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FORMULATION OPTIMIZATION OF EDAMAME PASTE AND MORINGA LEAF INCORPORATION IN MODIFIED CASSAVA FLOUR NOODLES

Optimasi Formula Pasta Edamame dan Daun Kelor pada Mi Berbasis Tepung Singkong Termodifikasi

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ABSTRACT

Noodles are commonly made from wheat flour, while Indonesia still relies heavily on imported wheat. Modified cassava flour (mocaf) has potential as an alternative to wheat flour; however, mocaf-based noodle products still require improvement in their sensory and physicochemical quality. This study aimed to determine the optimum proportion of edamame paste and moringa leaves to improve the sensory and physicochemical properties of dried mocaf noodles. Optimization was performed using response surface methodology with a Central Composite Design with edamame paste (0–30%) and moringa leaves (0–10%) as factors, generating 14 experimental runs. Target responses included green and brown color intensity, cassava, beany, and green flavors within acceptable ranges; maximum elasticity, chewiness, elongation, and overall acceptability; and minimum rehydration time and cooking loss. Most responses were well fitted by quadratic models with satisfactory determination coefficients (R^2 = 0.59–0.97). The optimum formulation was obtained at 17.53% edamame paste and 1.46% moringa leaves. Increasing edamame paste enhanced green and brown color intensity, beany flavor, elasticity, rehydration time, and elongation but reduced cassava flavor and chewiness. Increasing moringa leaves enhanced green color intensity and green flavor but decreased brown color intensity and overall acceptability. The optimum noodles met the defined sensory and physicochemical criteria.

Keyword: *edamame; gluten-free; mocaf; moringa; noodle; optimization; RSM*

ABSTRAK

Produk mi umumnya berbahan dasar tepung terigu, sementara kebutuhan terigu di Indonesia masih bergantung pada impor gandum dalam jumlah besar. Tepung singkong termodifikasi (mocaf) berpotensi sebagai alternatif pengganti terigu, namun produk mi berbasis mocaf sebelumnya masih memerlukan perbaikan kualitas sensori dan fisikokimia. Penelitian ini bertujuan untuk menentukan proporsi optimum pasta edamame dan daun kelor guna meningkatkan kualitas sensori dan fisikokimia mi kering berbasis mocaf. Optimasi dilakukan menggunakan *Response Surface Methodology* dengan *Central Composite Design* untuk mengoptimasi formulasi dengan faktor proporsi pasta edamame (0–30%) dan daun kelor (0–10%), menghasilkan 14 run percobaan. Target respon meliputi intensitas warna

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hijau dan cokelat, *cassava* flavor, *beany* flavor, *green* flavor dalam rentang yang diinginkan, kekenyalan, elastisitas, kesukaan, dan elongasi yang maksimal, serta waktu rehidrasi dan *cooking loss* yang minimal Sebagian besar respon mengikuti model kuadratik dengan koefisien determinasi (R^2) sebesar 0.59–0.97. Formula optimum diperoleh pada proporsi pasta edamame 17.53% dan daun kelor 1.46%. Peningkatan pasta edamame meningkatkan intensitas warna hijau dan cokelat, *beany* flavor, elastisitas, waktu rehidrasi, dan elongasi, namun menurunkan *cassava* flavor dan kekenyalan. Sementara itu, peningkatan daun kelor meningkatkan intensitas warna hijau dan green flavor, tetapi menurunkan intensitas warna cokelat dan tingkat kesukaan. Produk mi optimum yang dihasilkan memiliki karakteristik sensori dan fisikokimia yang sesuai dengan kriteria optimasi yang ditetapkan.

Kata Kunci: edamame; gluten-free; kelor; mi; mocaf; optimasi; RSM

INTRODUCTION

Noodles are among the most widely consumed staple foods in Asia, particularly in East and South-east Asia (Alamanda et al., 2024; Spohrer et al., 2013). Their high carbohydrate content makes them an important dietary energy source, and in many countries, including Indonesia, noodles serve as a practical alternative to rice. The convenience of preparation further contributes to their popularity. According to the World Instant Noodles Association (WINA), Indonesia consumed approximately 12.64 billion servings of instant noodles in 2020, accounting for about 10.8% of global consumption and ranking as the second-largest consumer worldwide (Devina & Rahayu, 2022). Most commercial noodles are produced from wheat flour (Asiyah et al., 2023). However, Indonesia relies heavily on imported wheat due to unfavorable tropical climate conditions and unsuitable soil characteristics for wheat cultivation. In 2020, Indonesia imported approximately 10.3 million tonnes of wheat, making it the largest wheat importer globally (Pokatong & Budiman, 2026). This dependency highlights the urgency of developing alternative noodle products based on locally available raw materials to enhance food security and reduce import reliance.

