey *et al*. (2015) found that sorghum flours particle size can affect product quality. The characteristics of bread are significantly affected by the flour properties, including particle size, starch damage, and fiber content. The particle size of sorghum flour affects the water absorption capacity and its swelling power. Biscuits made from sorghum flour with a particle size of 152, 104, or 75 µm had a harder texture and lower acceptability than those made from flour with a particle size of 251 µm or 180 µm (Rao, 2016).

Dehulling sorghum seeds and soaking treatments are needed to reduce the undesirable properties of the seeds and improve the food quality of sorghum flour. Dehulling can be done before or after soaking the seeds in water. The determination of the treatment is considered for the commercial production of sorghum flour and produces appropriate technology. The process of milling sorghum seeds into flour produces a variety of particle sizes, both coarse and fine. All flour fractions are expected to be usable. The characteristics of sorghum flour (including the particle size) resulting from a combination of pre-submerging seeds and subsequent soaking are unknown. Dehulling is essential for increasing the usability of sorghum flour as food. Dehulling is carried out in combination with soaking and particle size fractionation to produce sorghum flour with superior characteristics. This study aimed to investigate the physicochemical properties of flour at various particle size obtained from soaked white sorghum seeds before and after dehulling.

2. Materials and methods

2.1 Materials

The main ingredient used in the research was white sorghum seeds KD-4 varieties, obtained from Patihan Village, Babat District, Lamongan Regency, East Java, Indonesia. Chemicals used for the analysis of aquadest, petroleum ether, H_2SO_4, NaOH, K_2SO_4, HCl, ethanol, Kjeldahl tablets, pp indicator, methyl red indicator, boric acid, acetic acid, and Iod solution. The chemicals and reagents used are pro analytical grade, ladder marker.

2.2 Sorghum flour preparation

The method using a modification of the Alvarenga *et al.* (2018) to make sorghum flour. Dry sorghum seeds (moisture content of 10±1%) were either (1) dehulled after soaking the seeds and (2) dehulled before soaking the seeds. Dehulling is a process that removes the pericarp layer on the surface of the sorghum seeds and uses an abrasive type of scraper. Sorghum seeds (500 g) were soaked in water for 0, 12, 24, 36, and 48 hrs with a 1:3 ratio of seeds to water. The seeds were then dried in an oven at 60±1°C for 18 hrs until the moisture content had reached 10±1%. Dry sorghum seeds were ground in a hammer mill, and the flour was separated by particle size by passing through 40, 60, 80, and 100 mesh sieves.

2.3 Physical properties of sorghum flour

2.3.1 Whiteness of the flour

Sorghum flour samples were placed in a transparent container (such as petri dish) and the whiteness measured by a Kett Whiteness Meter. The whiteness of $BaSO_4$ was used as a standard with a value of 85.7%.

2.3.2 Bulk density

The bulk density was determined using the method proposed by Elkhalifa and Bernhardt (2010). Ten grams of sorghum flour were placed in a 25 mL measuring cup. The cup was slowly tapped ten times on the table from a height of 3 cm. The final volume of the flour was measured in g/L.

2.3.3 The pasting properties of flour

The pasting properties were measured with a (Rapid Visco Analyzer) of sorghum flour were determined using a Brookfield DV-II + Pro Programmable Viscometer. The flour's pasting properties were determined by its gelatinization behavior, which included measurements of the initial temperature and time gelatinization, the viscosity of the flour at 50°C, and the setback viscosity (AOAC, 2006; Marston *et al*., 2014).

Sorghum flour (1 g) was put into the sample chamber of the viscometer. The flour was dissolved with 10 mL of distilled water and stirred with a spatula. The spindle was mounted on a mixer, on the primary device (DV-II Pro) viscometer. The sample chamber was installed on the heating circulation device (water jacket). The heat monitor cable from the primary device (DV-II Pro) viscometer was connected to the sample chamber. Next, the heat circulation controller (TC-112P) was turned on. The heating temperature was set from the device up to 30°C by pressing and turning the knob. Afterwards, the primary tool (DV II-Pro) viscometer was turned on.

All operational parameters to be applied were filled in by pressing the program menu keypad in the primary tool or turning on the computer with the Viscometer program "Main Menu". All operational parameters were loaded and analyzed. The parameter entries needing to be entered into the program menu included spindle rotation speed, graduate time/warm-up interval, model, and spindle number used, as well as the total analysis time required. The next step was to press or click the start mark (^{0}N), then the primary tool of the viscometer worked according to the parameters of the program. After that, the temperature of the heat circulation device was immediately set to 95°C. After all stages of amylograph analysis were done, the viscometer sample chamber was removed from the heating circulation device, and the existing suspension/flour paste was removed and washed cleanly (Brookfield, 2005).

2.4 Chemical properties of sorghum flour

Chemical properties were measured by proximate analysis (moisture, ash, protein, fat, carbohydrate, and amylose content). Gravimetric methods at 105°C determined the moisture content, the ash content was determined after placing the sample in a muffle furnace at 600°C, the fat content was determined by first subjecting the sample to Soxhlet extraction, and the protein content was determined by Kjeldahl methods (AOAC, 2006). The carbohydrate content was determined by the method of reducing moisture, ash, fat, and protein content (by difference). The amylose content was determined with a UV-Vis spectrophotometer at a wavelength of 620 nm, using a modification of the Boudries *et al.* (2009) method.

2.5 Experiment design and data analysis

This study used a randomized block design with three factors: (1) soaking sorghum seeds in water (two levels) before and after dehulling; (2) soaking duration of sorghum seeds in water (five levels): 0, 12, 24, 36, and 48 hrs; and (3) the particle size of sorghum flour (four levels) through the sieve: 40, 60; 80; and 100 mesh. The experiment was repeated three times. Data were analyzed by variance (ANOVA) using SPSS 16.00 software for Windows program at a 95% confidence level. Duncan's test was carried out to determine if there was a significant difference between treatments.

3. Results and discussion

3.1 The whiteness of sorghum flour

The whiteness of the sorghum flour is shown in Table 1. The highest whiteness was obtained by soaking the seeds for 24 hrs before dehulling. The values of 73.53±0.64 – 74.27±0.38% were almost the same for flour passed through 60–100 mesh sieves. In contrast, seeds that were not soaked before dehulling produced flour with a low whiteness (61.78±0.03%). The whiteness of flour obtained from seeds that were soaked before dehulling (71.22%) was higher than those that were soaked after dehulling (68.73%).

