CHARACTERIZATION AND FINANCIAL FEASIBILITY, ANALYSIS OF SORGUM STICKS: UTILIZING RED SORGUM, WHEAT, AND TAPIOCA FLOUR BLENDS

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ABSTRACT

This study aims to determine the optimal formulation for sorghum sticks by combining red sorghum flour, wheat flour, and tapioca flour, while also assessing the financial feasibility of its production. The research employed a Randomized Block Design (RBD) with five formulation treatments (S1–S5). Parameters observed included chemical characteristics (protein, moisture, and ash content) and organoleptic properties (taste, texture, aroma, and color). The results indicated that the formulation variations significantly affected the product's chemical properties. The optimal treatment was achieved by formulation S5 (34% sorghum flour, 32% wheat flour, and 22% tapioca flour), which contained 7.60% protein, 4.62% moisture, and 1.34% ash. The organoleptic scores for this formulation were 4.18 for taste, 4.08 for texture, 3.88 for aroma, and 3.73 for color. Based on the financial analysis, the sorghum stick production is considered feasible for development, with an R/C ratio of 1.52.

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1. Introduction

Sorghum (*Sorghum bicolor* L. Moench) is a food crop well-suited for cultivation in drylands, possessing a nutritional profile comparable to rice and maize, with even higher protein content [1-3]. Given this potential, sorghum has the opportunity to be developed as an alternative food source in Indonesia [4-5]. However, its utilization remains limited and has yet to receive optimal attention, despite the crop being long-established and cultivated across various regions [6].

Moreover, Red sorghum is rich in protein, fiber, vitamins, minerals, and bioactive compounds, such as tannins and anthocyanins, which possess antioxidant properties [7]. Although it contains antinutritional factors that may reduce consumer acceptance, processing sorghum into flour has been shown to decrease these antinutrients without eliminating antioxidant activity [8]. Furthermore, sorghum flour is gluten-free, making it safe for individuals with celiac disease or those on a gluten-free diet [9]. Additional advantages include its low glycemic index, drought resistance, and eco-friendly cultivation characteristics [10].

One form of sorghum product diversification is the snack stick, a savory snack made from a blend of sorghum, wheat, and tapioca flours [11]. These sticks are characterized by their crunchy texture and savory flavor, making them popular across various consumer groups [5]. Currently, the utilization of sorghum as a raw material for snacks in Indonesia remains low; therefore, the development of sorghum-based sticks is expected to enhance both the nutritional and economic value of this crop.

2.Method

2.1 Material

This research was conducted from July to October 2025 at the Agricultural Industrial Engineering Laboratory, University of Tribhuwana Tunggadewi, Malang. The primary raw material used was red sorghum cultivated in Maumere, East Nusa Tenggara, representing a distinctive local commodity. This sorghum was subsequently blended with other ingredients, specifically wheat flour and tapioca flour, for the production of sorghum sticks.

2.2 Research Design

This study employed a Randomized Block Design (RBD) based on the proportions of red sorghum flour, wheat flour, and tapioca flour, consisting of five formulations. Each treatment was replicated three times, resulting in a total of 15 experimental units. The research was conducted in two stages: the preparation stage and the production of sorghum sticks.

2.3 Red Sorghum Flour Preparation

The red sorghum grains were initially washed to remove impurities and damaged kernels. Subsequently, the grains were soaked in clean water for 6 hours. Following the soaking process, the grains were drained to remove excess water. The drying process was carried out using a cabinet dryer at 40°C for 8 hours until the moisture content was reduced. The dried sorghum grains were then ground using a grain milling machine. Finally, the resulting flour was sifted through an 80-mesh sieve to obtain fine and homogeneous sorghum flour. Figure 1 shows how to proceed with the sticks of sorghum.