Cassava (*Manihot esculenta*) represents a promising local commodity for flour diversification. Central Java alone produced approximately 2.6 million tons of cassava in 2020, while Banyumas Regency contributed around 29,630.60 tons, positioning cassava as one of the region's leading agricultural commodities (Aryaputra et al., 2024). Through fermentation, cassava can be processed into modified cassava flour (mocaf), which exhibits improved functional properties compared to native cassava flour, including enhanced viscosity, gelation

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capacity, rehydration ability, and solubility (Putri et al., 2022). Previous research has demonstrated the feasibility of producing gluten-free noodles from modified cassava flour using tapioca, xanthan gum, sodium tripolyphosphate (STPP), egg yolk, and other supporting ingredients (Astuti et al., 2023). Although the resulting dried noodles exhibited acceptable physical characteristics, the protein content remained relatively low (2.37%). This limitation suggests the need for formulation improvement, particularly through the incorporation of protein-rich ingredients to enhance nutritional quality.

Edamame, a young soybean variety, is increasingly cultivated in Indonesia but remains underutilized despite its high nutritional value. Edamame is rich in protein, dietary fiber, essential amino acids, and various micronutrients and phytochemicals with potential health benefits. Fresh edamame contains approximately 11.22 g of protein per 100 g, comparable to egg protein content (Hettiarachchy et al., 2020). Preliminary trials in the present study indicated that the incorporation of edamame paste produced better dough cohesiveness, brighter color, and improved elasticity compared to edamame flour. The minimal heat treatment applied during paste preparation is also expected to help preserve its nutritional value. In addition to legumes, green leafy vegetables such as moringa (*Moringa oleifera*) leaves offer substantial nutritional benefits. Fresh moringa leaves contain approximately 9.4 g of protein per 100 g, significantly higher than spinach and broccoli (Srivastava et al., 2023). On a dry weight basis, moringa leaves may contain 25–30% protein, making them a potential plant-based protein source (Gusrinisa et al., 2025). Despite their nutritional richness, moringa leaves remain underexploited in processed food applications. Their incorporation into noodle formulations may not only enhance protein content but also contribute natural color and functional compounds.

In food product development, formulation optimization plays a critical role in achieving desirable quality attributes while maintaining efficiency. Response surface methodology (RSM), particularly the central composite design (CCD), is widely applied to model and optimize multi-factor systems with a relatively limited number of

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experimental runs (Yolmeh & Jafari, 2017). This approach enables the simultaneous evaluation of multiple variables and response parameters efficiently and systematically.

Therefore, this study aims to optimize the proportion of edamame paste and moringa leaves in the production of 100% modified cassava flour-based dried noodles using RSM-CCD. The optimized formulation is expected to meet targeted sensory attributes (green and brown color intensity, cassava flavor, beany flavor, and green flavor within acceptable ranges), maximize texture parameters (elasticity, chewiness, elongation, and overall liking), and minimize undesirable properties such as rehydration time and cooking loss. Furthermore, the physicochemical and sensory characteristics of the optimized formulation will be evaluated and compared with wheat flour-based noodles as a control. This research contributes to the development of nutritionally enhanced, locally sourced, gluten-free noodle products and supports sustainable food diversification strategies in Indonesia.

METHOD

Experimental design

The experimental design in this study uses the Response Surface Methodology (RSM) method with Design Expert V.10 software and formula optimization using the basic Central Composite Design (CCD) layout. The factors studied include 2 factors, namely the proportion of edamame paste (0-30%) and moringa leaves (0-10%). The upper and lower limits of the factors were determined based on preliminary research. Subsequently, the lower and upper limit values of these factors were input into the Design Expert V.10 software, resulting in 14 recommended formulas (Table 1). This research was conducted at the Dukuhwaluh Food Innovation Center and the Processing and Food and Nutrition Technology Laboratory, Faculty of Agriculture, Jenderal Soedirman University, Purwokerto. The preliminary research began in October 2021 and continued until August 2022.

Preparation of modified cassava flour

The process of making modified cassava flour follows the method of (Astuti et al., 2017), which includes the preparation of 1 kg of cassava tubers to be used, peeling and

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reducing the tuber dimensions to 0.5-1 cm, and washing with water. After that, the first soaking of the cassava tubers is done in 4 g of 0.25% citric acid solution and 2 L of water for one h in a closed container, then drained, and followed by the second soaking in 2 L of water with 4 g of 0.2% commercial Bimo CF inoculum for 48 h in a closed container. Next, the drying of cassava chips is carried out using a cabinet dryer at a temperature of 60°C until they are brittle, which takes approximately 12 h. After that, grinding and sieving are carried out using an 80-mesh sieve until modified cassava flour is produced.

