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Formulation and Quality Study of Mocaf Substitute Noodles with the Addition of Multigrain

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***Abstract*—This study aimed to determine the optimum formula and the characteristics of mocaf and multigrain (sorghum, kidney beans, mung beans) based noodle products. A design expert determined the optimum formula for the noodles. The noodles were tested for their gelatinization profile and tensile elongation profiles, protein content, and sensory evaluation using descriptive and preference tests to determine the optimum formula. The optimum formula was then compared to the noodle with the highest protein content for its nutrient, color, cooking properties, energy, fiber, and mineral content. The different formulas of multigrain noodles significantly affected the gelatinization and tensile elongation profiles. The higher content of mung beans and kidney beans increased the protein content. Multigrain noodles were accepted by consumers. The optimum formula for the multigrain noodle was 0% sorghum, 6.14% kidney beans, and 8.86% mung beans. Noodles with the highest protein content contained carbohydrates (83-84%), protein (7-8%), moisture content (6-8%), fat (0.3-0.5%), and ash (1-1.2%). The total energy of the noodles was about 365-372 Kcal/100g, while the energy from fat was about 2.75-4.46 Kcal/100g. These noodles contained high dietary fiber, consisting of 1.33-4.09% of soluble dietary fiber and 7.1-9.78% of insoluble dietary fiber. They had color and cooking properties comparable to other noodles that existed. The major minerals found in the noodles were potassium and sodium, followed by magnesium, calcium, iron, and zinc, respectively.**

***Keywords*—Noodles; multigrain; mocaf; stunting; nutritional adequacy.**

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I. Introduction

From 2017 to 2018, Indonesia was predicted by the United States Department of Agriculture (USDA) to surpass the United States as the world's top importer of wheat. Meanwhile, several problems, such as climate change and conflicts between countries, affect the availability and prices of commodities, thereby threatening the fulfillment of the food demand (food security) [1]. According to data from the Central Bureau of Statistics, 3.6 million tons of wheat flour were used in Indonesia, with 60% dedicated to noodle production (20% as instant noodles, 30% as fresh noodles, and 10% as dry noodles) [2]. The World Instant Noodle Association's latest update in May 2023 shows that Indonesia ranks second in global demand for instant noodles after China. On the other hand, there has been an increase in public knowledge regarding adverse reactions to wheat, such as celiac disease, gluten sensitivity, and allergies [3]. Additionally, increased consumption of fats, carbohydrates, and preservatives has heightened the risk of chronic diseases, leading to a demand for healthier food options, especially instant noodles, which are claimed to be healthier [4]. Substituting ingredients in noodle making will help decrease wheat consumption and produce healthier noodles. Gluten-free noodles are one of the products claimed to be more nutritious than wheat noodles. These noodles can also be consumed by people with celiac disease and those allergic to gluten, as they are generally made from rice flour, cassava, mung beans, and potatoes, among other ingredients. Moreover, these noodles can be incorporated into diets to reduce body weight and mitigate the risk of digestive diseases [5].

Previous studies have examined the development of a noodle formula based on local ingredients such as sago, sorghum, and mung beans to produce noodles with sensory quality similar to wheat noodles, high nutritional content, and containing bioactive compounds and dietary fiber beneficial to health. The development of mocaf-based noodle products with sorghum, kidney bean, and mung bean substitutions is expected to be an alternative product as a source of nutrients [6], [7], [8], [9], [10].

Mocaf flour (modified cassava flour) is being studied as a partial or complete substitute for the flour used in various food products. Mocaf flour, made from cassava, abundant in most parts of Indonesia, can be used as a substitute for wheat flour to produce biscuits, bread, and noodles. Several studies have shown that mocaf flour can replace wheat flour in the range of 20-100% [11]. Sorghum, known as a good source of complex carbohydrates, contains 8-16% protein, along with several micronutrients such as phosphorus, sodium, magnesium, potassium, calcium, iron, zinc, as well as polyphenols and anthocyanins [12], [13]. Mung beans contain protein and essential amino acids that can help increase milk production [14], [15], while kidney beans are rich in dietary fiber (29.32-46.77%), resistant starch (9.16-18.09%), and protein (22.06-32.63%) [16]. Therefore, this study aims to determine the best formula, characteristics, and product development of mocaf and multigrain-based noodles (sorghum, mung beans, and kidney beans) as a high-nutrient food product, predicted to have the potential to reduce the consumption of wheat noodles.

II. Materials and Method

A. *Materials*

The mocaf and multigrain-based noodle samples used in this study were made from cassava, which was processed into mocaf flour from Grobogan Regency, Central Java; sorghum, mung beans, and kidney beans flours obtained from local farmers in Central Java; high-protein flour, and water. The chemicals utilized for analysis were obtained from Sigma-Aldrich (Missouri, USA).

