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Development of Oat-Based Fried Pie with Salak Jam Filling as a Healthier Snack

Muhammad Rifky Satria Arianto, Ruwaida Fajriasanti, Muhammad Adieb Hidayatullah

Politeknik Pariwisata Lombok, Indonesia

*Correspondence: E-mail: adieb@ppl.ac.id

ABSTRACT

Pie is one of the most popular pastry dishes worldwide that has undergone extensive innovations. This study aimed to develop a fried pie product incorporating oat flour substitution and snake fruit (salak) jam filling, providing a healthier low-gluten snack alternative while integrating local Indonesian flavors. In addition, the cooking method was modified using an air-frying technique to reduce saturated fat content, which has become the main drawback of deep-frying. The study focused on two main aspects: recipe formulation and consumer acceptance, employing methods that combined the 4D model (define, design, develop, disseminate) with acceptance testing. Findings indicated that the optimal pie crust can be produced using approximately a 4:2:1 ratio of oat flour, butter, and ice water, while the preferred salak jam filling was obtained from a 5:1 ratio of salak fruit to brown sugar powder. Sensory evaluation involving 30 untrained panelists revealed generally positive consumer acceptance, with mean scores of 4.4 (88%) for appearance, 4.2 (84%) for aroma, 4.2 (84%) for texture, and 4.4 (88%) for taste. This study contributes to the literature by presenting a case of healthier snack innovation that combines international pastry traditions with local resources, while also promoting food diversification and adding economic value to salak as Indonesia's indigenous commodity.

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1. INTRODUCTION

Snacking between meals has become a common habit in many parts of the world (Senturk & Cakir, 2023). A study by Bauer (2024) reported an increasing trend of snacking behavior among Generation Z and Millennials over the past decade, with 71% of global consumers eating snacks at least twice per day. In Indonesia, snacks contribute around 20% of the daily intake of adolescents (Dwijayanti & Chao, 2021). These findings highlight the growing significance of snacks in the daily diet, to the point of replacing some portions of the main meals. This phenomenon creates an opportunity for healthier innovations in various popular snack products (Bauer, 2024; Nadhifah & Suhud, 2025; Senturk & Cakir, 2023), including pies.

Pie is a widely recognized pastry product in Europe and the United States, generally prepared with a pastry crust that lines or covers either sweet or savory fillings (Clarkson, 2009; Edge, 2004). The oven-baked method is considered the oldest and most authentic preparation technique, with Clarkson (2009) even asserting that it remains the only acceptable method of cooking pies. However, culinary development has expanded pie-making techniques to include frying. In the United States, especially in the Southern and Midwest regions, fried pies emerged as a practical alternative to baked apple pies, rooted in home cooking traditions that relied on preserved fruits and frying as a more accessible method than oven-baking (Edge, 2004).

In Indonesia, pies are more often consumed as sweet snacks. The Balinese milk pie, for instance, combines Portuguese shortcrust pastry with egg custard filling reminiscent of Hong Kong egg tarts (Anggraeni, 2018). Similarly, nastar, another popular Indonesian cookie, is believed to be an adaptation of a pie—its name derived from the Dutch words *ananas* (*nanas* or pineapple) and *taart* (tart/pie) (Helena & Supartini, 2023; Shafira et al., 2023). More recently, fried pie adaptations from the United States have begun to gain attention, including through the international restaurant chain McDonald's.

Despite its popularity, pie consumption poses certain health challenges, particularly related to the use of wheat flour in the crust. The gluten content in wheat flour may trigger adverse reactions in individuals with celiac disease, gluten intolerance, wheat sensitivity, or autism spectrum disorders. In addition, its high glycemic index can contribute to rapid spikes in blood sugar levels (Finani & Putra, 2023). To address these issues, several studies have explored alternatives to wheat flour in pie production, including cassava flour (Rosyidah & Mulyatiningsih, 2021), potato flour (Rezona & Gusnita, 2021), banana flour (Kartiyani et al., 2022), and jackfruit seed purée (Adelia et al., 2022). Another promising substitute is oat flour, which is rich in beta glucan fiber, vitamins, minerals, and antioxidants, offering benefits for the heart and controlling blood glucose level (Astiz et al., 2022; Juliana et al., 2022).