Table 1. Experimental design matrix of Response Surface Methodology using Central Composite Design showing the combinations of edamame paste and moringa leaf proportions with corresponding mocaf flour and water levels

Run	Block	Factor 1	Factor 2	Mocaf flour (%)	Water (%)
		Edamame Pasta (%)	Moringa leaf (%)		
1	Block 1	25,61	8,54	74,39	91,46
2	Block 1	4,39	1,46	95,61	98,54
3	Block 1	4,39	8,54	95,61	91,46
4	Block 1	25,61	1,46	74,39	98,54
5	Block 1	15	5	85	95
6	Block 1	15	5	85	95
7	Block 1	15	5	85	95
8	Block 2	15	5	85	95
9	Block 2	15	10	85	90
10	Block 2	15	5	85	95
11	Block 2	15	0	85	100
12	Block 2	0	5	100	95
13	Block 2	15	5	85	95
14	Block 2	30	5	70	95

Preparation of edamame paste and crushed moringa leaf

Edamame paste was made following the method (Astuti et al., 2014) with modifications, including 500 g of whole edamame beans (harvested at the immature stage, characterized by fully filled green pods) soaked for 12 h in 1500 mL of water with the addition of 30 g of baking soda. Then, the edamame is washed with running water until the air bubbles and sour aroma disappear. Edamame beans were boiled at 100°C for 15 min until the beans became soft and the beany odor was reduced. The boiled edamame was then drained, and the outer skins were removed. The peeled edamame

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was blended with the addition of 70 mL of water. Subsequently, 50 g of mocaf flour was added to the mixture until a uniform edamame paste was obtained. For the preparation of moringa leaves, 5 g of fresh moringa leaves were weighed and subjected to hot water blanching at 80 °C for 1.5 min. The blanched leaves were then drained and crushed using a mortar and pestle until a smooth crush was formed.

Making of mocaf dry noodles

Mocaf dry noodles are made following slight modifications (Astuti et al., 2023). Mocaf dry noodles are made as follows: The ingredients are prepared and weighed according to the treatment, then tapioca (12%), salt (1%), STPP (Sodium Tripolyphosphate) (0.4%), xanthan gum (1%), khi water (1%), and suji leaf extract (5%) (w/w of total dough weight) are dissolved with 60 mL of water. Then, heat the mixture of previously dissolved ingredients until it thickens. After thickening, the dough is placed in a container. Then, mocaf flour, edamame paste, and crushed moringa leaves are added gradually while kneading until it is half-kneaded. Then, add the eggs (3% w/w) slowly and knead until all the ingredients are perfectly mixed and a smooth dough is formed. The smooth dough is rounded and left to rest for about 30 min, then kneaded again for about 5 min. The dough is divided into 2 parts, then flattened using a noodle maker with 3 repetitions until it becomes sheets. The sheets of dough are cut into pieces with the noodle maker to form strands of noodles. The noodles are steamed at 100ºC for 15 min, then air-dried for 12 h. Next, the noodles are dried using a cabinet dryer at 60°C for 4 h.

Response variables and measurements

The response variables observed in this study include the sensory and physical properties of the produced dry noodles. The sensory analysis conducted used a numerical scale scoring test with sensory attributes including green color intensity, brown color intensity, cassava flavor, beany flavor, green flavor, chewiness, elasticity, and preference level for the dry noodle product on a scale of 1-7, where 1 represented the lowest score and 7 represented the highest score (Koh et al., 2022). The sensory attributes consisting of green color intensity, brown color intensity,

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cassava flavor, beany flavor, and green flavor were set within the desired range with a moderately important level (+++), while the preference level was targeted to be maximized with a very important level (+++++). Texture parameters, namely chewiness and elasticity, were also set to be maximized with a very important priority (+++++), while elongation was targeted to be maximized with an important level (++++). In terms of cooking quality, rehydration time was set within the desired range with a moderately important level (+++), while cooking loss was targeted to be minimized with an important level (++++). The importance scale used in the desirability function is: + (not important), ++ (less important), +++ (moderately important), ++++ (important), and +++++ (very important). All these weights are integrated into the analysis to obtain a combination of edamame paste and moringa leaf proportions that can optimally and simultaneously meet the quality criteria. Sensory testing was conducted in two stages. The first stage was the optimization of samples based on recommendations from the Design Expert software. The second stage was verification and validation, where the optimum noodle samples were given to 30 semi-trained panelists, repeated 5 times to assess sensory attributes. The physical analyses conducted were rehydration time (Tuhumury et al., 2020), elongation profile (Kumalasari et al., 2022), and cooking loss (Violalita et al., 2020).