B. *Preparation of Mocaf Starch*

The mocaf starch was obtained using the method described by Wahjuningsih and Kunarto [17]. The cassava tubers were washed, peeled, and sliced (2-3 mm). The soaking solution was prepared by mixing 20 ml/L of mocaf starter with water, which could be obtained from tapioca waste. The sliced cassava was thoroughly soaked in the solution for 24 hours, then washed and dried in the cabinet dryer for 12-24 hours until the moisture content of the sliced cassava reached 10-12%. The dried chips were ground in a flour mill and sifted with an 80-mesh sieve to obtain cassava flour with finer-sized particles. The flowchart of the method is presented in Fig. 1.

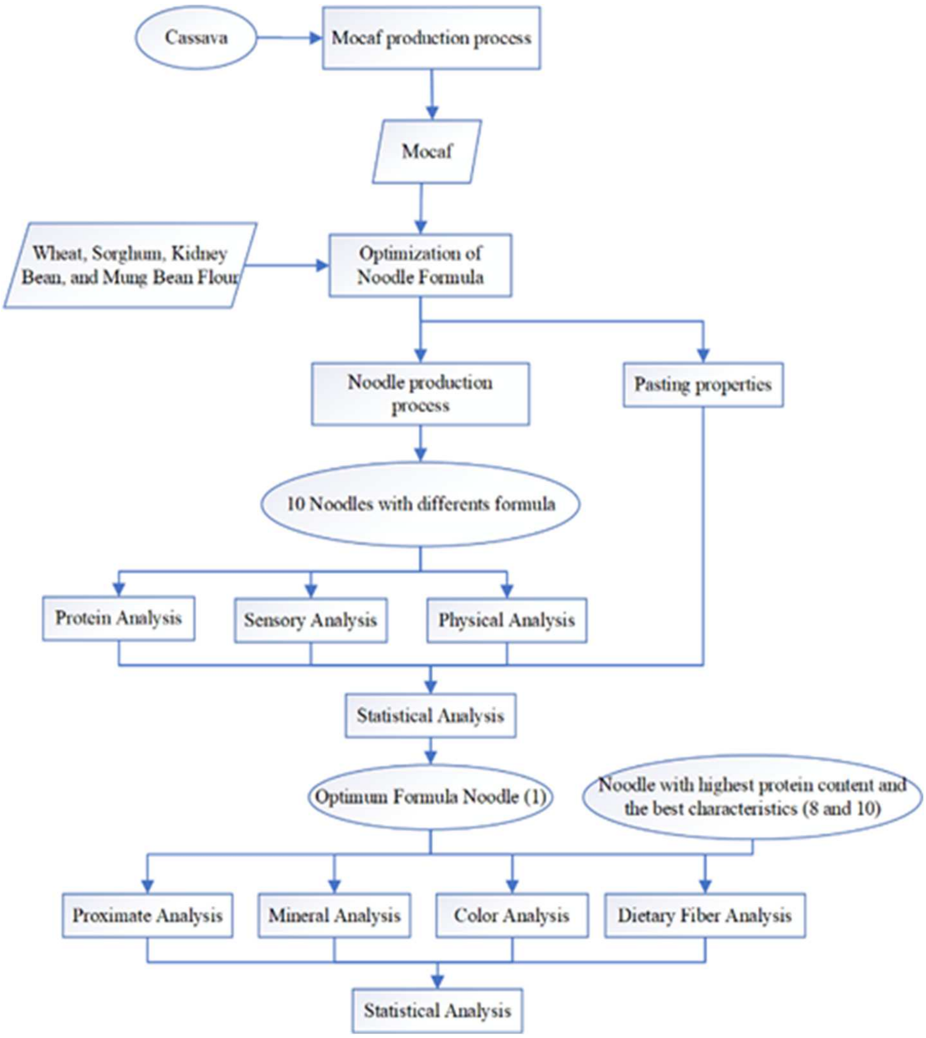

Fig. 1 Flow chart of the method

C. Preparation of Noodle

Mocaf flour was added to the dry noodles' preparation at 55%, with 30% wheat flour, 15% multigrain, and 2% CMC. The dry ingredients were mixed in a basin and then combined with water at a dry ingredient-to-water ratio of 1:0.5 (b/v). The mixture was steamed for 15 minutes and then passed through the extruder until the noodle dough was formed. Wet noodles were dried for 12 hours at 50°C to produce dry noodles. The flowchart of noodles production is shown in Fig. 2.

