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Determination of the Optimal Formulation of Goroho Banana and Gedi Leaf Composite Flour Based on Antioxidant Activity and Physicochemical Properties

Mercy I R Taroreh[1*], Edi Suryanto[1], Thelma D.J. Tuju[2]

[1] Master of Food Science Study Program, Postgraduate Program, Sam Ratulangi University, Manado, Indonesia
[2] Food Technology Study Program, Faculty of Agriculture, Sam Ratulangi University, Manado, Indonesia

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Corresponding Author:
Mercy I R Taroreh
mercytaroreh@unsrat.ac.id

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Abstract: Goroho bananas (*Musa acuminata L.)* and gedi leaves (*Abelmoschus manihot L.*) have potential as functional foods due to their antioxidant content and nutritional properties. However, the use of these two ingredients in the form of composite flour and the determination of the optimal formulation to produce high antioxidant activity while maintaining acceptable physicochemical characteristics are still limited. This study aims to determine the optimal formulation of gedi leaf and goroho banana composite flour based on antioxidant activity and physicochemical properties. The study used a completely randomized design (CRD) with three replicates, consisting of five treatments, namely single gedi leaf flour, gedi leaf:goroho banana ratios of 75:25, 50:50, and 25:75, and single goroho banana flour. Antioxidant activity was analyzed by measuring total phenolic compound (TPC) content and DPPH free radical scavenging ability, while physicochemical characteristics included moisture, ash, fat, protein, carbohydrate, and crude fiber content. The results showed that increasing the proportion of gedi leaf flour significantly increased the protein, fat, ash, fiber, total phenolic content, and antioxidant activity, while increasing the proportion of goroho banana flour increased the carbohydrate content. These findings indicate a compromise between antioxidant capacity and energy contribution in composite flour formulations. Based on the balance between antioxidant activity and nutritional composition, the 50:50 and 75:25 gedi leaf:goroho banana formulations were determined to be the optimal formulations. The results of this study indicate that both formulations have the potential as functional composite flours for the development of antioxidant-rich food products.

Keywords: Antioxidant activity; Composite flour; Gedi leaves; Goroho banana; Physicochemical properties

Introduction

The use of local food has a strategic role in supporting the sustainability of the food system through the diversification of raw materials and increasing the added value of agricultural commodities. The development of alternative food ingredients based on local resources, particularly non-wheat flour, is an important approach to reducing dependence on imported raw materials while maximizing the use of regional biodiversity (Arifin et al., 2023; Sutrisno and Edris, 2009).

The scientific development of flour based on local plant materials is not only aimed at increasing the utility value of commodities, but also at exploring the potential of their natural bioactive compounds (Hasan, 2013). Goroho bananas (*Musa acuminata L.*) are known to contain antioxidant compounds that contribute to the functional characteristics of food ingredients (Suryanto et al., 2011). Meanwhile, gedi leaves (*Abelmoschus manihot* L.) are reported to be rich in phenolic compounds with antioxidant activity and chemical characteristics that support their use as food ingredients (Taroreh et al., 2015). The phenolic compounds in both

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ingredients play a role in inhibiting oxidative reactions that can affect the quality and stability of food products.

Although the antioxidant potential of goroho bananas and gedi leaves has been reported separately, research combining these two local food ingredients in processed products is still limited. Until now, the use of goroho bananas and gedi leaves has generally been done conventionally or as single ingredients, while processing in the form of composite flour has not received much scientific attention. The limited information on the characteristics of phenolic compounds and the antioxidant activity of composite flour based on these two ingredients is an obstacle to the development of value-added local food products. In addition, there is no data available that explains the effect of composite ratio variations on phenolic characteristics and antioxidant activity as a basis for determining the optimal formulation.