Dehulling sorghum seeds is the initial process before further processing into food products. Dehulling aims to release the outer bran (pericarp) of the sorghum seeds and the testa layer. In sorghum, the removal process is done more than once because the outer layer of sorghum seeds (epidermis), which protects the seed endosperm, has a slippery bran surface, and the bran sticks firmly to the endosperm, causing problems in seed dehulling (Rooney and Awika, 2004). The KD-4 variety of white sorghum seeds has a layer on the brown seeds' surface, affecting the whiteness of sorghum flour. Thus, the

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Table 1. ANOVA whiteness and bulk density of sorghum flour, various particle sizes of flour by soaked seeds before and after dehulling

Soaking Duration (hr)	Particle passed through sieve (mesh)	Whiteness (%)		Bulk Density (g/L)	
		Soaking Before Dehulling	Soaking After Dehulling	Soaking Before Dehulling	Soaking After Dehulling
0	40	71.53±0.47^{mnopq}	61.78±0.03^{a}	470.50±6.24^{gh}	524.18±0.98^{kl}
	60	72.57±0.42^{pqrst}	63.85±0.25^{b}	464.00±11.82^{efgh}	487.75±1.93^{g}
	80	69.50±0.46^{hi}	63.85±0.35^{b}	428.33±8.25^{b}	486.28±2.53^{g}
	100	71.27±0.15^{lmnop}	65.45±0.35^{c}	411.50±5.29^{a}	441.45±1.35^{f}
12	40	66.87±3.58^{d}	70.50±0.60^{ijklm}	475.17±10.02^{hi}	555.05±0.85^{n}
	60	67.90±0.78^{def}	72.23±0.73^{nopqrst}	471.33±9.93^{gh}	522.55±2.15^{jkl}
	80	71.37±0.64^{mnop}	73.40±1.00^{tuv}	471.67±9.45^{gh}	515.30±1.60^{ijk}
	100	72.40±1.40^{opqrst}	72.95±0.65^{rstuv}	470.33±3.33^{gh}	521.74±1.41^{jkl}
24	40	72.87±0.25^{qrstu}	66.85±0.85^{d}	488.50±11.72^{i}	514.35±0.95^{ij}
	60	73.53±0.64^{tuv}	73.44±0.99^{tuv}	477.33±8.02^{hi}	561.35±0.56^{n}
	80	74.27±0.38^{v}	69.95±0.65^{hijkl}	457.50±2.78^{efg}	584.10±1.00^{o}
	100	74.10±0.70^{uv}	70.95±0.15^{jklmn}	455.83±4.65^{ef}	527.47±1.41^{l}
36	40	69.60±0.95^{hij}	68.60±0.30^{efgh}	457.50±10.39^{efg}	558.46±2.14^{n}
	60	71.93±2.08^{nopqrs}	71.05±0.55^{klmno}	464.50±3.50^{efgh}	536.82±1.61^{m}
	80	72.27±0.25^{nopqrst}	71.05±0.05^{klmno}	434.00±3.12^{bc}	506.40±2.90^{hi}
	100	73.20±0.20^{stuv}	71.60±0.20^{mnopqr}	470.67±4.04^{gh}	525.80±0.20^{l}
48	40	67.43±0.29^{de}	68.95±0.75^{fgh}	487.83±2.47^{i}	558.63±1.88^{n}
	60	69.43±0.32^{ghi}	67.95±0.05^{def}	467.50±2.29^{fgh}	537.69±1.56^{m}
	80	70.50±0.53^{ijklm}	68.10±0.90^{defg}	452.17±10.91^{de}	505.15±1.15^{h}
	100	71.83±0.57^{mnopqrs}	69.70±0.50^{hijk}	442.33±5.11^{cd}	488.23±1.58^{g}
DMRT 5%.		1.4		9.11	

Values in each row and column accompanied by the same superscript are not significantly different in the 5% DMRT test for each parameter

dehulling process was repeated three times.

In the dehulling process, friction occurs between the grinder stones and the sorghum seeds, which creates heat. This heat can cause Maillard reactions, which occur between reducing sugars and amino acids, resulting in a brown color (Michalska *et al.,* 2008). Sorghum seeds contain polyphenol compounds in dehulling, decreasing polyphenols (El Hag *et al*., 2002). Mba *et al.* (2019) found that there was a loss of natural phenolic compounds from sorghum seeds as a result of degradation during processing. There is a total reduction of phenols and flavonoids after soaking sorghum seeds in water for 20 hrs. The level of degradation depends on the processing conditions applied. Longer soaking times can increase the degradation of polyphenols (Afify *et al.,* 2011). After soaking, dehulling sorghum seeds can remove the pericarp (bran) because the seeds absorb water during soaking. Water absorption causes the cells in the pericarp to become unstable (Shafaei *et al.,* 2016). After soaking, dehulling the seeds can make it easier to remove the sorghum seed pericarp, so that the heat generated in the dehulling process is minimized and the whiteness of the sorghum flour is maximized.

Soaking seeds after dehulling means that sorghum seeds are soaked without the bran so that hydrolysis and other physicochemical changes occur more quickly. These changes affect the color of the seeds and the whiteness of the flour. Otegbayo *et al.* (2001), Ibukun (2008), and Sareepuang *et al.* (2008) have noted that soaking washes substances into the soaking water. Soaking also caused the diffusion of substances such as color pigments and fat clots from the outer layer into the endosperm (Otegbayo *et al*., 2001; Dutta and Mahanta, 2014). Spontaneous fermentation occurs when microorganisms are activated by the surrounding environment and grow, which can cause a decrease in pH (an increase in acidity). The activity of microorganisms that grow in the soaking medium could affect the sensory properties and nutritional value and reduce toxic and anti-nutritional factors (Misihairabgwi and Cheikhyoussef, 2017). One result of these processes is that sorghum seeds soaked after dehulling produced darker flour.

Soaking the seeds in water for long periods affected the whiteness of the sorghum flour. The whiteness increased after 24 hrs of soaking (72.00%) but decreased to 69.24% after 48 hrs of soaking. Initially, the whiteness increased because soaking can inhibit the enzymatic browning reaction caused by the enzyme phenolase, which is found in sorghum seeds. Soaking the seeds in water triggers spontaneous fermentation processes and bacteria growth, including lactic acid and proteolytic bacteria. Fermentation can increase the whiteness of the flour because it reduces the fiber content. Lu *et al.* (2003) and Kumoro *et al.* (2020) found that fermentation by yeast flour detoxified using *L. plantarum* significantly reduced the fiber content. Loss of some nutrients can be attributed to leaching out or the utilization of nutrients by microflora. Most microorganisms can breakdown starch, protein, and fat. During fermentation, lactic acid bacteria (LAB) perform a vital role in the breakdown and acidification of polysaccharides and fiber. It is used for growth, energy, and other metabolic activities (Ojokoh and Bello, 2014). Microorganisms produce amylase and glucoamylase to reduce starch and different types of polysaccharides (Phothiset and Charoenrein, 2007).

During the fermentation process, microorganisms produce specific metabolites such as enzymes, acids, alcohols, antibiotics, and carbohydrates. LAB plays a role in most fermentation processes for maintaining and improving the quality of nutrition, sensory properties, and the safety of the final product (Saeed *et al.,* 2014). Zhang *et al.* (2020) stated that the soaking solution's abnormal odor and turbidity showed that soaking could cause germination and fermentation of seeds. The process of soaking, germination, and fermentation increased the mineral solubility in the seeds and softened the grain texture. The soaking process, germination, and fermentation caused the elements to decrease. The soaking process affected the parts distributed in the endosperm and encouraged seed germination, mainly in the endosperm.