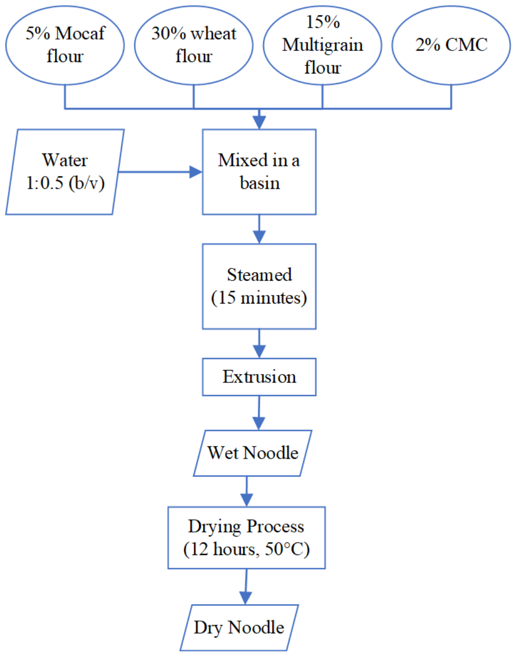

Fig. 2 Flow chart of Noodle Production

D. Protein Analysis

The protein analysis was conducted using the AOAC Method [18], also known as the Kjeldahl method. In this process, 1 gram of the sample was subjected to hydrolysis with 15 ml of concentrated sulfuric acid, along with two copper catalyst tablets, at 420°C for 2 hours. The total nitrogen content in the samples was then multiplied by the conventional conversion factor of 6.25 and species-specific conversion factors to determine the total protein content (Mæhre et al., 2018).

E. Sensory Analysis

A sensory analysis was performed through hedonic evaluations. A total of 30 pre-screened panelists participated in this evaluation. These panelists were students aged 20 to 23 years who had received training in sensory evaluation. Samples (5 grams) were presented with unique three-digit codes, and the hedonic scale employed ranged from 1 to 9, with 1 denoting "strongly disliked" and 9 signifying "strongly liked." The attributes under examination encompassed color, visual appearance, chewiness, springiness, taste, aftertaste, and overall acceptability.

F. Pasting Properties

The parameters measured using the RVA included paste temperature, peak viscosity, breakdown, final viscosity, and setback. A suspension sample was created by mixing 3 grams of starch (on a dry basis) with water, reaching a combined weight of 28.0 grams. The mixture was stabilized at 50°C for 1 minute. Subsequently, it was gradually heated from 50 to 95°C at 6°C per minute. The suspension was maintained at 95°C for a while, after which it was cooled down from 95°C to 50°C at a rate of 6°C per minute. An additional holding phase at 50°C for 2 minutes followed.

G. Noodle Formula Optimization

Mixture design was used to optimize the noodle formula to obtain the best formula for parameters such as protein content, elongation, and sensory properties [19].

TABLE I
MIXTURE DESIGN APPLIED TO OPTIMIZE MOCAF NOODLES

Sample	Mocaf (%)	Wheat (%)	Sorgum (%)	Kidney Bean (%)	Mung Bean (%)
1	55	30	0.38	5.27	9.35
2	55	30	0.38	5.27	9.35
3	55	30	9.15	5.85	0
4	55	30	2.16	10	2.84
5	55	30	11.14	0.14	3.72
6	55	30	4.07	4.26	6.67
7	55	30	5.73	9.27	0
8	55	30	7.15	0.79	7.06
9	55	30	0	0	15
10	55	30	3.46	0.52	11.02

H. Proximate Analysis

The AOAC method [18] was used for the proximate analysis. Total carbohydrates were calculated by subtracting 100 from protein, fat, ash, water content, and fiber. 10 grams sample of noodles was used.

I. Color Analysis

The color of the noodles (5 grams) was ground and analyzed using a colorimeter, using the CIE, L a b color scale [20].

J. Dietary Fiber Analysis

The dietary fiber content of the noodles was analyzed using the method of Asp et al. [21]. The first step involved incubating 1 gram of the sample, homogenized with phosphate buffer (pH 6) and amylase for 15 minutes at 80°C. The second step was incubation for 60 minutes at 40°C with pepsin and buffer (pH 1.5). The third step was incubation with pancreatin and buffer (pH 6.8) at the same temperature and duration as before—the last step involved filtration using a porosity crucible 2 with adding 0.5 grams of celite. The residue was then reduced by the weight of residual ash to measure the insoluble fiber, while the soluble fiber was calculated using the filtrate.

K. Mineral Analysis

Mineral analysis refers to Ngigi and Muraguri [22] with slight modifications. Samples were ground into a uniform powder, and 0.5 g was weighed into digesting vessels with 5 mL of concentrated nitric acid. Vessels were closed and digested using a microwave system. After cooling, solutions were transferred to 50 mL centrifuge tubes and adjusted with 5% nitric acid for ICP-OES analysis. Reagent blanks were prepared with the same reagents. Wavelength selection was sequentially optimized for sensitivity. Calibration standards ranged from 2 to 10 mg L−1.

L. Statistical Analysis

The data were displayed as mean ± standard deviation (SD). Statistical analysis was carried out using IBM SPSS Statistics 26, which involved an analysis of variance (ANOVA). Subsequently, a Duncan multiple range test was applied to detect significant variations at a significance level of $p < 0.05$.

III. RESULTS AND DISCUSSION

A. Protein Content of Noodles

The protein contained in mocaf and multigrain noodles is presented in Table 2. The protein content contained in the noodles analyzed in this study was higher than wheat noodles that were substituted with sago and sorghum (5.98%) but lower than noodles made from sorghum, sago, and mung beans with a protein content ranging from 9.64 to 11.83 % [6], [23].

