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Physicochemical Characterization of Red Sorghum and White Sorghum Starch

Dwi Akhiriani Ramadani¹, Dedin Finatsiyatul Rosida^{1,2*}

¹ Food Technology Department, Faculty of Engineering and Science, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Indonesia

² Innovation Center of Appropriate Food Technology for Lowland and Coastal Area, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Indonesia

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CORRESPONDING AUTHOR

*E-mail: dedin.tp@upnjatim.ac.id

A B S T R A C T

Sorghum (*Sorghum bicolor* L. Moench) is a local cereal with high starch content and considerable potential as a raw material for food applications. However, the physicochemical properties of sorghum starch vary among varieties, thereby influencing its functional characteristics and suitability for food processing. This study aimed to characterize and compare the physicochemical properties of native starch extracted from red and white sorghum. The physicochemical properties evaluated included moisture content, starch content, swelling power, and water solubility. The experimental data were analyzed using analysis of variance (ANOVA) at a 95% confidence level ($\alpha = 0.05$) to determine the effect of sorghum variety on the physicochemical properties of native sorghum starch. White sorghum starch exhibited higher starch content (85.73%), swelling power (2.36 g/g), and water solubility (12.49%) than red sorghum starch. Conversely, red sorghum starch showed higher moisture content (7.83%). These differences were attributed to variations in starch composition and molecular structure between the two sorghum varieties. Overall, sorghum variety significantly affected the physicochemical properties of native starch, indicating that red and white sorghum starches possess distinct functional characteristics and are suitable for different food applications.

Contribution to Sustainable Development Goals (SDGs):

SDG 2: Zero Hunger

SDG 3: Good Health and Well-being

SDG 9: Industry, Innovation, and Infrastructure

SDG 12: Responsible Consumption and Production

1. INTRODUCTION

1.1. Research Background

Indonesia is endowed with abundant natural resources, particularly in the agricultural sector. To strengthen national food security, the utilization of locally available food resources has become an important priority. Sorghum (*Sorghum bicolor* L. Moench) is one of the indigenous cereal crops with considerable potential that remains underutilized. Globally, sorghum ranks as the fifth most widely produced cereal crop after rice, wheat, maize, and barley. Owing to its adaptability to marginal

environments and favorable nutritional composition, sorghum has attracted increasing attention as an alternative raw material for starch production [1].

Sorghum starch has broad potential for use in the food industry due to its functional properties. According to Putri and Anggreini [21], sorghum starch can partially substitute for wheat flour in various food products, including cookies at 50–80% and noodles at 15–20%, depending on the formulation and desired product characteristics. In addition, sorghum contains 80.42% starch, which is slightly higher than the starch content of corn flour 79.95% [18]. This high starch content highlights the potential of sorghum as an alternative carbohydrate source for



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food diversification and reducing dependence on conventional cereal crops.

Starch is the predominant component of sorghum grains, accounting for more than 70% of their dry weight. It is a complex carbohydrate composed of two major polysaccharides, amylose and amylopectin, which largely determine the physicochemical and functional properties of starch. In the food industry, starch is widely utilized as a thickening agent, texturizer, stabilizer, and flavor encapsulating material [15]. Variations in the proportions of amylose and amylopectin among sorghum varieties contribute to differences in starch functionality and industrial applications.

Red and white sorghum exhibit distinct starch compositions. Red sorghum contains 51.32% starch, consisting of 17.34% amylose and 33.98% amylopectin. In contrast, white sorghum contains a higher starch content 65.86%, with 19.59% amylose and 46.27% amylopectin [4]. Despite the considerable potential of sorghum as an alternative starch source, comparative information regarding the physicochemical characteristics of native starch from red and white sorghum remains limited. Such information is essential for selecting suitable sorghum varieties for specific food applications and for providing a scientific basis for further studies on starch modification. Therefore, this study aimed to compare the physicochemical properties of native starch extracted from red and white sorghum by evaluating moisture content, starch content, swelling power, and water solubility.