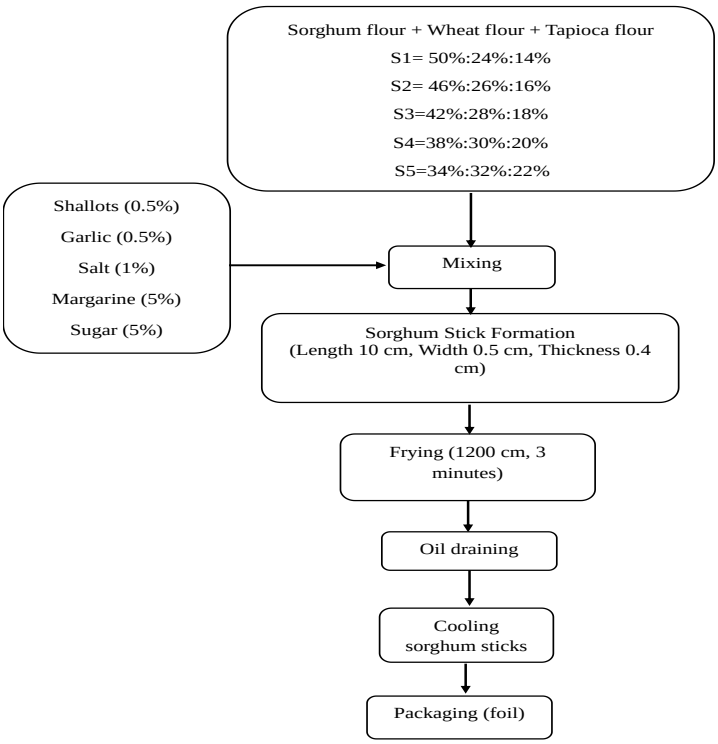


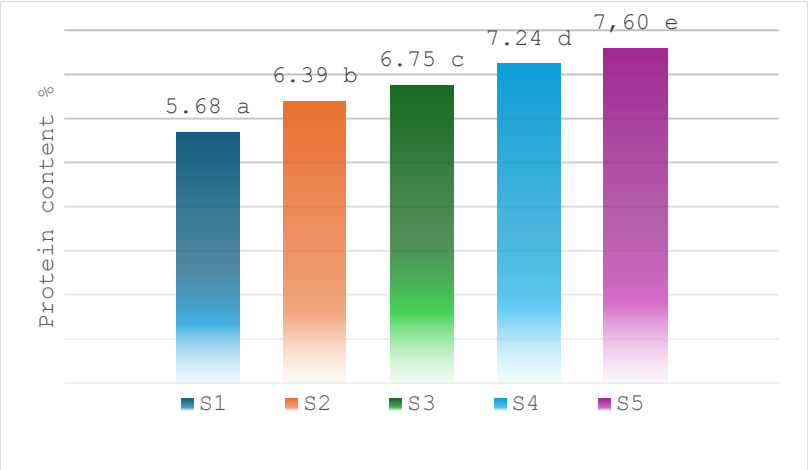
Figure 1. Sticks of sorghum production

3. Results and Discussion

3.1 Protein Content

Protein content is a critical indicator in evaluating the quality of food products, particularly flour-based snacks such as sticks. Protein serves as a vital structural nutrient and significantly influences the texture and overall quality of the final product. Based on the Analysis of Variance (ANOVA), the calculated F-value was 143.97, which is greater than the F-table value of 7.01 at the 1% significance level (8.65). Since the F-calculated (143.97) exceeds the F-table (7.01), the treatments had a highly significant effect on the protein content of the sticks. This indicates the variations in formulations led to significant effects in the product's protein levels.

To determine which treatment exerted the most substantial influence on protein content, a Least Significant Difference (LSD) post-hoc test was conducted at the 5% level. The calculation yielded an LSD value of 0.12. The results of the LSD test demonstrated that each treatment had significantly different average protein contents. The mean protein values for each treatment are presented in the bar chart shown in Figure 2.



Proportions of red sorghum flour, wheat flour, and tapioca starch
S1= 50%:24%:14%
S2= 46%:26%:16%
S3=42%:28%:18%
S4=38%:30%:20%
S5=34%:32%:22%

Figure 2. Protein Content

The results of the protein content analysis for the sorghum sticks are presented in Figure 3. The protein analysis was conducted across five different treatments, utilizing various compositions of sorghum flour, wheat flour, and tapioca starch [12]. The findings reveal that the protein content ranged from 5.68% to 7.60%, indicating that the varying proportions of each ingredient significantly influenced the nutritional content of the product. Statistically, the highest protein content was observed in the treatment consisting of 34% sorghum flour, 32% wheat flour, and 22% tapioca starch. Conversely, the lowest value was found in the treatment with 50% sorghum flour, 24% wheat flour, and 14% tapioca starch. In general, it was observed that the protein content increased with a higher proportion of wheat flour and decreased as the proportion of sorghum flour became more dominant