RESULT AND DISCUSSION

Optimization of Mocaf-Based Dried Noodle Formulation

Based on the observations from 14 experimental treatments (Table 2), the elongation value of modified cassava flour-based noodles ranged from 17.59% to 66.75%, with the highest value observed in treatment 11 and the lowest in treatment 10. The cooking loss values ranged from 11.18 to 16.60 g, where treatment 3 exhibited the lowest solid loss, while treatment 1 showed the highest value. The higher cooking loss observed in treatment 1 can be explained by its formulation, which contained relatively high levels of edamame paste (25.61%) and moringa leaves (8.54%) and a lower proportion of mocaf flour (74.39%). The

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reduced starch content limits the formation of a compact starch gel matrix, thereby weakening the structural integrity of the noodles during cooking. As a result, more soluble components are leached into the cooking water (Sugiyama et al., 2022). Rehydration time varied between 9 and 21 min; treatment 1 demonstrated the shortest rehydration time, whereas treatments 2 and 12 required the longest time. Green color intensity ranged from 3.00 to 6.33, with the highest values recorded in treatments 1 and 9, while brown color intensity ranged from 3.00 to 4.67, with the highest value observed in treatment 14.

Table 2. Physical Responses of Mocaf-Based Dried Noodles

Treatments	Elongation±SD * (%)	Cooking Loss±SD* (g)	Rehydration Time ±SD* (menit)
1	33,12±2,85	16,60±0,75	9±1,41
2	26,06±0,45	13,24±3,59	21±2,12
3	38,24±4,95	11,18±1,84	18±2,12
4	43,38±15,80	11,69±0,64	12±0,71
5	45,61±4,35	13,01±0,96	15±1,41
6	59,43±0,45	13,63±0,67	18±1,41
7	31,51±4,66	12,15±0,75	15±2,83
8	31,03±0,76	13,03±0,12	15±3,54
9	32,64±7,93	15,23±0,49	18±4,24
10	17,59±0,58	15,40±0,17	15±3,54
11	66,75±2,39	14,49±0,09	18±2,83
12	34,92±8,84	15,93±0,59	21±2,12
13	30,07±1,20	13,68±1,37	18±3,54
14	36,73±1,84	15,47±2,66	12±0,71

*SD=standard deviation

For sensory flavor attributes (Table 3), cassava flavor ranged from 2.47 to 3.53, beany flavor from 2.27 to 2.83, and green flavor from 1.77 to 2.83, indicating variations in panelists' perceptions due to the addition of edamame paste and moringa leaves. Texture parameters showed that chewiness ranged from 4.53 to 6.50, with the highest values observed in treatments 5 and 14, while elasticity ranged from 2.83 to 4.57, with the highest value recorded in treatment 11. The high chewiness in treatments 5 and 14 is likely due to the balanced proportion of mocaf starch and edamame protein, which

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promotes a more compact and cohesive matrix. In treatment 14, the higher edamame level may further strengthen the structure through protein–starch interactions. Meanwhile, the highest elasticity in treatment 11 (15% edamame without moringa leaves) suggests that the absence of fiber allows better development of the starch–protein network. In contrast, fiber from moringa leaves may disrupt matrix continuity. These findings are consistent with previous studies on gluten-free noodles (Łysakowska et al., 2025; Zheng et al., 2023). The overall liking scores ranged from 3.90 to 5.33, where treatment 11 obtained the highest score. Overall, the data indicate variations in the physicochemical and sensory characteristics among treatments, suggesting that the proportions of edamame paste and moringa leaves influenced the final quality of the noodles produced, as reported by Sugiyama et al. (2022).