In line with the latest research developments, studies on the production and characterization of composite flour based on goroho bananas and gedi leaves through a composite ratio variation approach have not been discussed systematically. This study offers a novel aspect by structurally analyzing the effect of different proportions of goroho banana and gedi leaves on the total phenolic compound content and antioxidant activity of composite flour, which were evaluated using the Total Phenolic Content (TPC) method and the DPPH free radical scavenging assay. This approach was used to determine the composite ratio that produced the most optimal functional characteristics. The objective of this study is to determine the optimal formulation of composite flour based on goroho banana and gedi leaves based on antioxidant activity, which includes total phenolic content and DPPH free radical scavenging ability, as well as physicochemical characteristics, including moisture, ash, fat, protein, carbohydrate, and dietary fiber content. The urgency of this research lies in providing applicable scientific data that can be used in the development of innovative local non-wheat food products, increasing the added value of regional commodities, and strengthening a sustainable food system based on local resources.

Method

Materials

The main materials used in this study were physiologically ripe goroho bananas obtained from farmers in North Minahasa Regency, North Sulawesi, and young gedi leaves (*Abelmoschus manihot L.*) harvested from healthy plants aged 2–3 months. The chemicals used included technical ethanol, methanol (Merck), Folin–Ciocalteu reagent, sodium carbonate (Na_2CO_3), and 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Sigma-Aldrich). The equipment used included a drying oven (Memmert), electric furnace, Soxhlet apparatus, Kjeldahl apparatus, UV–Vis spectrophotometer (Shimadzu UV-1800), and analytical balance.

Experimental Design and Data Analysis

This study used a completely randomized design (CRD) with one factor, namely the comparison of the composition of goroho banana flour and gedi leaf flour. This study used five types of flour samples with different formulations as shown in Table 1. Sample A consisted of 100% gedi leaf flour, and sample E consisted of 100% goroho banana flour, each of which served as a single control. Meanwhile, samples B, C, and D were composite flours resulting from mixing gedi leaves and goroho bananas in different proportions.

Table 1. Formulation of composite flour made from gedi leaves and goroho bananas

Sample Code	Formulation
A	100% gedi leaf flour
B	75% gedi leaf flour: 25% goroho banana flour
C	Gedi leaf flour 50%: goroho banana flour 50%
D	Gedi leaf flour 25%: goroho banana flour 75%
E	100% goroho banana flour

Each treatment was repeated three times. The observation data were analyzed using analysis of variance (ANOVA) at a 95% confidence level. If there were significant differences between treatments, Duncan's Multiple Range Test (DMRT) was performed to determine the differences between treatments.

Research Procedure

Production of Goroho Banana Flour

Before making composite flour, preliminary research was conducted on several methods of making goroho banana flour. Previous research showed that goroho banana flour contains phenolic compounds in the fruit flesh, so that when the banana is peeled, enzymatic browning easily occurs due to the polyphenolase enzyme, causing the banana to turn brown when peeled. There are three ways to prevent enzymatic browning in bananas before they are processed into banana flour. The three prevention methods are: a). First, the goroho bananas are peeled and sliced into 2 mm thick slices and soaked in a 1% calamansi solution for 15 minutes. b). The second method involves peeling and slicing the bananas into 2 mm thick slices, then soaking them in a 0.5% sodium metabisulfite solution for 15 minutes. The third method involves steaming the bananas at 85°C for 5 minutes, then slicing them into 5 mm thick slices. After pre-treatment with these three methods, the banana slices are dried, then ground and sieved through an 80-mesh screen. The three types of flour are then analyzed for yield, total phenols, and color.

After conducting preliminary research and testing on both goroho banana flour and gedi leaf flour, it was determined that goroho banana flour would be made by blanching goroho bananas at 85°C for 5 minutes, then peeling and slicing them into 2 mm thick pieces. The banana slices were then dried in a drying cabinet at50°Cfor 8 hours. They were then ground with a grinder and sieved through an 80-mesh sieve. The flow chart for making goroho banana flour is shown in Figure 1.

