

Potential Substitution of Plantain Peel (*Musa paradisiaca* var. Raja) Waste Flour for High-Fiber Crispy Brownies

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ABSTRACT

Plantain peel (*Musa paradisiaca* var. Raja) is a high-fiber by-product, containing 50.3% fiber, with 16.54% pectin as a prebiotic. Plantain peel utilization is a response to 13 million tons produced annually, which contributes to environmental issues. Utilization of plantain peel in crispy brownies production offers a potential solution as ingredients with health benefits. Additionally, chicken eggshell from the previous steps were incorporated to reduce food by-product. The aim of this study is to identify the utilization of plantain peel and chicken eggshell for crispy brownies production as a functional food. The research was conducted using a systematic literature review based on research articles from 2015 until 2025 from digital base research articles, regarding the potential of plantain peel and eggshell in crispy brownies production. The addition of plantain peel has multiple health benefit like prebiotic, improvement of SCFAs production, and high phenolic components with antioxidant activity. The utilization of chicken eggshell is not just increase the calcium concentration in crispy brownies, which can improve teeth, bone and immune system, but also supporting the circular economy concept. The application of plantain peel and chicken eggshell utilization supports the sensory properties to crispy brownies.

KEYWORDS: Crispy brownies, Chicken eggshell, Fiber, Pectin, Plantain peel

Introduction

The Indonesian population's daily fiber intake is only 11 grams out of 30 grams, which is far below the recommended number (Putri *et al.*, 2020). Whereas, deficiency of fiber intake would lead to some metabolic diseases, such as obesity, diabetes, cardiovascular disease, and affects intestinal health. Fiber intake associated with gut microbiome's metabolism influencing the gastrointestinal immune and endocrine responses (Ioniță-Mîndrican *et al.*, 2022). Additionally, plantain banana peel is rich in nutrients, such as minerals and fiber (Oyeyinka & Afolayan, 2019). Plantain peel (*Musa paradisiaca* var. Raja) contains a high amount of fiber, approximately 50.3% of banana peel, with 16.54% pectin (Anggerika *et al.*, 2020; Subagio *et al.*, 2020). Raja is classified as *Musa paradisiaca*, which refers to a specific banana group called plantain, that must be put through a cooking process before consuming due to its high starch content (Pérez-Donado *et al.*, 2023).

Pectin is a fiber which can be fermented by the gut microbiome. Therefore, it produced Short Chain Fatty Acids (SCFAs) such as butyrate, propionate, and acetate. Short chain fatty acids provide additional energy to increase protein synthesis and oxygen utilization of colon mucosa, as well as increase its protective function. Moreover, pectin can be used as an antidiarrheal due to its ability to bind water and fat, remove excess mucus in the

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digestive system, and also absorb and bind bacterial toxins and irritants (Subagio *et al.*, 2020). Additionally, pectin also acts as prebiotic, which has the ability to selectively stimulate the growth of the beneficial gut's microbiome and beneficially influence health (Blanco-Pérez *et al.*, 2021).

Plantain peel takes up about 30% of the total mass itself. Furthermore, the waste of plantain peel might reach 13 million tons each year (Xie *et al.*, 2023). Plantain is largely utilized locally due to the high numbers of snack industries that consumed the flesh (Ali, 2022). The utilization of plantain peel is a response to the abundance of the unutilized peel. One potential application of plantain peel utilization is by processing them into plantain peel flour. The plantain peel flour can be applied in the crispy brownies production to enhance nutrients value, especially fiber, since the conventional crispy brownies generally contain low fiber.

This innovation is supporting a circular economy, for the process is considering the impact on the environment while using all the ingredients efficiently. It also aims to implement the zero-waste concept by utilizing the eggshell yielded during the production of the crispy brownies to enhance the calcium content. Eggshell contains 34–38% of calcium and can be processed into eggshell powder which can be further applied to various food products. The previous study concluded that the supplementation of eggshell powder may increase the calcium content number significantly (Pebrianti & Ilyas, 2024). Even though several researchers studied the potential of plantain peel and eggshell utilization, the application of this food by-product as the main ingredient for crispy brownies is still limited. Whereas plantain peel and eggshell probably have a health benefit if consumed and also still have an economic value to support a circular economy. Therefore, the aim of this study is to provide a systematic literature review regarding the potential utilization of plantain peel and eggshell in crispy brownies production.

Literature Review Method

Data Analysis

This research was conducted using a systematic review based on research articles published ranging from 2015 until 2025 from digital base research articles. The scope of the review includes the potential nutritional aspects of plantain peel, utilization of plantain peel waste as functional food, plantain peel and chicken eggshell powder processes, and technological aspects of crispy brownies. Collected data from the systematic review analyze using descriptive analysis.

Results and Discussion

Crispy Brownies Preparation

Several studies had developed various methods to make crispy brownies (Mailisa *et al.*, 2024; Dewi & Putra, 2024). Generally, the preparation of crispy brownies consisted of the preparation of flour, eggshell powder, and mixing of the ingredients. The preparation of the plantain peel flour began with the use of fresh plantain peel obtained from plantain-based food industry (cake, snack, and others). The common steps to make plantain peel flour are peels that were washed, cut (approximately 1 cm x 1 cm), and blanched for 10 minutes. This process aims to deactivate the polyphenol oxidase (PPO) (Manalu & Srimati, 2020). Several drying methods are applicable to make plantain peel flour, such as sun drying, oven drying, and microwave dryer (Apaliya *et al.*, 2023). The use of dehydrator was also reported, commonly operated at 60°C for 8 hours. Dried plantain peel was ground and sieved through an 80-mesh sieve to obtain fine flour (Manalu & Srimati, 2020).