TABLE II
PROTEIN CONTENT OF NOODLES

Sample	Protein
1	8.68 ± 0.20^{g}
2	7.68 ± 0.16^{f}
3	6.23 ± 0.17^{ab}
4	7.19 ± 0.18^{de}
5	6.11 ± 0.15^{a}
6	6.86 ± 0.16^{cd}
7	6.53 ± 0.17^{bc}
8	7.73 ± 0.17^{f}
9	6.59 ± 0.16^{bc}
10	7.29 ± 0.19^{e}

Note: Values mean ± standard deviation. Different superscripts in the column show a significant difference ($p<0.05$).

Based on the analysis of protein content, it was observed that the variation in the multigrain formulation consisting of sorghum, mung beans, and kidney beans had a significant impact on the protein content within the noodles. Noodle sample 1 exhibited the highest protein content with a composition of 0.38 sorghum, 5.27 kidney beans, and 9.35 mung beans.

Meanwhile, noodle sample 5 had the lowest protein content with a multigrain composition of 11.14 sorghum, 0.14 kidney beans, and 3.72 mung beans. It was noted that sorghum had a protein content ranging from 8.92% to 18.7% [24]. When compared to the protein content in kidney beans and mung beans, sorghum exhibited the lowest protein content due to kidney beans containing approximately 22% protein and mung beans having a protein content ranging from 20.5 to 25.4% [25], [26]. Therefore, mung beans were suspected to be the primary contributor to the protein content of the noodles, followed by kidney beans and sorghum. Sample 2 had the highest composition of kidney and mung beans among the other samples, leading to a high protein content within the noodles. On the other hand, the prominent grain of sample 5 was sorghum which had a lower protein content than the other ingredients.

B. Starch Gelatinization Characteristics in Composite Formulas

The gelatinization profile of starch in this study is shown in Table 3. The gelatinization profile of starch used as a noodle-making formula in this study was not much different from that of other research regarding wheat noodles substituted with Zimbabwean sorghum with peak viscosity values of 2427-2603, trough 1472-1764, breakdown 819-996, final viscosity 3033-3778, and setback 1583-2027, while the peak time and temperature values were respectively 6.33-6.40 and 71-74C[27]The composition of sorghum, kidney beans, and mung beans did not significantly affect the peak time and pasting temperature values obtained. Peak time is when the viscosity peak occurs, while the pasting temperature is when the solution's viscosity increases for the first time.

TABLE III
STARCH GELATINIZATION PROFILE IN 10 DESIGN FORMULAS

Sample	Peak Viscosity	Trough Viscosity	Breakdown Viscosity	Final Viscosity	Setback Viscosity	Peak Time	Pasting Temperature
1	3340	2087	1253	3256	1169	9.20	71.85
2	3002	1917	1085	2959	1042	9.53	72.10
3	3056	2198	858	3220	1022	9.73	72.45
4	3112	2016	1096	3121	1105	9.33	72.15
5	3014	2198	816	3139	941	9.67	72.50
6	3238	2157	1081	3174	1017	9.20	71.35
7	2716	1870	846	2646	776	9.20	68.10
8	2364	1553	811	2286	733	9.13	68.10
9	2429	1343	1086	2058	715	8.60	68.45
10	2470	1587	883	2346	759	9.13	68.45

Based on Table 3, sample 1 with a formula consisting of mocaf flour (55%), wheat flour (30%), sorghum (0.38%), kidney beans (5.27%), and mung beans (9.35%) had the highest value of peak viscosity, breakdown, final, and setback. Peak viscosity is a condition when the viscosity reaches a peak during the heating or pasting process. The peak viscosity of starch is related to the ability of starch to bind water. The high peak viscosity indicates a high ability of starch granules to absorb water and swelling, which can produce a soft noodle texture and result in an increased breakdown value [28]. Breakdown viscosity is a value that can describe the level of stability of starch against the heating process. The lower the breakdown value, the more stable the starch is when being heated [29]. A high peak viscosity indicates that the starch granules are more brittle, increasing the breakdown and setback value [30]. The setback of starch describes its ability to retrograde. A high setback value was preferred in the noodle-making process, considering the retrogradation will be high, thereby noodles with a firm texture were produced [31].

Sorghum concentration has a positive correlation with peak viscosity and trough values and has a negative correlation with breakdown values. Sorghum has an amylose content of 8-26%. Low amylose levels with short to medium-chain types tend to result in higher peak and trough viscosity values of starch [32], [33]. The increased concentration of mung beans will decrease the through and final viscosity value. Meanwhile, peak viscosity increases and decreases when the concentration of mung beans is above 11%. It was known that starch with a low amylose content can produce a high final viscosity value [34]. The final viscosity value correlates positively with the noodle texture. A high final viscosity value generally results in a soft noodle texture [35], [36]. In addition to kidney beans, it was known that a higher concentration of kidney beans tends to increase the breakdown value. In the research by Chisenga et al. [37], it was known that kidney beans have an amylose content of 14-15%. This amylose content was lower than that of mung beans. Therefore, it was suspected that in this study, the breakdown value was lower due to the low amylose content of kidney beans.