3.2 Moisture Content

Moisture content represents the amount of water present within a food material or product. This component plays a vital role in determining food quality and shelf life. Excessive moisture content makes products more susceptible to spoilage, whereas excessively low moisture levels can alter texture and sensory properties. This is consistent with the findings of [], who stated that moisture content significantly influences the stability and final quality of food products. Based on the Analysis of Variance (ANOVA), the calculated F-value was 5.19, which is greater than the F-table value of 3.84 at the 5% significance level, though lower than the 7.01 value at the 1% level. Since the F-calculated (5.19) exceeded the F-table (3.84), the treatment had a significant effect on the moisture content. Consequently, a Least Significant Difference (LSD) post-hoc test was performed. The calculation yielded an LSD value of 0.79. The results of the LSD test demonstrated that each treatment possessed significantly different mean moisture contents, as illustrated in Figure 3.

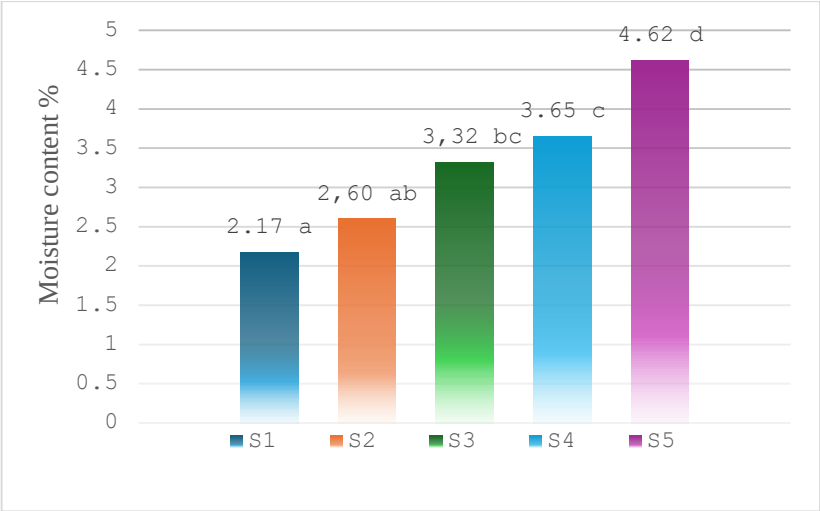


Figure 3. Moisture Content

Proportions of red sorghum flour, wheat flour, and tapioca starch
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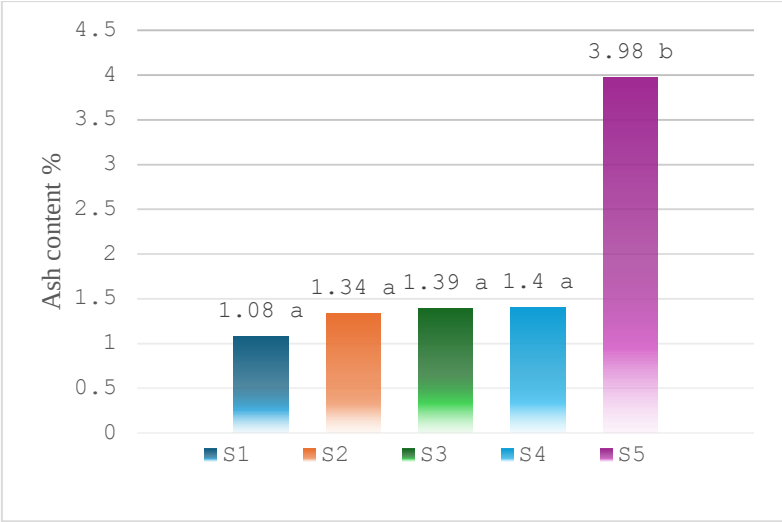
S5=34%:32%:22%

The results of the moisture content analysis for the sorghum sticks are presented in Figure 4. The diagram illustrates the variations in moisture content among sorghum stick products formulated with different proportions of sorghum flour, wheat flour, and tapioca starch [7]. Each treatment (S1–S5) resulted in distinct moisture levels, which were influenced by the specific composition of the ingredients used [13]. As shown in the chart above, the moisture content of the sorghum sticks varied across each flour formulation. Treatment S5 exhibited the highest moisture content (4.62%), attributable to the higher proportions of wheat flour and tapioca starch, which enhance water-binding capacity. Conversely, treatment S4 recorded the lowest moisture content (2.17%) due to the high proportion of sorghum flour, which possesses lower water absorption properties. The moisture content in food products plays a crucial role in determining both freshness and shelf life [14].