Beyond the crust, innovations can also be applied to the fillings, such as by using salak (snake fruit) jam. Salak, a tropical indigenous fruit widely grown in Indonesia, is rich in vitamins that support eye and digestive health, regulate blood sugar, and improve skin complexion (Helena & Supartini, 2023). National production is among the highest of various types of fruits, reaching 1.120.739 tons in 2023 (Badan Pusat Statistik, 2024) while regional production in West Nusa Tenggara, though small, has demonstrated an increasing trend in 2020—2024, reaching 458,112 tons in 2024 (Badan Pusat Statistik Nusa Tenggara Barat, 2025). Utilizing salak, especially *salak pondoh* (*Salacca zalacca var pondoh*) as pie fillings promotes local resource use, encourages food diversification, creates economic value, and reduces potential food waste.

This study aims to develop an innovative pie with oat flour crust and salak jam filling as a healthier snack alternative. Frying was chosen as the cooking method to introduce a more

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practical variation of pies, with modifications using an air fryer. Compared to traditional baked pies, fried pies are characterized by a golden, crisp crust with a soft interior, and a warm, sweet filling of fruit and cinnamon with a soft, slightly thick, jam-like texture (Edge, 2004). The use of air-frying is intended not only to reduce saturated fat content which has become the primary concern regarding deep-frying (Zaghi et al., 2019), but also to respond to opportunities for alternative production technologies that enable the development of healthier snack products with promising market potential (Senturk & Cakir, 2023). The product is designed to appeal particularly to Generation Z and Millennials, consumer groups known for their established snacking habits and openness to novel food innovations (Bauer, 2024).

This study focuses on two main problems: (1) recipe formulation and production method, and (2) consumer acceptance. The contribution of this study encompasses the following aspects: (1) offering an alternative food with lower gluten and glycemic index through oat flour substitution; (2) enhancing the economic value of salak as a local commodity to support food diversification; and (3) introducing a healthier food production method through the use of air-fryer. Consumer acceptance was assessed through a sensory evaluation method—specifically, acceptance testing—with findings expected to guide future healthy snack innovations that adapt international dishes and local ingredients.

2. METHODS

2.1. Research Design

This study employed a research and development (R&D) approach using a the 4D model (Define, Design, Develop, Disseminate). The 4D model, introduced by Thiagarajan et al. (1974), provides a structured framework for iterative product development and refinement based on empirical evidence (Indaryanti et al., 2025). In this study, the model was adapted to guide the process of recipe identification, innovation design, trials and validation, and sensory evaluation for the development of a fried pie with oat flour substitution and a local ingredient filling. Unlike similar studies applying the 4D model and sensory evaluation (e.g., Rosyidah & Mulyatiningsih, 2021), the sensory evaluation in this research did not compare the final recipe against the base formulation. Instead, the final product was evaluated independently, in line with the study's primary aim of testing a novel recipe innovation.

2.2. Product Development Process

2.2.1. Define and Design Stage

In the initial stage, literature sources including journal articles, books, research reports, and social media were studied to identify pie characteristics, ingredients, production challenges, cooking methods, and sensory evaluation techniques. Two reference recipes were selected for trials, and the most suitable recipe—determined through experimentation and direct observation—was adopted as the base formulation. Product innovation was then designed from the base formulation, focusing on four key aspects: pie crust, filling, cooking method, and product presentation. The design aimed to produce a healthier fried pie by incorporating s local ingredient and s distinctive aesthetic value (Table 1).