C. The Optimization of Noodle

The tensile strain and elongation of noodle samples with various concentrations of sorghum, mung bean, and kidney bean are shown in Table 4. Based on the result, the beans significantly affect the elongation and tensile strain values of the noodle samples. Tensile strain is the maximum force required until the noodle is broken, while the length of the noodle when it is cut compared to the size of the initial noodle is the percentage of elongation [38].

TABLE IV
ELONGATION VALUE AND TENSILE STRENGTH OF NOODLE FORMULA DESIGN

Mixtures	Tensile Strength (MPa)	Elongation (%)
1	0.02 ± 0.00^{abcd}	17.31 ± 1.42^{b}
2	0.02 ± 0.01^{d}	16.46 ± 0.82^{b}
3	0.02 ± 0.00^{cd}	12.68 ± 0.32^{a}
4	0.02 ± 0.00^{bcd}	17.24 ± 0.24^{b}
5	0.02 ± 0.00^{abc}	12.45 ± 0.22^{a}
6	0.01 ± 0.00^{a}	14.02 ± 0.94^{a}
7	0.01 ± 0.00^{ab}	20.51 ± 1.79^{c}
8	0.01 ± 0.00^{ab}	14.08 ± 0.83^{a}
9	0.01 ± 0.00^{ab}	25.31 ± 0.01^{d}
10	0.01 ± 0.00^{a}	13.55 ± 1.12^{a}

Note: Values mean ± standard deviation. Different superscripts in the column show a significant difference ($p<0.05$).

Both elongation and tensile strain are affected by protein levels, especially gluten contained in the starch. The result indicated that the noodle formulation made from mung beans, kidney beans, and sorghum affects the elongation and tensile strain properties despite being gluten-free, suggesting that other factors contribute to these characteristics. One potential factor is the presence of proteins. Additionally, Chisenga et al.[40], [39] pointed out that a higher amylose crystalline content in the starch can increase the tensile strain and elongation of noodles, making them more compact and less prone to breaking when subjected to pulling forces. These factors collectively contribute to the unique properties of gluten-free noodles. In the research by [40], wheat noodles mixed with arrowroot flour and modified arrowroot flour had tensile values of 0.12 and 0.11 mPa, which were lower than the tensile strain values of control wheat noodles of 0.18 mPa.

TABLE V
SENSORY EVALUATION SCORE OF NOODLE FORMULA DESIGNS

Mix	Hedonic Test						
	Color	Appearance	Chewiness	Springiness	Taste	Aftertaste	Overall
1	7.05 ± 2.06^{e}	7.25 ± 1.77^{c}	5.30 ± 1.69^{a}	5.65 ± 1.84^{ab}	6.85 ± 1.46^{b}	6.62 ± 1.76^{cd}	6.69 ± 1.74^{b}
2	7.15 ± 1.63^{e}	7.55 ± 1.5^{c}	5.70 ± 1.59^{ab}	6.05 ± 1.7^{b}	6.81 ± 1.6^{b}	6.86 ± 1.23^{d}	6.63 ± 1.36^{b}
3	6.35 ± 1.76^{de}	6.40 ± 1.5^{b}	6.70 ± 1.66^{b}	5.95 ± 1.57^{ab}	5.75 ± 1.71^{a}	6.15 ± 1.81^{bcd}	6.60 ± 1.43^{b}
4	5.25 ± 1.33^{abc}	4.95 ± 1.32^{a}	5.55 ± 1.82^{ab}	5.30 ± 1.56^{ab}	5.80 ± 1.4^{ab}	5.60 ± 1.39^{abc}	5.70 ± 1.45^{ab}
5	6.05 ± 1.73^{cd}	6.30 ± 1.87^{b}	5.90 ± 1.8^{ab}	5.10 ± 1.37^{ab}	5.55 ± 1.39^{a}	5.80 ± 1.47^{abc}	5.78 ± 1.4^{ab}
6	4.95 ± 1.5^{ab}	4.65 ± 0.93^{a}	5.95 ± 1.61^{ab}	5.35 ± 1.87^{ab}	5.90 ± 1.68^{ab}	5.75 ± 1.68^{abc}	5.47 ± 1.39^{a}
7	4.25 ± 0.79^{a}	4.30 ± 0.66^{a}	5.10 ± 1.37^{a}	5.25 ± 1.68^{ab}	5.00 ± 1.21^{a}	5.00 ± 1.38^{a}	5.06 ± 1.3^{a}
8	4.75 ± 1.25^{ab}	4.20 ± 0.7^{a}	4.85 ± 1.6^{a}	4.80 ± 1.61^{a}	4.90 ± 1.37^{a}	4.85 ± 1.35^{a}	5.00 ± 1.54^{a}
9	4.40 ± 0.82^{ab}	4.15 ± 0.49^{a}	5.00 ± 1.59^{a}	4.80 ± 1.44^{a}	5.60 ± 1.27^{a}	5.05 ± 1.1^{ab}	4.89 ± 1.41^{a}
10	5.30 ± 1.45^{bc}	4.55 ± 0.94^{a}	5.55 ± 1.67^{ab}	5.75 ± 1.62^{ab}	5.55 ± 1.73^{a}	5.30 ± 1.56^{ab}	5.85 ± 1.66^{ab}

Note: Values mean ± standard deviation. Different superscripts in the column show a significant difference ($p<0.05$).