The whiteness of flour with a particle size passed 40-60 mesh sieve, which was lower than flour passing through a 100-mesh sieve (71.35%). Flour with larger particle sizes (passed through a 40-mesh sieve) had a lower whiteness (68.50%), which might result from more endospermic outer layers with more crude fiber, color pigments, and phenol compounds in the flour. This result is consistent with the findings of Trappey *et al.* (2015), who reported that the value of L* (brightness) increased significantly with a decrease in particle size.

3.2 Bulk density

The bulk density of sorghum flour is shown in Table 1. The highest bulk density of sorghum flour (584.10±1.00 g/L) was obtained from seeds soaked for 24 hrs after dehulling and which passed through an 80-mesh particle size. In contrast, sorghum flour from seeds soaked for 0 hrs before dehulling and passed through a 100 mesh sieve produced flour with the lowest bulk density (411.50±5.29 g/L). The bulk density of sorghum flour increased during soaking from 287.10 g/L at 0 hrs to 320.51 g/L after 24 hrs but then decreased to 304.96 g/L after 48 hrs; the more refined the sorghum flour, the lower the bulk density. Coarse flour (passing through a 40-mesh sieve) had a bulk density of 318.66 g/L, but this decreased to 293.58 g/L for fine flour passed through a 100-mesh sieve.

Sorghum seeds were soaked after dehulling so that water could penetrate the cells. The dehulling process leads to a higher water absorption capacity, which can reduce seed hardness. During seed soaking, the seeds imbibe water and a diffusion process marked by the entry of water into the intercellular space so that the cell wall expands. Soaking can dissolve oligosaccharide compounds such as water-soluble food fiber, but spontaneous fermentation causes the degradation of this food fiber. Natural (spontaneous) fermentation can occur during the soaking process and is characterized by the presence of foam in the soaking water. Excessive fermentation is unexpected because it affects the functional flour produced (Coffigniez *et al.*, 2019).

Parveen and Hafiz (2003) reported that some complex compounds broke down into simpler ones during the soaking process, which could change the texture, taste, and aroma. Soaking and germination under different conditions and at different times significantly improved the physicochemical and functional properties of horse gram flour (Handa *et al.,* 2017). The processes that occur during soaking occur more easily with seedless bran, resulting in a higher bulk density. A high bulk density is desirable for packaged food products with high nutritional content (Hassan *et al.,* 2013). The smaller the bulk density of the flour, the larger the space needed for storage, and the greater the transportation costs (Awolu, 2017).

Sadeghi *et al.* (2010) found that when the sphericity of flour granules was higher, a more orderly arrangement of granules was possible, and the cavities between the grains were smaller, resulting in a higher bulk density. The bulk density is a measure of the mass of material and the volume it occupies, including any spaces between particles. For flour, the bulk density is generally influenced by particle size. It is essential to determine packaging requirements, material handling, and application in wet processing conditions in the food industry (Ajanaku *et al.*, 2012; Kajihausa *et al.,* 2014).

3.3 Pasting properties of sorghum flour

The results of a pasting properties analysis of sorghum flour are shown in Table 2 and Figures 1. The pasting properties analysis measured the initial

Table 2. ANOVA pasting properties of sorghum flour, various particle sizes of flour by soaked seeds before and after dehulling

Soaking Duration (hr)	Particle passed through sieve (mesh)	Initial Temperature of Gelatinization (°C)		Gelatinization Time (minute)		Viscosity at Temperature 50°C (Cp)		Setback Viscosity (Cp)	
		Soaking Before Dehulling	Soaking After Dehulling	Soaking Before Dehulling	Soaking After Dehulling	Soaking Before Dehulling	Soaking After Dehulling	Soaking Before Dehulling	Soaking After Dehulling
0	40	79.20±2.86^{bcdefg}	93.50±0.60^{m}	13.67±0.58^{ab}	20.00±0.87^{i}	4089.1±54.7^{mno}	1545.0±25.0^{a}	1877.8±39.1^{efg}	1545.0±25.0^{d}
	60	79.10±2.29^{bcdefg}	93.20±0.30^{lm}	14.33±0.58^{bc}	18.00±0.01^{gh}	3490.0±65.0^{hij}	2313.9±110.7^{b}	1587.5±37.5^{d}	2313.9±110.7^{i}
	80	76.43±0.78^{ab}	91.70±0.50^{ijklm}	17.00±0.01^{ef}	17.00±0.01^{ef}	4700.0±85.0^{p}	4331.7±383.9^{o}	2023.3±170.3^{gh}	4331.7±383.9^{p}
	100	76.94±2.46^{abcde}	93.55±0.15^{m}	18.50±0.58^{h}	18.50±0.50^{h}	3345.0±235.0^{fghi}	2208.3±200.6^{b}	1232.5±42.5^{ab}	2208.3±200.6^{hi}
12	40	76.88±3.03^{abcd}	92.15±0.45^{jklm}	14.33±0.58^{bc}	17.50±0.50^{fg}	4768.8±231.3^{p}	2135.0±150.0^{b}	2973.8±200.8^{l}	2135.0±150.0^{ghi}
	60	78.63±1.39^{bcdefg}	90.85±0.75^{hijklm}	14.33±0.58^{bc}	17.00±0.01^{ef}	3535.0±265.0^{hijk}	3376.1±145.3^{fghi}	1647.5±187.5^{def}	3376.1±145.3^{m}
	80	81.00±2.30^{fg}	91.30±2.60^{ijklm}	14.33±0.58^{bc}	17.00±0.87^{ef}	3372.5±147.5^{fghi}	2985.0±300.0^{de}	1632.5±47.5^{de}	2985.0±300.0^{l}
	100	80.13±2.20^{defg}	89.25±0.25^{hij}	14.67±0.58^{c}	16.50±0.50^{de}	4680.6±149.4^{p}	3712.5±292.5^{jkl}	2400.6±84.4^{ij}	3712.5±292.5^{no}
24	40	76.62±3.49^{abc}	87.80±1.20^{h}	14.33±0.58^{bc}	16.00±0.01^{d}	4231.3±188.6^{o}	3568.3±230.9^{hijkl}	1983.8±185.7^{gh}	3568.3±230.9^{mn}
	60	78.60±3.87^{bcdefg}	91.80±1.40^{ijklm}	13.67±0.58^{ab}	17.50±0.50^{fg}	2692.5±42.5^{cd}	1250.1±46.7^{a}	1080.0±50.0^{a}	1250.6±46.7^{abc}
	80	80.13±2.11^{defg}	91.95±0.25^{ijklm}	13.67±0.58^{ab}	17.00±0.01^{ef}	3150.0±95.0^{efg}	3523.3±317.5^{hijk}	1440.0±90.0^{bcd}	3523.3±317.5^{mn}
	100	78.40±1.78^{abcdef}	92.25±1.45^{jklm}	13.67±0.58^{ab}	18.00±1.00^{gh}	3560.0±85.0^{hijkl}	3316.7±245.4^{fgh}	1661.7±88.1^{def}	3316.7±245.4^{m}
36	40	81.83±1.76^{g}	90.40±0.50^{hijklm}	14.33±0.58^{bc}	16.50±0.50^{de}	3143.3±91.7^{ef}	3869.4±195.8^{lmn}	1428.3±103.2^{bcd}	3869.4±195.8^{o}
	60	80.53±2.06^{fg}	90.75±2.75^{hijklm}	14.33±0.58^{bc}	16.50±0.50^{de}	3817.5±67.5^{klm}	1403.3±75.06^{a}	1629.2±133.5^{de}	1403.3±75.1^{bcd}
	80	78.57±3.00^{bcdefg}	88.70±4.50^{hi}	13.67±0.58^{ab}	16.00±0.87^{d}	3560.0±115.0^{hijkl}	2632.2±272.3^{c}	1923.3±147.5^{fgh}	2632.2±272.3^{jk}
	100	79.07±2.91^{bcdefg}	91.45±0.55^{ijklm}	14.33±0.58^{bc}	17.50±0.50^{fg}	3655.0±185.0^{ijkl}	3416.7±336.3^{fghij}	1562.5±102.5^{d}	3416.7±336.3^{m}
48	40	79.80±1.32^{cdefg}	89.75±0.55^{hijk}	14.33±0.58^{bc}	16.50±0.50^{de}	3315.6±69.4^{fgh}	2896.7±269.9^{cde}	1520.6±5.6^{bcd}	2896.7±269.9^{kl}
	60	76.93±2.01^{abcde}	89.95±0.75^{hijkl}	13.33±0.58^{a}	17.00±0.01^{ef}	3712.5±277.5^{jkl}	2152.8±91.41^{b}	1475.0±120.0^{bcd}	2152.8±91.4^{ghi}
	80	75.14±3.28^{a}	92.75±0.15^{klm}	13.67±0.58^{ab}	18.00±0.01^{gh}	4150.0±200.0^{no}	1530.6±96.23^{a}	1530.6±32.5^{cd}	1530.6±96.2^{cd}
	100	80.23±1.62^{efg}	89.55±1.85^{hijk}	14.33±0.58^{bc}	16.50±0.50^{de}	4153.3±85.2^{no}	3456.7±206.40^{ghij}	3456.7±114.5^{mn}	3456.7±206.4^{mn}
DMRT 5%		3.32		0.88		312.68		288.5	

