Potential of Local Light Brown Waxy Sorghum as a Healthy Rice Substitute

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Abstract

Sorghum rice, developed from local light brown waxy sorghum, is a potential alternative staple food to replace conventional rice. This study evaluated the effects of polishing (milling) frequency and soaking conditions on sorghum rice quality and determined the best formulation. A Factorial Completely Randomized Design (CRD) was used with two factors: polishing frequency (once and twice) and soaking conditions (water at 100℃ for 24 h and 36 h at room temperature, baker's yeast 0.25% w/v for 24 h and 36 h at room temperature). Parameters analysed included physical quality (stickiness), chemical quality (sugar, dietary fiber, amylose, tannin, antioxidant activity), and sensory attributes. Data were analysed by ANOVA with Duncan's and Dunnett's tests. The best treatment was two-time polishing with soaking in water at 100℃ for 24 h. The product showed desirable characteristics: hardness 1686.7 gf, adhesiveness -77.29 g·s, elasticity 61.62%, cohesiveness 0.294, sugar 0.277 g/100 g, amylose 5.09%, tannin 32.91%, dietary fiber 2.97% (high), and antioxidant activity IC_{50} 5.782 ppm (very strong). Sensory results indicated a slightly brown color, no acidic odor, slightly sticky texture, moderately sweet, and no sour taste. These findings demonstrate that local waxy sorghum can produce rice-like products with high nutritional and functional value, supporting its potential as a healthy rice substitute.

Keywords: stickiness, local, polishing, soaking, light brown waxy sorghum.

1 Introduction

Rice is the main staple food widely consumed by the Indonesian population. Along with the increasing population, the demand for rice continues to rise [1]. In 2021, rice production in Indonesia reached 31.36 million tons, increasing to 32.07 million tons in 2022, or a growth of 2.29% [2]. However, the high dependency on rice consumption has led to a decline in the consumption of alternative staple foods. To reduce this dependency, diversification of local food products is necessary, with sorghum being one promising candidate as an alternative carbohydrate source.

Sorghum *(Sorghum bicolor L. Moench)* is a cereal crop tolerant to both drought and waterlogging conditions, making it more adaptable than many other crops. It also has a low glycemic index (GI 46.12), compared to rice (GI 64), making it suitable for people with diabetes mellitus [3, 4]. In addition, sorghum contains beneficial bioactive compounds such as phytosterols, antioxidants, and tannins [5]. However, tannins, particularly condensed tannins found in sorghum, may impart an astringent or bitter taste [6, 7]. Processing methods such as polishing, soaking, boiling, and fermentation can reduce tannin levels and improve stickiness [8].

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This study used local light brown waxy sorghum from Lamongan, which is highly preferred by the community. Waxy sorghum varieties, with low amylose (0–15%) and high amylopectin (85–100%), are suitable for producing sorghum rice due to their sticky texture [9]. Considering its nutritional and functional advantages, this research aimed to investigate the effects of polishing frequency and soaking duration on the quality of local light brown waxy sorghum rice. The findings are expected to serve as a basis for selecting and developing sorghum-based food products.

2 Materials and methods

2.1 Place and Time of Research

The research was conducted at the Food Processing and Chemistry Laboratory of Sahid University, PT Vicma Lab Indonesia, and the Laboratory of Bogor Agricultural University (IPB). The study was carried out from March to August 2023.

2.2 Equipment

The equipment used in the preparation of local light brown waxy sorghum rice included a Camry digital scale, a Matrix analytical balance, plastic containers, sealed containers, a Taffware Digital Food Thermometer, and a Miyako Warmer Plus PSG-607 rice cooker. The instruments used for sample analysis included Pyrex glassware, parchment paper No. 41, a UV-Vis spectrophotometer (CECIL CE 1021), a Memmert GE-175 gravity oven, an XLAB-02 vortex mixer, an IKA C-MAG HS 7 hot plate magnetic stirrer, and a TA-XT2i texture analyzer.

2.3 Research Method

This study was divided into two stages: a preliminary study and the main study. The research variables consisted of two factors: Factor A (polishing frequency), which included one-time polishing and two- time polishing, and Factor B (soaking conditions), which included soaking in boiling water (100°C) for 24 h, soaking in boiling water (100°C) for 36 h, soaking in baker's yeast 0.25% w/v for 24 h, and soaking in baker's yeast 0.25% w/v for 36 h at room temperature.