For the chicken eggshell powder, heat treatment process including boiling and oven drying had been utilized. Chicken eggshell, which was previously washed, boiled at 100 °C for 30 minutes, followed by oven drying methods at 180 °C for 3 hours (Yuliana *et al.*, 2021). Additionally, it is suggested to clean and wash the eggshell many times before the drying process to remove contaminants (Hossain *et al.*, 2024). Sun drying methods for chicken eggshells are not recommended, since it is not effective enough to eliminate microbial contamination (Bartter *et al.*, 2018). Grinding and sifting processes were also applied, with 100-mesh sieves recommended to produce fine flour (Yuliana *et al.*, 2021).

Crispy brownies were formulated by substituting the medium protein wheat flour, which is generally used, with the plantain peel flour, and added with chicken eggshell powder (Soewondo *et al.*, 2023). The preparation involved mixing fine sugar and egg until evenly distributed followed by the addition of wheat flour, chocolate powder, and salt. Some literature also added baking powder and milk powder to the mixture (Sugiman & Suroto, 2024). Plantain peel flour and chicken eggshell powder incorporated and mixed until uniform. Melted chocolate and margarine were added and mixed thoroughly. The dough transferred into a baking tray, flattened, baked, and cooled. The common temperature used for baking is 150 °C, around 30-40 minutes (Soewondo *et al.*, 2023).

Plantain Peel Waste

Plantain is an important crop around the world, especially in tropical countries like Africa, Southeast America and Southeast Asia. Tropical countries can produce plantain up to 43 million tons in 2020 (Xie *et al.*, 2023). However, the utilization of the plantain also has a massive by-product. The by-product is about 30%–40% of the plantain part, which is peel, only act as a waste, and is estimated to reach 13 million tons of plantain peel in a single year from the food industry (Sial *et al.*, 2019; Xie *et al.*, 2023). Plantain peel waste can be dangerous for the environment, because it is just thrown away, especially since plantains are highly consumed (Putri *et al.*, 2022).

Plantain as a highly consumed fruit, will dispose peel which is bad for the environment. Like other organic waste, plantain peel will degrade into methane gas (CH₄), a greenhouse gas. High amounts of methane gas lead to a high greenhouse effect (Tuhumury *et al.*, 2024). This condition will increase the temperature of the earth, and make the temperature continue to rise. Plantain peel that degrade also tend to cause convenience issues, as it causes an uncomfortable odor when decomposing (Jordan *et al.*, 2022; Tuhumury *et al.*, 2024).

Plantain Peel Nutrition

The utilization of plantain peel is based on the nutrition compositions. Plantain peel is rich in organic components and mineral contents. There is no significant difference between the unripe and ripe plantain peel. The nutrition composition, which is found in plantain peel, is summarized in Table 1., and Table 2.

Table 1. Nutrition composition of unripe plantain peel.

Nutrition Composition	Total Content (%)	References
Fiber	50.3	Anggerika <i>et al.</i> (2020)
Pectin	16.54	Subagio <i>et al.</i> (2020)
Pectin	4.65	Oyawaluja <i>et al.</i> (2020)
Sodium	0.047	Uzairu & Kano (2021)
Calcium	0.176	Uzairu & Kano (2021)
Magnesium	0.082	Uzairu & Kano (2021)
Zinc	0.002	Uzairu & Kano (2021)
Crude Protein	0.041	Jesumirhewe <i>et al.</i> (2020)
Fat	0.788	Jesumirhewe <i>et al.</i> (2020)

Table 2. Nutrition composition of ripe plantain peel.

Nutrition Composition	Total Content (%)	References
Fiber	50.3	Anggerika <i>et al.</i> (2020)
Pectin	16.54	Subagio <i>et al.</i> (2020)
Pectin	61	Oyawaluja <i>et al.</i> (2020)
Sodium	0.047	Uzairu & Kano (2021)
Calcium	0.176	Uzairu & Kano (2021)
Magnesium	0.081	Uzairu & Kano (2021)
Zinc	0.003	Uzairu & Kano (2021)
Iron	0.026	Uzairu & Kano (2021)
Potassium	0.788	Uzairu & Kano (2021)
Copper	0.001	Uzairu & Kano (2021)
Crude Protein	4.38	Jesumirhewe <i>et al.</i> (2020)
Fat	11.74	Jesumirhewe <i>et al.</i> (2020)

The highest number of nutrients found in plantain peel is fiber. The result may have some difference from each literature, such as pectin, which can be affected by geographical location. Plantain peel is also rich in potassium, which has a potential to reduce and prevent high blood pressure (Arogbodo *et al.*, 2021). Besides that, plantain peel also contains protein, an essential macromolecule, which is playing a vital role in supporting the immune systems, and optimal brain growth (Ajomiwe *et al.*, 2024). Furthermore, another important nutrient found in plantain peel is fat, since it has crucial functions for human body, for example, as structural units of cellular membranes, precursors to metabolic compounds involved in inflammatory and immune system, storage of energy, and playing roles in fat-soluble vitamins metabolism as well (Bajželj *et al.*, 2021). Another composition that has a role in many health benefits is bioactive components like phytochemicals. Some bioactive components have a role as antioxidants, like phenolic components. Plantain peel have various phenolic components, like gallic acid, catechin, epicatechin, tannins, and anthocyanins. Total phenolic component of the plantain peel is about 7.71 mg GAE/g. Phenolic components in plantain peel can be categorized as hydroxycinnamic acid, flavonols, flavan-3-ols and catecholamines that have antioxidant activity (Zaini *et al.*, 2022).