Table 3. Sensory Responses of Mocaf-Based Dried Noodles

Treatments	Green color intensity ±SD*	Brown Color Intensity ±SD*	Cassava Flavor ±SD*	Beany Flavor±SD*	Green Flavor±SD*	Chewiness ±SD*	Elasticity ±SD*	Overall liking ±SD*
1	6,33±0,61	4,07±0,52	2,50±0,51	2,70±0,60	2,83±0,79	5,80±0,61	2,90±0,55	3,93±0,64
2	3,30±0,47	3,37±0,49	3,53±0,82	2,27±0,52	2,27±0,74	4,80±0,66	4,27±0,69	4,73±0,64
3	5,50±0,51	3,33±0,48	3,30±0,60	2,33±0,66	2,67±0,55	4,77±0,82	3,97±0,67	4,13±0,57
4	4,10±0,71	4,50±0,57	2,57±0,57	2,80±0,66	1,83±0,53	6,00±0,69	2,87±0,57	4,43±0,57
5	4,33±0,48	3,50±0,57	2,70±0,53	2,63±0,56	2,37±0,56	6,50±0,63	4,23±0,68	4,50±0,63
6	5,30±0,79	3,60±0,56	2,67±0,55	2,50±0,57	2,57±0,63	5,47±0,63	4,30±0,70	4,20±0,66
7	4,73±0,45	3,53±0,57	2,83±0,59	2,67±0,71	2,07±0,64	6,00±0,79	4,30±0,65	4,60±0,62
8	5,03±0,61	3,57±0,63	2,73±0,64	2,43±0,73	2,50±0,68	5,80±0,71	4,50±0,63	4,13±0,63
9	6,03±0,76	3,47±0,57	2,67±0,48	2,47±0,68	2,70±0,65	5,03±0,76	3,33±0,61	3,90±0,61
10	4,90±0,55	3,60±0,56	2,80±0,71	2,67±0,71	2,33±0,55	5,53±0,63	3,93±0,69	4,87±0,68
11	3,00±0,59	3,73±0,58	3,13±0,68	2,53±0,57	1,77±0,50	5,67±0,66	4,57±0,63	5,33±0,71
12	4,67±0,55	3,00±0,53	3,47±0,86	2,33±0,61	2,63±0,67	4,53±0,68	3,67±0,66	4,93±0,64
13	5,47±0,51	3,50±0,68	2,77±0,57	2,50±0,63	2,57±0,63	5,83±0,70	3,73±0,64	4,73±0,59
14	5,33±0,55	4,67±0,88	2,47±0,57	2,83±0,65	2,43±0,50	6,50±0,78	2,83±0,59	4,50±0,63

*SD=standard deviation. Values represent the results of a scoring test using a 7-point scale (1 = lowest score, 7 = highest score).

Based on the observations from 14 experimental treatments (Table 2 and 3), the results indicate that the proportions of edamame paste and moringa leaves significantly influenced the physicochemical and sensory properties of mocaf-based noodles. A higher proportion of edamame paste tended to increase elongation, elasticity, and rehydration time, indicating improved structural integrity and water

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absorption capacity of the noodles. However, it also increased beany flavor and reduced cassava flavor, which may affect consumer acceptance. In addition, higher edamame levels were associated with increased green and brown color intensity due to pigment contribution from edamame. In contrast, a higher proportion of moringa leaves enhanced green color intensity and green flavor, reflecting the presence of chlorophyll and characteristic leafy notes. However, excessive addition of moringa leaves tended to decrease brown color intensity and overall liking, possibly due to the development of a stronger herbal taste that was less preferred by panelists.

Table 4. Mathematical Models and RSM Analysis Results for the Physical and Sensory Responses of Noodles

No	Response	Model Type	Mathematical Equation	Sig. (p<0,05)					R^2
				Model	*Lack of Fit*	A	B	AB	
1	Green color intensity	*Quadratic*	$5{,}09 + 0{,}29\,(A) + 1{,}12\,(B) - 0{,}025\,(AB) - 0{,}027\,(A^2) - 0{,}27\,(B^2)$ ….. 1	0,0001*	0,7731	0,0075*	0,0001*	0,8298	0,95
2	Brown color intensity	*Quadratic*	$3{,}55 + 0{,}53\,(A) - 0{,}10\,(B) - 0{,}097\,(AB) + 0{,}17\,(A^2) + 0{,}051\,(B^2)$ ….. 2	0,0001*	0,0683	0,0001*	0,0110*	0,0586	0,97
3	*Cassava flavor*	*Quadratic*	$2{,}75 - 0{,}40\,(A) - 0{,}12\,(B) + 0{,}040\,(AB) + 0{,}12\,(A^2) + 0{,}085\,(B^2)$ ….. 3	0,0001*	0,1767	0,0001*	0,0059*	0,3835	0,94
4	*Beany flavor*	*Linear*	$2{,}55 + 0{,}20\,(A) - 0{,}016\,(B)$ …….. 4	0,0002*	0,8514	0,0001*	0,6183		0,78
5	*Green flavor*	*Quadratic*	$2{,}40 - 0{,}070\,(A) + 0{,}34\,(B) + 0{,}15\,(AB) + 0{,}069\,(A^2) - 0{,}079\,(B^2)$ … 5	0,0058*	0,9141	0,2506	0,0005*	0,1009	0,77
6	Chewiness	*Quadratic*	$5{,}85 - 0{,}63\,(A) - 0{,}14\,(B) - 0{,}042\,(AB) - 0{,}19\,(A^2) - 0{,}27\,(B^2)$ …… 6	0,0116*	0,7337	0,0012*	0,2763	0,8097	0,72
7	Elasticity	*Quadratic*	$4{,}17 + 0{,}46\,(A) - 0{,}25\,(B) + 0{,}083\,(AB) - 0{,}48\,(A^2) - 0{,}13\,(B^2)$ …… 7	0,0160*	0,2135	0,0085*	0,0850	0,6578	0,69
8	Overall liking	*Linear*	$4{,}49 + 0{,}14\,(A) - 0{,}39\,(B)$ ……… 8	0,0020*	0,9234	0,1281	0,0009*		0,65
9	Rehydration time	*Linear*	$16{,}07 + 3{,}84\,(A) - 0{,}75\,(B)$ …..… 9	0,0002*	0,6104	0,0001*	0,2227		0,78