2.4 Preliminary Study

This stage was conducted to determine the preferred type, color, taste, and cooking method of white rice among consumers. A survey was conducted through an online questionnaire with 207 respondents. White rice was used as a control in the sensory evaluation of the main study. The respondents' satisfaction survey results are presented in Table 1.

Table 1. Survey Results of Preferred White Rice

No	Description	Percentage (%)
1	Type of rice: soft and medium texture	51.7
2	White rice color	97.1
3	Pandan aroma	63.8
4	Slightly sweet taste	72.0
5	Cooking method: rice cooker	92.8

Based on Table 1, the preferred type of rice was soft and medium texture, with a percentage of 51.7%. The most favored rice color was white (97.1%), while 63.8% of respondents preferred rice with a pandan aroma. In terms of taste, 72.0% of respondents favored rice with a slightly sweet flavor. Furthermore, the most common cooking method preferred by respondents was using a rice cooker, reported by 92.8% of participants. These results indicate that the majority of respondents tend to choose rice with specific sensory characteristics that are familiar and practical in daily cooking.

2.5 Main Research

The main research was conducted by producing waxy sorghum rice (local light brown variety) subjected to polishing and soaking treatments. In this study, polished once refers to sorghum grains that underwent a single mechanical polishing process to partially remove the bran layer, whereas polished twice refers to sorghum grains that underwent two consecutive mechanical polishing processes to further remove the bran layer.

The procedure referred to and modified the sorghum grain soaking and cooking methods described by Widowati [6], as well as Rahmawati and Yaniansah [10]. The process began with weighing the polished sorghum grains separately, followed by washing three times with running water. The soaking treatments were conducted using bottled water at 100 °C for 24 hours, bottled water at 100°C for 36 hours, baker's yeast solution at 0.25% (w/v) for 24 hours, and baker's yeast solution at 0.25% (w/v) for 36 hours, with a sorghum-to-water ratio of 1:3 (w/v). After soaking, the grains were drained, washed three times again, and reweighed. Cooking was performed using a rice cooker with a sorghum-to-water ratio of 1:2.5 (w/v) until the grains were fully cooked into sorghum rice.

2.6 Analytical Methods

The quality of light brown waxy sorghum rice was evaluated based on physical, sensory, and chemical parameters. Physical parameter stickiness [11]. Sensory Evaluation Quality scoring test: color, acidic aroma, texture, sweet taste, and sour taste. Hedonic test: color, aroma, texture, and taste. Chemical parameters analysis was conducted only on the best-selected sample, including: Total sugar content [12, 13], amylose content [14], tannin content [15], dietary fiber content [16], antioxidant activity [17].

3 Results and Discussion

3.1 Stickiness (Texture Profile Analysis)

Stickiness was evaluated using Texture Profile Analysis (TPA) with a texture analyzer. The test employed a probe that compressed the sample twice, simulating the chewing or biting process in the mouth. Four parameters were measured: hardness, adhesiveness, elasticity, and cohesiveness. The average hardness value of local light brown waxy sorghum rice with one-time polishing was 4477.8 gf, while two-time polishing produced a lower average hardness of 1948.5 gf. Under different soaking conditions, the average hardness ranged from 2972 gf to 3605.7 gf (Table 2).

Two-time polishing produced lower hardness values than one-time polishing. The results of the present study indicate that polishing removes the outer seed layers, resulting in softer grains and producing rice with a more desirable sticky texture. Budiyanto [8] reported that mechanical polishing can separate the endosperm layer. Furthermore, polishing of sorghum involves the removal of the testa, pericarp, aleurone, sub-aleurone, embryo, and germ layers [9], which contributes to grain softening [6]. Table 2 presents the hardness values (gf) of sorghum rice under different treatments.

