

Cowpea-Plantain Composite Flour: An Educational Approach to Dietary Intervention for Blood Pressure Management

Zulfiana Dewi¹, Sajiman^{1*}

¹Poltekkes Kemenkes Banjarmasin, City of Banjarmasin, Province South Kalimantan, Indonesia

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Corresponding Author:

Sajiman

sajimanadje@gmail.com

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Abstract: Hypertension is a major risk factor for cardiovascular diseases and remains highly prevalent in Indonesia, particularly in South Kalimantan. This study aims to formulate a cowpea-plantain composite flour as a functional food with synergistic potential for blood pressure regulation. Composite flours were produced by processing raw materials through drying, milling, and sieving into formulations ranging from 10:90 to 90:10. Sensory attributes, including color, aroma, texture, and taste, were evaluated by 30 panelists, and the best formulation was determined using the De Garmo effectiveness index. Proximate composition, mineral content (potassium and sodium), and amino acid profiles were analyzed in an accredited laboratory. Sensory evaluation revealed that higher proportions of cowpea decreased taste acceptability, whereas plantain improved organoleptic characteristics. The optimal formulation was identified as KTPR8020 (80% cowpea : 20% plantain), which achieved a balanced profile of texture, aroma, and taste. Nutritional analysis indicated that cowpea increased protein (17.50%) and fat (1.56%) contents, while plantain contributed mainly to carbohydrates. The KTPR8020 formulation contained 5.98 mg/100 g potassium with a K/Na ratio of 7.1, supporting potassium-induced natriuresis. Amino acid profiling showed dominance of lysine, leucine, isoleucine, valine, and arginine, which are known precursors of bioactive peptides with ACE-inhibitory activity.

Keywords: Bioactive peptides; Composite flour; Cowpea (*Vigna unguiculata*); Hypertension; Plantain (*Musa paradisiaca* L.)

Introduction

One of the most prevalent long-term health issues in the world, hypertension is a significant risk factor for cardiovascular disease. Persistently high blood pressure, with a systolic blood pressure of at least 130 mmHg and a diastolic blood pressure of at least 80 mmHg, is the hallmark of this syndrome. According to the 2018 Basic Health Research, 34.1% of Indonesians have hypertension, a significant rise from 25.8% in 2013. South Kalimantan has the second-highest rate of hypertension in Indonesia, making it a serious health issue. Particularly in Banjarbaru City, the number of cases is significantly increasing, necessitating a thorough examination of the underlying reasons and treatment initiatives. According to the Health Development Policy

Agency's 2023 Indonesian Health Survey (SKI) (BKPK Kemenkes, 2023), South Kalimantan had a higher prevalence of hypertension (34.1%) than the rest of Indonesia (29.2%). This shows that South Kalimantan Province has the second-highest prevalence of hypertension in Indonesia, after Central Kalimantan, and it is greater than the national prevalence rate (Kemenkes RI, 2022). This phenomenon shows a worrying increasing trend, in line with changes in people's lifestyles and eating patterns.

Non-pharmacological efforts, particularly through dietary modification, are an important strategy in controlling hypertension. The Dietary Approaches to Stop Hypertension (DASH) has been shown to effectively lower blood pressure through the consumption of foods rich in potassium, magnesium,

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calcium, protein, and fiber (Astuti et al., 2021; Filippou et al., 2020). Among these nutrients, potassium plays a key role in increasing sodium excretion and reducing extracellular fluid volume, thus contributing directly to blood pressure reduction (Chan et al., 2022; Palmer & Clegg, 2020).

Apart from minerals, bioactive proteins may also play a part in controlling blood pressure. Angiotensin-converting enzyme (ACE-1), an enzyme involved in the conversion of angiotensin I to angiotensin II, is known to be inhibited by peptides found in cowpea (*Vigna unguiculata*) protein hydrolysate, raising blood pressure (Martin Alain, 2023; Tejasari et al., 2020). Cowpeas are also rich in protein, essential amino acids, minerals, and dietary fiber, making them a potential candidate for antihypertensive functional foods (Abebe & Alemayehu, 2022; Affrifah et al., 2022; Karuwal et al., 2023). On the other hand, plantain (*Musa paradisiaca* L.) is one of the highest natural sources of potassium, with a content of up to 435 mg/100 g. Potassium in bananas plays a role in regulating body fluid balance and supporting blood pressure-lowering mechanisms (Al-dairi et al., 2024; Noviyanti, 2020).

A functional diet with two synergistic mechanisms—the potassium natriuretic effect of plantains and the suppression of ACE-1 by cowpea bioactive peptides—could be created by combining cowpea and plantain in the form of composite flour. Nevertheless, there is still little research on composite flour formulations made with these two regional constituents, especially with reference to their biological action in controlling blood pressure. This research offers a novelty approach by integrating a protein source producing ACE-1-inhibiting bioactive peptides and a high potassium source into a single composite food product based on local ingredients. This approach is expected to not only enrich the literature on antihypertensive functional foods but also provide an affordable and acceptable dietary intervention alternative to support hypertension prevention efforts.

This study aims to develop a composite flour formulation based on cowpea and plantain as a potential functional food for blood pressure management. Specifically, it seeks to explore the synergistic contribution of bioactive peptides from cowpea as ACE-1 inhibitors and the potassium-mediated natriuretic effect of plantain, as well as to evaluate the biological potential of their combination in supporting blood pressure regulation.

Method

Dried cowpeas and plantains from Batuah Market in Banjarbaru, South Kalimantan, are the basic ingredients used to make Composite Flour. Sodium

bisulfite and baking soda (NaHCO_3) are additional components. A basin, a nutcracker, a Chin KU AS-1060G autoclave, a GTK electric oven, a blender, a food processor, an 80-mesh sieve, and a 60-mesh sieve are among the tools utilized.

Making Cowpea Flour

Soaking and washing cowpeas is the first step in sorting them. While soaking in a NaHCO_3 solution lessens the distinctive offensive smell of beans, washing eliminates dirt. Low-quality beans will float and be thrown out after eight hours of soaking in a 1:3 ratio of beans to water. To obtain clean, skinless beans, the husks are then removed. Before drying, the lipoxygenase enzyme is inactivated by steaming, which further lessens the offensive smell. After that, the beans are dried for eight hours at 60°C in a cabinet dryer to remove any remaining moisture. To produce flour with a consistent particle size, they are pounded into a fine powder and sieved using an 80-mesh sieve.

Making Plantain Flour

Plantains are selected at an optimal ripeness level (not too soft) to maintain a high potassium content. After peeling and cleaning, the fruit flesh is soaked in a sodium bisulfite solution (1 liter, 1500 ppm) for 10 minutes to prevent enzymatic browning through sulfurization. The banana slices are then drained for 15 minutes before being dried in an oven at 60°C for 8 hours until the moisture content reaches 10–12%. This drying temperature is chosen because it effectively reduces the moisture content without compromising nutritional quality, particularly potassium and protein. Next, the dried bananas are ground using a dry blender and sieved through a 60-mesh sieve to obtain flour with a uniform particle size.

