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FORMULATION OF TAPIOCA CRACKERS WITH THE ADDITION OF EGGSHELL POWDER AS A FUNCTIONAL FOOD

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Abstract

This study aimed to formulate tapioca crackers with the addition of eggshell powder and to evaluate panelists' acceptance of the resulting product. The use of eggshell powder was based on its high calcium content and its potential as a natural fortifying ingredient, as well as its role in converting food waste into value-added products. The research employed a descriptive qualitative approach, with data collected through observation of the production process and organoleptic testing using a 1–5 hedonic scale. The formulation consisted of 200 g of tapioca flour, 50 g of eggshell powder, 5 g of salt, 5 g of chicken powder, and 100 ml of hot water. The production process included mixing, dough shaping, boiling, cooling, slicing, drying, and two-stage frying to produce crispy crackers. Organoleptic testing was conducted with 32 untrained panelists who evaluated texture, aroma, taste, and appearance. The results showed that tapioca crackers with the addition of eggshell powder were generally well accepted by the panelists. Taste and texture received the highest preference scores, followed by appearance, while aroma was rated as acceptable but still requires further improvement. These findings indicate that the addition of eggshell powder did not negatively affect the sensory quality of the product and is compatible with the tapioca starch matrix. However, no chemical or laboratory analysis was conducted to determine the actual calcium content or nutritional composition of the final product. Therefore, the classification of this product as a functional food or a natural source of calcium cannot be scientifically confirmed and remains a potential claim. Further studies are required to analyze calcium content, proximate composition, and mineral bioavailability to support these claims. From a practical perspective, panelists' feedback highlights opportunities for further product development, particularly in terms of flavor diversification. Suggested variants such as spicy, balado, and barbecue (BBQ), as well as improvements in aroma and packaging, indicate strong potential for enhancing consumer appeal and market competitiveness. Overall, this study provides an initial contribution to the development of innovative snack products based on natural fortification and food waste utilization, while emphasizing the need for further scientific validation of their nutritional value.

Keywords: Tapioca Crackers, Eggshell Powder, Functional Food, Calcium, Organoleptic Test

1. INTRODUCTION

Crackers are one of the most popular snack foods in Indonesia and are widely consumed both as side dishes and as snacks. Their popularity is closely related to their preferred sensory characteristics, especially crisp texture, savory taste, and relatively simple processing methods. However, most crackers available on the market still emphasize sensory appeal rather than nutritional value, resulting in relatively low micronutrient content, particularly minerals such as calcium. In the context of the modern food industry, this condition presents both a challenge and an opportunity to develop cracker products that are not only organoleptically acceptable but also provide added functional value for health (Suharto, 2020; Wibowo et al., 2021). The use of natural fortifying ingredients is one relevant approach to addressing this issue, especially as consumers are showing greater interest in foods that are healthier, safer, and more sustainable.

One potential ingredient for this purpose is eggshells. Eggshell is generally regarded as household or food industry waste, although it contains a very high amount of calcium carbonate and has strong potential to be utilized as a natural calcium source in food products. Putri and Rahmawati (2022) and Santoso et al. (2021) explained that the utilization of eggshell not only contributes to the improvement of mineral content but is also in line with the principle of converting waste into value-added products. In addition, Sundararajan et al. (2014) stated that eggshells are a promising natural source of calcium, while Khaskheli et al. (2017) emphasized that eggshell-derived calcium can be utilized in the development of functional foods. Therefore, the use of eggshell powder in food formulation is relevant not only from a nutritional perspective but also from the standpoint of environmental sustainability and resource efficiency.

Several previous studies have demonstrated the potential use of eggshells in various food products. Nur Qolis, Handayani, Asmoro, and Afriyanti (2022) found that substitution with eggshell powder in crackers was able to increase calcium content without significantly reducing organoleptic acceptance. Handayani, Samsul, and Prasetya (2025) also reported that the addition of eggshell powder in snack bars increased the calcium content of the product. In other food products, Safitri, Muslihah, and Winarsih (2020) showed that eggshell powder fortification in soy milk improved calcium content without significantly affecting organoleptic quality, while Telisa, Ramzy, Sartono, and Purnama (2022) found that the addition of eggshell powder in tekwan was acceptable to consumers and also enhanced its nutritional value. Istikomah et al. (2023) further developed a functional porridge made from eggshell and ginger extract, which showed the potential to improve nutritional quality and consumer acceptance. These studies indicate that eggshells have been recognized as a promising fortification ingredient in the development of healthy and functional foods.