The noodle samples were generally acceptable to consumers regarding color, appearance, chewiness, springiness, taste, aftertaste, and overall noodles since the hedonic values ranged from 5-7, which means neutral to like. Based on the results obtained, it was known that the color and appearance of samples 1 and 2 were the most favored by the panelist, which has a dark color and a relatively smooth and uncracked appearance. Moreover, the taste and aftertaste of noodle samples 1 and 2 were also preferred. Both samples contained 0.38 sorghum, 5.27 kidney beans, and 9.35 mung beans. The color formed in the noodles was suspected to occur due to the presence of pigment compounds from sorghum, kidney beans, and mung beans. Based on the springiness parameter, noodle sample 2 was preferred because it has a complex mouthfeel and is somewhat non-sticky to the teeth. The characteristics of the elasticity or ability of the noodles to stick to the teeth were affected by the presence of amylopectin in the starch. The higher the amylopectin, the noodles tend to stick to the teeth [41]. Kidney beans have a high amylose content and a low long-chain amylopectin content compared to other legumes [42]. The ratio of amylose to amylopectin in kidney beans was similar to that of mung beans. Mung beans also have a high amylose content [43]. Based on research by [44]It was known that non-waxy normal protein sorghum has an amylopectin content of 79%. Based on these opinions about the amylopectin content of the three materials used, it was suspected that the slightly sticky characteristics of the samples are influenced by the amylopectin content in sorghum. Samples 1-3 had the most favorable overall parameters.

The optimization of the noodle-making formula was based on the sensory test parameters, the elongation value, and the protein content of the noodles. To obtain the optimization of sensory properties, the following regression equation was used:

$$y = 7.00662A + 4.03247B + 5.19435C + 2.31205AB - 2.01372AC + 11.5136BC - 44.3496ABC$$

The elongation optimization value (%) was calculated using the following regression equation:

$$y = 18.8316A + 21.9333B + 24.563C - 1.64499AB - 39.5751AC - 27.2991BC$$

The protein optimization value (%) was calculated using the following regression equation:

$$y = 3.71685A + 6.22281B + 6.49547C + 5.96184AB + 10.122AC + 8.48595BC - 41.1865ABC$$

Based on the optimization process carried out, the optimum formula results were obtained, which consisted of sorghum 0%, kidney bean 6.14%, and mung bean 8.86%. These data were similar to samples 1 and 2, which is the sample with the highest preference value in the overall parameter of sensory assessment and the highest protein content.

D. *Nutritional Characteristics of Noodles*

The optimum formula obtained in this research consisted of 0% Sorghum, 6.14% kidney beans, and 8.86% mung beans. Based on these results, it could be predicted that the optimum noodle characteristics were similar to sample 1, which consisted of 0.375% sorghum, 5.27233% kidney beans, and 9.35267% mung beans. Next, samples 1, 8, and 10, with the highest protein content and the best characteristics, underwent further analysis, including proximate analysis, total energy, fiber, physical characteristics, and heating characteristics.

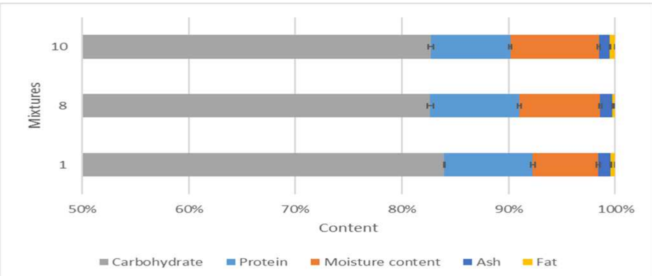

Fig. 3 Chemical composition of noodle

Based on the results in Fig. 3, the three multigrain noodles, especially samples 1 and 8, contained relatively high protein (7.4-8.3%) with low-fat content (0.3-0.5%). The protein content in the mix grain was higher than the research by [39], which examined noodles made from cassava flour with the addition of egg yolk whites and nuts, with the protein content ranging from 1-3.4%. However, when compared with previous research, namely noodles made from sorghum flour, mung beans, and sago conducted by [6], the protein content of the noodles in this study was slightly lower. The fat content in this study was not much different from the research by [10], which examined wheat noodles substituted with sorghum and mung beans, which had a fat content of 0.23-1.16%. The main component contained in noodles was carbohydrates, with 82.6-83.9%. This level was not much different from the carbohydrate levels in noodles analyzed by [39] but higher than the carbohydrate content in noodles made from gluten and soy protein (23-47%). The water content of the noodles analyzed in this study complied with the standard for instant noodles CXS 249-2006, which limited the water content in fried instant noodles to a maximum of 10% and for non-fried instant noodles to a maximum of 14%. The ash content contained in multigrain noodles was around 1%.