Table 2. Hardness values (gf) of sorghum rice under different treatments

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	4665.7±134.2^{c}	4129.6±62.3^{b}	5101.3±43.3^{a}	4014.7±6.1^{b}	4477.8±61.48^{a}
2 times	1686.7±48.2^{a}	2068.0±68.1^{b}	2110.1±91.2^{b}	1929.3±30.7^{b}	
Average	3605.7±67.25^{a}	2972.0±18.4^{c}	3176.2±91.2^{b}	3098.8±65.0^{ab}	

Remarks: numbers followed by the same letter in the same column or row indicate that the results are not significantly different based on the 5% DMRT test

Soaking also influenced hardness: longer soaking times increased water absorption, resulting in softer and more porous grains [18]. Soaking in baker's yeast (0.25% w/v) further softened the texture and reduced astringency [10]. Extended fermentation enhanced water uptake, leading to a softer sorghum rice texture [9].

Lower hardness values indicate softer textures in local waxy sorghum rice [19]. Accordingly, the treatment with two-time polishing and soaking in water at 100℃ for 24 h produced the lowest hardness value (1686.7 gf), indicating the softest texture. Adhesiveness represents the energy required to overcome the attractive forces between the food surface and the probe during measurement [20]. As shown in Table 3, one-time polishing produced an average adhesiveness of –91.17 g·s, while two- time polishing resulted in a slightly lower adhesiveness of –79.83 g·s. Under different soaking conditions, the average adhesiveness ranged from –52.27 g·s to –105.8 g·s. Soaking in baker's yeast 0.25% w/v for 36 h yielded higher adhesiveness values compared to other soaking treatments, suggesting increased stickiness under prolonged fermentation.

Indrianti et al. [21] reported that the adhesiveness value of sorghum noodles was −22.7 g·s, while instant corn noodles were reported to have adhesiveness values ranging from −16.76 to −37.05 g·s [22]. These results indicate that the local light brown waxy sorghum rice produced in the present study exhibited a higher level of adhesiveness compared to those reported in the previous studies. This difference is likely influenced by the polishing and soaking treatments applied in this study. Polishing aims to soften the grains by removing the aleurone layer, which can affect the textural properties of the resulting noodles [6].

Table 3. Adhesiveness (g·s) of sorghum rice under different treatments

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	–105.8±1.2	–112.2±3.4	–26.93±0.6	–119.73±8.5	-91.17±3.43^{a}
2 times	–77.29±5.2	–72.51±1.1	–77.61±1.1	–91.87±4.1	-79.83±2.88^{b}
Average	–91.55±3.2	–92.36±2.3	–52.27±0.9	–105.80±6.3	

Remarks: numbers followed by the same letter in the same column or row indicate that the results are not significantly different based on the 5% DMRT test.

Soaking is one of the factors contributing to adhesiveness, since water absorbed by starch granules can act as a plasticizer in the amorphous region, resulting in a chewy and sticky texture [20]. The low amylose content may reduce the adhesiveness of the light brown local sorghum rice produced [22]. The lower the amylose content, the weaker the gel structure formed, which increases soluble solids and consequently, leads to higher adhesiveness [23]. Thus, the sample polished once and soaked in 0.25% w/v yeast solution for 24 hours showed a relatively high adhesiveness value of -119.73 g·s.

Elasticity or springiness is defined as the ability of a food product to return to its original shape and size after being subjected to force [24]. As shown in Table 4, the average elasticity value for sorghum polished once was 52.73%, while sorghum polished twice yielded a higher average elasticity of 56.13%. Meanwhile, the average elasticity values under different soaking conditionsranged from 50.66% to 59.24%.

Table 4. Elasticity Test Results (%)

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	56.85 ± 0.6^{d}	48.71 ± 1.5^{a}	47.87 ± 0.2^{a}	57.48 ± 0.3^{d}	52.73 ± 0.65^{a}
2 times	61.62 ± 1.5^{e}	52.61 ±1.5^{b}	56.18 ± 1.7^{cd}	54.11 ± 1.5^{bc}	56.13 ± 1.55^{b}
Average	59.24 ± 1.05^{c}	50.66 ± 1.5^{a}	52.05 ± 0.95^{a}	55.80 ± 0.9^{b}	

Remarks: numbers followed by the same letter in the same column or row indicate that the results are not significantly different based on the 5% DMRT test.

Indrianti et al. [21] reported that the elasticity value of sorghum noodles was 0.93%, while Prabawa et al. [25] reported that the elasticity value of wet sorghum noodles ranged from 10.58% to 40%. These findings indicate that the young brown local waxy sorghum rice produced in the present study exhibited a higher level of elasticity compared to those reported in previous studies. Furthermore, among all treatments, the sample subjected to two-time polishing and soaked in hot water at 100°C for 24 hours showed the highest elasticity value, reaching 61.62%.