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No	Response	Model Type	Mathematical Equation	Sig. (p<0,05)					R^2
				Model	*Lack of Fit*	A	B	AB	
10	Elongation	*Linear*	37,65 + 14,80 (A) – 1,82 (B) …… 10	0,0001*	0,1192	0,0001*	0,4076		0,80
11	*Cooking loss*	*2FI*	13,91 + 0,40 (A) + 0,49 (B) + 1,74 (AB) ……………………………… 11	0,0369*	0,4259	0,3200	0,2346	0,0504	0,59

* indicates statistical significance at $p < 0.05$.

The RSM analysis showed that most responses were well described by quadratic models, except for beany flavor, overall liking, rehydration time, and elongation, which followed linear models, while cooking loss followed a two-factor interaction (2FI) model (Table 4). All models were statistically significant ($p < 0.05$), indicating that variations in the proportion of edamame paste (A) and moringa leaves (B) significantly affected all observed parameters. The coefficient of determination (R^2) ranged from 0.59 to 0.97, indicating that the models explained approximately 59–97% of the data variation (Wang et al., 2016). The highest R^2 values were observed for brown color intensity (0.97) and green color intensity (0.95), indicating an excellent model fit. Furthermore, the non-significant lack-of-fit values ($p > 0.05$) for all responses suggest that the developed models adequately represent the experimental data.

Partially, factor A (edamame paste) significantly affected most responses, including green color intensity, brown color intensity, cassava flavor, beany flavor, chewiness, elasticity, rehydration time, and elongation. Meanwhile, factor B (moringa leaves) showed significant effects mainly on green color intensity, brown color intensity, cassava flavor, green flavor, overall liking, and several other parameters. The interaction between A and B (AB) was generally not significant for most responses, except in certain cases, such as cooking loss. Overall, these results indicate that the proportions of edamame paste and moringa leaves play an important role in determining the physicochemical and sensory characteristics of modified cassava flour-based noodles,

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with individual factor effects being more dominant than their interaction (Fatima et al., 2024).

Effect of factors on dried noodle responses

The optimization results using Response Surface Methodology (RSM) indicated that variations in the proportions of edamame paste (A) and moringa leaves (B) affected each physicochemical and sensory response differently. This trend can be observed from the contour plots presented in Figure 1. Increasing the proportion of edamame paste and moringa leaves significantly increased green color intensity due to the contribution of chlorophyll pigments. Previous studies reported that chlorophyll in moringa leaves and young soybeans remains relatively stable under mild heat treatments and contributes to the visual quality of plant-based food products (Iswahyono et al., 2026; Matabura & Rweyemamu, 2022).

An increase in edamame paste also increased brown color intensity, which may be attributed to the Maillard reaction between proteins and reducing sugars during heating, producing brown melanoidin pigments commonly found in legume–starch-based foods (Khairunnisa & Sofyan, 2025). The addition of edamame paste and moringa leaves reduced cassava flavor due to the substitution effect and flavor masking by volatile compounds from legumes and leafy vegetables. Fermentation during mocaf production is also known to reduce the characteristic cassava aroma (Ningrum & Saidi, 2023). Increasing the edamame paste proportion enhanced beany flavor due to the activity of lipoxygenase enzymes that produce volatile compounds such as hexanal and alcohol derivatives typical of soybean products (Yang et al., 2023). Meanwhile, increasing the moringa leaf proportion significantly increased green flavor due to the presence of phenolic compounds, saponins, and volatile components characteristic of leafy vegetables. The herbal flavor intensity of moringa has been reported to increase with higher fortification levels (Trigo et al., 2023).