Values in each row and column accompanied by the same superscript are not significantly different in the 5% DMRT test for each parameter

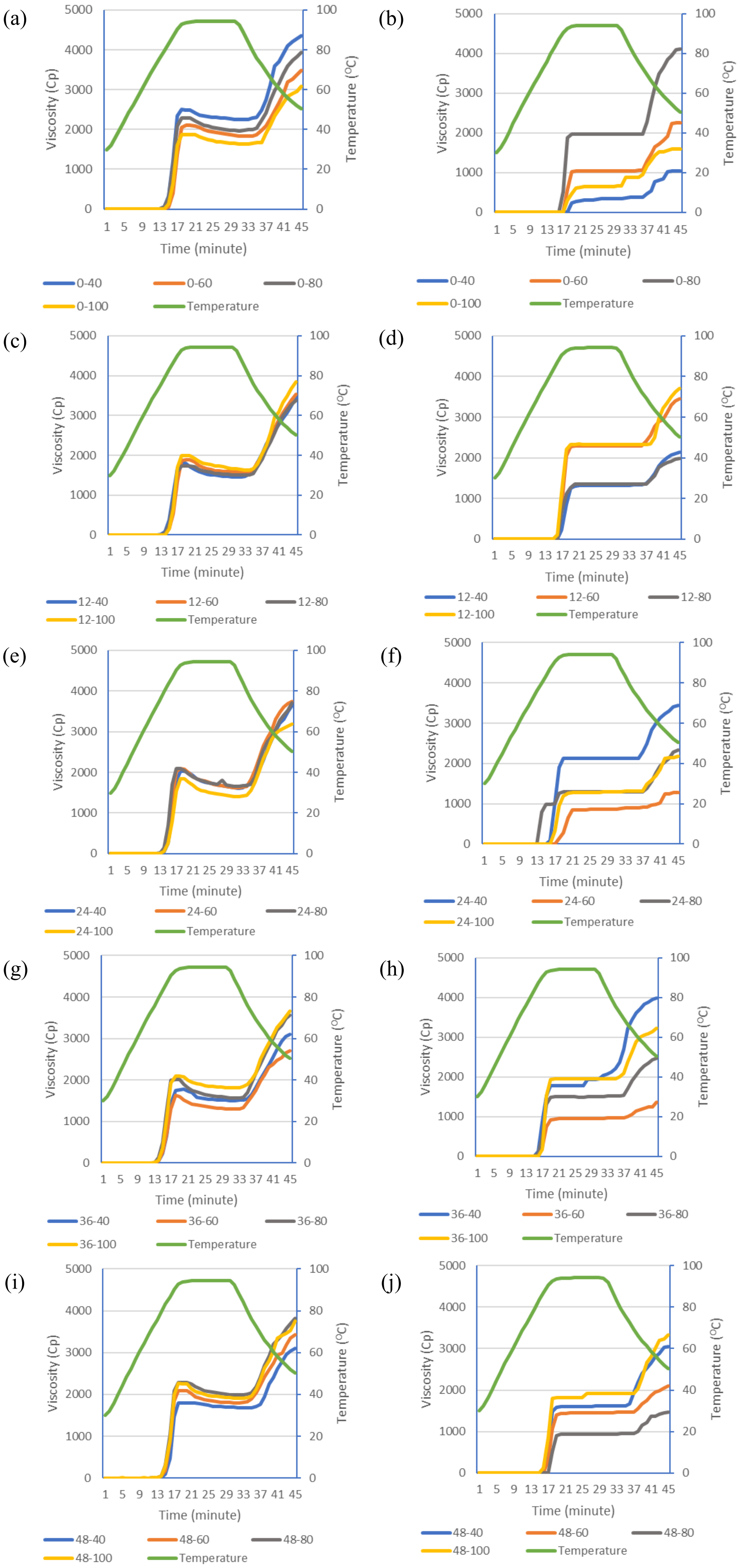

Figure 1. Pasting properties of sorghum flour by seeds soaking for 0 hrs before (a) and after (b) dehulling: 12 hrs before (c) and after (d) dehulling; 24 hrs before (e) and after (f) dehulling; 36 hrs before (g) and after (h) dehulling; and 48 hrs before (i) and after (j) dehulling, in various flour particle sizes

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temperature and time of gelatinization; as well as peak and reverse viscosity (Marston *et al.,* 2014). The gelatinization initial temperature for sorghum flour was influenced by the soaking seed before and after the dehulling process, the seed soaking duration, and the flour particle size. The highest gelatinization temperature (93.55±0.15°C) was obtained from flour with unsoaked seeds (passed through a 100 mesh sieve), after dehulled. This value was almost unchanged for the soaking duration of 0–48 hrs, and particles passed through 60–100 mesh sieves. In contrast, sorghum flour from seeds soaked (48 hrs) before dehulling, and particle size passed through an 80 mesh sieve had a low gelatinization temperature (75.14±3.28°C). A similar temperature was found for flour soaked for 0–48 hrs and particle size passed through 40–100 mesh sieves (76.43–78.40°C).