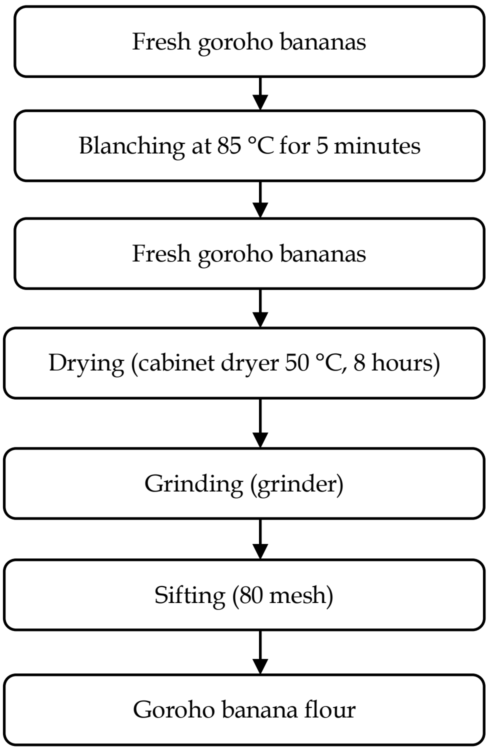

Figure 1. Flow chart of goroho banana flour production

Production of Gedi Leaf Flour

Before making composite flour from goroho banana flour and gedi leaf flour, preliminary research was conducted on the production of gedi leaf flour. The preliminary research involved drying gedi leaves in a drying cabinet at a temperature of 50°C for 1, 2, and 3 hours, then analyzing the moisture content of the gedi leaves. After 1 and 2 hours of drying, the gedi leaves were not yet dry, with a moisture content still above 20%, while after 3 hours of drying, the moisture content of the gedi leaves was 12%. The gedi leaves were then analyzed for their fiber content and the minerals contained in the gedi leaf flour. Gedi leaf flour was made by washing the gedi leaves thoroughly, then drying them in a cabinet dryer at a temperature of 50 °C for 3 hours. Next, the dried gedi leaves were ground and sieved through an 80 mesh sieve to obtain gedi leaf flour. The production of gedi leaf flour is shown in Figure 2.

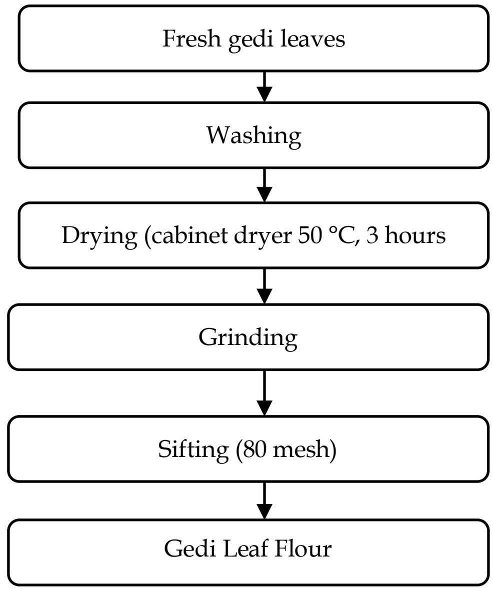

Figure 2. Flow chart of gedi leaf flour production

Composite Flour Production

Goroho banana flour and gedi leaf flour were mixed according to the treatment proportions. Each mixture was homogenized using a dry mixer for 5 minutes to obtain a uniform flour mixture. The composite flour was then analyzed according to the observation parameters. The production of composite flour is shown in Figure 3.