Fiber on Plantain Peel

One of the most potential nutrition from plantain peel is fiber. Dietary fiber are non-digestive until the large intestine. However, it would be broken down by the microbial organisms (Wagner *et al.*, 2024). Plantain peel contains various types of fiber with different total content. Different types of fiber and the total content in plantain peel is summarized in Table 3.

Table 3. Total content of different fiber type in plantain peel.

Fiber Type	Total Content (%)	References
Holocellulose	16.54	Castañeda-Niño <i>et al.</i> (2025)
Cellulose	12.78	Castañeda-Niño <i>et al.</i> (2025)
Hemicellulose	4.89	Castañeda-Niño <i>et al.</i> (2025)
Lignin	22.43	Castañeda-Niño <i>et al.</i> (2025)
Resistant starch	2.3-2.5	Wani & Dhanya (2025)
Cellulose	7-12	Wani & Dhanya (2025)
Hemicellulose	6-9	Wani & Dhanya (2025)
lignin	6-12	Wani & Dhanya (2025)
Pectin	5-10	Wani & Dhanya (2025)

Table 3. shows that plantains peel is rich in Insoluble Dietary Fiber (IDS) and Soluble Dietary Fiber (SDF). Plantain peel contains a high number of cellulose and lignin, which is characterized as an insoluble dietary fiber. Mostly, the proportion of insoluble dietary fiber is higher than the soluble dietary fiber, such as pectin. Soluble dietary fiber is intestinally

fermentable fiber, whereas the insoluble dietary fiber is responsible for water binding activities which can prevent syneresis and modify the rheology of some food applications. Resistant starch is considered as a dietary fiber as well (Wagner *et al.*, 2024).

Fiber Functions

As previously mentioned, each type of fiber has its own function. Some fiber has the ability to blend between the insoluble and soluble fiber which affects their functional properties (Wagner *et al.*, 2024). Dietary fiber generally associates with overall metabolic health and affects microflora functions, including the regulation of appetite (Barber *et al.*, 2020). Multiple benefit of fiber are shown in Table 4.

Table 4. Functions of various fiber in plantain peel.

Nutrition Composition	Functions	References
Cellulose	Potential of prebiotic, increase the richness of colonic microbiota, intestinal architecture, metabolic functions and susceptibility to colitis	Fischer et al. (2020)
Hemicellulose	Increase bifidobacterium (<i>Bacteroides</i> , <i>Ruminococcus</i> , and <i>Faecalibacterium</i>)	Fuso et al. (2025)
Lignin	Antioxidant, antimutagenic, and antidiarrheal effect, antimicrobial	Karagoz et al. (2023)
Pectin	Prebiotic, produce SCFAs, immunoregulatory, & anti-inflammatory	Blanco-Pérez et al. (2021)
Resistant Starch	Resistant Starch is a substrate for SCFAs synthesis, increase glucose tolerance and sensitivity to insulin	Bojarczuk et al. (2022)
Resistant Starch	Reduce low density lipoprotein, accelerating transformation mineral to soluble ion, modulating glucose homeostasis.	Han et al. (2023)

The results from Table 4. which taken from multiple literature has shown that the various types of fiber are very beneficial. The role of dietary fiber is also related to the immune system through the gut microflora. A healthy gut microflora can develop normal immune and metabolic, and even regulation of emotional function and mental health. Insoluble dietary fiber also appears to improve insulin resistance. The by-products from gut microbes, especially SCFAs, cross the Blood Brain Barrier (BBB) and exert direct effect on hypothalamic regulation (Barber *et al.*, 2020).

Functional Food Potential of Plantain Peel

Plantain peel has a high potential and clearly provides a wide range of health benefits. It has been observed that plantain peel may enhance the nutrient value of food products, especially in fiber. Furthermore, some previous research stated that plantain peel contains a lot of amino acid, including lysine and leucine, which is classified as essential amino acids that cannot be synthesized by human or mammalian cells (Ndarubu *et al.*, 2021; Lopez & Mohiuddin, 2024). Table 5. showed multiple health benefit from the plantain peel.

Table 5. Health benefits of plantain peel on various food products.

Health Benefits	Effect on Food Products and Health Benefits	References
Antioxidant and Radical Scavenging	Cookies with addition of 10% plantain peel will improve total phenolic component from 3.21 mg GAE to 4.87 mg GAE. Phenolic components in plantain peel have a potential as antioxidant, that can scavenge the radical using DPPH test. 10% addition of plantain peel will have a lower IC50 number (around 2000 µg/mL) than control (2500 µg/mL).	Arun et al. (2015)
Prebiotic	Plantain peel (powder) that is added to biscuit have a prebiotic function which can increase bacteria <i>Lactobacillus</i> spp. Plantain peel powder also increases growth of the <i>Lactobacillus</i> spp. compared to inulin as a pure prebiotic	Tan et al. (2024)
Anti-Cholesterol and Anti-Inflammatory	Dietary fiber from plantain peel also decreased total and LDL level, because soluble fiber from plantain peel can improve cholesterol absorption, and also reduce the inflammation on endothelial cells	Zaini et al. (2022)
Anti-Cholesterol	Dietary leucine in plantain peel can reduce weight gain, hyperglycemia and hypercholesterolemia	Zaini et al. (2022)
Cancer Cells Treatment	Lysine conjugates in plantain peel have a potential effect in cancer treatment and by causing cancer cells to self-destruct	Zaini et al. (2022)