E. *Color Characteristics and Cooking Properties of Noodles*

Color was an important parameter as it determined consumer acceptance of noodles, especially among children. Generally, brightly colored noodles were more popular. The L notation described the product's brightness; the higher the L value, the brighter/whiter it was. The notation described the range from reddish to a greenish color, while the b notation described the range from yellow to blue [45]. The addition of mung beans tended to reduce the brightness of the noodles. Higher sorghum content resulted in lower a value, while higher kidney beans content led to higher b values. The color of the noodles was influenced by the grains used. Mung beans, kidney beans, and sorghum contained pigments such as anthocyanin compounds, carotenoids, tannins, and chlorophyll, which played a role in determining the color [46], [47]. Lower concentrations of kidney beans were associated with higher rehydration values, bulk density, and longer cooking times. The rehydration value indicated the amount of water the noodles could absorb during cooking. In research by [45], Shirataki noodles had a high rehydration value, ranging from 66% to 105%, attributed to the glucomannan content. Therefore, the lower rehydration value in multigrain noodles was believed to be due to the lower level of water-soluble compounds or compounds with water-binding ability.

Bulk density describes the porosity of a product, which influenced the design and choice of packaging materials [48]. High-quality noodles were characterized by high yields and low cooking loss [20]. Additionally, noodles with faster cooking times were generally preferred [49]. The cooking loss of multigrain noodles was positively correlated with sorghum concentration, with higher sorghum concentrations resulting in more significant cooking loss. Based on research by [50], wheat noodles with the addition of fenugreek experienced a cooking loss of 1-2%, a value that fell within the acceptable range, namely <10 g/100 g. In line with this perspective, the cooking loss of multigrain noodles remained within acceptable limits.

TABLE VI
COLOR CHARACTERISTICS AND COOKING PROPERTIES OF NOODLES

Sample	Color parameters			Cooking properties			
	L	a	b	Rehydration (%)	Cooking time (Minutes)	Bulk Density (g/cm3)	Cooking Loss (%)
1	57.6 ± 0.35^{b}	0.11 ± 0.14^{b}	17.805 ± 0.05^{c}	0.39 ± 0.03^{a}	8.59 ± 0.13^{c}	0.61 ± 0.04^{a}	2.03 ± 0.10^{a}
8	57.39 ± 0.20^{b}	-1.35 ± 0.25^{a}	16.125 ± 0.05^{b}	0.85 ± 0.01^{b}	7.22 ± 0.09^{b}	0.76 ± 0.00^{b}	3.47 ± 0.05^{c}
10	51.175 ± 0.21^{a}	-0.17 ± 0.21^{b}	15.845 ± 0.04^{a}	1.55 ± 0.03^{c}	5.17 ± 0.01^{a}	0.85 ± 0.00^{c}	2.80 ± 0.24^{b}

Note: Values are mean ± standard deviation. Different superscripts in the column show a significant difference ($p<0.05$).

F. *Total Energy and Dietary Fiber Content*

The total energy of the optimum noodle formulation was greater than that of other noodle formulas. As indicated in the table, it can be observed that mung beans contributed more energy from fat, followed by kidney beans and sorghum. According to [51], mung bean flour contains high levels of fat in the form of unsaturated fatty acids, which are beneficial for heart health and individuals dealing with obesity. The total energy from fat in multigrain noodles exceeded that of wheat noodles substituted with sorghum and mung beans (1.48-2.92 kcal/100g). However, the overall total energy in multigrain noodles was not significantly different from these noodles [10].

Sample 8 exhibited the highest soluble fiber content, while sample 1 had the highest insoluble fiber content, followed by samples 8 and 10. These findings suggest that both soluble and insoluble fiber tend to be influenced by the concentration of sorghum and kidney beans. In research by [4] regarding adding insoluble fiber from wheat bran to wheat noodles, it was noted that the recommended insoluble fiber content in noodles is 4%. Exceeding this value can result in increased cooking loss (0.4-0.7%) due to gluten becoming brittle, which releases amylose during cooking. This corresponds with the results obtained, where multigrain noodles exhibited an insoluble fiber content of 7-9% and a higher cooking loss of 2-3%. However, as per [52], noodles with a dietary fiber content above 6% can be classified as high-fiber noodles, which are considered beneficial for human health.

TABLE VII
TOTAL ENERGY AND DIETARY FIBER CONTENT OF NOODLES

Sample	Total Energy (Kcal/100g)	Energy from fat (Kcal/100g)	Soluble Fiber (%)	Insoluble fiber (%)
1	372.89 ± 0.76^{b}	3.83 ± 0.06^{b}	1.33 ± 0.01^{a}	9.78 ± 0.09^{c}
8	366.83 ± 0.50^{a}	2.75 ± 0.06^{a}	4.09 ± 0.03^{c}	8.19 ± 0.11^{b}
10	365.10 ± 0.45^{a}	4.46 ± 0.06^{c}	2.49 ± 0.03^{b}	7.10 ± 0.04^{a}

Note: Values are mean ± standard deviation. Different superscripts in the column show a significant difference ($p<0.05$).