Sensory Quality Analysis and Best Formulas

Sensory quality testing was conducted using 30 panelists in an organoleptic testing laboratory. The color, aroma, texture, and taste of each sample were assessed by the panelists. After the sensory quality testing, the data were calculated using the deGarmo analysis method to obtain the best results (DeGarmo et al., 1984). The following step was a descriptive analysis of the composite flour's proximate, sodium, potassium, and amino acid levels. Plantains flour (PR100), cowpea flour (KT100), and a chosen composite flour (KTPR8020) were the treatments that were tested further. A technique for identifying the optimal formula based on its efficacy value is the de Garmo test. The De Garmo test starts by weighing the panelists' scores, computing each parameter's productivity value (NP), adding up each parameter's output values, and selecting the optimal formula from the formula with the highest NP.

Proximate Analysis of Potassium, Sodium, and Amino Acid Profiles of Composite Flour

Laboratory analysis of composite flour was conducted at the Saraswanti Indo Genetech (SIG) Laboratory. Proximate analysis included fat content testing, using procedures based on 18-8-5/MU (gravimetry). The ash content test procedure was based on SNI 01-2891-1992, point 6.1. The protein test procedure was based on 18-8-31/MU (titrimetry). The moisture content test procedure was based on SNI 01-2891-1992, point 5.1. The carbohydrate test used a different method. The potassium analysis procedure used the 18-13-1/MU (ICP-OES) method. The sodium analysis procedure used the 18-13-1/MU (ICP-OES)

method. Amino acids were analyzed using procedures based on the internal method 18-5-17/MU/SMM-SIG (UPLC-PDA).

Result and Discussion

Sensory Quality of Cowpea-Plantain Composite Flour

The following treatments were applied to the formulation design results for the quantities of cowpea and plantain composite flour: P1 (10:90); P2 (20:80); P3 (30:70); P4 (40:60); P5 (50:50); P6 (60:40); P7 (70:30); P8 (80:20); and P9 (90:10). Figure 1 shows how the composite flour with these different treatments looks.



Figure 1. Visual of Cowpea-Plantain Composite Flour with Various Treatments

Color Sensory

Figure 2 shows a consistent trend between ingredient proportions and panelists' color acceptance. Formulations with higher cowpea flour content generally achieved higher preference scores, indicating that the deeper hue was perceived as appealing. However, in the KTPR9010 formulation, scores decreased significantly compared to the previous

treatment. This confirms the finding that although cowpea positively contributes to color intensity, there is an optimal threshold that should not be exceeded. Thus, the visualization in Figure 2 not only confirms the statistical test results showing a significant effect ($p=0.001$) but also provides a practical illustration of the balance point between cowpea and plantain proportions in producing the most preferred composite flour color.

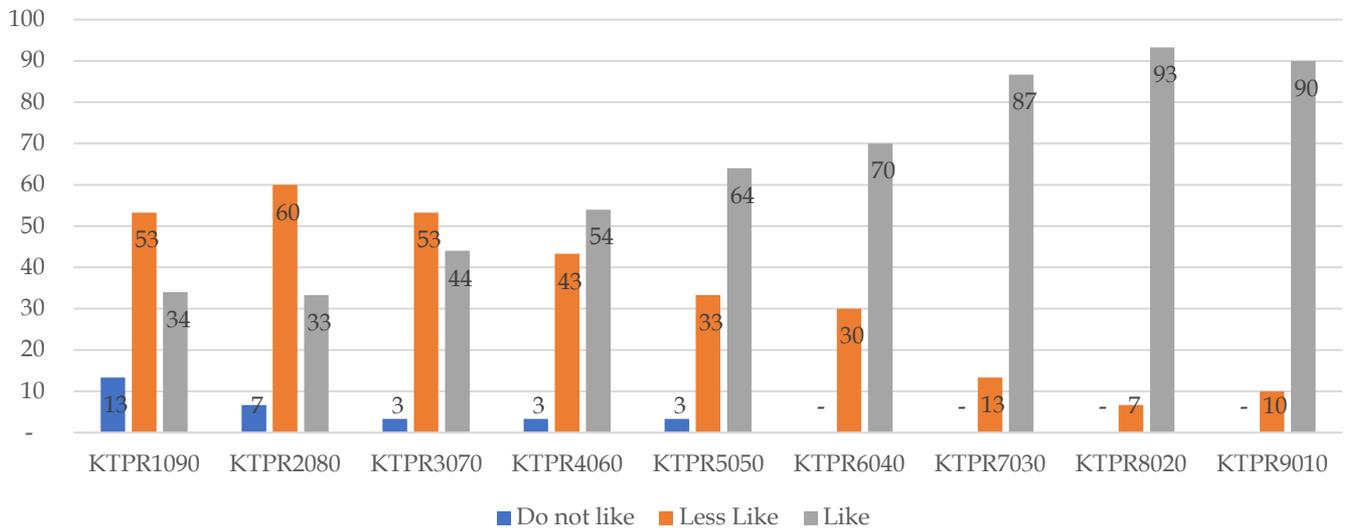


Figure 2. Sensory Quality of Color of Cowpea-Plantain Composite Flour

Aroma Sensory

Sensory testing showed that the proportions of cowpea flour and banana flour play a role in shaping the aroma character of the composite flour. When cowpea flour was added at moderate levels, panelists gave more positive aroma ratings. This indicates a balance point in proportion where the legume aroma is still acceptable. However, at high proportions ($\geq 80\%$), the dominance of the typical legume aroma, characterized by "beany" nuances, caused the assessment score to decline.

Conversely, the addition of high amounts of banana flour resulted in negative responses from panelists. This may be due to the relatively neutral and less complex aroma character of banana, which reduces the intensity and uniqueness of the composite aroma profile. Statistical test results supported this finding with a probability value of 0.176, indicating that varying the proportions of the two flours had no significant impact on aroma acceptance. Panelists' responses to overall aroma quality can be seen in Figure 3.

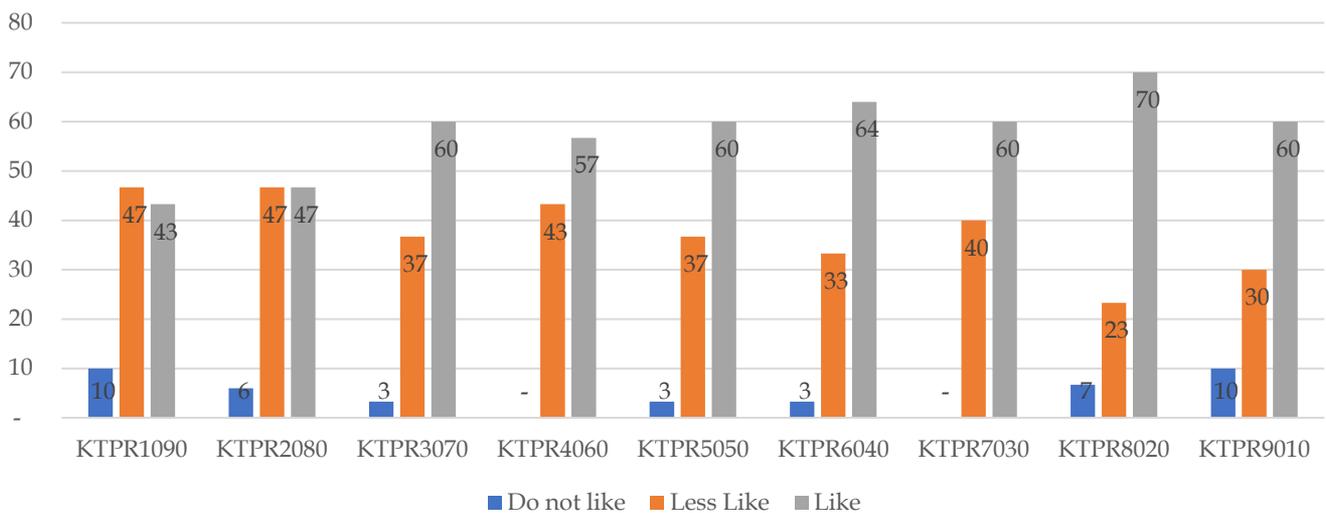


Figure 3. Sensory Quality of Aroma of Cowpea-Plantain Composite Flour

Texture Sensory

Figure 4. Texture sensory quality scores for composite cowpea and plantain flour based on panelist assessments. The graph shows that increasing the proportion of cowpea flour tends to increase panelist preference for texture, while adding larger amounts of

plantain flour actually decreases acceptance scores. Statistical test results ($p = 0.001$) confirm that differences in the proportions of the two types of flour significantly influence texture quality, so formulation balance significantly determines panelist acceptance of the final product.