Various health benefits of plantain peel at Table 5. shown that plantain peel has various functional benefits that can lead to health benefits if consumed. The potential of plantain peel led to utilization of plantain peel as a cookies like crispy brownies ingredient. High dietary fiber number of plantain peel in cookie-like products can increase dietary fiber number, and act as prebiotic to increase gut microbiome bacteria (Tan *et al.*, 2024; Zaini *et al.*, 2022). According to Blanco-Pérez *et al.* (2021), plantain peel can increase gut microbiome because of the soluble fiber content like pectin, which is fermentable for bacteria, and acts as a substrate. High number of gut microbiomes, especially good bacteria, can improve the quality of the digestive system, like production of SCFAs, that is directed to cholesterol absorption and inflammation on the digestive system, especially gut (Barber *et al.*, 2020; Zaini *et al.*, 2022).

Eggshell Potentials

Eggshell, which is a food by-product that produces 10% part from a single egg, isn't consumed because there is no utilization from it. Most of the eggshell will end up as waste, with no treatment to reduce the quantity of the eggshell. Eggshell waste is abrasive and produces an offensive odor in the absence of proper treatment. However, eggshell has a big potential as a source for many nutrients like minerals and trace elements (Pebrianti & Ilyas, 2024).

Eggshell is a potential source of calcium, since eggshell has a high content of natural calcium, and has a high absorption ability up to 45% (Pebrianti & Ilyas, 2024). The

bioavailability of the eggshell is also higher than commercial carbonate, hence eggshell is a good source of calcium (Singh *et al.*, 2021). Calcium plays a key role as an essential nutrient in supporting growth and bone health. Children who don't reach minimum calcium daily intake will be potentially stunted. Women, especially postmenopausal women who don't reach minimum calcium daily intake, will potentially have a low density bone at risk (Suryono *et al.*, 2020).

Chicken eggshell is not just rich in calcium content, but also rich in various minerals like Mg (36,200 mg/100 g), P (106 mg/100 g), Na (80 mg/100 g), K (60.20 mg/100 g), Zn (0.67 mg/100 g), and Fe (11.47 mg/100 g). Some of minerals was also higher than wheat flour like Ca (54.54 mg/100 g), Mg (74.68 mg/100 g), Na (48.29 mg/100 g), Zn (0.59 mg/100 g), and Fe (0.92 mg/100 g). Adding 5% of eggshell that turned into flour or powder also improves calcium absorption from biscuit when digested, from 37.47% (control) to 31.83%, but will decrease if addition of chicken eggshell powder over 5% (Shahnila *et al.*, 2022). Gingerbread that is added with 3% chicken eggshell flour will improve calcium content from 0.57% to 0.73% (Arnold *et al.*, 2022). Despite being a food without a side effect, chicken eggshell has a side effect if over consumed, because it can lead to hypercalcemia and attendant health consequences (Awogbemi *et al.*, 2022).

High calcium content in chicken eggshell, has the potential to give several health benefits as a functional food. According to Mas'udah *et al.* (2023), calcium has the ability to prevent stunting and boost the immune system. Calcium has a function in maintaining bone and teeth formation, acid-base regulation, calcitonin hormone and parathyroid hormone. Calcium also has a function in intracellular signaling that induces proliferation, cytokine production and regulation of the immune system. However, many benefits of chicken eggshell can be utilized as a crispy brownies ingredient to improve the functional benefit or crispy brownies.

Sensory Aspects

Plantain peel have attributes to sensory quality like colour, taste, and texture, when added 10% to cookies product (Zaini *et al.*, 2022). The colour of the product, that added with plantain peel will increase a brown colour appearance at bun product. This is because plantain peel have a brown colour, from the drying process that makes oxidation due to the existence of polyphenol oxidase (PPO) (Liyana & Naemma, 2025). Plantain peel also affect the colour of cookie product, which causes the color change to brown because PPO will react with still polyphenol in plantain peel, and make enzymatic browning which causes the brown colour (Manalu & Srimati, 2020). Colour is not only one factor that can affect the quality of food that is added with plantain peel, because flavour, and texture is also affected.

The flavour quality to the product that added banana flour (*Kepok* banana) to the biscuit is also affected, like aroma, taste and aftertaste. Too much substitution of banana makes the product have a bitter aftertaste. This is because banana flour has a high content in tannins, which can react with PPO (Hernawati, et al. 2017). Cookies and biscuits with addition of banana peel 10% also improve taste and texture and are desirable than other formulations (Arun et al., 2015; Zaini et al., 2022). Chicken eggshell powder is a hydrophilic filler, which is increasing the water absorption (Quddoos *et al.*, 2022). Water content is an important factor that affects the crispiness of food products, especially cookies. High water content will decrease the crispness significantly (Boudina *et al.*, 2023). However, some articles stated that the eggshell powder has an ability to increase the hardness of the cookies, hence high value of hardness will decrease the crispiness of a product (Therdthai *et al.*, 2023; Pratama *et al.*, 2018). The addition of eggshell powder doesn't give any sticky feeling in the mouth (Zerek *et al.*, 2022).

Eggshell powder gives creamy colour but doesn't give any significant change in the appearance (Zerek *et al.*, 2022). Eggshell powder won't give a significant effect to the flavour

(Zerek *et al.*, 2022). Based on the previous organoleptic evaluation held by Zerek *et al.* (2022), the addition of eggshell powder didn't cause any significant changes in the taste and acceptability of the cookies.