G. *Mineral Content of Noodles*

Fig. 4 reveals that the mineral content in multigrain noodles follows a descending order from high to low, with potassium, sodium, magnesium, calcium, iron, and zinc, respectively. The mineral composition of noodles is strongly influenced by the primary ingredients used, with legumes being particularly rich in mineral content. In the research by [53], it was found that kidney beans and mung beans contain various minerals, including calcium (104 mg/100g; 96 mg/100g), sodium (53 mg/100g; 21 mg/100g), potassium (1517 mg/100g; 972 mg/100g), magnesium (118 mg/100g; 139 mg/100g), iron (7 mg/100g; 3.9 mg/100g), and zinc (2.3 mg/100g; 1.55 mg/100g). Sorghum, another key component, contains minerals such as potassium (26-35 g/kg), magnesium (8-16 g/kg), calcium (1.25-2.88 g/kg), sodium (0.42-0.54 g/kg), iron (346-655 mg/kg), and zinc (180-284 mg/kg) [54].

The National Academy of Medicine provides dietary reference intake (DRI) values for vitamins and minerals, including potassium (2300-340mg), magnesium (310-420mg), sodium (1500 mg), zinc (8-11 mg), iron (8-18mg), and calcium (1200mg). The mineral content in 100g of multigrain noodles does not exceed adults' daily mineral intake limits. Multigrain noodles boast a competitive mineral content compared to other noodle varieties. Compared to sorghum noodles, multigrain noodles have similar levels of magnesium and iron, approximately 42mg/100g and 4.21 mg/100g, respectively. Sorghum noodles have even lower zinc content, with levels around 0.58 mg/100g [55]. The zinc and iron levels in this study were comparable to those in noodles made from kalinga (rice, sesame, and mung beans) mixed with moringa leaves and wheat, which had levels of 1.2 mg/100g and 5.6-7.4 mg/100g, respectively.

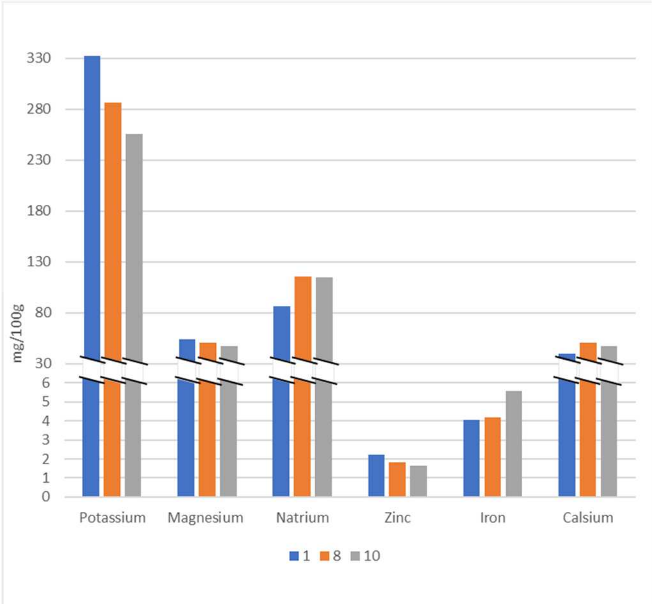

Fig. 4 Mineral composition of noodles

However, the calcium content in kalinga-moringa noodles-wheat was higher, ranging from 113-125 mg/100g [56]. Buckwheat noodles were found to have higher levels of magnesium (1137.11–1935.24 µg/g) and potassium (3607.46–5454.97 µg/g) than multigrain noodles [57].

Introducing Mocaf and multigrain noodles to the market has several practical implications, including potential challenges and limitations. Using locally sourced ingredients like cassava, sorghum, and mung beans can enhance food sustainability. Mocaf and multigrain noodles offer higher protein and fiber content than traditional wheat noodles, catering to health-conscious consumers, including those with gluten-related issues. However, the taste and texture differences may pose challenges for both consumers and manufacturers. While consumer acceptance of multigrain noodles has been observed, market success remains uncertain, requiring compliance with food safety regulations and potential adaptation of manufacturing processes.

IV. CONCLUSION

Based on the results, the optimum noodle formula was 0% sorghum, 6.14% kidney beans, and 8.86% mung beans. Its concentration is similar to sample 1, which has a dark color, a rather rough and cracked appearance, a hard mouthfeel, a bit not springy and a bit inelastic, a bit sticky to the teeth, and a strong aroma. Noodles made with sorghum, mung bean, and kidney bean have been proven to have high protein, fiber, and minerals. The differences in noodle formula affected the physical characteristics of the noodles, such as gelatinization profile, cooking properties, and color. The multigrain noodle products were acceptable to consumers. For further research, exploration of the addition of other local ingredients, such as rice and corn, could be considered. Additionally, future studies could investigate the long-term health impacts of consuming mocaf and multigrain noodles. This might involve examining their effects on blood sugar levels, insulin sensitivity, and nutritional adequacy. Understanding the long-term health implications of these noodles could empower consumers and manufacturers to make more informed decisions regarding their consumption and production.

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