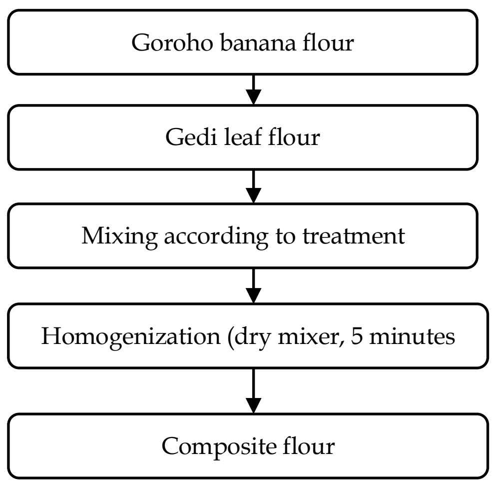

Figure 3. Diagram Flow chart of composite flour production

Analysis Procedure

Total Phenols

Total phenol content was determined using the Folin–Ciocalteu method according to the procedure described by Singleton et al. (1999). One gram of powder was extracted using 20 mL of 80% methanol, homogenized, and centrifuged for 10 minutes at 4000 rpm, then the supernatant was collected. A total of 0.1 mL of extract was added to 0.5 mL of Folin–Ciocalteu reagent and 1.5 mL of 7.5% Na_2CO_3 solution, then incubated for 30 minutes at room temperature in the dark. Absorbance was measured at 765 nm using a UV–Vis spectrophotometer. The results were expressed as mg gallic acid equivalent (GAE) per gram of dry sample based on a gallic acid standard curve (20–200 mg/L).

Antioxidant Activity (DPPH)

Antioxidant activity was measured using the DPPH method according to Brand-Williams et al. (1995) with modifications. A total of 2 mL of 0.1 mM DPPH solution in methanol was mixed with 0.1 mL of sample extract, homogenized, and incubated for 30 minutes in the dark at room temperature. Absorbance was read at 517 nm. The percentage of radical scavenging () was calculated using the formula:

$$\text{Inhibisi (\%)} = \frac{A_0 - A_s}{A_0} \times 100 \quad (1)$$

Notes:
A_0 = absorbance of the control (DPPH without sample)
A_s = absorbance of the sample solution

Physical-Chemical Properties Analysis

Moisture content

The moisture content was determined using the oven drying method (AOAC 925.10). Approximately 3 g of the flour sample is placed in a pre-dried and pre-weighed porcelain dish. The sample is dried in an oven at 130 ± 3°C for 1.5 hours, then cooled in a desiccator and weighed until a constant weight is achieved. The moisture content is calculated using the following formula:

$$\text{Moisture Content (\%)} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100 \quad (2)$$

where W_1 = weight of empty dish, W_2 = weight of dish + sample before drying, and W_3 = weight of dish + sample after drying. The moisture content value indicates the amount of water lost during heating.

Fat Content

The fat content was analyzed using the Soxhlet method (AOAC 920.39) with petroleum ether solvent (boiling point 40–60°C). Approximately 2–3 g of dry sample was placed in a filter paper (thimble) and extracted for 6 hours at the boiling point of the solvent. After extraction, the solvent was evaporated with a rotary evaporator and the fat residue was dried at 105°C to a constant weight. The fat content was calculated using the following formula:

$$\text{Fat Content (\%)} = \frac{\text{Fat residue weight}}{\text{Sample weight}} \times 100 \quad (3)$$

This method extracts the free fat fraction present in the composite flour.

Protein Content

The protein content was determined using the Kjeldahl method (AOAC 981.10). A total of 0.5 g of sample was placed in a digestion tube, added with 5 mL of concentrated H_2SO_4 and 1 catalyst tablet (a mixture of $CuSO_4$ and K_2SO_4), then destroyed at a temperature of ±420°C until the solution was clear. After cooling, the digestion product is diluted and distilled using a Kjeldahl apparatus, then the ammonia formed is captured with a 4% boric acid solution containing a mixed indicator (methyl red–bromocresol green). The distillate is titrated with 0.1 N HCl until a color change occurs. The nitrogen content is calculated, then converted to protein content using a factor of 6.25:

$$\text{Protein (\%)} = \text{N (\%)} \times 6.25 \quad (4)$$

This method is used to determine the total protein content (based on total nitrogen) in composite flour.

Ash Content

The ash content is measured using the direct combustion method (AOAC 923.03). Approximately ±3 g of sample is placed in a weighed ash dish, then heated on a hot plate until it is smoke-free. Next, the crucible is placed in an electric furnace (muffle furnace) and incinerated at 550°C for 4–6 hours, until a light gray residue is obtained. The crucible is then cooled in a desiccator and weighed until a constant weight is achieved. The percentage of ash content is calculated using the formula:

$$\text{Ash Content (\%)} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100 \quad (5)$$

This value represents the total minerals contained in the flour sample.