The cohesiveness of young brown waxy local sorghum rice reflects the extent to which the product resists breaking when bitten [22]. The results presented in Table 5 show that sorghum rice with one- time polishing had an average cohesiveness value of 0.301, whereas two-time polishing resulted in a lower average value of 0.278. The average cohesiveness values under different soaking conditions ranged from 0.285 to 0.296.

Table 5. Cohesiveness Test Results

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	0.298±0.0^{b}	0.294±0.0^{b}	0.303±0.0^{bc}	0.274±0.0^{a}	0.295±0.0^{b}
2 times	0.275±0.0^{a}	0.308±0.0^{c}	0.269±0.0^{a}	0.301±0.1$^{a\ c}$	0.278±0.1^{b}
Average	0.296±0.0^{b}	0.289±0.0^{a}	0.285±0.0^{a}	0.288±0.0^{a}	

Muhandri et al. [21] reported that the average cohesiveness value of sorghum noodles was 0.64. Cohesiveness refers to the ability of starch to form a gel through gelatinization, and previous studies have shown that strong stickiness generated by high amylopectin content plays an important role in elasticity formation [22]. Based on the results of the present study, the sample subjected to one-time polishing and soaked in a 0.25% (w/v) yeast solution for 36 hours exhibited the highest cohesiveness value of 0.308, indicating improved stickiness.

3.2 Organoleptic Test

The organoleptic test consisted of a hedonic test and a quality score test. The evaluation was conducted by 30 untrained panelists with hedonic parameters including color, texture, aroma, and taste. Meanwhile, the quality score parameters included color, aroma, texture, and sweet taste. The hedonic assessment criteria used a 6-point scale: 1 (Dislike very much), 2

(Dislike slightly), 3 (Neutral), 4 (Like slightly), 5 (Like), and 6 (Like very much).

3.2.1 Color

Color is the first impression perceived by panelists before recognizing other sensory stimuli. It plays a crucial role in all types of food as it strongly influences the level of panelists' acceptance [26]. As shown in Table 6, the sample polished twice and soaked in water at 100°C for 24 hours obtained the highest color preference score of 4.9 (Like). When compared to rice, the color preference score was relatively similar, reaching 5.4 (Like).

In Table 7, the sample with a "Like" hedonic score had a color value of 3.8 (slightly brown). Compared to rice, which had a color score of 5 (not brown), this indicates that the sorghum sample has a darker, more brownish color than rice.

Table 6. Hedonic Test Results for the Color of Local light brown waxy sorghum Rice

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	**100℃, 36 h**	**Yeast 0.25% w/v, 24 h**	**Yeast 0.25% w/v, 36h**	
1 time	3.2	3.9	4.0	3.9	4.1±1.2
2 times	4.9	4.6	4.4	4.6	4.3±0.5
Average	4.1±0.4	4.3±0.2	4.2±0.3	4.3±0.5	
Comparator (Rice)	5.4±0.0				

Remaks**:** 6 = Like very much, 5 = Like, 4 = Like slightly, 3 = Neutral, 2 = Dislike, 1 = Dislike very much

Table 7. Quality Score Test Results for the Color of Local light brown waxy sorghum Rice

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	**100℃, 36 h**	**Yeast 0.25% w/v, 24 h**	**Yeast 0.25% w/v, 36h**	
1 time	1.4	1.9	1.7	2.1	1.8±0.3
2 times	3.8	3.8	4.2	3.8	3.9±0.2
Average	2.6±1.7	2.9±1.3	3.0±1.8	3.0±1.2	
Comparator (Rice)	5.0±0.0				

Remaks: 5 = White, 4 = Slightly yellow, 3 = Moderately brown, 2 = Brown, 1 = Dark brown

Light brown waxy sorghum rice polished once tended to have a darker brown color compared to rice polished twice (Table 6). This is likely influenced by the color of the sorghum pericarp, the presence of pigments in the testa layer, and secondary plant pigments [27]. A possible factor affecting the color of local waxy sorghum is the degree of polishing; the more it is polished, the more the brown color of the sorghum diminishes.