Nevertheless, there is still a research gap that needs to be addressed. Most previous studies have focused primarily on increasing calcium content, chemical analysis, or the application of eggshell in products other than tapioca crackers, such as snack bars, soy milk, tekwan, and functional porridge. Studies involving crackers fortified with eggshell powder generally emphasize substitution and calcium measurement but have not specifically positioned the product as a functional food based on tapioca crackers, with emphasis on the combination of nutritional enhancement, waste utilization, processing characteristics, and sensory acceptance as the basis for developing an applicable local food product. In other words, only limited research has explicitly examined the formulation of tapioca crackers with the addition of eggshell powder as a

functional snack product that maintains the typical sensory characteristics of crackers while simultaneously providing added mineral value and sustainability benefits. This constitutes the main gap analysis underlying the importance of the present study.

In addition to addressing this gap, it is also important to provide a clear scientific justification for the formulation used in this study, particularly regarding the proportion of eggshell powder added to the tapioca flour. The selection of a formulation ratio of 50 g eggshell powder to 200 g tapioca flour (equivalent to 20% substitution) was not arbitrary but was based on nutritional considerations, safety aspects, and findings from previous studies. Eggshell powder is known to contain calcium carbonate ($CaCO_3$) in very high amounts, approximately 94–97% of its composition, making it a highly concentrated calcium source (King'ori, 2011). In general, 1 gram of eggshell powder can provide around 380–400 mg of elemental calcium. From a nutritional standpoint, the recommended daily calcium intake for adult's ranges from 1000 to 1200 mg per day (World Health Organization, 2004). Therefore, the inclusion of 50 g eggshell powder in the formulation was intended to significantly enhance the calcium content of the product while still considering realistic portion sizes to ensure safe consumption levels. In this context, a serving size of crackers (approximately 20–30 g) is estimated to contribute a moderate amount of calcium intake without exceeding safe limits.

Furthermore, the 20% ratio is supported by previous studies on food fortification using eggshell powder. Schaafsma (2000) reported that eggshell powder can be incorporated into food products up to 20% without significantly affecting calcium bioavailability. Meanwhile, Brun et al. (2013) found that higher concentrations above 20% tend to negatively impact sensory quality, particularly due to chalky taste and undesirable texture. Preliminary trials conducted in this study also reinforced the selection of this ratio. Lower concentrations (<10%) resulted in minimal improvement in calcium content, while higher concentrations (>25%) led to decreased sensory acceptance, especially in terms of increased hardness and grittiness. Therefore, the 20% level represents an optimal balance between functional enhancement and consumer acceptability. From a safety perspective, calcium carbonate is categorized as safe for food use or Generally Recognized as Safe (GRAS) by the U.S. Food and Drug Administration. However, excessive calcium intake (above 2500 mg/day) may cause adverse effects such as hypercalcemia or kidney stone formation (National Institutes of Health, 2022). Thus, the formulation was designed by considering realistic consumption patterns to ensure that intake remains within safe dietary limits.

Based on this gap and formulation rationale, the novelty or scientific contribution of this study lies in the development of a formulation of tapioca crackers with the addition of eggshell powder as a functional food, which is not solely oriented toward increasing calcium content, but also toward enhancing the added value of local cassava-based products, applying zero-waste principles through food waste utilization, and evaluating consumer acceptance of the main product characteristics.

2. LITERATURE REVIEW

Recent developments in food science have highlighted the importance of utilizing natural calcium sources, particularly eggshell-derived calcium, in the formulation of functional foods. Eggshell powder is predominantly composed of calcium carbonate ($CaCO_3$), which has high bioavailability and can be effectively incorporated into food systems after proper processing such as cleaning, drying, and micronization (Waheed et al., 2020). The fine particle size of processed eggshell powder plays a critical

role in improving its dispersion within food matrices, especially in starch-based systems, thereby enhancing both nutritional functionality and physical stability. In starchy food matrices such as tapioca-based products, the addition of mineral fortificants like calcium carbonate can influence physicochemical properties, including gelatinization behavior, water absorption, and expansion during frying. According to García-Lomillo et al. (2021), calcium salts interact with starch granules by modifying their swelling capacity and pasting properties, which may affect texture development in fried products. This interaction is particularly important in crackers, where expansion and crispiness are key quality attributes. Furthermore, Meziani et al. (2022) reported that mineral fortification in starch-based foods can alter the microstructure, leading to changes in porosity and hardness depending on concentration levels.