The addition of edamame paste tended to reduce chewiness due to the reduction in mocaf starch (particularly amylopectin), which plays an important role in forming elastic gel structures. The starch–protein ratio is known to strongly influence

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the texture of gluten-free noodles (Sugiyama et al., 2022). Conversely, the increased protein content from edamame improved elasticity by strengthening the protein–starch network within the noodle matrix. Protein–starch interactions have been reported to improve tensile strength in gluten-free noodles (Thirathumthavorn et al., 2022). Overall liking increased with the addition of edamame paste but decreased at higher concentrations of moringa leaves, suggesting a balance between improved texture and the potential dominance of herbal flavor. Similar trends have been reported in food products fortified with moringa leaves (Summaya et al., 2016).

An increase in edamame paste proportion also prolonged rehydration time because protein–starch interactions limit water penetration into starch granules. Protein–amylose complexes are known to inhibit hydration and starch retrogradation (Ciaramitaro et al., 2023). Elongation increased with higher protein content from edamame, as proteins strengthen the dough matrix and improve resistance to tensile force. A positive relationship between protein content and elongation has been reported in legume-based gluten-free noodles (Sahu et al., 2024). The cooking loss values remained within an acceptable range and were not significantly affected by individual factors, indicating that the starch–protein matrix remained relatively stable during cooking. The structural stability of the noodle matrix plays an important role in minimizing solid loss during boiling (Canti et al., 2020).

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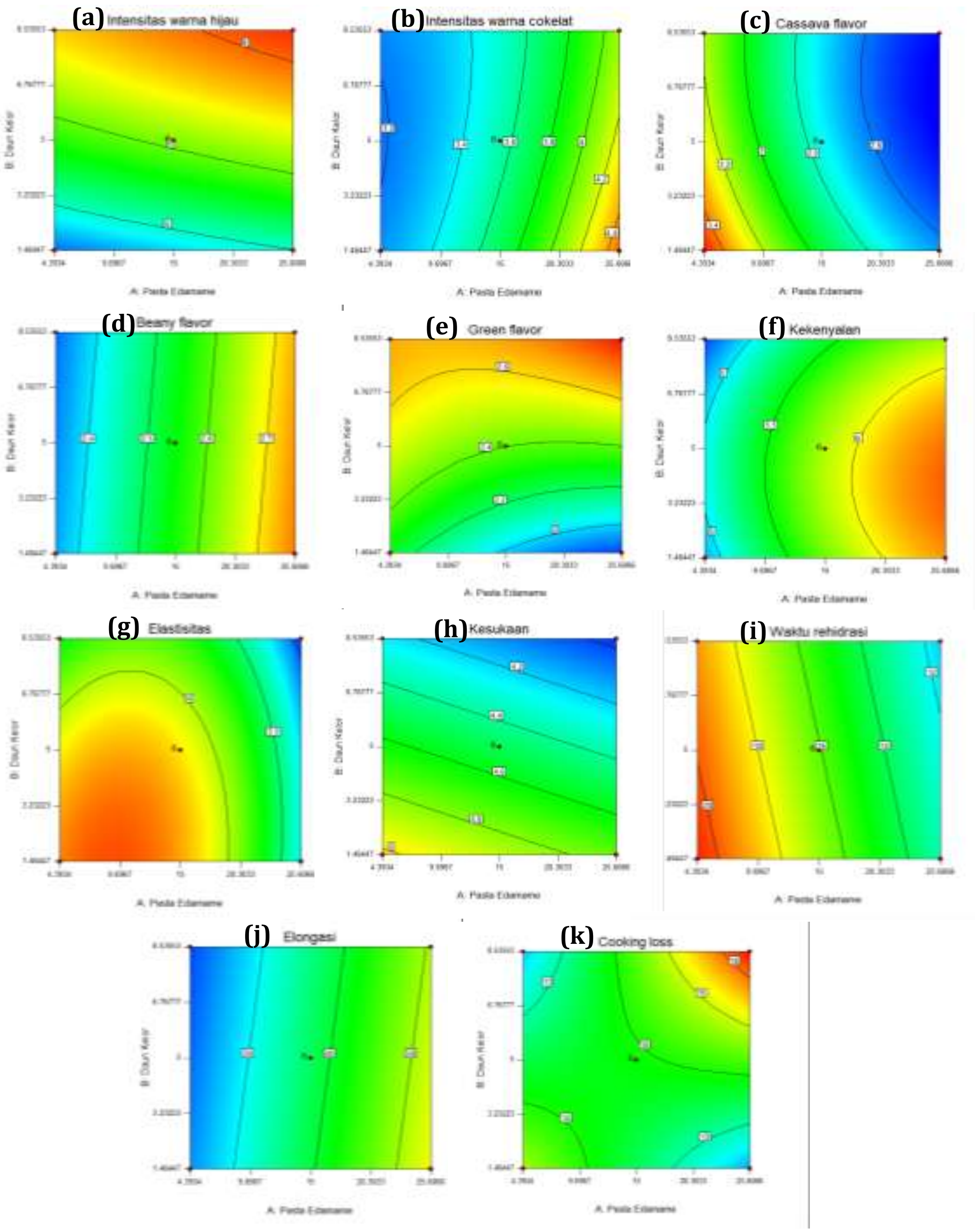

