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Nutraceutical Content in Gayam Flour as a Potential Functional Food

Nur Setiawati Rahayu[1,2], Ahmad Sulaeman[3], Budi Setiawan[3], Mokhamad Fahrudin[4], Debby Endayani Safitri[2]*

[1]Postgraduate in nutrition science, Department of Community Nutrition, Faculty of Human Ecology IPB University, Bogor, 16680, Indonesia

[2]Nutrition study program, Faculty of Health Sciences University Muhammadiyah Prof. Dr. HAMKA (UHAMKA), Jakarta, Indonesia

[3]Department of Community Nutrition, Faculty of Human Ecology, IPB University, Bogor, 16680, Indonesia

[4]Department of Anatomy, Physiology, and Pharmacology, School of Veterinary Medicine and Biomedicine, IPB University, Indonesia

Correspondence: E-mail: Nur_setiawati@uhamka.c.id

ABSTRACTS

Gayam (*Inocarpus fagifer*), an underutilized legume widely found in Indonesia, is traditionally consumed as a local food source. However, comprehensive research on its nutraceutical potential remains limited. This study aims to identify the nutritional and nutraceutical composition of Gayam seed flour, focusing on dietary fiber, resistant starch, and amino acid profiles. Gayam seeds were processed into flour through boiling, drying, and milling. Nutraceutical analyses included soluble and insoluble dietary fiber (AOAC gravimetric method), resistant starch (spectrophotometric method), and amino acid profile (UPLC-PDA). Amino acid scores were calculated based on the WHO/FAO reference pattern. The results showed that Gayam flour contains 2.12 g/100 g of soluble fiber, 13.64 g/100 g of insoluble fiber, and 11.62 g/100 g of resistant starch. The essential amino acids with the highest concentrations were phenylalanine + tyrosine (9.93 mg/g) and threonine (6.25 mg/g). At the same time, methionine + cystine was identified as the limiting amino acid with the lowest score (5.56). Compared to other legumes, Gayam showed higher soluble fiber content but lower insoluble fiber content. The presence of resistant starch and a balanced amino acid profile suggests potential benefits for glycemic control, gut health, and enhanced protein quality. Gayam seed flour demonstrates promising nutraceutical properties, particularly as a source of resistant starch and essential amino acids. These findings support its potential application as a functional food ingredient, although further *in vivo* and clinical studies are needed to validate its health benefits.

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1. INTRODUCTION

Food processing using plant-based ingredients is growing in popularity due to its perceived health benefits. Indonesia is an agricultural country with many edible plant species. Daily consumption of fruits, vegetables, and legumes is highly recommended for a healthy diet. One type of plant that thrives in Indonesia is Gayam (*Inocarpus fagifer*). Gayam, also known as Tahitian chestnut, is a plant with an outer skin, shell, and seed. The edible part of Gayam is its seed. In Indonesia, Gayam is known by various names, including Djatep in West Java, Ampite in Papua, Katinda in Sulawesi, Giang in Maluku, and many more (Wawo et al., 2011). The growth of the Gayam fruit is still highly influenced by the season. One Gayam tree can produce 50 to 150 kilograms of fruit (Setyowati & Wawo, 2015).

Gayam seeds are typically consumed boiled, steamed, or made into chips. Several researchers have attempted to process Gayam into various other forms, such as crackers, cakes, pies, and white bread (Angkih et al., 2018; Ningsih & Pangesthi, 2013). Several studies have revealed that Gayam offers health benefits. Gayam contains carbohydrates, fats, protein, and dietary fiber (Rahayu et al., 2024). In addition to its nutritional content, Gayam seeds also contain vitamins, minerals, and various nutraceutical compounds such as fatty acids, soluble and insoluble fiber, resistant starch, amino acids, antioxidants such as phenols, and secondary metabolite compounds in the form of alkaloids, terpenoids, tannins, saponins, and flavonoids as well as negative steroids (Huml et al., 2016; Widayati & Umarudin, 2022).

Nutraceuticals are products derived from food ingredients that offer additional health benefits, including the prevention and treatment of non-communicable diseases such as diabetes mellitus, hypertension, heart disease, and cancer, which are the leading causes of death in many countries. Preclinical research in obese rats showed that Gayam seed extract can lower blood sugar levels and increase short-chain fatty acids (SCFAs) (Wijanarka et al., 2020). Extraction of Gayam seeds can yield ethanol, which can significantly reduce TNF-α expression (Sukadana & Santi, 2017). Ethanol extract of Gayam seeds is effective in preventing atherosclerosis (Sukadana & Santi, 2015). The compounds maltol and nicotinamide, identified in *Inocarpus fagifer*, are effective antibacterials against *S. aureus* and *E. coli* (Santi et al., 2023).