3.2.2 Aroma

Aroma is an important factor in determining consumer acceptance of a food product. The aroma of a product can provide a perception of stickiness [26]. The results of the hedonic aroma test are shown in Table 8.

Table 8 shows that the sample polished twice and soaked in 100℃ water for 24 hours had one of the highest aroma preference scores, 4.4 (like). Compared to white rice, the preference score was similar at 5.5 (like).

Table 9 shows that one sample with a hedonic "like" score had a quality score for aroma of 4.6 (not sour). For comparison, white rice had a score of 4.9 (not sour). Soaking in baker's yeast 0.25% w/v for 36 hours produced a relatively strong sour aroma (2.8). The dominant volatile compounds in sorghum are esters and alcohols, followed by alkanes, and straight-chain monocarboxylic fatty acids (C4–C16), which contribute to sour, rancid, and cheesy notes [25]. Some heterocyclic compounds, such as furans, furanones, and pyrroles, derived from lipid peroxidation, were also detected in sorghum.

These compounds are generally less preferred by panelists [28]. During soaking, carbohydrates/polysaccharides are broken down into sugars, which are then metabolized by yeast into alcohol and acids. Therefore, longer soaking results in higher acid production, leading to a stronger sour aroma [29].

Table 8. Hedonic Test Results for Aroma of Local light brown waxy sorghum Rice

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	4.3	4.4	4.2	4.4	4.3±1.0
2 times	4.4	3.0	3.8	1.8	3.3±1.1
Average	4.4±0.1	3.7±0.7	4.0±0.8	3.1±1.3	
Comparator (Rice)	5.5±0.0				

Remaks: 6 = Like very much, 5 = Like, 4 = Slightly like, 3 = Neutral, 2 = Dislike, 1 = Strongly dislike.

Table 9. Quality Score Test Results for Aroma of Local light brown waxy sorghum Rice

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	4.6	4.4	4.6	4.1	4.4±0.2
2 times	4.6	3.6	4.4	1.5	3.5±1.4
Average	4.6±0.0	4.0±0.6	4.5±0.1	2.8±1.8	
Comparator (Rice)	4.9±0.3				

Remaks: 5 = No aroma, 4 = Slightly sour aroma, 3 = Moderately sour aroma, 2 = Strong sour aroma, 1 = Very strong sour aroma

3.2.3 Texture

Texture refers to the overall evaluation of a food material perceived by the mouth when chewed. Each food type has its own textural properties depending on its physical state, cell size, and structure [30]. Table 10 shows that the sample polished twice and soaked in 100℃ water for 24 hours had one of the highest texture preference scores, 4.9 (like). Compared to white rice, the preference score was similar at 5.5 (like). Table 11 shows that one of the samples with the highest hedonic score had a texture quality score of 3.7 (slightly sticky). Compared to white rice, which was stickier, with a texture score of 4.6 (sticky).

Table 10. Hedonic Test Results for Texture of Local light brown waxy sorghum Rice

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	3.7	3.1	3.8	4.0	3.7±0.4
2 times	4.9	4.4	4.3	4.1	4.4±0.3

Average	4.3±0.8	3.8±0.9	4.1±0.4	4.1±0.7	
Comparator (Rice)	5.5±0.0				

Remaks: 6 = Like very much, 5 = Like, 4 = Slightly like, 3 = Neutral, 2 = Dislike, 1 = Strongly dislike.

Table 11. Quality Score Test Results for Texture of Local light brown waxy sorghum Rice

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	2.7	3.2	2.7	3.3	3.0±0.3
2 times	4.6	4.6	4.6	4.7	4.6±0.1
Average	3.7±1.3	3.7±1.3	3.7±1.0	4.0±1.0	
Comparator (Rice)	4.6±0.6				

Remaks: 5 = Sticky, 4 = Slightly sticky, 3 = Slightly dry, 2 = Dry, 1 = Very dry

The use of baker's yeast produces a sticky, soft texture. This soft texture is mainly caused by the soaking treatment. Soaking sorghum in water softens the grains because water molecules are absorbed into the sorghum kernels [8]. In addition, soaking with 0.25% w/v yeast has the potential to further soften the sorghum texture and reduce its astringent taste [10]. Therefore, the longer the fermentation process, the higher the water absorption capacity, resulting in an increasingly softer sorghum texture [9].