Crispy Brownies

Crispy brownies are chocolate cakes with crunchy texture. Crispy brownies are generally the same as brownies cake, but it has lower water content which makes them possible to have crispy texture (Mutyasih *et al.*, 2023). The production process of the crispy brownies itself doesn't require any high development, so it's relatively easy and simple. The ingredients used for crispy brownies has a potential to be modified with the purpose of enhancing the nutrient value (Dewi & Putra, 2024). Some modification on its ingredients will affect the organoleptic properties, such as colour, texture, smell, and the taste of the product.

Colour is a crucial thing that should be paid attention to, since it influences consumer perceptions of products, especially food products, as well as significant quality parameters of the product (Oguntoyinbo *et al.*, 2023). Plantain peel flour has a dark brown colour, which is incorporated with the colour of the biscuits produced. The addition of a high ratio of plantain peel flour will produce deeper brown colour products. The colours are also affected by pH, temperature, sugar, protein, as well as the fiber content. The lightness in the cookies decreases as the percentage of the fiber increases (Oladipo *et al.*, 2020). The darker colour from the plantain peel flour doesn't give any undesirable visual effect since the natural colour of crispy brownies is dark brown.

Plantain peel flour contains approximately 11% of fat (Jesumirhewe *et al.*, 2022). Fat influences the cookie dough, which results in cookies that tend to break easily (Oladipo *et al.*, 2020). The addition of plantain peel flour gives effect to the aroma of the products. The unique aroma of plantain peel comes from the interaction between the polyphenol component in the plantain peel with the protein, fat, and sugar from the cookie dough during the production process. Another factor that affects the aroma and flavour of the cookies is the Maillard reaction, which involves the carbohydrate and protein component. Maillard reaction is able to keep the unique aroma and flavour of the plantain peel in the cookies (Tazhkira *et al.*, 2020).

Plantain peel flour also has many benefits if consumed. This benefit will improve the functional quality of crispy brownies, because the crispy brownies will have some health benefits like antioxidants, prebiotic and anti-cholesterol. According to Arun *et al.* (2015), plantain peel flour contains antioxidants. Antioxidant activity on plantain peel that are added as ingredients of crispy brownies will improve the bioactive component in crispy brownies. Plantain peel flour added to crispy brownies as an ingredient also improve the total fiber quality that have a relation to gut microbiome. The reason is because plantain peel can increase gut microbiomes because they contains soluble fiber like pectin, which is fermentable by bacteria, and act as a substrate (Blanco- Pérez *et al.*, 2021). High concentration of gut microbiomes has a correlation to increase SCFAs production, that is directed to cholesterol absorption and inflammation on the digestive system (Barber *et al.*, 2020; Zaini *et al.*, 2022).

Crispy brownies are made using some ingredients, and one of them is chicken eggshell. Chicken eggshell from the production of crispy brownies can be used as an ingredient. Utilization of the chicken eggshell to crispy brownies by-product is to optimize and reduce a food by-product from production. Chicken eggshell then contains much calcium that can affect sensory quality of the crispy brownies.

The eggshell powder is not just enhancing the calcium content but also affects the crispy brownies sensory quality. However, the addition of the eggshell powder up to 10% doesn't give any undesirable sensory attributes (Raghul, 2023). This theory is corresponding to Zerek *et al.* (2022), that eggshell powder doesn't give any significant changes to the

organoleptic properties, based on the organoleptic test result from 30 participants. Still, it needs to be noted that the white- coloured eggshell powder may reduce a bit of the brown colour from the brownies (Therdthai *et al.*, 2023). The addition of eggshell powder increases the diameter, the thickness, and the hardness of the cookies (Zerek *et al.*, 2022).

The eggshell powder also can improve the health benefits of crispy brownies. The reason is because eggshell powder is high in calcium, that improves the development of teeth and bones and also has a correlation with the immune system. According to Mas'udah *et al.* (2023), calcium has a function in maintaining bone and teeth formation, acid-base regulation, calcitonin hormone level and parathyroid hormone level. Calcium also has a function in regulating in immune system. Utilization of plantain peel flour and chicken eggshell is a response to the high number of plantain peel and eggshell by-products. The utilization of plantain peel waste as crispy brownies can optimize the plantain by-product as an ingredient with various health benefits. The utilization of chicken eggshell as a powder from crispy brownies also has a benefit to make it full of nutrition and functional purpose. Utilization of plantain peel flour and chicken eggshell can reduce the food by-product of plantain by-product, which is good for the environment. This method of approach will also be good for the environment and support the circular economy in the community in a simple way.

Conclusion

Plantain peel contains numerous nutrients which are beneficial for human health, especially pectin with the ability to produce SCFAs and plays a key role as a prebiotic. The utilization of plantain peel is not just reducing food waste, but also enhancing the nutrients value to food products, specifically crispy brownies, by increasing the minerals and fiber content, as well as the phenolic components which has a potential as an antioxidant to scavenge radical compounds. The addition of eggshell powder is reflecting the support of the circular economy concept and increasing the calcium content of food products at once. The application of plantain peel and eggshell powder utilization supports the sensory properties to crispy brownies. Crispy brownies made with plantain peel flour and eggshell powder gives various benefits, especially health benefits, including reducing inflammation and LDL level, developing the immune system through gut microbiome relating to prebiotic, and plays a role as a cancer treatment at a time. As a result, crispy brownies made with plantain peel flour and the supplementation of eggshell powder reflect eco-friendly products that support a circular economy and zero-waste concept.

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Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

T.S. and M.R. conducted the conceptualization, T.S. conducted methodology, T.S. conducted the formal analysis, T. S. and M. R. investigation, writing-review and editing, T. S. and B.Y. revised the manuscript. All authors agreed to the final version of this manuscript.