1.2. Literature Review

Red sorghum is characterized by higher crude fiber and phenolic contents, which contribute to its distinctive grain color and nutritional value. The chemical composition of sorghum, particularly its starch and fiber contents, is largely determined by genotype and varietal characteristics [13]. The endosperm, the major component of the sorghum grain, contains approximately 80% of the total grain protein and consists of about 82.5% starch. Meanwhile, the bran contains approximately 34.6% starch and a relatively high crude fibre content of 8.6% compared with other cereal grains, including rice [19].

White sorghum is characterized by its white to cream-colored grains, which are attributed to its relatively low phenolic pigment content. This lower phenolic concentration contributes to a milder flavor, lighter flour color, and improved digestibility compared with red sorghum. Consequently, white sorghum is widely preferred as a raw material for flour production and as a partial substitute for wheat flour in bread, bakery products, and various extruded food products [14].

Starch is a naturally occurring polysaccharide synthesized by plants through photosynthesis. At room temperature, it is a white, odorless, and tasteless powder that is insoluble in water. Structurally, starch is composed of glucose monomers linked by glycosidic bonds, which are formed through the condensation of the hydroxyl group at the C-1 position of one glucose unit with the hydroxyl groups at the C-2, C-4, or C-6 positions of another glucose unit [17].

Starch is the predominant component of sorghum grains, accounting for more than 70% of their dry weight. It is a complex carbohydrate composed of two major polysaccharides, amylose and amylopectin, both of which are polymers of glucose [15]. The starch composition varies among sorghum varieties. Red

sorghum contains 51.32% starch, consisting of 17.34% amylose and 33.98% amylopectin. In contrast, white sorghum contains a higher starch content 65.86%, comprising 19.59% amylose and 46.27% amylopectin. These compositional differences are expected to influence the physicochemical properties and functional performance of sorghum starch in food applications [4].

1.3. Research Objective

This study aimed to characterize and compare the physicochemical properties of native starch extracted from red sorghum and white sorghum.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in this study included the sorghum variety red and white sorghum. Chemicals employed for analysis included ethanol, diethyl ether, D-glucose, iodine, sodium carbonate, sodium bicarbonate, sodium potassium tartrate tetrahydrate, sodium sulfate, copper(II) sulfate pentahydrate, sulfuric acid, and arsenomolybdate.

2.2. Research Procedures

This study employed a Completely Randomized Design (CRD) with a single factor, namely sorghum variety, consisting of red and white sorghum, with two replications for each treatment. Native starch was extracted from each sorghum variety and analyzed for moisture content, starch content, swelling power, and water solubility using standard analytical methods. The experimental data were analyzed using analysis of variance (ANOVA) at a 95% confidence level ($\alpha = 0.05$) to determine the effect of sorghum variety on the physicochemical properties of native sorghum starch.

2.3. Production of Sorghum Starch

A total of 1000 g of sorghum grains were suspended in 3000 mL of distilled water and soaked for 24 hours. The soaked grains were blended for 10 minutes to obtain a homogeneous slurry, then filtered through a filter cloth to separate the starch suspension from the solid residue. The residue was washed with distilled water and filtered again. The collected filtrate was centrifuged at 3000 rpm for 30 min to recover the starch. The starch was then dried in a cabinet dryer at 70°C for 6 hours and sieved through an 80 mesh sieve. The resulting sorghum starch was used for subsequent analyses.

2.4. Physicochemical Analysis

2.4.1 Moisture Content

An empty moisture dish was oven-dried at 105°C for 15 min, cooled in a desiccator for 10 min, and weighed to determine its initial mass (A). A known mass of sample (B) was transferred into the dish and dried at 105°C for 6 h. After drying, the dish was cooled in a desiccator for 15 min and reweighed. The drying, cooling, and weighing cycle was repeated until a constant mass (C) was achieved [2].