Table 1. Product Innovation Design

No	Aspects	Base Product	Developed Product
1	Pie Crust	Wheat Flour	Oat Flour
2	Filling	Apple	Salak Jam
3	Cooking Method	Deep-Frying	Air-Frying

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No	Aspects	Base Product	Developed Product
4	Presentation	Rectangle, typical of fried pies	Oval, shaped like salak fruit

2.2.2. Develop and Disseminate Stage

A series of trials and refinements were conducted to obtain an appropriate recipe formulation. Validation was carried out through expert judgement involving selected experts, whose feedback informed recipe adjustments until the developed product was deemed feasible. The final, validated product was then disseminated on a wider scale through an acceptance test involving untrained panellists.

2.2.3. Sampling Method

Expert validation involved purposive sampling of three experts (two culinary lecturers and one pastry chef) with proven expertise in pastry and food production. For acceptance testing, panelists selection was conducted following established standards such as SNI 01-2346-2006, ISO 6658:2017, and RSNI3 ISO 8586:2023 (Badan Standardisasi Nasional, 2006, 2024; International Organization for Standardization, 2017). Thirty untrained panelists or naïve sensory assessor—i.e., individuals without prior experience in sensory testing and not classified as selected, trained, or expert sensory assessors—were recruited from the campus community and the surrounding area, representing the Generation Z and Millennials (20-35 years old) group residing in urban Lombok, primarily Mataram and Praya. Inclusion criteria required willingness to participate, the absence of dietary restrictions related to the tested product, and a personal interest in pastry, sweet, or fruit-based goods. Recruitment was conducted through an online questionnaire.

2.2.4. Sensory Evaluation

Consumer acceptance was measured using a five-point hedonic scale adapted from existing standards and previous studies in sensory evaluation (Badan Standardisasi Nasional, 2006; Mihafu et al., 2020) (Table 2). Due to venue limitations, testing was carried out at the panelists' respective locations. To minimize potential bias, the conditions were ensured to be quiet, with adequate lighting and free from distracting odors. Testing was scheduled between 9:00-11:00 or 14:00-17:00, aligning with the intended consumption of the product as a snack between main meals. Each panelist evaluated one product sample served under homogeneous conditions and rated its four sensory attributes in sequence: appearance, aroma, texture, and taste. In this study, appearance is used as a sensory attribute rather than color, as it covers broader attributes including physical form, surface texture, and color itself.

Table 2. Hedonic Scale for Acceptance Testing

Score	Specification
1	Like
2	Like Slightly
3	Neither Like nor Dislike (Neutral)
4	Dislike Slightly
5	Dislike

Source: Badan Standardisasi Nasional (2006); Mihafu et al. (2020)

2.2.5. Data Analysis

A series of trials and refinements were conducted to obtain an appropriate recipe formulation. Validation was carried out through expert judgement involving selected experts, whose feedback informed recipe adjustments until the developed product was deemed feasible. Both expert validation results and panelists' responses were recorded using

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standardized forms. Validation outcomes were analyzed descriptively, and recipe improvements were made based on expert feedback until the optimal formulation was achieved. For acceptance testing, hedonic scores were tabulated as mean values (Equation 1) and converted into percentages (Equation 2):

$$\overline{\boldsymbol{x}} = \frac{\sum_{i=1}^{k} f_i x_i}{\sum_{i=1}^{k} f_i} \qquad (1)$$

$$[\boldsymbol{P} = \left(\frac{\sum x_i f_i}{\boldsymbol{N}}\right) \times \mathbf{20}] \qquad (2)$$

where $\overline{\boldsymbol{x}}$ is the mean, x_i the rating score, and f_i the frequency of each score or the number of panelists who gave the score [1]; and P is the acceptance score in percentage, N the total number of panelists, and 20 the conversion factor from the 1-5 hedonic scale to a 0-100 percentage [2]. P percentages were interpreted as follows: 81-100%=like; 61-80%=like slightly; 41-60%=neither like nor dislike (neutral); 21-40%=dislike slightly; 0-20%=dislike. The scores were analyzed descriptively to provide a detailed insights into the sensory characteristics of the product and the degree of panelists' acceptance across each attribute.