References

- Ajomiwe, N., Boland, M., Phongthai, S., Bagiyal, M., Singh, J., & Kaur, L. (2024). Protein nutrition: understanding structure, digestibility, and bioavailability for optimal health. *Foods*, 13(11), 1771.
- Ali, N. M. (2022). The effect of plantain and banana peel ash on the properties of concrete. *International Journal of Innovations in Engineering Research and Technology*, 9(4), 31-37.
- Anggerika, N. N. Y., Laenggeng, A. H., & Baculu, E. P. H. (2020). Analisis kandungan serat dan vitamin C serta uji organoleptik es krim berbasis limbah kulit pisang raja (*Musa paradisiaca* var. Raja). *Jurnal Kolaboratif Sains*, 3(4), 190-196.
- Apaliya, M. T., Kwaw, E., Osa, R., Alolga, R. N., Aidoo, P., Mensah, L. A., Aikins, A. S. S., & Wilson, C. L. (2024). Effect of different drying methods on the rehydration kinetics, physicochemical and functional properties of unripe plantain (*Musa paradisiaca*) flour. *Food Chemistry Advances*, 4, 100610.
- Arnold, M., Rajagukguk, Y. V., Sidor, A., Kulczyński, B., Brzozowska, A., Suliburska, J., Wawrzyniak, N., & Gramza-Michałowska, A. (2022). Innovative Application of Chicken Eggshell Calcium to Improve the Functional Value of Gingerbread. *International Journal of Environmental Research and Public Health*, 19(7), 4195.
- Arogbodo, J. O., Olowookere, S. O., Igbe, F. O., & Adebayo, I. A. (2021). Assessment of unripe peel of plantain (*Musa paradisiaca* L.) as high quality feedstuff for livestock in Nigeria. *Nigerian Journal of Animal Production*, 48(3), 111-121.
- Arun, K.B., Persia, F., Aswathy, P.S., Chandran, J., Sajeev, M. S., Jayamurthy, P. & Nisha, P. (2015). Plantain peel - a potential source of antioxidant dietary fibre for developing functional cookies. *Journal of Food Science Technology*, 52, 6355-6364.
- Awogbemi, O., Von Kallon, D.V., Aigbodion, V.S. (2022). Pathways for Sustainable Utilization of Waste Chicken Eggshell. *Journal of Renewable Materials*, 10(8), 2217-2246.
- Bajželj, B., Laguzzi, F., & Röss, E. (2021). The role of fats in the transition to sustainable diets. *The Lancet Planetary Health*, 5(9), E644-E653.
- Barber, T. M., Kabisch, S., Pfeiffer, A. F. H., & Weickert, M. O. (2020). The Health Benefits of Dietary Fibre. *Nutrients*, 12(10), 3209.
- Bartter, J., Diffey, H., Yeung, Y. H., O'Leary, F., Häslér, Maulaga, W., & Alders, R. (2018). Use of chicken eggshell to improve dietary calcium intake in rural sub-Saharan Africa. *Maternal & Child Nutrition*, 14, e12649.
- Blanco-Pérez, F., Steigerwald, H., Schülke, S., Vieths, S., Toda, S., & Scheurer, S. (2021). The dietary fiber pectin: health benefits and potential for the treatment of allergies by modulation of gut microbiota. *Current Allergy and Asthma Reports*, 21,43.
- Bojarczuk, A., Skąpska, S., Khaneghah, A. M., & Marszałek, K.(2022). Health benefits of resistant starch: A review of the literature. *Journal of Functional Foods*, 93, 105094.
- Boudina, I., Delalonde, M., Koegel, L. Maraval, I., Forestier-Chiron, N., Domingo, R., Ricci, J. Sharkawi, T., & Rondet, E. (2023). Mechanical approach for the evaluation of the crispiness of food granular products. *Journal of Texture Studies*, 54,633-645.
- Castañeda-Niño, J. P., Mina-Hernández, J. H., & Solanilla-Duque, J. F. (2025). Effect of cellulose nanofibers and plantain peel fibers on mechanical, thermal, physicochemical properties in bio-based composites storage time. *Results in Engineering*, 25, 104185.
- Dewi, I. G. A. B. M., & Putra, I. G. A. M. (2024). Characteristics of crispy brownies from diversified arrowroot starch and black soldier fly larvae (BSFL) flour and its potential as