2.4.2 Starch Content

Approximately 2–5 g of finely ground solid or liquid sample was mixed with 50 mL of distilled water, stirred for 1 h, and filtered through Whatman No. 42 filter paper. The residue was washed with distilled water until the filtrate reached a volume of 250 mL. For lipid-containing samples, the residue was washed with diethyl ether, *then with* 10% ethanol. The residue was transferred into an Erlenmeyer flask, hydrolyzed with 20 mL of 25% hydrochloric acid (specific gravity 1.125) under reflux in a boiling water bath for 2.5 h, neutralized with 45% sodium hydroxide solution, diluted to 500 mL with distilled water, and filtered. The glucose concentration in the filtrate was determined using the reducing sugar determination method, and the starch content was calculated by multiplying the glucose concentration by a factor of 0.9 [3].

2.4.3 Swelling Power

Swelling power was determined by dispersing 0.1 g starch in 10 mL of distilled water in a test tube. The suspension was heated in a water bath at 60°C for 30 min with continuous stirring. The suspension was then centrifuged at 2500 rpm for 15 min to separate the supernatant from the starch paste. The starch paste was weighed, while the supernatant was dried in an oven at 110°C until a constant weight was obtained. Swelling power was calculated using the following equation:

$$\text{Swelling power} = \frac{\text{weig st paste}}{\text{weig dry sample}} \quad [11]$$

2.4.4 Water Solubility

Solubility was determined by dispersing 1 g of starch in 20 mL of distilled water, then heating at 60°C for 30 min with gentle stirring. The suspension was centrifuged at 3000 rpm for 20 min to completely separate the supernatant from the starch paste. Subsequently, 10 mL of the supernatant was collected and dried in an oven at 105°C until a constant weight was obtained. The dry weight of the supernatant was then used to calculate starch solubility using the following equation:

$$\text{Solubility (\%)} = \frac{\text{weight dry sediment}}{\text{volume supernatant}} \times 100\% \quad [12]$$

3. RESULT AND DISCUSSION

The physicochemical properties of sorghum starch, including moisture content, starch content, swelling power, and water solubility, are presented in Table 1.

Table 1. Physicochemical Properties of Native Sorghum Starch

Parameters Analyzed	Red Sorghum	White Sorghum
Moisture Content	7.83 ± 0.08 ^a	7.17 ± 0.25 ^a
Starch Content	84.17 ± 0.04 ^a	85.73 ± 0.11 ^b
Swelling Power	1.14 ± 0.03 ^a	2.36 ± 0.27 ^b
Water Solubility	10.12 ± 0.02 ^a	12.49 ± 0.46 ^b

Values are expressed as mean ± standard deviation (n = 2). Different superscript letters within the same row indicate significant differences between sorghum varieties according to ANOVA (p < 0.05).

3.1. Moisture Content

The moisture content of native red sorghum starch was 7.83%, which was higher than that of native white sorghum starch 7.17%. The difference in moisture content between the two starches is attributed to varietal differences, as moisture levels are influenced by genetic factors, grain structure, chemical composition, and environmental conditions during plant growth and postharvest handling. Red sorghum grains contain higher moisture 11.20–12.50% than white sorghum grains 11.08–11.92% [7]. Red sorghum generally possesses a thicker pericarp and a higher concentration of phenolic compounds than white sorghum. Phenolic compounds can interact with cell wall polysaccharides, proteins, and starch via hydrogen bonding, thereby strengthening the grain matrix and reducing moisture diffusion during drying. Consequently, water is removed more slowly from red sorghum than from white sorghum, resulting in slightly higher residual moisture content. Genotypic variation influences the physicochemical characteristics of sorghum starch, including its interaction with water. Starch granules with a greater affinity for water tend to retain higher moisture contents after drying than those with a more compact granular structure [6].

The differences in moisture content between red and white sorghum starch are also associated with variations in grain structure and chemical composition. Red sorghum flour had a higher moisture content, 12.28%, than white sorghum flour, 11.96%. These differences are mainly attributed to varietal characteristics, grain structure, and chemical composition [14]. Red sorghum contains higher levels of phenolic compounds, flavonoids, and dietary fiber than white sorghum. These compounds are predominantly concentrated in the pigmented pericarp, enhancing the grain's water-binding and water-retention capacities. Consequently, the thicker and more complex pericarp structure of red sorghum contributes to its higher moisture content compared with white sorghum [5].