Crude fiber content

Crude fiber analysis was performed according to the gravimetric method (AOAC 962.09). A total of 2 g of dry sample was digested sequentially using 1.25% (v/v) H_2SO_4 for 30 minutes at boiling temperature, then filtered, and the residue was washed until neutral. The filtered residue was then digested again with 1.25% NaOH (w/v) for 30 minutes, filtered, washed, dried in an oven at 105°C to a constant weight, and then incinerated in a furnace at 550°C for 4 hours. The percentage of crude fiber was calculated by subtracting the weight of the residue before and after incineration from the initial weight of the sample.

Carbohydrate content

The carbohydrate content is calculated by difference, i.e., by subtracting the amounts of water, ash, fat, protein, and fiber from 100 (AOAC, 2019):

$$\text{Carbohydrates (\%)} = 100 - (\text{Water} + \text{Ash} + \text{Fat} + \text{Protein} + \text{Fiber}) \quad (6)$$

This approach is commonly used for dry foodstuffs such as flour, where the contribution of other components is considered small.

Result and Discussion

Total Phenols in Composite Flour

The results of the analysis of total phenols and antioxidant activity as DPPH free radical scavengers in composite flour from gedi leaves and goroho bananas are shown in Table 2.

Table 2. Effect of composite flour formula on antioxidant activity

Flour Formula	Total Phenols (mg gallic acid/g sample)	DPPH free radical scavenging (%)
A	10.97±0.09e	71.43±0.27e
B	8.47±0.29d	60.9±0.32d
C	5.38±0.38c	41.98±0.47c
D	3.17±0.05b	26.2±0.11b
E	0.58±0.02a	4.45±0.16a

*Note: Different letters in the same column indicate significant differences ($p<0.05$)

The analysis results show that the total phenolic content (TP) in Goroho banana–Gedi leaf composite flour ranges from 0.58 to 10.97 mg gallic acid/g sample (Table 2). The total phenol content in goroho banana flour in this study was 0.58 mg GAE/g sample, lower than the 0.97 mg GAE/g sample reported by Suniati and Purnomo (2019). This difference is likely due to variations in processing methods, the part of the banana used, and sample conditions; Suniati and Purnomo used steam for 5 minutes, while this study applied brief blanching to prevent enzymatic browning. Other factors such as variety, ripeness, and differences in analysis methods can also affect the total phenol value.

Pure Gedi leaf flour (sample A) had the highest TP (10.97 mg gallic acid/g), while pure Goroho banana flour (sample E) had the lowest (0.58 mg gallic acid/g). Composite formulations B, C, and D showed TP of 8.47, 5.38, and 3.17 mg gallic acid/g, respectively, showing a downward trend in TP as the proportion of gedi leaves in the mixture decreased.

This phenomenon is consistent with the characteristics of leafy plant materials, which are generally rich in phenolic compounds, such as flavonoids and phenolic acids, which act as natural antioxidants (Dai & Mumper, 2010; Shahidi & Ambigaipalan, 2015; Pateiro et al., 2023). These phenolic compounds play a role in neutralizing free radicals and inhibiting lipid oxidation, thereby enhancing food stability and the functional potential of flour. Goroho banana flour, despite its low TP, provides good starch structure for food applications but contributes relatively little to antioxidant activity (Sarawong et al., 2014; Khoza et al., 2021; Zhang et al., 2021).

In the context of formulation optimization, this TP data is highly relevant because it helps determine the optimal proportion of gedi leaves to enhance the antioxidant properties of composite flour without compromising its physical properties and energy content. Intermediate composite formulations, such as sample C, show a balance between sufficient TP content (5.38 mg/g) and stable physical characteristics of the flour, thus providing an optimal compromise between antioxidant activity, nutritional value, and food applications. This is in line with the principles of functional product development, where the addition of phenol-rich ingredients can increase antioxidant potential without compromising the sensory quality or structure of the product (Awolu et al., 2016; Khoozani et al., 2020; Ou et al., 2019).