The gelatinization temperature indicates the temperature when the viscosity first begins to increase. The gelatinization temperature (91.13°C) of sorghum flour from seeds that were soaked after dehulling was higher than for flour from seeds that were soaked before dehulling (78.71°C). Soaking the seeds after dehulling gave flour that took longer to gelatinize. The gelatinization temperature of each flour sample was different and within a specific range because of the differences in the granule size population and shape and energy of the flour in the combination of the three factors needed to expand. The gelatinization temperature was measured when the starch granules contained in the flour begin to break down (Zavareze and Dias, 2011). The properties of paste formation involve granule development, the release of granule components, and finally, granule breakdown (Chanapamokkhot and Thongngam, 2007). This series of changes ultimately lead to the irreversible destruction of the starch granules molecules and gelatinization (Boudries *et al.,* 2009).

The soaking duration (0 to 48 hrs) was not different from the initial temperature of gelatinization because it was in the range of 84.26 - 85.45°C, as well as the particle size (passing the sieve of 40-100 mesh), which was in the range of 84.79 - 85.08°C. These findings show that the soaking duration and particle size did not significantly increase the initial temperature of gelatinization, so they cannot reduce sorghum flour gelatinization's maximum viscosity. When sorghum starch is gelatinized, there is an increase in sorghum starch granules viscosity (Schober *et al.,* 2007).

In gelatinization, the starch amylose structure begins to diffuse out of the granules due to the hydrogen bonds' breakdown between amylose and amylopectin. This is followed by an increase in viscosity to a maximum, and the structure of the sorghum starch granules breakdown, and sorghum starch paste forms at a temperature of 93°C (Marston *et al*., 2014). The stability of sorghum starch to heating can be tested by holding the sample at 93°C for 20 mins. If there is a significant decrease in viscosity during the holding process, the sorghum starch was unstable to heating (Marston *et al.,* 2016).

The time of gelatinization of sorghum flour was influenced by the seed soaking before and after the dehulling process, the seed soaking duration, and the particle size of the sorghum flour. The highest initial time of gelatinization (20.00±0.87 mins) was obtained with flour from seeds that were not soaked after dehulling, which was passed through a 40 mesh sieve. In contrast, sorghum flour from seeds was soaked 48 hours before dehulling, resulting in flour with a low gelatinization time (13.33±0.58 mins), which was passed through a 60 mesh sieve. Sorghum flour from soaking seeds before dehulling produced flour with a lower gelatinization time compared to flour from soaking seeds after dehulling. It appears that the higher the gelatinization temperature, the longer the gelatinization time.

Viscosity is one of the crucial parameters that affect the quality of food products. Viscosity measures the resistance to flow in a liquid. Energy is essential to breakdown the molecular structure that is firmly bound between a solid material and its liquid. The viscosity of sorghum flour at 50°C was influenced by the seed soaking before and after the dehulling process, the seeds soaking duration, and the particle size of the sorghum flour. The viscosity of sorghum flour was highest at 50^0C, was obtained by soaking the seeds (12 hrs) before dehulling. The viscosities for particle sizes obtained by passing the flour through 40 and 100 mesh sieves were similar to 4768.75±231.3 and 4680.63±149.4 Cp. In contrast, sorghum flour from seeds soaked for 24 hrs after dehulling and the flour through a 60 mesh sieve had the lowest viscosity (1250.1±46.7 Cp). Soaking the seeds before dehulling gave a viscosity of 3756.1 Cp and soaking the seeds after dehulling resulted in a lower viscosity (2781.2 Cp). Seed soaking before dehulling resulted in higher viscosity, whereas sorghum flour from seeds that were soaked after dehulling had a lower viscosity due to a more compact structure. This compact structure was seen in the bulk density of larger seeds (Table 1). The formation of such compact structures has been found to cause a decrease in viscosity (Farrés and Norton, 2014).

The highest setback viscosity (4331.7±383.9 Cp) for sorghum flour was obtained without soaking the seeds after dehulling and passing the flour through an 80 mesh sieve. Sorghum flour from seeds soaked for 24 hrs before dehulling, and which was passed through a 60 mesh sieve, produced flour with low setback viscosity

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(1080.0±50.0 Cp). Sorghum flour from seeds soaked after dehulling had a higher viscosity (2781.2 Cp) than flour from seeds soaked before dehulling (1803.4). After 12 hrs of soaking, the setback viscosity of sorghum flour increased (267.9 Cp), but decreased (2252.5 Cp) if the soaking was longer (48 hrs).

Soaking decreases the ability of sorghum flour to reach a sufficiently high setback viscosity to reshape the gel during cooling. That is because soaking lowers the pH of the soaking water, and acids can cause hydrolysis of the starch chains, so the gel formed is not as strong. Several acid-modified starches are thought to have been hydrolyzed. Similarly, esterified acetate groups replacing hydroxyl groups limit water-binding forces formation and can cause a decrease in viscosity (Ali *et al.,* 2020). Flour paste with a low setback viscosity was found to have some stability against retrogradation (Daramola and Osanyinlusi, 2006; Marston *et al.*, 2016). Setback viscosity was measured by cooling sorghum starch paste from 93°C to 50°C until a gel is formed (gelation). During the cooling process, there was an increase in viscosity due to hydrogen bonds re-formation between the amylose and amylopectin. This increase in the viscosity of the paste is associated with gel formation. The gel viscosity at 50°C is a measure of the starch ability to gelatinize and form a strong gel structure (Winger *et al.,* 2014).

The amylograph curves are classified into four types (A, B, C, and D). Type C does not show peaks as in type A or type B and is displayed by gels with a very high viscosity, which is constant or rises during cooking (Figures 1). An important property measured in starch amylography is the setback viscosity, which is the difference between the final viscosity after cooling at 50° C and the heat viscosity or maximum viscosity after heating to 95°C. The setback viscosity is the viscosity that describes the tendency of starch paste to undergo retrogradation after cooling. Besides looking at the viscosity profile, the amylograph type is shown by the amylograph curve's shape. If the amylograph curve shows an increase, it is classified into type C; if the curve is flat, it is classified as type D (Chen, 2003).