3.3 Ash Content

Ash content is a vital indicator in assessing the quality of food products, including sorghum sticks. This component represents the total mineral content remaining after organic matter is combusted at high temperatures. A higher ash value indicates a greater mineral content within the product. However, excessively high ash content may indicate contamination, such as dust, dirt, or other unintended residues (Winarno, 2004). Based on the Analysis of Variance (ANOVA), the calculated F-value was 52.09, which is significantly higher than the F-table value of 7.01 at the 1% significance level. Since the F-calculated (52.09) exceeded the F-table (7.01), the treatment had a significant effect on the ash content. Consequently, a Least Significant Difference (LSD) post-hoc test was performed. The calculation yielded an LSD value of 0.31. The results of the LSD test demonstrated that each treatment possessed significantly different mean ash contents, as illustrated in Figure 4.



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3.4 Sensory Evaluation: Taste

Taste is a critical factor in product development, as it is the primary stimulus perceived by the gustatory senses when food is consumed. The flavor profile of a food product is significantly influenced by its base ingredients. A product can only be deemed acceptable by consumers if its flavor meets their preferences (Wahdayani, 2021). Consequently, taste testing is a fundamental parameter in sensory evaluation to determine the level of consumer acceptance of a food product. In this study, the taste perception of sorghum sticks was affected by the raw material composition, specifically the proportions of red sorghum flour, wheat flour, and tapioca flour used in each formulation. These results are illustrated in the following figure.

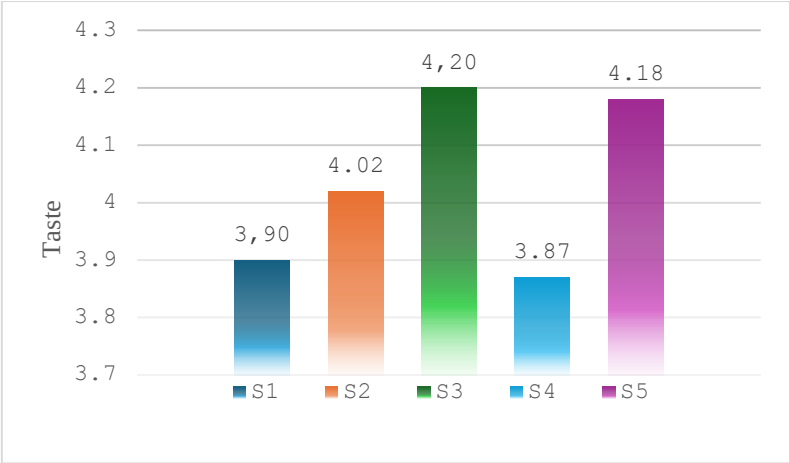

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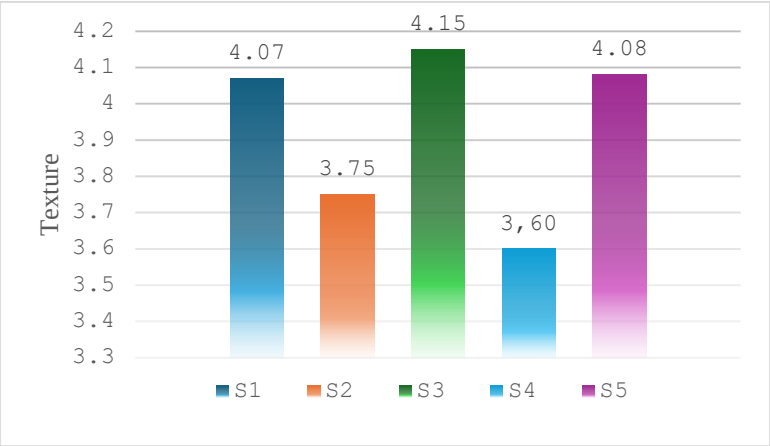
Figure 5. Sensory Evaluation: Taste