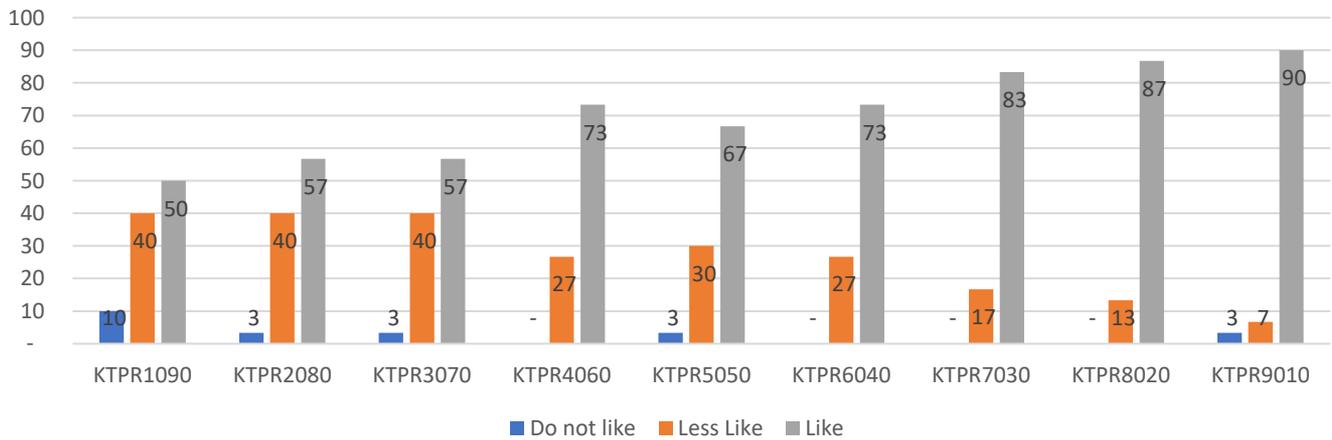


Figure 4. Sensory Quality of Texture of Cowpea-Plantain Composite Flour

Taste Sensory

Figure 5. Taste sensory quality of composite flour based on cowpea and plantain. The graph shows a tendency for panelists' preference to decrease as the proportion of cowpea flour increased, while the addition

of plantain flour resulted in a more positive response. Although there were differences in average scores between treatments, statistical analysis showed that the proportions of the two ingredients were not significantly affected by the taste attribute ($p = 0.676$).

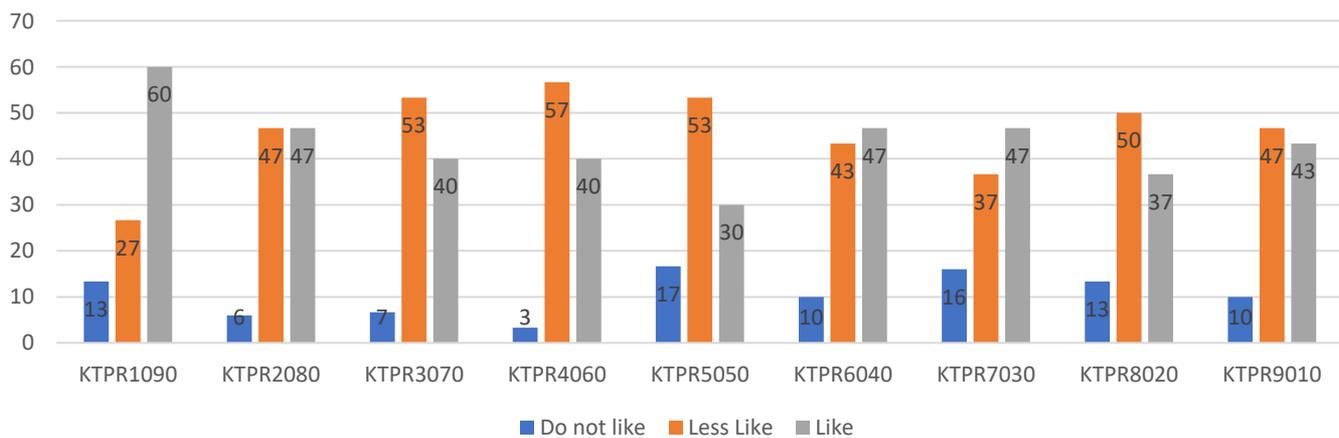


Figure 5. Sensory Quality of Flavor of Cowpea-Plantain Composite Flour

To find the most effective treatment overall, this study used the De Garmo effectiveness test method. This test is conducted by determining the highest and lowest values for each parameter, based on its productivity level. The De Garmo test results indicated that the best

proportion for the composite cowpea and plantain flour was 80% cowpea flour and 20% plantain flour. This combination produced the highest value, indicating that this composition was the most preferred and had the best sensory qualities.

Table 1. Results of the De-Garmo Test to Determine the Best Proportion of Cowpea-Plantain Composite Flour

Formulation	Total		Rank
	NE	NP	
KTPR1090	1.00	0.20	9
KTPR2080	1.40	0.30	8
KTPR3070	1.94	0.39	6
KTPR4060	2.61	0.60	5
KTPR5050	1.84	0.45	7
KTPR6040	2.99	0.72	4
KTPR7030	3.24	0.83	2
KTPR8020	3.31	0.86	1
KTPR9010	3.12	0.86	3

This proportion successfully balances the unique characteristics of both ingredients. Cowpea flour provides a high protein source and a firm texture, while plantain flour enhances natural sweetness and a distinctive aroma, while also improving the texture of the final product, making it softer. As a result, products prepared with this proportion have the optimal taste, aroma, and texture, making it a superior choice compared to other proportions.

Proximate Content of Cowpea-Plantain Composite Flour

Proximate analysis of cowpea and plantain composite flour revealed variations in nutritional content influenced by the proportions of each ingredient. The parameters analyzed included moisture, ash, protein, fat, and carbohydrate content, which collectively reflect its nutritional value and potential application in food formulations (Figure 6).