Based on setback viscosity, the increase in viscosity during the highest cooling process is shown by sorghum flour from seeds that were soaking after dehulled (2781.24 Cp), rather than seeds that were soaking before dehulled (1803.36 Cp). From these results, concluded that the treatment of soaking after dehulling increased the ability of sorghum flour to reform a gel at the cooling stage. Lower setback viscosity values indicate a starch grade with a slower retrograde (Varavinit *et al*., 2003; Liu *et al.*, 2012). The pasting properties of sorghum flour produced from soaking seeds after dehulling showed that this flour was more stable to heating than flour from soaking seeds before dehulled. It was seen in the increased viscosity of sorghum flour when held for 20 mins at 93^{0}C. The amylograph data led to conclude that sorghum flour from soaking seeds after dehulling, had a good gelatinization profile. This treatment produced stable and heat-resistant sorghum flour starch quality. The setback viscosity value gave the flour a good ability to form a gelatinized starch paste gel structure, as shown in Figure 1 (b, d, f, h, j). Sorghum flour treated in this way would be suitable for use as a raw material for making bread that requires heating at high temperatures (Marston *et al*., 2016).

3.4 Proximate compositions of Sorghum flour

Proximate composition, namely moisture content, ash content, fat content, protein content, carbohydrate content, and amylose content, are presented in Table 3 and Table 4. The highest moisture content of sorghum flour was obtained from soaking the seeds (48 hrs) before dehulling and passing the flour through a 40 mesh sieve (11.40±0.30% wet basis). Sorghum flour from seeds soaked (36 hrs) after dehulling and passing the flour through a 100 mesh sieve produced flour with a low moisture content (7.36±0.34% wet basis). During the soaking, there is a loss of components that can bind water, such as carbohydrates, proteins, fiber, and salt. Water molecules can form hydrogen bonds with other molecules and form hydrates with carbohydrates, proteins, fiber, and salt (Carcabal *et al.,* 2005). More of these components are lost when seeds without bran are soaked (after dehulling), and the moisture content after drying is lower than the flour from the soaking before dehulling treatment. Soaking also increases the concentration of acids, which can weaken hydrogen bonds. Weaker hydrogen bonds decrease the starch's molecular weight, and the structure becomes tenuous and fragile so that when drying, more water is lost (Yu *et al.*, 2017).

Moisture content is a crucial quality requirement for flour because it is related to flour durability. In its free form, water can damage food ingredients due to microbiological, chemical, and enzymatic processes, and it supports the activities of destructive insects. Lower moisture contents increasingly inhibit microbes. The higher the moisture content of food, the faster the microbial activity damage because microbes need free water for growth (Ijarotimi and Keshinro, 2013). The moisture content of food indicates dry matter in the food (Adebowale *et al.,* 2012).

The highest ash content (1.42±0.03% dry basis) for sorghum flour was obtained from seeds that were

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Table 3. ANOVA moisture, ash, and fat content of sorghum flour, various particle sizes of flour by soaked seeds before and after dehulling

Soaking Duration (hr)	Particle passed through sieve (mesh)	Moisture Content (%wb)		Ash Content (%db)		Fat Content (%db)	
		Soaking Before Dehulling	Soaking After Dehulling	Soaking Before Dehulling	Soaking After Dehulling	Soaking Before Dehulling	Soaking After Dehulling
0	40	10.16 ± 0.62^{ghijk}	10.03 ± 0.37^{ghi}	1.00 ± 0.06^{pqr}	1.38 ± 0.04^{t}	1.59 ± 0.05^{gh}	1.58 ± 0.02^{gh}
	60	9.61 ± 0.29^{efg}	10.32 ± 0.37^{hijkl}	0.96 ± 0.04^{mnop}	1.40 ± 0.04^{t}	1.85 ± 0.04^{j}	2.08 ± 0.01^{opq}
	80	9.95 ± 0.52^{fghi}	10.13 ± 0.48^{ghijk}	0.97 ± 0.01^{nop}	1.42 ± 0.03^{t}	2.04 ± 0.03^{mno}	2.08 ± 0.01^{nopq}
	100	9.68 ± 0.38^{efg}	10.41 ± 0.85^{ijkl}	0.99 ± 0.01^{opq}	1.41 ± 0.06^{t}	1.99 ± 0.01^{lm}	1.62 ± 0.03^{h}
12	40	8.83 ± 0.32^{cd}	10.76 ± 0.51^{klmn}	1.01 ± 0.04^{qr}	0.65 ± 0.02^{j}	2.01 ± 0.01^{mno}	1.09 ± 0.01^{d}
	60	9.65 ± 0.26^{efg}	10.08 ± 0.30^{ghij}	1.01 ± 0.01^{qr}	0.58 ± 0.03^{hi}	2.06 ± 0.05^{mnop}	0.73 ± 0.01^{ab}
	80	9.17 ± 0.46^{de}	10.40 ± 0.36^{ijkl}	0.95 ± 0.03^{mno}	0.61 ± 0.01^{ij}	2.16 ± 0.05^{r}	0.94 ± 0.01^{c}
	100	9.73 ± 0.55^{efgh}	10.72 ± 0.36^{jklm}	1.02 ± 0.06^{qr}	0.63 ± 0.03^{j}	2.17 ± 0.10^{r}	0.87 ± 0.01^{c}
24	40	9.35 ± 0.33^{def}	8.81 ± 0.26^{jklm}	1.05 ± 0.05^{r}	0.35 ± 0.02^{e}	2.26 ± 0.09^{s}	2.40 ± 0.01^{u}
	60	9.59 ± 0.17^{efg}	9.56 ± 0.30^{efg}	0.91 ± 0.02^{lm}	0.28 ± 0.01^{d}	2.12 ± 0.07^{pqr}	2.36 ± 0.02^{tu}
	80	8.92 ± 0.53^{d}	8.26 ± 0.14^{bc}	0.93 ± 0.02^{mn}	0.18 ± 0.01^{c}	2.31 ± 0.08^{st}	1.93 ± 0.01^{kl}
	100	8.86 ± 0.42^{cd}	9.35 ± 0.32^{def}	1.20 ± 0.05^{s}	0.14 ± 0.01^{ab}	2.17 ± 0.11^{r}	1.02 ± 0.01^{d}
36	40	9.68 ± 0.21^{cd}	7.79 ± 0.26^{ab}	0.92 ± 0.01^{lmn}	0.30 ± 0.01^{d}	1.63 ± 0.05^{h}	0.78 ± 0.03^{b}
	60	10.90 ± 0.58^{lmn}	7.59 ± 0.21^{a}	0.92 ± 0.03^{lm}	0.26 ± 0.01^{d}	1.83 ± 0.06^{j}	0.87 ± 0.01^{c}
	80	9.58 ± 0.19^{efg}	7.97 ± 0.16^{ab}	0.96 ± 0.03^{mnop}	0.13 ± 0.01^{ab}	1.76 ± 0.04^{i}	0.76 ± 0.01^{ab}
	100	10.09 ± 0.48^{ghij}	7.36 ± 0.34^{a}	0.88 ± 0.03^{l}	0.11 ± 0.01^{a}	1.88 ± 0.06^{jk}	0.70 ± 0.01^{a}
48	40	11.40 ± 0.30^{n}	9.22 ± 0.15^{de}	0.94 ± 0.04^{mno}	0.16 ± 0.01^{bc}	2.12 ± 0.03^{pqr}	1.52 ± 0.01^{g}
	60	9.92 ± 0.23^{fghi}	9.27 ± 0.20^{de}	0.77 ± 0.03^{k}	0.52 ± 0.01^{g}	2.00 ± 0.01^{mn}	1.22 ± 0.01^{e}
	80	11.07 ± 0.38^{mn}	9.25 ± 0.18^{efg}	0.61 ± 0.02^{ij}	0.42 ± 0.01^{f}	2.16 ± 0.07^{r}	1.18 ± 0.01^{e}
	100	11.10 ± 0.53^{mn}	9.66 ± 0.53^{efg}	0.55 ± 0.03^{gh}	0.39 ± 0.02^{ef}	2.14 ± 0.11^{qr}	1.42 ± 0.01^{f}
DMRT **5%**		0.636		0.048		0.074	