Figure 1. Contour plots of the responses: (a) green color intensity; (b) brown color intensity; (c) cassava flavor; (d) beany flavor; (e) green flavor; (f) chewiness; (g) elasticity; (h) overall liking; (i) rehydration time; (j) elongation; and (k) cooking loss.

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Verification and validation of the optimum formulation

Based on the predetermined response priorities, an optimum formulation was obtained using the RSM analysis. The Design Expert software recommended an optimum formulation consisting of 17.53% edamame paste and 1.46% moringa leaves. The predicted values for the optimized responses were as follows: green color intensity 3.77; brown color intensity 3.86; cassava flavor 2.86; beany flavor 2.61; green flavor 1.93; chewiness 5.87; elasticity 4.13; overall liking 4.85; rehydration time 15.9 min; elongation 43%; and cooking loss 13.10%, with an overall desirability value of 0.69 (Table 5).

Table 5. Validation of the optimum formulation showing the actual values (mean ± SD) of the responses and their corresponding 95% prediction intervals (PI).

Responses	Actual value±SD*	95% *Prediction Interval* (PI)	
		PI *Low*	PI *High*
Green color intensity	5,04 ± 0,81	4,52	5,66
Brown color intensity	3,38 ± 0,54	3,33	3,77
Cassava flavor	2,58 ± 0,65	2,53	2,97
Beany flavor	2,70 ± 0,52	2,35	2,75
Green flavor	2,03 ± 0,49	2,00	2,81
Chewiness	5,45 ± 0,57	4,98	6,72
Elasticity	4,72 ± 0,61	3,25	5,08
Overall liking	4,86 ± 0,75	3,95	5,04
Rehydration time	15,00 ± 1,41	12,31	19,83
Elongation	23,81 ± 0,25	23,00	51,35
Cooking loss	11,69 ± 0,64	11,38	16,44

The verification results showed that all actual values of the optimum formulation fell within the 95% Prediction Interval (PI), indicating that the developed RSM model had good predictive accuracy. The agreement between the experimental values and the prediction intervals suggests that the model adequately describes the mathematical relationship between independent variables and the observed responses. According to (Danbaba et al., 2015; Wangtueai et al., 2020), an RSM model is considered valid when the actual verification values fall within the 95% prediction interval, as this indicates that the experimental variation remains within an acceptable error range. In this study, all sensory responses, including green color intensity, brown color intensity, cassava flavor, beany flavor, green flavor, and overall liking, were within the PI range, indicating that the obtained optimum formulation is predictive and reproducible.

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A similar trend was observed for texture and cooking quality parameters, including chewiness, elasticity, rehydration time, elongation, and cooking loss, where the actual values were also within the prediction intervals. This finding further confirms that the optimization model adequately explains the variation in the data and can be applied for product development. (Prabudi et al., 2018; Rukmana et al., 2024) reported that validation of RSM models using prediction interval analysis is an essential step in food product optimization, as it ensures that the optimized results are not only statistically significant but also practically applicable. Therefore, the agreement between actual values and the 95% prediction intervals for all responses confirms that the model developed in this study is suitable for determining the optimum formulation of modified cassava flour-based noodles.

CONCLUSION

The result of this study demonstrated that both factors significantly influenced the physicochemical and sensory characteristics of the noodles. Edamame paste played a dominant role in improving structural properties, particularly elongation, elasticity, and rehydration behaviour, although it also intensified beany flavor and reduced cassava flavor. In contrast, moringa leaves contributed mainly to enhancing green color intensity and green flavor, but excessive addition negatively affected overall acceptability due to stronger herbal notes. Most responses were well described by quadratic models, with R^2= 0.59-0.70. The optimum formulation of mocaf-based dried noodles was obtained with proportions of 82.47% mocaf flour, 17.53% edamame paste, and 1.46% moringa leaves, resulting in a desirability value of 0.70. Model validation showed that all experimental values fell within the 95% prediction intervals, confirming the reliability and predictive accuracy of the developed models. This study demonstrates that the combination of edamame paste and moringa leaves can effectively improve the quality of mocaf-based noodles and provides a promising approach for developing nutritious, gluten-free noodle products while reducing dependence on wheat flour.

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