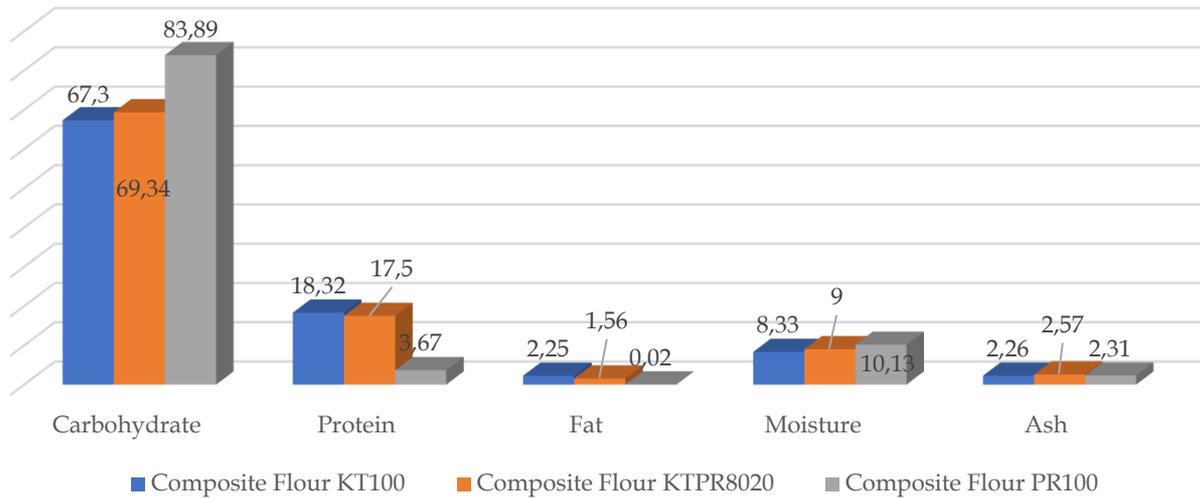


Figure 6. Proximat Profile of Cowpea-Plantain Composite Flour

Potassium and Sodium Content of Cowpea-Plantain Composite Flour

Figure 7. Potassium and sodium content in various cowpea and plantain composite flour formulations. The pure cowpea formulation (KT100) showed the highest potassium content and relatively high sodium, while the pure plantain (PR100) had the lowest potassium content

but with very low sodium content. A mixture of 80% cowpea and 20% plantain (KTPR8020) produced an intermediate mineral profile, indicating the role of cowpea as a major source of potassium and sodium, as well as the contribution of plantain in reducing sodium levels.

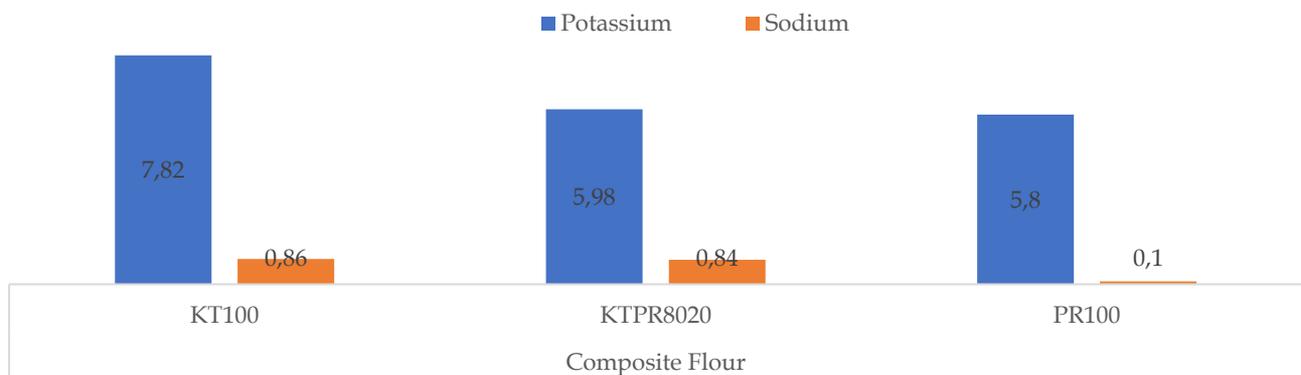


Figure 7. Potassium and Sodium Content of Cowpea-Plantain Composite Flour

Amino Acid Profile of Cowpea and Plantain Flour Composite

Table 2 Amino acid profiles of cowpea flour (KT100), the cowpea-plantain composite formulation (KTPR8020), and plantain flour (PR100). The data show

that cowpea flour and the composite formulation contain higher amounts of essential and non-essential amino acids than plantain flour, most of which were undetectable.

Table 2. Amino Acid Profile of Cowpea-Plantain Composite Flour

Amino Acid	Composite Flour		
	KT100	KTPR8020	PR100
Alanine	2.92	2.83	0.6
Arginine	1.2	1.25	ND
aspartic Acid	2.3	2.16	ND
Glisine	1.3	1.15	ND
Glutamic Acid	14.9	14.68	2.7
Histidine	0.32	0.29	ND
Isoleusine	0.9	0.83	ND
Sistine	1.6	1.55	ND
Leusine	1.8	1.76	ND
Lisine	3.67	3.52	ND
Metionine	2.32	2.2	0.03
Tryptophan	2.05	1.97	0.43
Valine	1.9	1.84	ND
Phenylalanine	3.54	3.64	0.3
Proline	1.07	0.99	0.4
Serine	0.87	0.29	ND
Threonine	ND	ND	ND
Tyrosine	ND	ND	ND

Among the non-essential amino acids, glutamic acid dominates with high concentrations in KT100 (14.9 g/100 g) and KTPR8020 (14.68 g/100 g), while in PR100 it only reaches 2.7 g/100 g. A similar pattern is also seen for alanine, aspartic acid, and glycine, which are present at high levels in KT100 and KTPR8020, but very low or undetectable in PR100. These findings confirm that cowpeas contribute the most to the non-essential amino acid content.

Among the essential amino acids, lysine was the most prominent component, with concentrations of 3.67 g/100 g in KT100 and 3.52 g/100 g in KTPR8020, but was not detected in PR100. Similarly, methionine (2.32 g/100 g in KT100; 2.2 g/100 g in KTPR8020) and tryptophan (2.05 g/100 g in KT100; 1.97 g/100 g in KTPR8020) were found only in very small amounts in PR100. Other essential amino acids, such as valine, leucine, isoleucine, and phenylalanine, were detected in cowpea flour and the blend formulation, but not in plantain. Only a few amino acids, such as proline, methionine, tryptophan, and phenylalanine, were detected in limited amounts in PR100, so plantain can be said to be neither a significant source of protein nor amino acids.

Color Sensory

The preference for the deeper color of cowpeas may be attributed to their bioactive compounds, such as flavonoids, tannins, and polyphenols, which act as natural pigments and antioxidants (Saini & Bajpai, 2024). These phenolic compounds are abundant in the seed coat, imparting a creamy to brown color, and can be intensified through the Maillard reaction during processing. This explains why increasing the proportion

of cowpeas can enhance the color of the product (Omar Y. Al-Abbasy, Sarah A. Younus, Aya I. Rashaan, 2024).

Conversely, the addition of plantain flour tends to reduce color brightness. This is consistent with previous research findings that combined plantain flour with wheat flour resulted in a 30% decrease in brightness (Bashmil et al., 2025). Natural banana pigments, including carotenoids, flavonoids, and catecholamines, impart a yellow to brownish color. Processing processes such as pre-gelatinization have also been reported to deepen red and yellow hues, resulting in darker colors (Kunyanee & Ngo, 2024).