- a snack food for stunting. *International Journal on Food, Agriculture, and Natural Resources*, 5(4),26-33.
- Fischer, F., Romero, R., Hellhund, A., Linne, U., Bertrams, W., Pinkenburg, O., Eldin, H. S., Binder, K., Jacob, R., Walker, A., Stecher, B., Basic, M., Luu, M., Mahdavi, R., Heintz-Buschart, A., Visekruna, A., & Steinhoff, U. (2020). Dietary cellulose induces anti-inflammatory immunity and transcriptional programs via maturation of the intestinal microbiota. *Gut Microbes*, 12(1).1-17.
- Fuso, A., Rossa, F., Bellani, L., & Caligiani, A. (2025). Full characterization of hemicellulose-derived supplements by multi-analytical approach. *Journal of Food Composition and Analysis*, 142, 107508.
- Han, J., Wu, J., Liu, X., Shi, J., & Xu, J. (2023). Physiological effects of resistant starch and its applications in food: a review. *Food Production, Process and Nutrition* 5,48.
- Hernawati, H., Aryani, A., & Shintawati, R. (2017). Physical characteristics, chemical composition, organoleptic test and the number of microbes in the biscuits with addition of flour banana peel. *Journal of Physics: Conference Series*, 812, 012118.
- Hossain, M., Islam, R., Rahman, M. N., Khan, M. I. S., Ahmed, F., Al-Amin, M., & Rabbi, M. A. (2024). A novel approach for the modification of eggshell powder and its application for lead and methylene blue removal. *Heliyon*, 10(16), e36160.
- Ioniță-Mîndrican, C. B., Ziani, K., Mititelu, M., Oprea, E., Neacșu, S. M., Moroșan, E., Dumitrescu, D. E., Roșca, A. C., Drăgănescu, D., & Negrei, C. (2022). Therapeutic benefits and dietary restrictions of fiber intake: a state of the art review. *Nutrients*, 14(13), 2641.
- Jesumirhewe, C., Umeobi, T. N., Owolabi, T. A., Olakojo, O. O., & Adedokun, O. (2022). The proximate analysis, mineral composition, phytochemical screening and antimicrobial activity of ripe and unripe peel extract of *Musa Paradisiaca*. *International Journal of Pharmaceutical and Bio-Medical Science*, 2(8), 280-286.
- Jordan, M., Prasetya, F. X. H., & Harnadi, B. (2022). Greenhouse effect education against climate change through an accelerometer-based android game. *Journal of Business and Technology*, 2(1), 34-41.
- Karagoz, P., Khiawjan, S., Marques, M.P.C., Santzouk, S., Bugg, T. D. H., Lye, G., J. (2023). Pharmaceutical applications of lignin-derived chemicals and lignin-based materials: linking lignin source and processing with clinical indication. *Biomass Conversion Biorefinery*, 14, 26553-26574.
- Liyana, N., L, & Naemaa, M. (2025). Effects of banana peel flour (*Musa paradisiaca* AAB (sub-group *Pisang Nangka*)) substitution on physicochemical and sensory properties of bun. *Food Research*, 8(Suppl. 8), 22-33.
- Lopez, M. J., & Mohiuddin, S. S. (2025). *Biochemistry, Essential Amino Acids*. StatPearls Publishing. Florida
- Mailisa, R., Saputra, A. D., Susanti, E., Wulandari, T., & Agrita, T. W. (2024). Pembuatan brownis krispy on-the-go: inovasi snack ringan program kreativitas mahasiswa. *Journal of Community Development*, 5(2), 305-314.
- Manalu, D. V. E., & Srimati, M. (2020). Pemanfaatan tepung kulit pisang pisang kepok (*Musa paradisiaca* linn) dalam pembuatan cookies. *Binawan Student Journal (BSJ)*, 2(1), 226-230.
- Mas'udah, L., Wijaya, D., Rahmita, N. A., & Rahmawati, U. V. (2023). Review article: high calcium boba from egg shells to prevent stunting and boost the immune system. *Jurnal Sains dan Kesehatan*, 5(2), 218-223.
- Mutyasih, K. J., Permana, I. D. G. M., & Hatiningsih, S. (2023). Pengaruh penambahan bubuk kulit biji kakao (*Theobroma Cacao* L.) terhadap sifat fisikokimia dan organoleptik. *Itepa: Jurnal Ilmu dan Teknologi Pangan*, 12(4), 1095-1113. Ndarubu, T. S., Rosemary, O. N.,

- Gboke, J. A., David, G., Binta, S., Rukiya, Z., & Zungeru, S. I. (2021). Proximate, Minerals, and Amino Acid Compositions of Banana and Plantain Peel. *BIOMED Natural and Applied Science*, 1(1),032-042.
- Oguntoyinbo, O. O., Folarin, M. F. & Kareem, K. O. (2023). Quality evaluation of cookies produced from wheat, unripe plantain flour and green pea flour. *Journal of Agricultural Engineering and Technology (JAET)*, 3,1-16.
- Oladipo, I. Y., Oladipo, A., & Oguntoye, E. (2020). Microbial and nutritional evaluation of biscuits produced from blends of wheat, orange peel, plantain peel and pineapple peel flours. *World Journal of Pharmaceutical and Life Science*, 6(1), 6-15.
- Oyawaluja, A., Oiseoghaede, J., Odukoya, O. A., & Aluka, T. E. (2020). Extraction and estimation of pectins from unripe, ripe and overripe banana (*Musa acuminata* L.) and plantain (*Musa paradisiaca* L.) peel and their antioxidant activities. *Nigerian Journal of Pharmaceutical Research*, 16(1), 87-96.
- Oyeyinka, B. O., & Afolayan, A. J. (2019). Comparative evaluation of the nutritive, mineral, and antinutritive composition of *Musa sinensis* L. (banana) and *Musa paradisiaca* L. (plantain) fruit compartments. *Plants*, 8(12), 598.
- Pebrianti, S. A., & Ilyas, F. M. (2024). Pemanfaatan hasil samping cangkang telur untuk fortifikasi kalsium pada berbagai produk pangan: tinjauan literatur. *Journal of Food and Agricultural Product*, 4(1), 8-18.
- Pérez-Donado, C. E., Pérez-Muñoz, F., & Chávez-Jáuregui, R. N. (2023). Nutritional composition and in vitro digestibility of two plantain cultivars (*Musa paradisiaca* spp.) in Puerto Rico. *Heliyon*, 9(7), e17563.
- Pratama, Y., Ulfah, T., & Bintoro, V. P. (2018). Effect of basil (*Ocimum americanum* L.) proportion on physical and organoleptical properties of basil cracker. *Journal of Applied Food Technology*, 5(1), 1-5.
- Putri, A., Redaputri, A. P., & Rinova, D. (2022). Pemanfaatan limbah kulit pisang sebagai pupuk menuju ekonomi sirkular (UMKM olahan pisang di Indonesia). *Jurnal Pengabdian UMKM*, 1(2), 104-109.
- Quddoos, M. Y., Mahmood, S., Yaqoob, M., Murtaza, M. A., Zahra, S. M., Din, G. M. U., Hussain, A., Rafique, A., Iftikhar, K., & Mustafa, S. (2022). The effects of natural and synthetic calcium utilization on quality parameters of cookies. *Applied Food Research*, 2(1), 100093.
- Raghul, M. (2023). waste valorisation of chicken egg shells and development of formulated biscuits with egg shell waste as a source of dietary calcium. *Journal of Faculty of Food Engineering*, 22(1), 15-21.
- Shahnila, S., Arif, S., Pasha, I., Iftikhar, H., Mehak, F., & Sultana, R. (2022). Effects of eggshell powder supplementation on nutritional and sensory attributes of biscuits. *Czech Journal of Food Science*, 40(1),26-32.
- Sial, T. A., Khan, M. N., Lan, Z., Kumbhar, F., Ying, Z., Zhang, J., Sun, D., & Li, X. (2019). Contrasting effects of banana peel waste and its biochar on greenhouse gas emissions and soil biochemical properties. *Process Safety and Environmental Protection*, 122, 366-377.
- Singh, A., Kelkar, N., Natarajan, K., & Selvaraj, S. (2021). Review on the extraction of calcium supplements from eggshells to combat waste generation and chronic calcium deficiency. *Environmental Science and Pollution Research*, 28, 46985-46998.
- Soewondo, G. A., Basuki, E., & Cicilia, S. (2023). Pengaruh rasio mocaf dan bubur rumput laut (*E. cottonii*) terhadap karakteristik keripik brownies. *Pro Food (Jurnal Ilmu dan Teknologi Pangan)*. 9(2),109-121.