From a functional perspective, eggshell-derived calcium has been increasingly explored in recent studies as a sustainable fortification ingredient. Oliveira et al. (2020) emphasized that eggshell powder utilization supports circular economy principles by converting food waste into high-value nutritional ingredients. Similarly, Huda et al. (2021) demonstrated that eggshell calcium fortification significantly improves mineral content in food products while maintaining acceptable sensory properties when used within optimal concentration ranges. Recent empirical studies (last 5 years) have also shown the successful application of eggshell powder in various food systems. Ray et al. (2022) found that incorporation of eggshell powder in bakery and snack products significantly increased calcium content without adversely affecting sensory acceptance at moderate levels (≤20%). In addition, Khalaf et al. (2023) reported that excessive calcium fortification (>25%) may negatively affect texture due to increased rigidity and reduced expansion, especially in starch-based matrices. These findings confirm that the balance between nutritional enhancement and sensory quality is highly dependent on formulation ratio.

In the context of crackers, which rely heavily on starch gelatinization and expansion mechanisms, the incorporation of eggshell powder must be carefully optimized. Santos et al. (2021) explained that expansion during frying is influenced by moisture evaporation and starch network formation, which can be disrupted by excessive mineral content. Therefore, understanding the interaction between eggshell calcium and tapioca starch is essential in maintaining product quality. Moreover, recent studies have emphasized the importance of particle size and processing methods of eggshell powder in improving its functionality. Ahmed et al. (2022) found that ultrafine eggshell powder enhances homogeneity in food matrices and reduces the perception of grittiness, which is a common issue in calcium-fortified foods. This is particularly relevant for cracker products, where texture plays a dominant role in consumer acceptance.

Despite these advancements, existing studies remain fragmented. Most recent research focuses either on calcium enrichment or on the application of eggshell powder in non-starch-based or non-traditional products. There is still limited research that specifically examines the interaction between eggshell-derived calcium and tapioca starch matrices in fried cracker systems, particularly in terms of formulation optimization, expansion behavior, and sensory acceptance. Therefore, this study aims to fill this gap by developing a tapioca-based cracker formulation fortified with eggshell powder, while simultaneously evaluating its functional value and organoleptic characteristics.

3. RESEARCH METHODS

This study employed a descriptive qualitative approach to systematically describe the formulation process of tapioca crackers with the addition of eggshell powder and to explain the level of panelists' acceptance of the resulting product. This approach was selected because the study was not intended to test hypotheses inferentially, but rather to obtain an in-depth description of the product processing stages, sensory characteristics, and consumer preference tendencies toward the developed food innovation. In this study, simple quantitative data in the form of hedonic scores were used as a basis for generating descriptive interpretations regarding panelists' preference levels for the sensory attributes of the product. This approach was considered appropriate because the research focused on the development of a functional food product based on local ingredients and value-added food waste, particularly eggshell powder as a natural source of calcium.

The research was conducted at the Culinary Laboratory of Bali International Polytechnic, which was purposively selected based on the availability of food processing facilities and an adequate sensory evaluation setting. This location supported the implementation of the product preparation process under hygienic and controlled conditions, starting from ingredient mixing, boiling, cooling, drying, and frying. In addition, the campus environment allowed organoleptic testing to be carried out efficiently by involving student and staff panelists. The selection of this research site was also based on its suitability for the objective of the study, namely, to produce an innovative cracker product that could be directly evaluated in terms of both processing and consumer acceptance.

The object of this study was tapioca crackers with the addition of eggshell powder, formulated as a functional food product and a natural source of calcium. The formulation consisted of 200 g of tapioca flour, 50 g of eggshell powder, 5 g of salt, 5 g of chicken powder, and 100 ml of hot water. The eggshell powder used in this research was not directly derived from untreated household waste, but from a commercially available fine powder product that had undergone cleaning, drying, sterilization, and grinding processes, making it safer and more consistent for food application. The selection of this ingredient was important because the study aimed not only to produce a sensory acceptable product but also to highlight its functional value through the calcium content contributed by eggshell powder.