Aroma Sensory

The aroma of cowpeas at low proportions gives a savory and mild impression, but at high proportions volatile compounds such as aldehydes and ketones, especially hexanal, are more dominant and give rise to an unpleasant aroma impression. This phenomenon is in line with the literature stating that the "beany flavor" originates from the oxidation of unsaturated fatty acids, producing aldehydes and short-chain alcohols (Bojňanská et al., 2021). In contrast, banana flour has a limited aroma contribution due to its high resistant starch content and low composition of volatile compounds. Increasing the proportion tends to reduce the aroma diversity, making the composite profile feel "flat" and less attractive (Hasmadi et al., 2020). Similar results were also reported by Siahaan, who found that the combination of banana and soybean in food products produces a neutral aroma and is only slightly preferred at moderate proportions (Siahaan et al., 2022).

The aroma profile of cowpea flour is determined by the presence of compounds such as hexanal, which

contribute to the characteristic aroma of legumes. However, during thermal processing, the intensity of these compounds can decrease due to their involvement in the Maillard reaction, producing new volatile compounds such as ketones, pyrazines, and more pleasant-smelling aldehydes, including 2,3-butanedione and 2-methoxy-3-isobutylpyrazine (Sun et al., 2025). Meanwhile, the aroma of banana is mainly influenced by ester compounds such as isoamyl acetate, butyl acetate, and ethyl acetate, which are responsible for the characteristic “bananeness” aroma (Zhu et al., 2018). The combination of these two ingredients, especially through roasting or heat treatment, can create a more balanced aroma profile. The interaction of the fruity and milky aromas of legumes with the characteristic ester aromas of banana can increase sensory complexity, resulting in a product with a more integrated aroma character.

Texture Sensory

Functionally, cowpea flour has finer particles and a relatively high protein and fiber content. The protein in this flour contributes to the ability to form structure, increase dough elasticity, and strengthen cohesiveness. The functional properties of protein, particularly water holding capacity and peak viscosity, have a positive effect on the textural characteristics of composite flour (Akinwande et al., 2023; Aljahani, 2022; Eid et al., 2025). In addition, the fiber content in cowpea also plays a role in increasing the cohesiveness and stability of the dough structure, resulting in a texture that is preferred by panelists (Abreu et al., 2023).

In contrast, banana flour, especially that derived from unripe bananas, has a high content of resistant starch and soluble fiber. These two components tend to produce a denser, stickier dough texture, and are prone to clumping if not processed properly. This is consistent with the findings of previous studies showing that the addition of green banana flour increases the peak viscosity, breakdown, and final viscosity values in the RVA profile. This condition results in a harder dough and reduces loaf volume, thus implicating panelists in decreasing texture preferences (Bashmil et al., 2025; Detchewa et al., 2021; Pakathip Thakaeng Thitirat Boonloom, 2021). High resistant starch content is also associated with low water-binding capacity and viscoelastic properties that result in a dough that is denser, less elastic, and prone to clumping if the water is not evenly distributed (Dibakoane et al., 2024; Zhang et al., 2023).

Taste Sensory

This phenomenon can be explained by the characteristics of its constituent ingredients. Cowpea flour has a distinctive legume flavor that, at high concentrations, produces a bitter or slightly bitter

sensation. This flavor is generally influenced by the presence of volatile compounds such as aldehydes, ketones, and free fatty acids, which are often found in legume flours with minimal processing (Karolkowski et al., 2021; Khrisanapant et al., 2019). Several studies have also reported that the use of large amounts of legume flour can reduce consumer acceptance due to the presence of anti-nutritional compounds and strong flavors (Badjona et al., 2023; Mohamad et al., 2024; Sun et al., 2025).

In contrast, plantain flour produced from unripe fruit generally has a more neutral to slightly sweet flavor profile, depending on the variety and ripeness. The resistant starch and simple sugars in plantain flour contribute to a milder flavor sensation and are able to mask the unpleasant aftertaste of cowpeas (Karaman et al., 2025; Lee et al., 2023). This explains why panelists preferred the increased proportion of plantain flour in the composite formulation, even though it was not statistically significantly different.

Proximate Content of Cowpea and Plantain Composite Flour

Carbohydrates were the dominant component in all formulations, with the highest levels found in PR100 (100% plantain flour) at 83.89%. This is consistent with the characteristics of bananas as the primary carbohydrate source (Karaman et al., 2025; Lee et al., 2023). The addition of cowpeas resulted in a decrease in carbohydrate content, seen in KTPR8020 (69.34%) and KT100 (67.3%). This finding confirms that the greater the proportion of cowpeas, the lower the total carbohydrate content in the composite (Abreu et al., 2023; Bhadkaria et al., 2022; Kanishka et al., 2023).

Conversely, protein content increased with increasing proportion of cowpeas. The KT100 formulation had the highest protein content at 18.32%, followed by KTPR8020 at 17.5%, while PR100 only had 3.67%. These results indicate that cowpeas are a potential source of vegetable protein (Abreu et al., 2023; Bhadkaria et al., 2022; Kanishka et al., 2023), while plantains serve more as a carbohydrate source (Lee et al., 2023; Syukriani et al., 2021).

Fat content showed a similar pattern to protein, with KT100 recording the highest value (2.25%), KTPR8020 at 1.56%, and PR100 at very low (0.02%). This is consistent with the general nature of nuts, which contain higher fat than fruits (Abreu et al., 2023; Bhadkaria et al., 2022; Kanishka et al., 2023; Khrisanapant et al., 2019; Lee et al., 2023; Syukriani et al., 2021).

The highest moisture content was found in PR100 at 10.13%, followed by KTPR8020 (9%) and KT100 (8.33%). The increase in moisture content in composites with a higher proportion of bananas is likely influenced by the hygroscopic nature of bananas and their natural water

content, despite the drying process (Lee et al., 2023; Syukriani et al., 2021).

Meanwhile, ash content, which reflects total mineral content, showed relatively little variation, at 2.26% (KT100), 2.57% (KTPR8020), and 2.31% (PR100). The highest value in KTPR8020 indicates a synergistic contribution from minerals in both constituent materials (27,36,38–40).

Overall, the differences in nutrient composition across the various formulations confirm that the combination of cowpea and plantain can produce composite flour with a more balanced nutritional profile. The high protein and fat content of cowpea can complement the dominant carbohydrate content of plantain, thus making the composite formulation potentially applicable in developing food products with improved nutritional value.

Potassium and Sodium Content of Cowpea Composite Flour and Plantain Flour

The KTPR8020 formulation (80% cowpea flour : 20% plantain flour) exhibits a balanced mineral profile with potassium levels of 5.98 mg/100 g and sodium levels of 0.84 mg/100 g, resulting in a K/Na ratio of approximately 7.1. Although this value is lower than that of PR100 (≈ 58), the formulation still provides a potassium-rich environment with relatively low sodium levels. This condition is physiologically important because it supports the potassium-induced natriuresis mechanism, thereby reducing sodium retention. Thus, the addition of 20% plantain flour not only increases the potassium contribution but also improves electrolyte balance without reducing the protein content and nutritional components of cowpea.

The mechanism of potassium-related natriuresis is explained by the activation of a “potassium switch” in the distal nephron. Higher potassium intake suppresses sodium-chloride cotransporter (NCC) activity via the WNK-SPAK/OSR1 pathway, which in turn decreases sodium reabsorption in the distal tubule and increases urinary sodium excretion. Molecular studies and recent reviews support this mechanism, showing that a low-potassium diet activates the NCC, thereby increasing sodium retention, while potassium supplementation suppresses NCC activity and improves salt sensitivity, which is implicated in lowering blood pressure (Kortenoeven et al., 2021; Thomson et al., 2020; Welling et al., 2024).