Based on these findings, Gayam seeds show promising potential for health applications. The research gap addressed in this study is the analysis of amino acid content, soluble fiber, insoluble fiber, and resistant starch in Gayam flour. This study aims to further explore its nutritional and nutraceutical properties, specifically focusing on resistant starch, soluble and insoluble dietary fiber, essential and non-essential amino acids, amino acid scores, and limiting amino acids in Gayam seed flour.

2. METHODS

This study used an experimental laboratory design, with all analyses conducted in a single laboratory and two replications. The laboratories used were the food experiment laboratory at IPB University and the chemical analysis laboratory at PT. Saraswanti Indo Genetech, located at Graha SIG, Jl. Rasamala No. 20, Taman Yasmin, Bogor 16113. The data presented are the results of analyses conducted on Gayam flour.

2.1. Gayam flour processing procedure

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The Gayam flour processing procedure involves several stages. The first stage is sorting fresh Gayam with a weight of 50–110 g. Selection was performed to ensure that the chosen Gayam fruit was of good quality. Gayam seeds were cleaned by washing with running water to remove soil, sap, or foreign matter. The sorted Gayam was then washed thoroughly and boiled at 100°C for 45 minutes. After boiling, the Gayam was drained and cooled at room temperature, then peeled, thinly sliced, and sun-dried for 3 days. The dried Gayam was ground using a disc mill and sieved through an 80-mesh sieve. The ground Gayam was stored in standing bags. The flow chart of the Gayam flour making process is shown in Figure 1 (Rahayu et al., 2024).

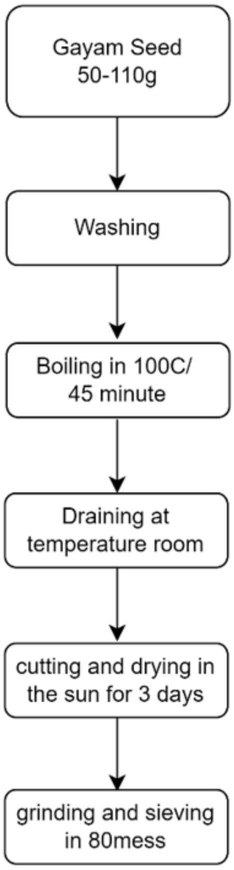

Figure 1. The process flow of making Gayam flour.

2.2. Method of analysis of nutraceutical content

In this study, the analysis of the nutraceutical content of Gayam flour focused on amino acids, resistant starch, and soluble and insoluble fiber. The analysis of essential and non-essential amino acid content in Gayam flour was conducted using Ultra Performance Liquid Chromatography-Photo Diode Array (UPLC-PDA). This method was chosen for its higher sensitivity and resolution compared to other methods, making it the appropriate choice for amino acid compound testing (Annissa et al., 2019). For soluble and insoluble fiber analysis, the gravimetric method based on the official AOAC method was used. After determining the amino acid content of Gayam flour, amino acid scores were calculated to identify the limiting amino acids, and resistant starch content was analyzed using a spectrophotometer.

3. RESULTS AND DISCUSSION

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Gayam, commonly known as Tahitian chestnut, belongs to the family Fabaceae and is native to the Pacific region. In Indonesia in the early 1900s, the fruit was quite popular due to its widespread distribution across the archipelago. Gayam flour contains 30.25% amylose and 69.75% amylopectin, making it a potential alternative carbohydrate source (Rahayu et al., 2024). In addition to its carbohydrate content, Gayam also contains 9.49% protein and 13.79% dietary fiber (Rahayu et al., 2024). Protein and dietary fiber play important roles in maintaining overall health.

Protein is essential for the growth, repair, and maintenance of body tissues, including muscle, skin, enzymes, and hormones (Deane et al., 2020; Harris et al., 2025). Protein also plays an important role in immune function, as antibodies that protect the body against pathogens are composed of protein (Harris et al., 2025). Adequate protein intake helps maintain bone density, preserve muscle mass (especially in the elderly) and promotes satiety, thereby contributing to weight management (Deane et al., 2020; Harris et al., 2025).