3.2.4 Taste

The acceptance of a product is also determined by its taste. Taste is a key factor in evaluating a product, as it can be sensed by the taste buds and strongly influences panelists' decisions to accept a food product. The results of the hedonic test and quality score of young local light brown waxy sorghum rice in terms of taste are presented in Tables 12, 13, and 14.

Table 12. Hedonic test results for the taste of young local light brown waxy sorghum rice

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	4.3	4.8	4.6	4.1	4.5±0.4
2 times	4.8	4.4	4.5	3.2	4.2±0.7
Average	4.6±0.4	4.6±0.3	4.6±0.7	3.7±0.7	
Comparator (Rice)	5.1±0.1				

Remaks: 6 = Like very much, 5 = Like, 4 = Somewhat like, 3 = Neutral, 2 = Dislike, 1 = Dislike very much

In Table 12, the sample milled twice and soaked in 100℃ water for 24 hours had one of the highest aroma preference scores, 4.8 (like). Compared to white rice, the taste preference score is similar at 5.1 (like).

Table 13. Quality score results for the sour taste of young local light brown waxy sorghum rice

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	4.3	4.7	4.6	4.6	4.5±0.1
2 times	4.6	4.2	4.4	2.9	4.0±0.8
Average	4.5±0.2	4.5±0.2	4.5±0.1	3.8±1.2	

Comparator (Rice)	4.7±0.1

Remaks: 5 = Not sour (bland), 4 = Slightly sour, 3 = Moderately sour, 2 = Sour, 1 = Very sour

Table 14. Quality score results for the sweet taste of young local light brown waxy sorghum rice

Polishing Frequency	Soaking Condition				Average
	100℃, 24 h	100℃, 36 h	Yeast 0.25% w/v, 24 h	Yeast 0.25% w/v, 36h	
1 time	4.2	3.9	4.4	4.5	4.3±0.3
2 times	4.2	4.3	4.2	4.5	4.3±0.1
Average	4.2±0.0	4.1±0.3	4.3±0.1	4.5±0.1	
Comparator (Rice)	4.4±0.1				

Remaks: 5 = Very sweet, 4 = Moderately sweet, 3 = Sweet, 2 = Slightly sweet, 1 = Not sweet (bland)

Sorghum contains tannins, which can create an astringent taste when consumed. The tannin content in the young local light brown waxy sorghum rice studied was 0.08% [9], which is relatively lower compared to other sorghum varieties. The use of yeast, as shown in Tables 13 and 14, tends to reduce the sour taste while enhancing sweetness. Yeast can potentially soften the texture and decrease astringency because the microorganisms in baker's yeast are highly active in forming flavor precursors. Amino acids, peptides, and reducing sugars act as precursors that form flavor components, thereby improving the organoleptic taste scores [29].

3.3 Supporting Tests

Supporting tests were conducted based on the best treatments determined from chewiness (hardness and elasticity) and the highest acceptance of color and texture. Therefore, the selected best treatment was young local light brown waxy sorghum rice milled twice and soaked in 100℃ water for 24 hours. The supporting tests performed in this study included: total sugar content, dietary fiber, amylose content, tannin content, and antioxidant activity.

3.3.1 Total Sugar Content Test

The results of the present study showed that the total sugar content of the young local light brown waxy sorghum rice was 0.277 g/100 g. Ishmah and Anugrah [31] explained that a decrease in glucose content may occur because rice stored in a rice cooker is exposed to room temperature during glucose measurement, which can lead to unstable temperature conditions and fluctuations in glucose levels.

3.3.2 Dietary Fiber Test

The dietary fiber content in the young local light brown waxy sorghum rice was 2.97%. A food can be considered a source of dietary fiber if it contains at least 3% fiber [32]. According to BPOM, dietary fiber claims in processed foods require a minimum of 3 g/100 g [33]. Sorghum grains contain 7.55–12.3% fiber [34]. Based on this data, young local light brown waxy sorghum rice milled twice and soaked in 100℃ water for 24 hours meets the criteria as a fiber-rich food product. Consuming fiber can prolong satiety because it slows gastric emptying and inhibits glucose transport. Fiber can also reduce intestinal contraction, thereby lowering glucose absorption [35].