From a clinical-population perspective, the potassium-to-sodium ratio has been shown to be an important indicator in the prevention of hypertension and cardiovascular disease. A diet high in potassium and low in sodium has been consistently associated with reduced blood pressure and cardiovascular risk. Although the K/Na ratio of KTPR8020 is not as high as

that of PR100, this formulation remains superior to combinations with higher sodium concentrations, potentially supporting blood pressure regulation through its natriuretic effect. (Kim et al., 2024; Kwon et al., 2022; Mosallanezhad et al., 2023).

Additionally, plantain, as a potassium-rich raw material, also contributes other components such as resistant starch, which is reported to play a role in metabolic health. The integration of plantain flour at 20% in the KTPR8020 formulation therefore not only increases potassium but also adds other functional values that support cardiometabolic benefits (Karaman et al., 2025; Munir et al., 2024).

Amino Acid Profile of Cowpea and Plantain Flour Composite

Among the non-essential amino acids, glutamic acid dominates with high concentrations in KT100 (14.9 g/100 g) and KTPR8020 (14.68 g/100 g), while in PR100 it only reaches 2.7 g/100 g. A similar pattern is also seen for alanine, aspartic acid, and glycine, which are present at high levels in KT100 and KTPR8020, but very low or undetectable in PR100. These findings confirm that cowpeas contribute the most to the non-essential amino acid content.

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Interestingly, the presence of lysine, leucine, isoleucine, valine, and arginine in relatively high concentrations in KT100 and KTPR8020 has important implications for the potential bioactivity of the proteins. These amino acids are known to play a role in the formation of bioactive peptides with the ability to inhibit the angiotensin-converting enzyme (ACE), which functions to lower blood pressure by inhibiting the conversion of angiotensin I to angiotensin II. Several studies have reported that peptides containing hydrophobic amino acids (leucine, isoleucine, valine) or positively charged amino acids (lysine, arginine) show high affinity for ACE, making them effective in inhibitory activity (Arámburo-Gálvez et al., 2022; Deka & Saikia, 2023; Tawalbeh et al., 2023). The relatively high tryptophan and phenylalanine content in KT100 and KTPR8020 further strengthens this potential,

considering that aromatic amino acids play a role in increasing interactions with the active site of ACE (Arámburo-Gálvez et al., 2022; Deka & Saikia, 2023; Tawalbeh et al., 2023).

In contrast, PR100, with its limited amino acid content, is thought to have significantly lower bioactive potential. The fact that the addition of 20% plantain flour did not significantly reduce the functional amino acid content of KTPR8020 suggests that this formulation maintains the nutritional value while enriching the functional characteristics of cowpea (Arámburo-Gálvez et al., 2022; Deka & Saikia, 2023; Tawalbeh et al., 2023).

Consistent with these findings, several studies have reported that enzymatically hydrolyzed legume proteins can produce peptides with ACE-inhibitory activity and exert antihypertensive effects in animal models. Therefore, cowpea has strong potential for development as a functional food ingredient, particularly in composite flour formulations aimed at cardiovascular health (Daza-Rodríguez et al., 2023; Goyal et al., 2023; Yi-Shen et al., 2018).

Conclusion

This study shows that a cowpea and plantain-based composite flour has the potential to develop into a functional food with a well-balanced nutritional and sensory profile. The optimal formulation was found at a ratio of 80% cowpea flour to 20% plantain flour (KTPR8020), which provided the most favored combination in terms of color, texture, scent, and taste, according to the findings of organoleptic tests. According to proximate analysis, this formulation was able to preserve cowpea's high protein and essential amino acid content while enhancing mineral balance thanks to plantain's potassium contribution. It is important for blood pressure control efforts because the predominant potassium content with comparatively little sodium produces a K/Na ratio that supports the natriuretic system. The dominant potassium content with relatively low sodium creates a K/Na ratio that supports the natriuretic mechanism, making it relevant for blood pressure control efforts. In addition, the presence of amino acids that make up bioactive peptides in cowpea strengthens the potential for ACE inhibitory activity. Thus, the composite flour of cowpea-plantain is not only worthy of being developed as a locally based alternative food ingredient, but also has the potential to support dietary interventions in preventing hypertension and improving cardiovascular health.

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Author Contributions

Conceptualization, SA., and ZD; methodology, SA., and ZD. and SA., and ZD; formal analysis, SA., and ZD and SA., and ZD; investigation, SA., and ZD. and SA., and ZD; resources, SA., and ZD. and SA., and ZD; writing—preparation of original draft, SA., and ZD; writing—reviewing and editing, SA., and ZD. and SA., and ZD; visualization, SA., and ZD; supervision, SA., and ZD; project administration, IKN; obtaining funding, SA., and ZD and SA., and ZD. All authors have read and approved the published version of the manuscript

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The authors declare no conflict of interest

References

- Abebe, B. K., & Alemayehu, M. T. (2022). A review of the nutritional use of cowpea (*Vigna unguiculata* L. Walp) for human and animal diets. *Journal of Agriculture and Food Research*, 10(October), 100383. <https://doi.org/10.1016/j.jafr.2022.100383>
- Abreu, B., Lima, J., & Rocha, A. (2023). Consumer Perception and Acceptability of Lupin-Derived Products: A Systematic Review. *Foods*, 12(1241), 1–19.
- Affrifah, N. S., Phillips, R. D., & Saalia, F. K. (2022). Cowpeas: Nutritional profile, processing methods and products – A review. *Legume Science*, 4(3), 1–12. <https://doi.org/10.1002/leg3.131>
- Akinwande, B. A., Oyedokun, J., Olajide, A. E., & Afolabi, O. E. (2023). Modelling the properties of composite flour of maize-Pleurotus tuber-regium sclerotium for meal production using simplex-centroid design. *Cogent Food and Agriculture*, 10(1). <https://doi.org/10.1080/23311932.2023.2293518>
- Al-dairi, M., Pathare, P. B., Al-yahyai, R., & Jayasuriya, H. (2024). Evaluation of chemical quality attributes in bruised bananas during storage. *LWT*, 197(December 2023), 115904. <https://doi.org/10.1016/j.lwt.2024.115904>
- Aljahani, A. H. (2022). Wheat-yellow pumpkin composite flour: Physico-functional, rheological, antioxidant potential and quality properties of pan and flat bread. *Saudi Journal of Biological Sciences*, 29(5), 3432–3439. <https://doi.org/10.1016/j.sjbs.2022.02.040>
- Arámburo-Gálvez, J. G., Arvizu-Flores, A. A., Cárdenas-Torres, F. I., Cabrera-Chávez, F., Ramírez-Torres, G. I., Flores-Mendoza, L. K., Gastelum-Acosta, P. E., Figueroa-Salcido, O. G., & Ontiveros, N. (2022).