3. RESULTS AND DISCUSSIONS

3.1. Results

The initial procedure in developing the final recipe formulation was to establish a base formula from a previously tested recipe. After two reference recipes were trialed and analyzed, one was selected for further modification. The base formula, adapted from Marie Saba's recipes—a culinary personality and cookbook author—demonstrated desirable fried pie qualities, characterized by a golden brown, crisp, and flaky crust with an adequately sweet filling (Table 3).

Table 3. Base Formulation for Fried Pie

	Recipe Yield	: 10 pcs	
	Portion Size	: 35 g	
No	Ingredient	Quantity	Unit
	Pie Crust:		
1	Wheat Flour	170	g
2	Sugar	12	g
3	Salt	1	g
4	Unsalted Butter	113	g
5	Ice Water	75	g
	Filling:		
1	Apple	400	g
2	Unsalted butter	30	g
3	Sugar	50	g
4	Brown sugar powder	30	g
5	Salt	1.25	g
6	Water	45	g
7	Cinnamon powder	2	g
8	Ground nutmeg	1	g

Source: Saba (2025)

The next phase involved three trials of the modified formula, where wheat flour was replaced with oat flour, apple with salak in the filling, and the cooking method was replaced

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with air-frying. Expert validations were conducted after each trial, and recipe adjustments were made accordingly. In the first trial, the proportions of the original base formula were retained, with no additional ingredients or steps. For the second trial, modifications were made by particularly increasing the proportion of oat flour, eliminating certain ingredients, and adding an egg wash for finishing. This trial yielded a product that was generally well-received by the experts: the appearance was appetizing and unique; the aroma displayed a mild fruity character; the texture was adequate—neither too fragile nor too firm—and the taste demonstrated a balanced profile between crust and filling. Finally, the third trial focused on refining minor aspects of the product. Table 4 details the final recipe formulation and production process, while Figures 1, 2, and 3 present documentations of some of the process. In addition, a comparison of products obtained through each trial is presented in Figure 4-6.

Table 4. Final Recipe Formulation

	Recipe Yield	: 19 pcs	
	Portion Size	: 25 gr	
No	Ingredient	Quantity	Unit
	Pie Crust:		
1	Oat flour	270	g
2	Sugar	15	g
3	Salt	1	g
4	Unsalted butter	113	g
5	Ice water	75	g
	Filling:		g
1	Salak pondoh	400	g
2	Unsalted butter	30	g
3	Brown sugar powder	80	g
4	Salt	2	g
5	Water	45	g
6	Cinnamon powder	2	g
	Egg Wash:		g
1	Egg yolk	15	g
2	Vanilla powder	5	g

Method:

1. Prepare the pastry crust by combining the dry ingredients (oat flour, brown sugar, and salt) with butter in room temperature. Mix until the mixture resembles coarse crumbs.
2. Gradually add ice water, mixing until a smooth dough is formed. Set aside.
3. Prepare the filling by dicing the salak into small pieces (approximately 0.5x0.5 cm) and set aside.
4. In a pan, melt the butter, add the diced salak and sauté until slightly softened.
5. Add brown sugar, salt, water, and ground cinnamon. Stir well, cook until the liquid reduces and the mixture reaches a jam-like consistency.
6. Taste and adjust the seasoning if necessary. Remove from the heat and allow to cool to room temperature.
7. Divide the pastry dough into 25 g portions.
8. Roll out each portion, place the filling in the center, fold the dough over, and shape it to resemble a salak fruit.
9. Repeat until all dough portions are filled. Brush the surface with an egg wash.
10. Air-fry at 150°C for 30 minutes, or until golden brown and fully cooked. Remove and serve.