3.3.3 Amylose Content Test

Testing the young local light brown waxy sorghum rice milled twice and soaked in 100℃ water for 24 hours yielded an amylose content of 5.09%. Sorghum typically contains 4.77–6.75% amylose [36]. Therefore, the sorghum in this study conforms to the reported range. Amylose and amylopectin content in sorghum is influenced by environmental and genetic factors. Environmental factors include drought and pests, while amylose content is also affected by the recessive wx gene. Waxy sorghum varieties possess three recessive waxy genes (wxwxwx) and typically contain almost 100% amylopectin. In this study, the young light brown waxy sorghum contained 94.91% amylopectin.

3.3.4 Tannin Content Test

The results of the present study showed that the tannin content of young local light brown waxy sorghum rice milled twice and soaked in water at 100 °C for 24 hours was 32.91 mg/100 g. Tannins are known to contribute to a slightly bitter or astringent taste in sorghum, as reported by Widowati [6]. Previous studies have reported that tannin levels in sorghum rice range from 0.14% to 0.45% [37], while Rahmawati et al. [9] reported a tannin content of 0.08% in dark brown local waxy sorghum seeds. Therefore, the tannin content observed in the present study can be considered relatively low. The results of the present study showed that the young local light brown waxy sorghum, although subjected to the best treatment, still contained a higher tannin level compared to those reported in other studies. This finding is not consistent with the results reported by Amrinola et al. [7], who demonstrated that tannin content in sorghum can be reduced through polishing of the outer seed coat, soaking, boiling, and fermentation.

In general, polishing is one of the key factors contributing to the reduction of tannin levels in sorghum. This process removes the outer layer of the sorghum seed (testa), where most tannin components are concentrated, resulting in tannin loss during polishing [7]. Soaking also plays an important role in tannin reduction, as longer soaking or fermentation periods increase the duration of contact between the grains and water, thereby enhancing tannin leaching. The water solubility of tannins is evidenced by the brownish color observed in the soaking water.

3.3.5 Antioxidant Activity Test

In this study, the results showed that young local light brown waxy sorghum rice milled twice and soaked in hot water at 100 °C for 24 hours exhibited antioxidant activity of 92.48%, with an IC_{50} value of 5.782 ppm. Previous studies have reported that sorghum contains total phenolic compounds of 313 μg/g with antioxidant activity of 53.83 μg/g [38]. In addition, the chocolate sorghum variety 1167048 showed an IC_{50} value of 6.05 ppm, while variety BRS 305 had an IC_{50} value of 4.40 ppm [39]. These comparisons indicate that the IC_{50} value of the young local light brown waxy sorghum rice obtained in this study is comparable to, and in some cases lower than, those reported in previous studies, suggesting strong antioxidant potential.

Sorghum contains polyphenolic compounds in the form of tannins, which can act as antioxidants [25]. The antioxidant activity was measured using the DPPH (1,1-diphenyl-2-picrylhydrazyl) method by recording absorbance values with a UV-Vis spectrophotometer. The young local light brown waxy sorghum rice samples, after incubation, were measured for absorbance using the UV- Vis spectrophotometer. An IC50 value of less than 50 ppm indicates that the sample possesses very strong antioxidant activity [40].

4 Conclusion

The number of stickiness and soaking conditions significantly affect the stickiness in terms of hardness, elasticity, and organoleptic properties (α = 0.05). Based on stickiness tests using hardness, adhesiveness, elasticity, cohesiveness, and texture parameters assessed through hedonic and quality score tests, the best-performing sample was young local light brown waxy sorghum rice milled twice and soaked in hot water at 100 °C for 24 hours. The quality characteristics of the best-performing young local light brown waxy sorghum rice were as follows: stickiness with hardness of 1686.7 gf, adhesiveness -77.29 g·s, elasticity 61.62%, cohesiveness 0.294; total sugar content 0.277 g/100 g; amylose 5.09%; tannin 32.91%; dietary fiber 2.97% (high); antioxidant activity with IC50 5.782 ppm (very strong); color 3.8 (slightly brown); aroma 4.6 (no sour aroma); texture 3.7 (slightly sticky); sour taste 4.6 (no sourness); and sweet taste 4.2 (moderately sweet). There is no tendency for difference between the white rice comparator and the best- performing young local light brown waxy sorghum rice. Therefore, young local light brown waxy sorghum rice can be accepted by the public.

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