3.2. Starch Content

The starch content of native red sorghum starch was 84.17%, whereas native white sorghum starch exhibited a slightly higher starch content of 85.73%. This difference is primarily attributed to varietal variations in grain chemical composition. White sorghum generally contains lower levels of phenolic compounds than red sorghum, resulting in a greater proportion of carbohydrates, particularly starch. Consequently, white sorghum exhibits a higher starch content than red sorghum. White sorghum grains contained 88.15% starch, compared with 83.81% in red sorghum [14]. The native starch content of white sorghum 65.86% was higher than that of red sorghum 51.32%. Chemical composition of sorghum, including its starch content, is strongly influenced by genotype and varietal characteristics [13].

White sorghum exhibited a higher starch content than red sorghum, which may be attributed to its lower concentrations of polyphenols and tannins. Polyphenols and tannins can interact with starch and proteins, thereby affecting the physicochemical properties of starch. The higher tannin content in red sorghum promotes the formation of starch–tannin complexes, resulting in a lower proportion of extractable starch than in white sorghum [8]. Pigmented sorghum varieties, including red sorghum,

contain higher levels of phenolic compounds, tannins, anthocyanins, and kafirin proteins than white sorghum [16]. The greater abundance of these non-starch components reduces the relative starch proportion in red sorghum grains, leading to a lower starch content than that of white sorghum.

3.3. Swelling Power

Swelling power of native red sorghum starch was 1.14 g/g, whereas native white sorghum starch exhibited a higher swelling power of 2.36 g/g. These results indicate that native white sorghum starch has a greater capacity to absorb water and swell than native red sorghum starch. The higher swelling power of white sorghum starch is not solely determined by the amylose-to-amylopectin ratio but is also influenced by starch molecular architecture, the presence of non-starch components, and the degree of crystallinity. Yan et al. (2023) reported that the swelling behavior of starch granules is strongly affected by the degree of crystalline order and the stability of double-helical structures, which play an essential role in maintaining granule integrity during heating. Consequently, variations in starch molecular organization among sorghum varieties contribute to differences in their swelling properties [20]. Similarly, Kaufman et al. (2017) demonstrated that different sorghum hybrids exhibited significant variations in starch granule size, amylose content, and thermal properties [9]. These structural and compositional differences influence the ability of starch granules to absorb water and undergo swelling during heating. Red sorghum contains higher levels of phenolic compounds, flavonoids, and anthocyanins than white sorghum. These phenolic compounds can interact with starch molecules through hydrogen bonding and other molecular interactions, forming starch-phenolic complexes that restrict water penetration into starch granules [10]. As a result, the water absorption capacity and swelling ability of red sorghum starch are reduced compared with those of white sorghum starch.

3.4. Water Solubility

The water solubility of native red sorghum starch was 10.12%, whereas native white sorghum starch exhibited a higher water solubility of 12.49%. These results indicate that native white sorghum starch possesses a greater capacity to dissolve in water than native red sorghum starch. The observed difference in water solubility between the two sorghum varieties can be attributed to variations in starch composition and granule structure. In particular, the higher water solubility of white sorghum starch is closely associated with its higher amylose content. Amylose is more readily released from starch granules during heating because of its predominantly linear molecular structure. Water solubility of white sorghum starch is associated with starch granules that are more susceptible to hydration and facilitate the release of starch components during heating compared with those of red sorghum starch. Differences in the internal organization of starch granules among sorghum varieties affect the extent of water penetration, granule disruption, and the diffusion of starch molecules into the aqueous phase [20]. Consequently, starches with granules that hydrate more readily generally exhibit higher water solubility. This increase in dissolved

solids results in higher water solubility values than those observed for red sorghum starch.

4. CONCLUSION

The physicochemical properties of native sorghum starch differed between red and white sorghum varieties. White sorghum starch exhibited higher starch content, swelling power, and water solubility, whereas red sorghum starch showed higher moisture. These differences indicate that sorghum variety plays an important role in determining the physicochemical characteristics of native starch and its potential applications in food products.

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