The results of the moisture content analysis for the sorghum sticks are presented in Figure 5. Regarding the sensory evaluation of taste, the findings indicate that variations in the proportions of sorghum, wheat, and tapioca flours influenced the panelists' level of acceptance [10]. Treatment S3 achieved the highest score (4.20), suggesting that the combination of 42% sorghum, 28% wheat, and 18% tapioca produced the most preferred flavor profile. This specific combination is considered to provide an optimal balance between the distinct taste of sorghum and the other flours. Treatment S5 also received a relatively high score (4.18), likely due to the higher proportions of wheat flour and tapioca starch, which resulted in a more neutral flavor and a texture that complemented the overall taste [17]. Conversely, treatment S4 recorded the lowest score (3.87), presumably due to a more dominant sorghum flavor that was less preferred by the panelists. Statistically, the treatments showed no significant difference, as the calculated Chi-square value was lower than the table value $X^2_{calc} < X^2_{table}$: 8.67 < 9.48 at alpha = 0.05 and df = 4)

3.5 Sensory Evaluation: Texture

Texture is a crucial parameter in assessing food quality. Key attributes often used to evaluate texture include the springiness and hardness of the product [18]. Based on the statistical analysis, the formulations had a significant effect on the texture scores of the sorghum sticks. This is evidenced by the calculated Chi-square (X^2) value of 10.40, which is greater than the X^2-table value of 9.48 at a significance level of alpha = 0.05 with 4 degrees of freedom (db = 4). These results indicate that the variations in the proportions of red sorghum, wheat, and tapioca flour significantly influenced the perceived texture of the final product. The average texture scores are presented in Figure 6.



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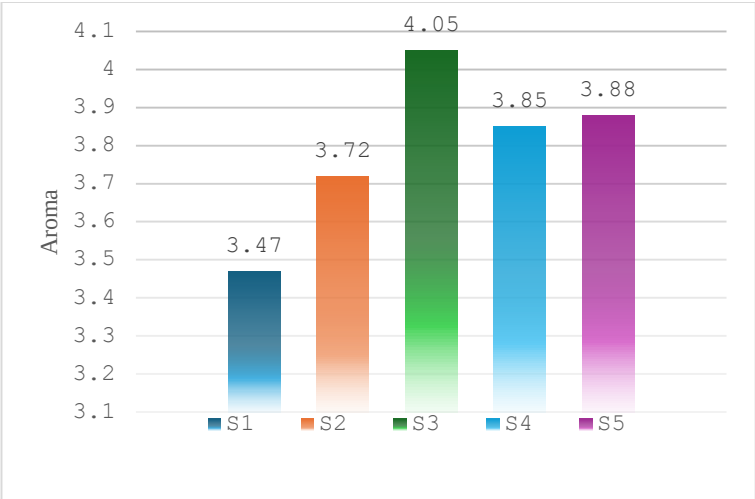
S5=34%:32%:22%

Figure 6. Sensory Evaluation: Texture

The results of the texture analysis for the sorghum sticks are presented in Figure 6. Based on the diagram, the texture scores of the sorghum sticks show variations across each treatment. Treatment S3 obtained the highest score (4.15), indicating that the panelists perceived its texture as the crispest and most preferred. Meanwhile, treatment S4 recorded the lowest score (3.60), suggesting a less crispy texture compared to the other treatments. These variations are influenced by the different proportions of sorghum flour, wheat flour, and tapioca starch used, as the combination of these ingredients determines the final product's brittleness and structural integrity. This finding is consistent with Kusnandar [19], who states that the composition of raw materials plays a vital role in shaping the textural characteristics of food products.

3.6 Sensory Evaluation: Aroma

Aroma refers to the odors produced by chemical stimuli that are detected by the olfactory nerves within the nasal cavity as food enters the mouth. Aroma is a key determinant of the perceived palatability of food products. Based on the statistical analysis, the formulations did not have a significant effect on the aroma scores of the sorghum sticks. The Analysis of Variance (ANOVA) indicated that the variations in the proportions of red sorghum, wheat, and tapioca flour were not significantly different, as the calculated Chi-square (X2) value of 8.80 was lower than the X2-table value of 9.48 at a significance level of alpha = 0.05 and 4 degrees of freedom (df = 4). These average aroma scores are illustrated in Figure 7.