- Prediction of ACE-I Inhibitory Peptides Derived from Chickpea (*Cicer arietinum* L.): In Silico Assessments Using Simulated Enzymatic Hydrolysis, Molecular Docking and ADMET Evaluation. *Foods*, 11(11). <https://doi.org/10.3390/foods11111576>
- Astuti, A. P., Damayanti, D., & Ngadiarti, I. (2021). Penerapan Anjuran Diet Dash Dibandingkan Diet Rendah Garam Berdasarkan Konseling Gizi Terhadap Penurunan Tekanan Darah Pada Pasien Hipertensi Di Puskesmas Larangan Utara. *Gizi Indonesia*, 44(1), 109-120. <https://doi.org/10.36457/gizindo.v44i1.559>
- Badjona, A., Bradshaw, R., Millman, C., Howarth, M., & Dubey, B. (2023). Faba Bean Flavor Effects from Processing to Consumer Acceptability. *Foods*, 12(11). <https://doi.org/10.3390/foods12112237>
- Bashmil, Y. M., Bekes, F., Ruderman, M., Suleria, H. A. R., Appels, R., & Dunshea, F. R. (2025). The Physicochemical and Rheological Properties of Green Banana Flour-Wheat Flour Bread Substitutions. *Plants*, 14(2). <https://doi.org/10.3390/plants14020207>
- Bhadkaria, A., Narvekar, D. T., Gupta, N., Khare, A., & Bhagyawant, S. S. (2022). Moth bean (*Vigna aconitifolia* (Jacq.) Marechal) seeds: A review on nutritional properties and health benefits. *Discover Food*, 2(1). <https://doi.org/10.1007/s44187-022-00019-3>
- Bojňanská, T., Musilová, J., & Vollmannová, A. (2021). Effects of adding legume flours on the rheological and breadmaking properties of dough. *Foods*, 10(5). <https://doi.org/10.3390/foods10051087>
- Chan, Q., Wren, G. M., Lau, C. H. E., Ebbels, T. M. D., Gibson, R., Loo, R. L., Aljuraiban, G. S., Posma, J. M., Dyer, A. R., Steffen, L. M., Rodriguez, B. L., Appel, L. J., Daviglius, M. L., Elliott, P., Stamler, J., Holmes, E., & Van Horn, L. (2022). Blood pressure interactions with the DASH dietary pattern, sodium, and potassium: The International Study of Macro-/Micronutrients and Blood Pressure (INTERMAP). *American Journal of Clinical Nutrition*, 116(1), 216-229. <https://doi.org/10.1093/ajcn/nqac067>
- Daza-Rodríguez, B., Martínez, A. R., Padilla, A. M., & Lázaro, J. M. (2023). Food-derived Bioactive Peptides with Angiotensin-Converting Enzyme Inhibiting Effect: A Systematic Review. *Journal of Pharmacology and Pharmacotherapeutics*, 14(1), 14-24. <https://doi.org/10.1177/0976500X231175217>
- DeGarmo, E., Sullivan, W., & Canada, J. (1984). *Engineering Economy The 7th Edition*. Macamillan Publishing Comp. New York.
- Deka, A., & Saikia, V. (2023). Prediction of ACE - inhibitory and antioxidant peptides from storage proteins of edible seeds and nuts using in silico approaches. *Sustainable Food Proteins*, 1(2), 84-98. <https://doi.org/10.1002/sfp2.1013>
- Detchewa, P., Prasajak, P., Sriwichai, W., & Moongngarm, A. (2021). the Effects of Unripe Banana Flour on Resistant Starch Content and Quality Characteristics of Gluten-Free Rice Cookies. *Journal of Sustainability Science and Management*, 16(2), 68-79. <https://doi.org/10.46754/jssm.2021.02.008>
- Dibakoane, S. R., Da Silva, L. S., Meiring, B., Anyasi, T. A., Mlambo, V., & Wokadala, O. C. (2024). The multifactorial phenomenon of enzymatic hydrolysis resistance in unripe banana flour and its starch: A concise review. *Journal of Food Science*, 89(9), 5185-5204. <https://doi.org/10.1111/1750-3841.17270>
- Eid, W. A. M., Abdelgalil, Z. A. H., Abd-Elsattar, H. H., Bakry, A. M., Tian, H., Huang, J., Wang, P., & Hamed, Y. S. (2025). Evaluation of the Quality of Wheat and Millet Composite Flour and Application for Production Biscuits Fortified with White Sweet Potato Flour. *Food Analytical Methods*, 18(4), 657-669. <https://doi.org/10.1007/s12161-024-02739-x>
- Filippou, C. D., Tsioufis, C. P., Thomopoulos, C. G., Mihas, C. C., Dimitriadis, K. S., Sotiropoulou, L. I., Chrysochoou, C., Nihoyannopoulos, P. I., & Tousoulis, D. M. (2020). Dietary Approaches to Stop Hypertension (DASH) Diet and Blood Pressure Reduction in Adults with and without Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Adv Nutr*, 11(5), 1150-1160. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7490167/>
- Goyal, N., Hajare, S. N., & Gautam, S. (2023). Release of an encrypted, highly potent ACE-inhibitory peptide by enzymatic hydrolysis of moth bean (*Vigna aconitifolia*) protein. *Frontiers in Nutrition*, 10. <https://doi.org/10.3389/fnut.2023.1167259>
- Hasmedi, M., Noorfarahzilah, M., Noraidah, H., Zainol, M. K., & Jahurul, M. H. A. (2020). Functional properties of composite flour: A review. *Food Research*, 4(6), 1820-1831. [https://doi.org/10.26656/fr.2017.4\(6\).419](https://doi.org/10.26656/fr.2017.4(6).419)
- Jamal, A. M. I. S. F. (2023). *Essential hypertension*. NCBI Bookshelf. A Service of the National Library of Medicine, National Institutes of Health. <https://doi.org/10.1001/jama.1949.02900460045024>
- Kanishka, R. C., Gayacharan, Basavaraja, T., Chandora, R., & Rana, J. C. (2023). Moth bean (*Vigna aconitifolia*): a minor legume with major potential to address global agricultural challenges. *Frontiers in Plant Science*, 14(June), 1-20.