- Subagio, M. A., Salim, C. N., Srisantoso, Q. P., Nindita, Y., Utomo, A. W., & Maharani, N. (2020). Utilization of banana (*Musa paradisiaca* L.) peel as pectin source as antidiarrheal on castor oil-induced diarrheal Wistar rats model. *Journal of the Medical Sciences*, 52(2), 102-107.
- Sugiman, & Suroto, A. (2024). Innovation in processing binahong leaves into crispy bina bite brownies to create small home industry businesses. *An International Journal Tourism and Community Review*, 1(4), 1-9.
- Suryono, S., Perdana, S. M., & Nizori, A. (2024). Nugget processing with addition of egg shell flour in Kotabaru Village, Jambi. *Abdi Masyarakat*, 6(1), 28-32.
- Tan, C. Y., Arifin, N. N. M., & Sabran, M. R. (2024). Banana peel as potential prebiotic and functional ingredient. *Jurnal Gizi Dan Pangan*, 19(Supp.1), 119-126.
- Tazhkira, A., Supriatiningrum, D. N., & Prayitno, S. A. (2020). optimalisasi kandungan zat gizi (protein, lemak, karbohidrat dan serat) dan daya terima cookies dengan penambahan tepung kulit pisang raja. *Ghidza Media Journal*, 2(1), 137-146.
- Therdthai, N., Soontrunnarudrungsri, A., & Khotchai, W. (2023). Modified eggshell powder using thermal treatment and its application in Ca-fortified dog biscuits. *Heliyon*, 9(2), e13093.
- Tuhumury, N. C., Sahetapy, J. M. F., Matakupan, J., & Rijoly, S. M. A. (2024). Processing banana peel organic waste in tourism areas as an effort to control aquatic environmental pollution. *Jurnal Ilmiah PLATAX*, 12(1), 400-407.
- Uzairu, S. M., & Kano, M. A. (2021). Assessment of phytochemical and mineral composition of unripe and ripe plantain (*Musa paradisiaca*) peel. *African Journal of Food Science*, 15(3), 107-112.
- Wagner, C. E., Richter, J. K., Ikuse, M., & Ganjyal, G. M. (2024). Classification of select functional dietary fiber ingredients based on quantitative properties and latent qualitative criteria. *Journal of Food Science*, 89(10), 6098-6112.
- Wani, K. M., & Dhanya, M. (2025). Unlocking the potential of banana peel bioactives: extraction methods, benefits, and industrial applications, *Discover Food*, 5(8).
- Xie, J., Zhang, Y., Klomklao, S., & Simpson, B. K. (2023). Pectin from plantain peel: green recovery for transformation into reinforced packaging films. *Waste Management*, 161, 225-233.
- Yuliana, P. H., Diwan, A. M., Permatasari, K. D., Lestari, G. D., Hariyanti, R., Puspita, S. E., Nurtiana, W., & Najah, Z. (2021). The Effect of Chicken Eggshell Flour Addition on the Characteristics of Cookies, *Proceedings of the 3rd International Conference on Social Determinants of Health (ICS DH 2021)*, 234-241.
- Zaini, H. M. Roslan, J., Saallah, S., Munsu, E., Sulaiman, N. S., & Pindi, W. (2022). Banana peel as a bioactive ingredient and its potential application in the food industry. *Journal of Functional Foods*, 92(12), 105054.
- Zerek, E., & Ersoy, N. (2022). Determination of some nutritional and quality properties of eggshell powder added cookies. *Journal of Food Measurement and Characterization*, 16, 3315- 3320.

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