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S5=34%:32%:22%

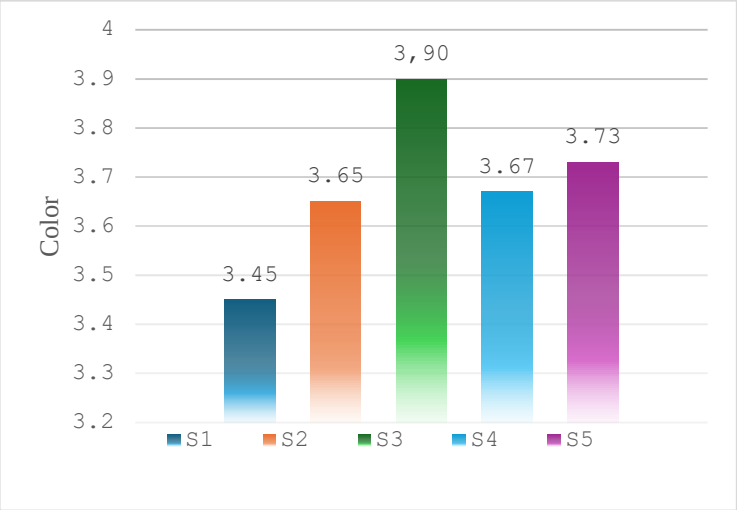
Figure 7. Sensory Evaluation: Aroma

The results of the aroma sensory evaluation for the sorghum sticks are presented in Figure 7. The aroma test was conducted to assess the acceptability of the product's scent, which was formulated from a blend of sorghum flour, wheat flour, and tapioca starch. Aroma is a critical parameter in sensory evaluation as it influences the initial impression and the overall preference of panelists toward a food product. A higher aroma score indicates a greater level of panelist preference for the resulting scent.

The results demonstrate that variations in the composition of sorghum, wheat, and tapioca flours significantly affected panelist preference. Formulation S1 received the lowest aroma score (3.47); the high sorghum content resulted in a more pronounced 'grassy' or 'beany' characteristic (*langu*) typical of sorghum, which was less accepted by the panelists. The addition of wheat flour and tapioca starch in formulations S2 through S4 refined the aroma, making it more neutral and leading to higher scores. Formulation S4 achieved the highest score (4.05), indicating that the combination of 38% sorghum, 30% wheat, and 22% tapioca produced the most preferred aroma. Meanwhile, the aroma score for formulation S5 decreased slightly to 3.88, although it remained superior to several previous treatments

3.8Sensory Evaluation: Color

According to Setyaningsih et al. (2010), the use of ingredients with neutral aromas can help enhance the aromatic quality of a product. This was observed in formulations S2 to S4, where increasing the proportions of wheat and tapioca flour resulted in a milder aroma that was more preferred by the panelists. Regarding the visual characteristics, the statistical analysis showed that the formulations did not have a significant effect on the color scores of the sorghum sticks. The results were not significantly different as the calculated Chi-square (X2) value of 7.33 was lower than the X2-table value of 9.48 (alpha = 0.05, df = 4). These average color scores are presented in Figure 8.



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S4=38%:30%:20%
S5=34%:32%:22%

Figure 8. Sensory Evaluation: Color

The results of the color sensory evaluation for the sorghum sticks are presented in Figure 8. The analysis indicates that variations in the composition of sorghum, wheat, and tapioca flours significantly influenced the panelists' preference for the product's visual appearance [20]. Formulation S1 received the lowest score (3.45), as the high sorghum content resulted in a darker color, which was perceived as less appealing by the panelists.