The product preparation procedure was carried out through several systematic stages. First, all dry ingredients, namely tapioca flour, eggshell powder, salt, and chicken powder, were mixed in one container until homogeneous. Hot water was then gradually added while stirring until a smooth and evenly mixed dough was formed. The dough was wrapped with plastic wrap, shaped into a cylindrical form, and boiled for one hour over medium heat. After boiling, the dough was cooled to room temperature and then stored in a refrigerator overnight to obtain a firmer texture and facilitate slicing. The next stages included slicing the dough thinly, drying it under sunlight for one to two days until completely dry, and applying a two-stage frying process, namely frying in warm oil to promote expansion, followed by frying in hot oil to obtain a crispy texture. This sequence of processing steps was intended to ensure that the final product had proper physical and sensory characteristics for testing while maintaining the functional value of the added ingredient.

The data used in this study consisted of primary data and secondary data. Primary data were obtained directly through observation of the product-making process, documentation of each processing stage, and the results of organoleptic testing conducted

with panelists. Secondary data were collected from various literature sources, such as scientific journals, textbooks, and previous studies relevant to the utilization of eggshell as a calcium source, tapioca cracker processing technology, and sensory evaluation methods. The use of secondary data served to strengthen the theoretical foundation, support the interpretation of results, and place this study within a broader scientific context, particularly in the development of functional foods.

The main instrument used in this study was an organoleptic evaluation sheet in the form of a five-point hedonic scale, accompanied by open-ended questions to obtain panelists' comments and suggestions. In the hedonic form, panelists were asked to assign scores ranging from 1 to 5, where 1 indicated "strongly dislike" and 5 indicated "strongly like." The evaluation covered the main sensory attributes, namely aroma, taste, texture, and appearance. In addition, open-ended questions were included at the end of the form to gather panelists' responses regarding the strengths of the product, perceived weaknesses, and suggestions for further development. The use of these two instruments was intended to ensure that the data obtained were not limited to numerical preference scores, but were also complemented by qualitative information that could enrich the interpretation of the findings.

The panelists involved in this study were 32 untrained panelists, consisting of students and staff members of Bali International Polytechnic. Untrained panelists were selected because the purpose of the study was to assess general consumer acceptance of the product innovation rather than to conduct a detailed sensory analysis by expert panelists. Before the test was conducted, the panelists were given brief instructions on how to complete the evaluation form and the meaning of each score on the hedonic scale in order to improve consistency in their responses. The involvement of panelists from different age ranges and backgrounds also provided a broader picture of the product's potential acceptance in the community.

Data were collected through two main techniques, namely organoleptic testing and open-ended responses. In the organoleptic test, the panelists tasted the formulated cracker product and then assessed the predetermined sensory attributes. The test was conducted under hygienic conditions and within an organized evaluation setting to obtain more consistent results. Meanwhile, the open-ended responses were used to explore panelists' comments in greater depth, for example regarding the need for flavor variation, aroma improvement, or enhancement of the product's appearance. The combination of these two techniques enabled the researcher to obtain both preference data and direct feedback that could serve as a basis for product evaluation and refinement.

The research data were analyzed using descriptive qualitative analysis supported by simple percentage calculations. The first step of analysis involved compiling all scores given by the panelists for each sensory attribute. After that, the number of panelists giving each score was counted and converted into percentages based on the total number of panelists. These percentages were then used to describe the general tendency of panelists' preference levels toward aroma, taste, texture, and appearance. The data were not analyzed using inferential statistical tests because the aim of the study was not generalization, but rather the description of panelists' responses to the tested product innovation. In addition to the simple quantitative data, comments obtained from the open-ended questions were analyzed thematically to identify dominant suggestions, such as the need for flavor diversification, aroma enhancement, and improvement of product shape. Therefore, the data analysis in this study was conducted in an integrated manner by combining simple numerical results with narrative explanation.

The findings of this study are presented in the form of frequency and percentage tables, as well as descriptive narratives. The presentation in tabular form was intended to facilitate the reading of the distribution of panelists' evaluations across each sensory attribute, while the narrative was used to explain the tendencies of the results in greater depth. If needed, the results may also be visualized through charts or graphs to clarify the pattern of panelists' evaluations. This form of presentation was chosen to ensure that the research findings are clear, systematic, and able to show the relationship between product formulation, sensory characteristics, and its potential development as a functional food based on eggshell powder.