DPPH Free Radical Scavenging Antioxidant Activity of Composite Flour

Measurement results show that the DPPH antioxidant activity of Goroho banana–Gedi leaf composite flour ranges from 4.45 to 71.43%, The DPPH activity of pure goroho banana flour in this study (4.45%) was lower than the 12.15% reported by Suniati and Purnomo (2019), possibly due to differences in processing methods and banana ripeness levels. The DPPH activity in the Goroho Banana–Gedi Leaf composite increased in line with the proportion of gedi leaves, with the highest value of 71.43% in pure gedi leaves, in line with the reports by Taroreh et al. (2015) and Prasetiyo et al. (2024) that gedi leaves have high antioxidant capacity. These results confirm the major contribution of gedi leaves in enhancing the antioxidant activity of composite flour. Composite formulations B, C, and D had activities of 60.9%, 41.98%, and 26.2%, respectively, which decreased as the proportion of Gedi leaves in the mixture decreased.

This decrease is consistent with total phenol (TP) data, where the high phenol content of gedi leaves (10.97 mg gallic acid/g) plays an important role in the flour's ability to neutralize free radicals. Phenolic compounds in gedi leaves, such as flavonoids and phenolic acids, act as electron or hydrogen donors to counteract free radicals, thereby increasing the antioxidant activity of the flour (Dai & Mumper, 2010; Shahidi & Ambigaipalan, 2015). Thus, the proportion of gedi leaves in the composite directly affects the antioxidant capacity of the flour.

From a formulation optimization perspective, this data is important for balancing the functional properties and nutritional value of the flour. Formulations with a high proportion of gedi leaves increase antioxidant activity, but energy and starch content decrease, while formulations with a high proportion of goroho bananas provide more energy but have low antioxidant activity. Therefore, sample C, which has a medium proportion, offers an optimal compromise, with sufficient antioxidant activity (41.98%) while maintaining adequate energy and carbohydrates. This strategy supports the achievement of the research objective, which is to produce nutritionally and functionally balanced composite flour.

Table 3. Physicochemical composition and energy content of composite flour in various formulations of goroho banana and gedi leaves

Composition	Formulation A	Formulation B	Formulation C	Formulation D	Formulation E
Moisture content (%)	12.85±0.03d	11.46±0.01c	11.29±0.02b	11.27±0.01b	11.18±0.01a
Fat content (%)	6.00±0.07e	4.49±0.02d	3.13±0.04c	1.77±0.01b	0.72±0.08a
Protein content (%)	23.87±0.26e	18.88±0.07d	13.45±0.19c	8.11±0.13b	2.91±0.07a
Ash content (%)	13.18±0.03e	10.37±0.03d	7.43±0.02c	4.85±0.04b	2.33±0.01a
Carbohydrate content (%)	45.66±0.33a	54.79±0.03b	64.33±0.23c	73.96±0.14d	82.86±0.10e
Fiber content (%)	10.84±0.31e	8.1±0.01d	7.58±0.08c	1.34±0.09b	0.31±0.01a

*Note: Different letters in the same row indicate significant differences ($p<0.05$)

Moisture content of composite flour

The results of moisture content analysis on various formulations of goroho banana-gedi leaf flour showed values ranging from 11.18 to 12.85 (Table 3). Sample A (100% gedi leaves) had the highest moisture content, namely 12.85%, while sample E (100% goroho banana) showed the lowest moisture content (11.18%), these results differ from those of Suniarti and Purnomo (2019), which were 3.96%. The moisture content values for composite flours B, C, and D were between the two, namely 11.27-11.46%, confirming the trend of increasing moisture content as the proportion of gedi leaves in the formulation increased.

This increase in water content can be explained by the high dietary fiber and hydrophilic compound content in gedi leaves, which have a greater water retention capacity than the starch in goroho banana flour. Based on preliminary research results, gedi leaf flour has 10.11% soluble fiber, 40.29% insoluble fiber, 50.4% total fiber, and 10.25% crude fiber, which indicates high water retention capacity. This fiber content, especially the insoluble fraction, contributes significantly to *water-holding capacity (*WHC), so that the moisture content of composite flour increases in proportion to the proportion of gedi leaves (Liu et al., 2024; Rindengan et al., 2018).