As the proportions of wheat flour and tapioca starch increased in formulations S2 through S4, the product's color became brighter and more preferred. This upward trend reached its peak in formulation S4 (3.90), which was rated as having the most attractive color. Meanwhile, in formulation S5, the color score slightly decreased to 3.73, although it remained within the range of good consumer acceptance

3.9 Optimal Treatment

The Effectiveness Index method, according to De Garmo (2004), was employed to determine the optimum treatment. This study analyzed several parameters to identify the best treatment, including protein content, moisture content, ash content, and organoleptic properties (texture, color, aroma, and taste). The total NH value indicated that the optimal treatment consisted of 34% sorghum flour, 32% wheat flour, and 22% tapioca starch. This formulation yielded the following average values: 7.60% protein content, 2.60% moisture content, 1.34% ash content, 4.48 for taste, 4.08 for texture, 3.88 for aroma, and 3.37 for color

Table 1. Optimal treatment by NH

Treatment	NH							Total NH
	Protein	Moist	Ash	Taste	Text	Aroma	Color	
S1	0,00	0,10	0,15	0,01	0,10	0,00	0,00	0,36
S2	0,07	0,07	0,15	0,06	0,03	0,04	0,04	0,47
S3	0,11	0,18	0,00	0,14	0,12	0,10	0,08	0,75
S4	0,17	0,00	0,16	0,00	0,00	0,07	0,04	0,44
S5	0,20	0,15	0,15	0,14	0,11	0,07	0,05	0,87

Based on Table 5, the results demonstrate that the optimum treatment was achieved with a formulation of 34% sorghum flour, 32% wheat flour, and 22% tapioca starch. This formulation yielded the following average values across all parameters: a protein content of 7.60%, moisture content of 2.60%, and ash content of 1.34%. Furthermore, the sensory evaluation scores were 4.48 for taste, 4.08 for texture, 3.88 for aroma, and 3.37 for color.

3.10 Financial feasibility

The business feasibility was analyzed based on the optimum treatment from the research, specifically formulation S5, which consists of 34% sorghum flour, 32% wheat flour, and 22% tapioca starch. Empirical results indicate that every 107 grams of raw material yields approximately 71 grams of onion sticks, representing a shrinkage rate of 33%. For the feasibility analysis, a production scale using 20,000 grams (20 kg) of raw materials was assumed. Applying the 33% shrinkage rate (6,600 grams), the net output is 13,400 grams (13.4 kg) of finished product.The product is packaged in 100-gram units. Based on the optimum treatment, the sorghum stick enterprise is deemed feasible with a Cost of Goods Sold (COGS) of IDR 9,220 and a selling price of IDR 14,000 per 100-gram package. The competitive advantage of this product lies in the addition of sorghum flour, which provides nutritional value through increased protein content. The financial analysis shows a Break-Even Point (BEP) of 7,794 units and a price BEP of IDR 109,120,222 per year. Furthermore, the Revenue-Cost Ratio (RCR) is 1.52, indicating that the business is viable as the RCR > 1. With a total output of 13,400 grams per production cycle, 134 packages are produced. Based on 25 working days per month, the monthly production reaches 3,350 packages, totaling approximately 40,200 packages annually.

4. Conclusion

The results of this study indicate that the optimal formulation for sorghum sticks consists of 34% red sorghum flour, 32% wheat flour, and 22% tapioca flour. This formulation (S5) yielded the following characteristics: 7.60% protein, 2.60% moisture, and 1.34% ash content. Sensory evaluation by panelists reflected high acceptance, with scores of 4.18 for taste, 4.08 for texture, 3.88 for aroma, and 3.73 for color. Financially, the production of these sorghum sticks is considered feasible, with a Cost of Goods Sold (COGS) of IDR 9,220 and a selling price of IDR 14,000 per 100g package. The competitive advantage of this product lies in the integration of sorghum flour, which provides nutritional added value through its protein content. The financial analysis showed a Break-Even Point (BEP) of 7,794 units and a price BEP of IDR 109,120,222 per year. Furthermore, the Revenue-Cost (R/C) ratio was 1.52; since the R/C ratio is > 1.0, the enterprise is deemed economically viable. For future research, it is recommended to include additional parameters such as fiber content, antioxidant activity, and shelf-life testing to provide a more comprehensive product profile. Alternative processing methods, such as baking, should be explored to develop healthier product variants. Regarding product development, the S5 formulation can serve as a baseline for production; however, its stability during storage must be verified. Additionally, exploring diverse flavor profiles and seasoning adjustments is necessary to enhance market appeal.

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Data and Software Availability Statements

The data supporting this study are derived from published literature included in Google Scholar and Elsevier. No new datasets or software were generated. Citation management was performed using **Mendeley**. Extracted data are available from the corresponding author upon reasonable request.

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