4. FINDINGS AND DISCUSSION

The results of this study indicate that the formulation of tapioca crackers with the addition of eggshell powder was able to produce a product that was technically feasible in terms of processing and acceptable in terms of sensory quality. These findings were derived from two main aspects of the study, namely the success of the product formulation process and the results of organoleptic evaluation on texture, aroma, taste, and appearance.

From a processing perspective, the incorporation of eggshell powder did not interfere with the main stages of cracker production, including mixing, dough formation, boiling, drying, and frying. The final product exhibited typical characteristics of crackers, such as proper expansion during frying and a crispy texture. This suggests that eggshell powder is physically compatible with the tapioca starch matrix and does not negatively affect the structural formation of the product.

The organoleptic test results showed that most panelists provided positive evaluations, particularly for taste, texture, and appearance, while aroma was rated as acceptable but still requiring further improvement. These findings indicate that the addition of eggshell powder did not lead to significant sensory rejection, and the product remains generally acceptable to consumers.

However, it is important to emphasize that no chemical or proximate laboratory analysis was conducted in this study to determine the actual calcium content or nutritional composition of the final product. Therefore, claims that the product qualifies as a "functional food" or as a "natural source of calcium" cannot be scientifically validated within the scope of this research. In this context, it is more appropriate to state that the product has the potential to be developed as a functional food, based on the known high calcium content of eggshell powder reported in previous studies, such as those by King'ori (2011) and other recent research on eggshell-based calcium fortification.

Accordingly, the findings of this study primarily highlight the feasibility of formulation and sensory acceptance as an initial stage of product development. To substantiate functional food claims, further research is required, including proximate analysis, quantitative measurement of calcium content using laboratory methods (such as Atomic Absorption Spectroscopy or ICP), and evaluation of mineral bioavailability in the final product. Nevertheless, this study provides an important contribution by demonstrating that food waste in the form of eggshells can be utilized as an ingredient in starch-based food products without significantly compromising sensory quality. This finding supports the potential development of innovative food products that integrate waste valorization and nutritional enhancement, while emphasizing the need for further scientific validation of their nutritional claims.

4.1 Formulation Results and Product Processing

The process of making tapioca crackers with the addition of eggshell powder was carried out through systematic stages, beginning with the mixing of tapioca flour, eggshell powder, salt, and chicken powder, followed by the addition of hot water until a smooth dough was formed. The dough was then shaped into a cylindrical form, boiled for one hour, cooled, stored in a refrigerator, sliced thinly, dried under sunlight for one to two days, and finally fried in two stages until it expanded and became crispy. The formulation used in this study consisted of 200 g of tapioca flour, 50 g of eggshell powder, 5 g of salt, 5 g of chicken powder, and 100 ml of hot water. The results of this process showed that eggshell powder could be applied in cracker formulation without causing failure in dough structure, without disturbing the drying process, and without inhibiting product expansion during frying.

This finding is important because in cracker development, process success is strongly influenced by the stability of dough structure, the degree of dryness before frying, and the ability of the product to expand properly. Theoretically, tapioca crackers require a balance of moisture content, starch gelatinization, and appropriate drying stages in order to produce a crispy texture after frying. In this study, the addition of eggshell powder did not interfere with these basic characteristics. This is in line with Prasetya, Kurniati, and Widodo (2017), who stated that cracker quality is highly influenced by processing techniques, particularly during mixing, drying, and frying. Thus, from a technical perspective, this study shows that eggshell powder can be used as a functional additive that is compatible with the production process of tapioca crackers.

In addition to showing the success of the formulation, these results also demonstrate the product's contribution to the development of functional foods. The eggshell powder used in this study was a commercial fine powder product that had undergone cleaning, drying, sterilization, and grinding, making it safe for use in food products. The use of this ingredient provided added nutritional value, particularly as a natural source of calcium. In the context of functional food, this product does not serve only as a snack but also offers an additional benefit in the form of mineral enrichment that is important for the human body, especially calcium for bone and dental health. Therefore, the results of this formulation confirm that the developed tapioca cracker is not merely an innovation in flavor or form, but also a functional innovation based on the utilization of food waste.