From a formulation optimization perspective, moisture content is a key parameter because it directly affects water activity (Aw) and storage stability. High moisture content can accelerate the growth of microorganisms and non-enzymatic browning reactions (Maillard) during storage (Qi et al., 2025; Madhumathy, 2021), while excessively low moisture content can reduce the rehydration capacity and solubility of flour due to damage to the pore structure during drying (Jiang et al., 2025).

The moisture content between 11.18-12.85%, for all samples except sample A, is still below the maximum limit of SNI 01-3841-1995 for banana flour (≤12%), so that the resulting flour product can be categorized as stable for medium-term storage while still having good rehydration properties in food applications.

Fat content of composite flour

The results of fat content analysis in various formulations of goroho banana flour and gedi leaves showed a range of 0.72-6.0% (Table 3). Sample A (100% gedi leaves) had the highest fat content (6%), while sample E (100% goroho banana) showed the lowest content (0.72%). Research results Suniarti and Purnomo (2019) showed that the fat content in goroho banana flour was 0.52%. The fat content values in flours B, C, and D were between these two (4.49-1.77%), indicating a trend of increasing fat content as the proportion of gedi leaves in the mixture increased.

Functionally, the presence of fat in balanced levels can contribute positively to the nutritional and sensory characteristics of products (Zaffarin et al., 2020). However, excessively high fat levels can reduce storage stability due to the potential for fat oxidation, which produces rancidity and reduces flour quality (Gulkirpik et al., 2021; BA et al., 2023). In the context of formulation optimization, a combination of goroho banana flour and gedi leaves in a ratio of 75:25 or 50:50 can be considered as a balanced formulation between storage stability and increased functional value of the product.

Protein content of composite flour

The protein content of the goroho banana-gedi leaf composite flour ranged from 2.91 to 23.87% (Table 3). Sample A (100% gedi leaf) had the highest protein content (23.87%), while sample E (100% goroho banana) had the lowest (2.91%), the results of the analysis of the protein content of goroho banana flour in this study were not much different from the results of the study by Suniarti and Purnomo (2019), which was 2.55%. The trend of increasing protein content consistently followed the increase in the proportion of gedi leaves in the formulation. This is in line with the general characteristics of leafy plants, which are rich in protein compared to starchy materials such as goroho bananas, which have a protein content of 3.0% (Suryanto et al., 2011). The addition of gedi leaf flour can thus be an effective strategy to increase the protein content of composite flour without significantly altering the basic characteristics of the flour, especially in the 50:50 or 75:25 formulations, which are considered the most balanced.

From an optimization perspective, increasing protein content is not only important for improving nutritional value, but can also affect functional characteristics such as water binding capacity, viscosity, and flour gelling power (Culetu et al., 2021; Ogbuagha, 2025). Therefore, the optimal formulation must consider the balance between protein enhancement and physical stability, as well as antioxidants, which are also functional targets in this study.

Ash content of composite flour

The analysis results show that the ash content of the goroho banana–gedi leaf composite flour ranges from 2.33 to 13.18% (Table 3). Sample A (100% gedi leaves) had the highest ash content (13.18%), while sample E (100% goroho banana) had the lowest (2.33%). The results of the ash content analysis of goroho banana flour were not significantly different from the results of the study by Suniarti and Purnomo (2019), which was 3.14%. Composite formulations B, C, and D were in the middle, at 10.37%, 7.43%, and 4.85%, respectively. The increase in ash content with increasing proportions of gedi leaves indicates the contribution of natural minerals in gedi leaves to the inorganic residue of the flour. Preliminary research showed the mineral content of gedi leaves, such as zinc 0.14 ppm, iron 0.35 ppm, magnesium 8.02 ppm, and calcium and potassium below detection (<0.0024 ppm and <0.0048 ppm), which explains the effect of gedi leaves on the ash content of flour.

In the context of formulation optimization, ash content is an important indicator for balancing the mineral nutritional value and physical quality of flour. A balanced mineral content can increase nutritional value, but high ash content has the potential to affect the processing properties, color, and taste of flour (Gujral et al., 2013). Therefore, composite formulations with moderate ash content, such as C or D, can be considered optimal because they offer a balanced combination of mineral enhancement and processing quality stability.