- <https://doi.org/10.3389/fpls.2023.1179547>
- Karaman, K., Pinar, H., Ciftci, B., & Kaplan, M. (2025). Effects of Banana Flour on Some Physicochemical, Textural, Bioactive, and Sensory Properties of Gluten-Free Cookie. *Food Science and Nutrition*, 13(1), 1–13. <https://doi.org/10.1002/fsn3.4756>
- Karolkowski, A., Guichard, E., Briand, L., & Salles, C. (2021). Volatile compounds in pulses: A review. *Foods*, 10(12), 1–27. <https://doi.org/10.3390/foods10123140>
- Karuwal, R. L., Sinay, H., Sangur, K., Purwaningrahyu, R. D., Yusnawan, E., & Nugraha, Y. (2023). Identification of metabolite profiles of local cowpeas (*Vigna unguiculata* L. Walp) from Southwest Maluku, Indonesia. *Journal of Agriculture and Food Research*, 14(April), 100788. <https://doi.org/10.1016/j.jafr.2023.100788>
- Kemenkes 2018. (2018). Laporan Riskesdas 2018 Nasional.pdf. In *Lembaga Penerbit Balitbangkes* (p. hal 156).
- Kemenkes RI. (2022). Hasil Survei Status Gizi Indonesia (SSGI) 2022. *Kemenkes*, 1–150.
- Khrisanapant, P., Kebede, B., Leong, S. Y., & Oey, I. (2019). A comprehensive characterisation of volatile and fatty acid profiles of legume seeds. *Foods*, 8(12), 6–9. <https://doi.org/10.3390/foods8120651>
- Kim, B. S., Yu, M. Y., & Shin, J. (2024). Effect of low sodium and high potassium diet on lowering blood pressure and cardiovascular events. *Clinical Hypertension*, 30(1), 1–13. <https://doi.org/10.1186/s40885-023-00259-0>
- Kortenoeven, M. L. A., Esteva-Font, C., Dimke, H., Poulsen, S. B., Murali, S. K., & Fenton, R. A. (2021). High dietary potassium causes ubiquitin-dependent degradation of the kidney sodium-chloride cotransporter. *Journal of Biological Chemistry*, 297(2), 100915. <https://doi.org/10.1016/j.jbc.2021.100915>
- Kunyanee, K., & Ngo, T. Van. (2024). Enhancing Banana Flour Quality through Physical Modifications and Its Application in Gluten-Free Chips Product. *Foods*, 13(593).
- Kwon, Y. J., Lee, H. S., Park, G., & Lee, J. W. (2022). Association between dietary sodium, potassium, and the sodium-to-potassium ratio and mortality: A 10-year analysis. *Frontiers in Nutrition*, 9(November), 1–10. <https://doi.org/10.3389/fnut.2022.1053585>
- Lee, J. S., Yusoff, N. D., Ho, A. L., Siew, C. K., Akanda, J. H., & Tan, W. X. (2023). Quality Improvement of Green Saba Banana Flour Steamed Cake. *Applied Sciences (Switzerland)*, 13(4). <https://doi.org/10.3390/app13042421>
- Martin Alain, M. M. (2023). Prediction and Evaluation of Bioactive Properties of Cowpea Protein Hydrolysates. *Journal of Food Biochemistry*, 2023. <https://doi.org/10.1155/2023/9095113>
- Mohamad, M. A., Ramli, S. S., & Jailani, F. (2024). Effect of Mung Bean on Physicochemical Properties of Waffle Premix Flour and Its Sensory Acceptability. *Proceedings of the International Conference on Science Technology and Social Sciences – Physics, Material and Industrial Technology (ICONSTAS-PMIT 2023), Advances in Engineering Research*, 238, 186–199. https://doi.org/10.2991/978-94-6463-500-3_17
- Mosallanezhad, Z., Jalali, M., Bahadoran, Z., Mirmiran, P., & Azizi, F. (2023). Dietary sodium to potassium ratio is an independent predictor of cardiovascular events: a longitudinal follow-up study. *BMC Public Health*, 23(1), 1–8. <https://doi.org/10.1186/s12889-023-15618-7>
- Munir, H., Alam, H., Nadeem, M. T., Almalki, R. S., Arshad, M. S., & Suleria, H. A. R. (2024). Green banana resistant starch: A promising potential as functional ingredient against certain maladies. *Food Science and Nutrition*, 12(6), 3787–3805. <https://doi.org/10.1002/fsn3.4063>
- Noviyanti, P. (2020). Pembuatan Kue Lumpur dengan Substitusi Tepung Pisang Raja sebagai Makanan Selingan Tinggi Kalium untuk Penderita Hipertensi. *Health Media*, 4(2), 1–17.
- Omar Y. Al-Abbasy, Sarah A. Younus, Aya I. Rahan, and O. A. S. A. (2024). Maillard reaction: formation, advantage, disadvantage and control. A review. *Food Science and Applied Biotechnology*, 7(1), 145–161.
- Pakathip ThakaengThitirat Boonloom, A. S. R. (2021). Physicochemical Properties of Bread Partially Substituted with Unripe Green Banana (*Cavendish* spp.) Flour. *Molecules*, 26(2070), 1–12.
- Palmer, B. F., & Clegg, D. J. (2020). Blood pressure lowering and potassium intake. *Journal of Human Hypertension*, 34(10), 671–672. <https://doi.org/10.1038/s41371-020-00396-1>
- Saini, R., & Bajpai, M. (2024). Formulation and Evaluation of Nutraceutical Dosage Form Derived from *Vigna aconitifolia*, *Eleusine coracana* and *Chenopodium quinoa*. *International Journal of Pharmaceutical Investigation*, 14(4), 1226–1234. <https://doi.org/10.5530/ijpi.14.4.135>
- Siahaan, C. W., Nurali, E. J. N., & Kandou, J. E. A. (2022). Karakteristik Sensoris Snack Bars dari Tepung Komposit Pisang Goroho (*Musa acuminata*, L), Kedelai (*Glycine max*) dan Kenari (*Canarium indicum* L.). *Jurnal Teknologi Pertanian (Agricultural Technology Journal)*, 13(2), 80–86. <https://doi.org/10.35791/jteta.v13i2.50348>
- Sun, J., Li, Y., Cheng, X., Zhang, H., Yu, J., Zhang, L., Qiu, Y., Diao, J., & Wang, C. (2025). Metabolomic Analysis of Flavour Development in Mung Bean

- Foods: Impact of Thermal Processing and Storage on Precursor and Volatile Compounds. *Foods*, 14(5). <https://doi.org/10.3390/foods14050797>
- Syukriani, L., Herawati, N., Asben, A., Suliansyah, I., & Jamsari, J. (2021). Physicochemical and Morphological Characteristics of Starch and Flour Obtained from Green Banana cv. Raja (*Musa paradisiaca* cv. Raja) in West Sumatra, Indonesia. *Pakistan Journal of Biological Sciences*, 24(11), 1175–1182. <https://doi.org/10.3923/PJBS.2021.1175.1182>
- Tawalbeh, D., Al-u, M. H., Amir, W., Wan, N., Ahmad, F., & Sarbon, N. M. (2023). ACE-Inhibitory and Anti-Inflammatory Peptides from Legume Protein Hydrolysates. *Molecules*.
- Tejasari, Yuwanti, S., Ahmadi, M. B., & Afsari, Y. L. (2020). The anti hypertensive nutraceuticals of *Vigna* sp bean protein hydrolyzed by alcalase and flavourzyme. *Journal of Functional Food and Nutraceutical*, 2(1), 63–73. <https://doi.org/10.33555/jffn.v2i1.40>
- Thomson, M. N., Cuevas, C. A., Bewarder, T. M., Dittmayer, C., Miller, L. N., Si, J., Cornelius, R. J., Su, X. T., Yang, C. L., McCormick, J. A., Hadchouel, J., Ellison, D. H., Bachmann, S., & Mutig, K. (2020). WNK bodies cluster WNK4 and SPAK/OSR1 to promote NCC activation in hypokalemia. *American Journal of Physiology - Renal Physiology*, 318(1), F216–F228. <https://doi.org/10.1152/ajprenal.00232.2019>
- Welling, P. A., Little, R., Al-Qusairi, L., Delpire, E., Ellison, D. H., Fenton, R. A., & Grimm, P. R. (2024). Potassium-Switch Signaling Pathway Dictates Acute Blood Pressure Response to Dietary Potassium. *Hypertension*, 81(5), 1044–1054. <https://doi.org/10.1161/HYPERTENSIONAHA.123.22546>
- Yi-Shen, Z., Shuai, S., & Fitzgerald, R. (2018). Mung bean proteins and peptides: Nutritional, functional and bioactive properties. *Food and Nutrition Research*, 62, 1–11. <https://doi.org/10.29219/fnr.v62.1290>
- Zhang, S., Zhao, K., Xu, F., Chen, X., Zhu, K., Zhang, Y., & Xia, G. (2023). Study of unripe and inferior banana flours pre-gelatinized by four different physical methods. *Frontiers in Nutrition*, 10(June), 1–11. <https://doi.org/10.3389/fnut.2023.1201106>
- Zhu, X., Li, Q., Li, J., Luo, J., Chen, W., & Li, X. (2018). Comparative study of volatile compounds in the fruit of two banana cultivars at different ripening stages. *Molecules*, 23(10). <https://doi.org/10.3390/molecules23102456>