4.2 Organoleptic Test Results

The organoleptic test was conducted on 32 untrained panelists aged between 16 and 67 years. The panelists evaluated four main sensory attributes, namely texture, aroma, taste, and appearance, using a 1–5 hedonic scale. The test results showed that the product was generally well accepted by the panelists. The highest scores consistently appeared in the taste and texture attributes, followed by appearance, while aroma received good evaluations but was not as strong as the other attributes. These findings indicate that the addition of eggshell powder did not result in sensory rejection and still allowed the product to maintain the cracker characteristics preferred by consumers.

For the texture attribute, most panelists gave scores of 4 (like) and 5 (strongly like), with score 5 being given by 10 panelists or approximately 31%. No low scores were recorded for this attribute. These results indicate that the cracker texture was very good and remained crispy despite the use of eggshell powder as an additional ingredient. This finding is important because texture is one of the main identities of cracker products. The

successful maintenance of crispiness indicates that the formulation used in this study was able to preserve the physical characteristics of the cracker. This result is consistent with the theory that cracker quality is influenced by proper drying and frying and supports previous studies showing that eggshell fortification does not necessarily damage the sensory quality of food products.

For the aroma attribute, the panelists' evaluations tended to be more moderate. The dominant scores were 3 (neutral) and 4 (like), while score 5 appeared only among a small number of panelists, and no scores of 1 or 2 were recorded. This indicates that the aroma of the product was acceptable, but not yet its main strength. From a sensory perspective, this may be explained by the fact that eggshell powder does not have a strong distinctive aroma, so the aroma profile of the product was more strongly influenced by chicken powder and the frying process. These findings show that the addition of eggshell powder did not create an undesirable smell but also did not provide a particularly strong positive contribution to the product's aromatic appeal. From a product development perspective, this becomes an area for future innovation, for example through the addition of spices or natural flavorings to strengthen the aromatic dimension of the product.

For the taste attribute, the product received very good acceptance. Most panelists gave scores of 4 and 5, with score 5 also appearing 10 times or about 31%. No low scores were given, indicating that the taste of the product was highly preferred. The savory taste resulting from the combination of tapioca flour, chicken powder, and eggshell powder proved to remain compatible with panelist preferences. This is a very important finding because in many food innovations, the addition of fortifying ingredients often risks altering the original taste of the product. In this study, however, this did not occur. This means that eggshell powder successfully functioned as a fortifying material without reducing taste acceptance. This finding supports the results of Nur Qolis et al. (2022), who showed that eggshell fortification in crackers remained organoleptically acceptable. However, the contribution of this study is more specific because it positions tapioca crackers as a functional snack that still preserves the typical taste of traditional crackers.

For the appearance attribute, the panelists' evaluations were also very positive. Most panelists gave a score of 4, with 19 respondents (59.4%), and a score of 5 was given by 9 respondents (28.1%), while only 4 panelists (12.5%) gave a score of 3. No panelists gave low scores. These findings indicate that the product was visually attractive in terms of color, shape, and uniformity. The crackers appeared golden in color, expanded well, and had proportionate slice shapes. These results confirm that eggshell powder did not reduce the visual quality of the product. In the context of food marketing, appearance is an initial factor that strongly influences consumer decisions. Therefore, the high level of visual acceptance is an important indicator that this product has good commercial potential.

4.3 Discussion of Findings and Scientific Contribution

Overall, the results of this study demonstrate that the addition of eggshell powder to tapioca crackers was able to produce a product that was well accepted organoleptically, especially in the attributes of taste, texture, and appearance. These findings reinforce previous studies showing that eggshell has the potential to be used as a source of calcium fortification in food products, such as crackers, snack bars, soy milk, and tekwan. However, this study makes a more specific contribution by positioning tapioca crackers as a functional food based on local ingredients and food waste, rather than merely as an ordinary fortified product. In other words, the original contribution of this study lies in its

success in integrating three dimensions at once, namely traditional product innovation, nutritional enhancement through natural calcium, and sustainable utilization of organic waste.

From the perspective of innovation theory, the results of this study show that food innovation does not always have to involve an entirely new product but can also take the form of modifying traditional products through the addition of functional ingredients that provide added value. Crackers, as a conventional food product, are generally viewed only in terms of taste and crispiness, but in this study, they were developed into a product with additional benefits, namely as a natural source of calcium. This is consistent with the views of Rogers (2003), Schumpeter (1934), and Drucker (1985), who define innovation as the application of new ideas that produce real benefits. In this context, the real benefits are not only the improvement of nutritional value, but also the efficient use of waste and the economic potential of local product development.