Values in each row and column accompanied by the same superscript are not significantly different in the 5% DMRT test for each parameter

Table 4. ANOVA protein, carbohydrate, and amylose content of sorghum flour, various particle sizes of flour by soaked seeds before and after dehulling

Soaking Duration (hr)	Particle passed through sieve (mesh)	Protein Content (% db)		Carbohydrate Content (% db)		Amylose Content (% db)	
		Soaking Before Dehulling	Soaking After Dehulling	Soaking Before Dehulling	Soaking After Dehulling	Soaking Before Dehulling	Soaking After Dehulling
0	40	8.60 ± 0.50^{klm}	7.66 ± 0.08^{ij}	78.66 ± 0.15^{efghi}	79.34 ± 0.42^{ij}	26.62 ± 1.28^{o}	20.36 ± 0.25^{k}
	60	9.31 ± 0.05^{pqrs}	7.13 ± 0.30^{fgh}	78.27 ± 0.23^{cdef}	79.07 ± 0.48^{ghij}	28.16 ± 0.95^{q}	17.43 ± 0.15^{hij}
	80	8.99 ± 0.28^{lmnop}	6.67 ± 0.12^{cde}	78.06 ± 0.29^{cde}	79.71 ± 0.53^{jk}	28.03 ± 0.55^{pq}	18.27 ± 0.07^{j}
	100	9.05 ± 0.14^{nop}	6.39 ± 0.07^{cd}	78.29 ± 0.27^{cdef}	80.18 ± 0.94^{k}	27.12 ± 1.30^{opq}	11.24 ± 0.04^{a}
12	40	9.18 ± 0.44^{opqr}	7.88 ± 0.09^{j}	78.96 ± 0.17^{fghij}	79.62 ± 0.57^{jk}	26.72 ± 0.58^{op}	16.31 ± 0.63^{fgh}
	60	8.97 ± 0.47^{klmnop}	7.26 ± 0.31^{ghi}	78.31 ± 0.48^{cdefg}	81.34 ± 0.38^{l}	26.89 ± 1.15^{opq}	14.39 ± 0.17^{cd}
	80	9.30 ± 0.27^{pqrs}	6.84 ± 0.12^{efg}	78.42 ± 0.57^{defgh}	81.21 ± 0.46^{l}	27.26 ± 0.82^{opq}	16.13 ± 0.06^{efgh}
	100	8.95 ± 0.37^{klmnop}	6.43 ± 0.05^{cde}	78.13 ± 0.43^{cde}	81.35 ± 0.39^{l}	27.30 ± 0.94^{opq}	21.46 ± 0.11^{kl}
24	40	9.62 ± 0.18^{s}	6.77 ± 0.38^{def}	77.72 ± 0.31^{bcd}	81.66 ± 0.60^{lm}	26.89 ± 0.71^{opq}	22.79 ± 0.12^{lm}
	60	9.58 ± 0.16^{rs}	5.41 ± 0.11^{ab}	77.80 ± 0.11^{bcd}	82.40 ± 0.35^{mn}	26.90 ± 0.86^{opq}	24.35 ± 0.06^{n}
	80	8.69 ± 0.25^{klmn}	5.30 ± 0.05^{a}	79.15 ± 0.70^{hij}	84.33 ± 0.18^{o}	27.18 ± 1.07^{opq}	23.47 ± 0.16^{mn}
	100	8.82 ± 0.45^{klmno}	5.60 ± 0.21^{ab}	78.96 ± 0.90^{fghij}	83.89 ± 0.50^{o}	27.36 ± 1.28^{opq}	12.43 ± 0.28^{ab}
36	40	9.51 ± 0.34^{qrs}	6.55 ± 0.06^{cde}	78.25 ± 0.46^{cdef}	84.58 ± 0.27^{o}	26.19 ± 1.46^{o}	13.84 ± 0.92^{c}
	60	9.15 ± 0.40^{opqr}	5.78 ± 0.07^{b}	77.20 ± 0.92^{ab}	85.50 ± 0.26^{p}	26.83 ± 2.11^{opq}	16.41 ± 0.40^{fgh}
	80	8.59 ± 0.05^{kl}	5.52 ± 0.11^{ab}	79.11 ± 0.20^{hij}	85.62 ± 0.20^{pq}	27.22 ± 1.74^{opq}	15.24 ± 0.42^{def}
	100	9.02 ± 0.29^{mnop}	5.49 ± 0.10^{ab}	78.12 ± 0.80^{cde}	86.34 ± 0.34^{q}	27.02 ± 0.89^{opq}	13.58 ± 0.06^{bc}
48	40	9.08 ± 0.48^{nopq}	7.30 ± 0.17^{hi}	76.46 ± 0.74^{a}	81.81 ± 0.01^{lm}	26.73 ± 1.05^{op}	16.82 ± 0.33^{ghi}
	60	9.54 ± 0.29^{rs}	6.78 ± 0.15^{def}	77.78 ± 0.22^{bcd}	82.21 ± 0.32^{mn}	26.61 ± 1.54^{o}	15.49 ± 0.24^{defg}
	80	8.55 ± 0.33^{k}	6.32 ± 0.14^{c}	77.62 ± 0.33^{bc}	82.83 ± 0.12^{n}	27.18 ± 0.72^{opq}	14.75 ± 0.02^{cde}
	100	8.60 ± 0.42^{klm}	5.82 ± 0.12^{b}	77.61 ± 0.19^{bc}	82.72 ± 0.55^{n}	28.15 ± 0.72^{q}	18.10 ± 0.70^{ij}
DMRT **5%**		0.432		0.76		1.389	