Carbohydrate content of composite flour

The analysis results show that the carbohydrate content of Goroho banana–Gedi leaf composite flour ranges from 45.66 to 82.86% (Table 3). Sample A (100% Gedi leaf flour) had the lowest carbohydrate content, namely 45.66%, while sample E (100% Goroho banana flour) showed the highest content, 82.86%. Composite formulations B, C, and D had carbohydrate contents of 54.79%, 64.33%, and 73.96%, respectively. The decrease in carbohydrate content with increasing proportions of gedi leaves can be explained by the fact that gedi leaves contain higher levels of non-starch components, such as water-soluble and insoluble fiber, thereby relatively reducing the carbohydrate fraction compared to goroho banana flour, which is predominantly starch (Mandey et al., 2014; Sakti et al., 2024).

From a formulation optimization perspective, carbohydrate content is an important parameter because it affects the energy value, texture, and functional properties of flour (Dega & Barbhai, 2025; Li et al., 2023). Formulations with high carbohydrate proportions (e.g., sample E) produce greater energy and starch-dominated flour properties—easily soluble and rapidly increasing viscosity—but tend to be low in fiber and bioactive compounds (Kayode et al., 2025). Conversely, formulations with low carbohydrate proportions (sample A) have higher fiber and bioactive content, but may reduce the functional properties of the flour for certain food applications. Therefore, formulations with medium proportions, such as sample C (64.33%), are considered the optimal compromise that balances energy content, fiber/bioactive content, and flour processing properties, in line with multi-criteria optimization objectives (Cankurtaran-Kömürcü & Bilgiçli, 2025; Vijayakumar & Mohankumar, 2009).

Crude fiber content of composite flour

The analysis results show that the fiber content in Goroho banana–Gedi leaf composite flour ranges from 0.31% to 10.84% (Table 3). Pure Gedi leaf flour (sample A) had the highest fiber content (10.84%), while pure Goroho banana flour (sample E) had the lowest fiber content (0.31%). The results of Suniarti and Purnomo's (2019) research were 0.79%. For the composite formulations, samples B, C, and D had fiber contents of 8.10%, 7.58%, and 1.34%, respectively, showing an increase in fiber as the proportion of gedi leaves in the mixture increased. The preliminary research results supported these findings, showing that gedi leaf flour contains 10.11% soluble fiber, 40.29% insoluble fiber, 50.4% total fiber, and 10.25% crude fiber. These fiber components contribute significantly to the functional properties of flour; soluble fiber increases water absorption and viscosity, while insoluble fiber enhances swelling power, water retention, and prebiotic potential. The addition of gedi leaves in composite flour directly improves the functional properties and nutritional value of the flour (Ariyarathna et al., 2025; Yang et al., 2019).

In the context of formulation optimization, fiber content is an important parameter that must be balanced with energy content, starch, and flour processing characteristics. Formulations with high fiber content (sample A) have high functional value but can affect texture and viscosity, while formulations with low fiber content (sample E) excel in starch content and texture but are less optimal in terms of functionality and health value. Therefore, intermediate composite formulations, such as samples B or C, are considered the optimal compromise between fiber content, texture, and the application capabilities of flour in food products.

Conclusion

The physicochemical properties and antioxidant activity of Goroho Banana–Gedi Leaf composite flour are greatly influenced by the proportion of each ingredient, where an increase in the proportion of gedi leaves increases protein, fat, ash, fiber, total phenols, and DPPH activity, while the proportion of goroho bananas increases carbohydrates. The 50:50 and 75:25 Gedi leaf:Goroho banana composite formulations show an optimal balance between antioxidant activity and nutritional content, with adequate protein, fiber, and carbohydrates, making them suitable for use as bioactive and nutritionally balanced functional flours.

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Author Contributions
M.I.R.T.: Developing ideas, analyzing, writing, reviewing, responding to reviewers' comments; E.S., T.D.J.T.: analyzing data, overseeing data collection, reviewing scripts, and writing.

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Conflicts of Interest
The authors declare no conflict of interest.

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