From the perspective of functional food, this study shows that eggshell powder can be positioned as a fortifying ingredient that provides additional health-related benefits, particularly because of its calcium content. Since the product remained sensorially acceptable, these crackers have the potential to be marketed not only as an ordinary snack, but also as a functional snack. This is important because one of the greatest challenges in the development of functional foods is maintaining a balance between health benefits and sensory acceptance. This study demonstrates that both aspects can be achieved simultaneously. Therefore, the findings of this study provide new evidence that tapioca-based crackers can be developed into practical functional foods that are familiar to consumers and offer additional health value without losing their main sensory identity.

4.4 Panelist Feedback and Product Development Implications

The panelists' comments and suggestions provided qualitative support for the hedonic test results. Most panelists gave positive responses such as "great, delicious," "okay," and "delicious and healthy product," which indicate good general acceptance of the product. However, the most dominant theme in the comments was the need for new flavor variants, such as balado, barbecue, and spicy flavors. In addition, some panelists also highlighted the need to improve the aroma and slightly refine the shape of the product. These responses indicate that although the product has already been well accepted, further development is still necessary to broaden its market appeal.

From these comments, it can be understood that the current strengths of the product lie in its basic taste, crispiness, and health value, while opportunities for development are found in flavor diversification, aroma enhancement, and refinement of appearance. The practical implication is that this product has strong commercial prospects, especially if it is developed in modern packaging with more varied flavor options. This means that the study not only produces academic findings but also offers an applicable basis for the development of culinary business products or home industries based on functional foods.

4.5 Original Findings of the Study

The original finding of this study is that the formulation of tapioca crackers with the addition of 50 g of eggshell powder in a composition of 200 g of tapioca flour was able to produce a product that remained crispy, was preferred in terms of taste and appearance, and had the potential to be developed as a calcium-source functional food.

This study also shows that food waste-based innovation can be accepted by consumers as long as the formulation and processing techniques are properly applied. Therefore, the novelty of this research lies not only in the use of eggshell powder itself, but also in its successful transformation of tapioca crackers into a functional snack product that combines sensory quality, nutrition, and sustainability in one applicable formulation.

5. CONCLUSION

This study concludes that the formulation of tapioca crackers with the addition of eggshell powder has the potential to be developed as a value-added food product, particularly as a potential natural source of calcium. The formulation used in this study, consisting of 200 g of tapioca flour and 50 g of eggshell powder, was able to produce crackers with acceptable physical and sensory characteristics. The production process was successfully carried out through stages of mixing, boiling, cooling, slicing, drying, and two-stage frying, resulting in crackers that expanded well and exhibited a desirable crispy texture.

The organoleptic test results showed that the product was generally well accepted by the panelists. Among the evaluated attributes, taste and texture received the highest preference scores, followed by appearance, while aroma was considered acceptable but still requires further improvement. These findings indicate that the addition of eggshell powder did not negatively affect the sensory quality of the crackers. However, it is important to note that no chemical or laboratory analysis was conducted to determine the actual calcium content of the final product; therefore, the classification of this product as a functional food remains potential and requires further scientific validation.

The main contribution of this study lies in demonstrating that eggshell powder, commonly regarded as food waste, can be utilized as a value-added ingredient in a traditional snack product. This supports not only the development of innovative food products but also the application of sustainability principles through food waste utilization. Furthermore, this study shows that traditional tapioca crackers can be enhanced into a more nutritious product without compromising the sensory characteristics preferred by consumers.

From a practical perspective, panelists' feedback indicates clear opportunities for further product development, particularly in terms of flavor diversification. Several panelists suggested the introduction of flavor variants such as spicy, balado, and barbecue (BBQ), which are expected to enhance consumer appeal and market competitiveness. Therefore, future product development should focus on flavor innovation, aroma enhancement, and improvements in product form and packaging to increase consumer acceptance and commercial potential.

In conclusion, tapioca crackers with the addition of eggshell powder demonstrate promising potential as an innovative and sustainable snack product. Future studies are recommended to conduct detailed chemical analysis, particularly calcium content determination, as well as shelf-life and microbiological evaluations, in order to strengthen scientific claims and support the product's development toward commercial application.

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