Dietary fiber significantly contributes to digestive health (Alahmari, 2024). Regular consumption of dietary fiber has been associated with a reduced risk of non-communicable diseases such as cardiovascular disease, type 2 diabetes, and certain types of cancer, including colorectal cancer (Alahmari, 2024; Yao et al., 2023). This study further examined the dietary fiber content of Gayam flour, classified into soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). Based on the study results, Gayam flour contains 2.12 g/100 g soluble fiber and 13.64 g/100 g insoluble fiber. The soluble fiber content of Gayam flour is higher than that of soybean (1.52 g/100 g) and red bean (1.69 g/100 g), although the insoluble fiber content of red bean flour (15.13 g/100 g) remains higher than that of Gayam flour.

Soluble fiber plays an important role in regulating postprandial blood glucose and lipid metabolism by delaying gastric emptying and reducing glucose absorption in the small intestine (Giuntini et al., 2022). In addition, soluble fiber stimulates the secretion of glucagon-like peptide-1 (GLP-1), which enhances satiety and glucose homeostasis (Guan et al., 2021). Therefore, the relatively high soluble fiber concentration in Gayam flour indicates its potential application in dietary management of metabolic disorders such as obesity and type 2 diabetes (Lu et al., 2023).

In individuals with high cholesterol, soluble fiber helps bind cholesterol in the digestive tract and facilitates its excretion, thereby lowering blood cholesterol levels (Surampudi et al., 2016). Conversely, the insoluble fiber content (13.64 g/100 g) is lower than that of red bean flour (15.13 g/100 g). Insoluble fiber promotes regular bowel movements and prevents constipation. Insoluble fiber in legumes absorbs liquid, increasing food volume and viscosity, thereby enhancing satiety and facilitating the movement of food through the digestive tract, shortening transit time.

Other benefits of insoluble dietary fiber from legumes include antioxidant, anti-inflammatory, and anticancer properties, as it promotes the growth of beneficial bacteria while suppressing the proliferation of harmful pathogens, thereby supporting optimal gut health (Perry & Ying, 2016). Both soluble and insoluble fiber work synergistically to improve gastrointestinal health and modulate gut microbiota composition, which is a key mechanism underlying the physiological benefits of plant-based functional foods.

The resistant starch (RS) content of 11.62 g/100 g further supports the classification of Gayam as a functional carbohydrate source. Resistant starch behaves similarly to dietary fiber

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as it resists digestion in the small intestine and undergoes fermentation in the large intestine, producing short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate. These metabolites play important roles in improving insulin sensitivity, regulating blood glucose levels, reducing hepatic cholesterol synthesis, thereby potentially lowering blood cholesterol levels, and enhancing intestinal barrier integrity and satiety (Das et al., 2024; Wijanarka et al., 2016). The RS levels observed in this study are consistent with previous findings, confirming that processing and thermal treatment significantly affect RS formation in Gayam flour (Farooq & Yu, 2024; Wijanarka et al., 2016).

Table 1. Amino acid content, soluble and insoluble fiber in Gayam flour.

Amino Acid	Content
Essential	
Isoleucine (mg/g)	5.23
Leucine (mg/g)	8.75
Lysine (mg/g)	5.12
Methionine + cystine (mg/g)	1.95
Phenylalanine + Tyrosine (mg/g)	9.93
Threonine (mg/g)	6.25
Tryptophan (mg/g)	1.78
Valine (mg/g)	5.71
Non-Essential	
L-Alanine (mg/g)	4.3
L-Arginine (mg/g)	7.2
L-Aspartic acid (mg/g)	10.1
Glycine (mg/g)	5.2
L-Glutamate (mg/g)	11.1
L-Histidine (mg/g)	2.2
L-Proline (mg/g)	5.6
L-Serine (mg/g)	6.9
Dietary Fiber	
Soluble Fiber (g/100g)	2.12
Insoluble Fiber (g/100g)	13.64
Resistant Starch (g/100g)	11.62

Table 2. Amino acid score in Gayam flour.

Amino Acid Essential	AAE content in Sample	AAE Reference WHO	Score Amino Acid
Isoleucine	5.23	40	13.07
Leucine	8.75	70	12.50
Lysine	5.12	55	9.31
Methionine + cystine	1.95	35	5.56
Phenylalanine + Tyrosine	9.93	60	16.55
Threonine	6.25	40	15.63
Tryptophan	1.78	10	17.80
Valine	5.71	50	11.42

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Figure 2. Procedure for making Gayam flour.