Values in each row and column accompanied by the same superscript are not significantly different in the 5% DMRT test for each parameter without soaked, and the flour passed through an 80 mesh sieve. A similar ash content (1.38±0.04–1.41±0.06% dry basis) was found for flour passed through 40–100 mesh sieves. Sorghum flour from seeds soaked for 36 hrs after dehulling and passed through a 100 mesh sieve had a low ash content (0.11±0.01% dry basis). A similar ash content (0.13±0.01% dry basis) was found for flour passed through an 80 mesh sieve. The ash content (0.93% dry basis) of sorghum flour soaked before dehulling was higher than for flour from seeds soaked after dehulling (0.57% dry basis). Longer soaking duration and smaller particle sizes decreased the ash content of sorghum flour. This decrease in ash content due to soaking results from components dissolving in the soaking water, enzyme activity (Yagoub and Abdalla, 2007; Kajihausa *et al.,* 2014), and the loss of mineral components during soaking (Kale *et al.,* 2015). Thus, seeds soaked after dehulling (without the bran) lose more of these components. The ash content can be used as an index of the total mineral material present in the flour because ash is an inorganic residue that remains after water and organic matter have been removed by heating using an oxidizing solution (Kajihausa *et al.,* 2014).

The highest fat content (2.40±0.01% dry basis) was obtained from seeds that were soaked for 24 hrs after dehulling, and the flour passed through a 40 mesh sieve. Flour passed through a 60 mesh sieve had a similar fat content (2.36±0.02% dry basis). Sorghum flour from seeds soaked for 36 hrs after dehulling and passed through a 100 mesh sieve had a low-fat content (0.70±0.01% dry basis). A similar value (0.76±0.01% dry basis) was found for flour passed through an 80 mesh sieve. The fat content of sorghum flour that was soaked before dehulling was higher (2.01% dry basis) than that in the flour from seeds that were soaked after dehulling (1.36% dry basis). Sorghum seeds are classified as having a low-fat content, but soaking the seeds and smaller particle size caused a decrease in sorghum flour's fat content. A reduction in fat content during soaking was a result from the breakdown of complex compounds into simpler ones and the disruption of the cell structure during processing (Kajihausa *et al.,* 2014).

The highest levels of protein (9.62±0.18% dry basis) were in sorghum flour from the seeds that were soaked for 24 hrs before dehulling, and the flour passed through a 40 mesh sieve. Similar protein contents (9.31±0,05–9.58±0.16% dry basis) were found for flour passed through 60 and 80 mesh sieves. Sorghum flour from seeds soaked for 24 hrs after dehulling, and passed through an 80 mesh sieve, had a low protein content (5.30±0.25% dry basis). Similar values (5.41±0.11–5.52±0.11% dry basis) were found for flour passed through 60-100 mesh sieves. The protein content (9.06% dry basis) of sorghum flour soaked before dehulling was higher than flour from seeds soaked after dehulling (6.54% dry basis). Longer soaking times and smaller particle sizes caused a decrease in the protein content of sorghum flour. The decrease in protein levels during soaking was the result of hydrolysis and the breakdown of complex compounds into simpler ones (Kajihausa *et al.,* 2014; Kale *et al*., 2015; Sousa *et al.,* 2020).

The highest levels of carbohydrates (86.34±0.34% dry basis) in sorghum flour were obtained from seeds that were soaked for 36 hrs after dehulling, and the flour was passed through a 100 mesh sieve. Similar values (85.62±0.20% dry basis) were found for flour passed through an 80 mesh sieve. Sorghum flour from seeds soaked for 48 hrs before dehulling and passed through a 40 mesh sieve had a low carbohydrate content (76.46±0.74% dry basis). Similar values (77.20±0.92% dry basis) were found for seeds soaked for 36 hrs, and the flour passed through a 60 mesh sieve. The carbohydrate content (82.29% dry basis) of sorghum flour soaked after dehulling was higher than in flour from seeds that were soaked before dehulling (78.14% dry basis).

The highest levels of sorghum flour amylose (28.16±0.95% dry basis) were found for seeds that were without soaked before dehulling, and the flour passed through a 60 mesh sieve. Similar values were found for seeds that were not soaked and for seeds that were soaked for 12–36 hrs before dehulling, and the flour passed through 40–100 mesh sieves (26.83±2.11–28.15±0.72% dry basis). Sorghum flour from the seeds that were without soaked after dehulling, whose particle size passed through a 100 mesh sieve, had a low amylose content (11.24±0.04% dry basis). The value was almost the same for seeds soaked for 24 hrs (12.43±0.28% dry basis).

Soaking the seeds and smaller particle sizes resulted in a decrease in the amylose content of sorghum flour. This decrease was the result of a breakdown of complex compounds into simpler ones (Kajihausa *et al.,* 2014). According to Sareepuang *et al.* (2008) and Kale *et al.* (2015), soaking the seeds causes a decrease in starch content because amylose is part of the starch. Starches with a high amylose content generally have a higher final viscosity (viscosity at 50^0C), and they can be used as raw materials for forming gels and films and as raw materials for vermicelli making (Winger *et al.*, 2014). Starch with a high amylopectin content has a final viscosity below 50°C, making it suitable as a thickening agent (Trappey *et al.,* 2015).

The amylose content (27.12% dry basis) of sorghum flour from seeds soaked before dehulling was higher than for flour from seeds that were soaking after dehulling (17.14% dry basis). Based on amylose levels classification, the sorghum flour resulting from soaking before dehulling had a high amylose content. On the other hand sorghum flour from the soaking seeds after dehulling had a low amylose content. Ali *et al*. (2020) classified the amylose content of flour as low (less than 20%), moderate (21-25%), and high (more than 26%). The amylose content can be used as a reference in evaluating the quality of the flour and as an essential indicator in determining the sensory product qualities.

4. Conclusion

Soaking in the water of dehulled white sorghum seed was better than soaking before dehulling, and the best time for soaking was 24 hrs. Sorghum flour could be provided in various particle sizes of 40, 60, 80, and 100 mesh sieves that could be selected for suitable processing. Increasing soaking time and decreasing particle size enhanced the whiteness of the flour for both soakings before and after dehulling. The soaking before dehulling produced better whiteness of the flour. Bulk density tended to decrease by increasing soaking time and decreasing particle size for both soakings before and after dehulling. Pasting properties and proximate composition were affected by soaking time and particle size. Soaking after dehulling increased initial temperature gelatinization, gelatinization time, and setback viscosity, meanwhile, viscosity at 50°C decreased for all particle sizes. It meant that soaking after dehulling improved pasting properties. The protein, ash, fat, amylose, and moisture content of the flour tended to be higher for the treatment of soaking before dehulling compared to soaking after dehulling, meanwhile carbohydrate content tended to decrease. The soaking after dehulling was recommended for sorghum flour processing.

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