Amino acid profile analysis showed that Gayam flour contains essential and non-essential amino acids in relatively balanced proportions. The highest concentrations in the essential amino acid group were found in phenylalanine + tyrosine (9.93 mg/g) and threonine (6.25 mg/g). Phenylalanine and tyrosine serve as the main precursors of catecholamine neurotransmitters, including dopamine and norepinephrine, which influence cognitive function and hormonal regulation (He & Wu, 2020). Threonine, on the other hand, plays an important role in energy metabolism, macromolecular biosynthesis, and maintenance of intestinal homeostasis through MAPK and TOR signaling pathways (Tang et al., 2021). These findings indicate that Gayam flour has the potential to support cognitive and metabolic functions when consumed regularly.

Amino acid score calculations showed that methionine + cystine was the limiting amino acid with the lowest score value (5.56) compared to the WHO reference pattern. The presence of a limiting amino acid is a key factor in determining overall protein quality, as protein utilization in the body depends heavily on the availability of essential amino acids in adequate, balanced amounts (Wolfe et al., 2024). A deficiency of a single essential amino acid, such as methionine, can inhibit protein synthesis even when other amino acids are available in sufficient amounts (Matthews et al., 2025). Comprehensive protein quality assessment not only considers the AAS score, but also involves methods such as the digestible indispensable amino acid score (DIAAS), which more accurately reflects the biological availability of amino acids (Herreman et al., 2020; Monsonego Ornan & Reifen, 2022).

The limitation of sulfur-containing amino acids is a common characteristic of plant protein sources, particularly legumes, as legumes are generally low in methionine and cystine. At the same time, cereals are low in lysine (Hertzler et al., 2020). This condition indicates that plant protein quality is not solely determined by total protein content, but also by the balance of essential amino acid composition. A food combination strategy (protein complementation) can be used to improve the protein quality of Gayam flour, as mixing complementary plant proteins has been shown to produce an essential amino acid profile comparable to that of animal proteins (Broucke et al., 2025; Dimina et al., 2022). Combining Gayam flour with other methionine-rich food sources, such as cereals (e.g., rice or wheat), has the potential to produce a more complete amino acid profile and improve the overall biological value of protein, as demonstrated through DIAAS calculations for legume-cereal blends (Duque-Estrada et al., 2023; Han et al., 2021).

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Gayam flour shows potential as a valuable plant protein source despite limitations in one or two essential amino acids. Consuming a diverse, balanced diet can optimize the utilization of its nutritional content. These findings affirm that protein quality evaluation depends not only on total protein content, but also on the balance of its amino acid profile.

Overall, Gayam is a traditional Indonesian food source rich in nutraceutical compounds. The combination of resistant starch, dietary fiber, and essential amino acids indicates that Gayam flour has great potential as a functional food ingredient, given that resistant starch has been recognized as a functional fiber component that provides tangible benefits for metabolic health, blood glucose levels, lipid profiles, and colon health (Walsh et al., 2022; Baptista et al., 2024). Its nutritional and nutraceutical profile makes it a promising candidate for the development of food products to improve metabolic health and prevent chronic diseases (Zhang et al., 2025; Niu et al., 2025). Further research is recommended to evaluate the bioavailability of these compounds, the sensory acceptability of Gayam-based food products, and clinical validation of their physiological effects in humans.

4. CONCLUSION

Gayam (*Inocarpus fagifer*) seed flour demonstrates considerable nutraceutical potential as a functional food ingredient. The flour contains soluble dietary fiber (2.12 g/100 g), insoluble dietary fiber (13.64 g/100 g), and resistant starch (11.62 g/100 g), all of which synergistically support gastrointestinal health, glycemic regulation, and lipid metabolism. Its amino acid profile reflects a relatively balanced composition of essential and non-essential amino acids, with phenylalanine + tyrosine and threonine present at the highest concentrations, suggesting contributions to cognitive and metabolic functions. Methionine + cystine was identified as the limiting amino acid (a characteristic common among legume-based proteins) which can be addressed through protein complementation strategies with methionine-rich cereals such as rice or wheat. Collectively, these nutraceutical properties position Gayam flour as a promising ingredient for the development of functional food products to manage metabolic disorders and reduce the risk of non-communicable diseases. Future *in vivo* and clinical studies are warranted to validate these physiological benefits and to optimize the incorporation of Gayam flour into practical food systems.

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