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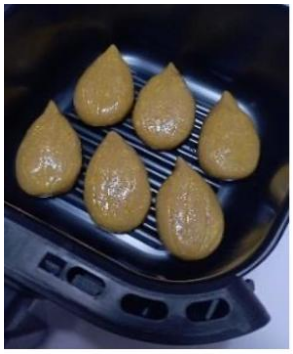
Figures 1 & 2. Filling and Shaping Process



Figures 3. Final Product After Frying

Figures 4 & 5. First and Second Trial Product

Figures 6. Third Trial and Final Product

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The final formulation was subjected to sensory evaluation in the final stage of the research. Prior to acceptance testing, a screening questionnaire was distributed to recruit potential panelists. A total of 42 individuals responded, of whom 85% met the eligibility criteria, including a good health condition, absence of aversion to the product's ingredients, interest in trying the product, and willingness to participate. Ultimately, 30 untrained panelists were selected. The panelists were predominantly students aged 20-35 years old, residing in Praya (Central Lombok) and Mataram, with a balanced distribution of male and female participants. The demographic profile of the panelists is summarized in Table 5.

Table 5. Panelist Demographic Profile

Criteria	Description	Percentage
Gender	• Female	43.8%
	• Male	56.2%
Age	• 20-25 y.o	76.7 %
	• 26-30 y.o	16.7 %
	• 31-35 y.o	6.6 %
Occupation	• Student	68.5%
	• Private sector	15.6%
	• Teacher/lecturer	3.1%
	• Cook	6.3%
	• Nurse	3.1%
	• Freelance	3.1%
Place of Residence	• Central Lombok	60 %
	• Mataram City	40 %

Table 6 presents the results of the acceptance test on four attributes: appearance, aroma, texture, and taste. Overall, the majority of panelists rated the product positively, with 43-53% giving a "like" (score 5) and 27-43% giving a "like slightly" (score 4). Specifically, taste received the strongest preference, with 16 panelists (53,3%) rating it "like" and 9 panelists (30%) rating "like slightly". Appearance and aroma each received 14 "like" responses (46,7%), while texture received 13 (43,3%). Neutral responses were relatively low, ranging between 10-26,7% across all attributes, and importantly, no panelist expressed dislike (score 1-2). The mean scores further confirm this favorable trend, with appearance obtaining mean score of 4,4 (88%), aroma 4,2 (84%), texture 4,2 (84%) and taste 4,4 (88%). These findings are elaborated further in the next discussion sub-section.

Table 6. Acceptance Test Data Tabulation

Score	Specification	Appearance	Aroma	Texture	Taste
5	Like	14	14	13	16
4	Like Slightly	13	8	10	9
3	Neither Like nor Dislike (Neutral)	3	8	7	5
2	Dislike Slightly	0	0	0	0
1	Dislike	0	0	0	0
Total Number of Panelists (N)=		30	30	30	30
Mean Score ($\bar{x}$)=		4.4	4.2	4.2	4.4
Percentage (P)=		88%	84%	84%	88%

Source: Data Analysis (2025)

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3.2. Discussion

The sensory evaluation results indicate that fried pie product with oat flour substitution and salak filling was generally well received by the panelists, with all attributes scoring within the "like slightly" range and corresponding percentages in the "like" category. While this suggests that consumer acceptance is not yet optimal, the findings highlight areas where further refinement and product development may enhance overall appeal.

Appearance and taste emerged as the most influential attributes, underscoring the importance of visual appeal and flavor in shaping consumer perceptions of novel food products. For appearance, the significant visual appeal was partly due to the product's distinctive shape resembling salak fruit, which added its aesthetical value. Previous studies have shown that attractive presentation can enhance consumer taste perception and emotional experience, as visually appealing foods are more likely to be better liked and elicit more positive responses (Uçuk et al., 2025). Similarly, the novelty of salak-like shape contributed to visual distinctiveness and likely reinforced positive impressions (Nishida et al., 2024). The smaller portion size compared to conventional fried pies may also have supported its appeal, aligning to findings that Generation Z consumers prefer healthy snack products with practical, portable, and visually appealing designs (Nadhifah & Suhud, 2025). The use of air-frying technique, which applies hot air circulation with minimal oil, not only reduced fat content but also yielded smoother product surface. This observation corresponds with findings from other experimental products, such as doughnuts and French fries, where air frying produced comparable or improved texture while reducing oil content (Ghaitaranpour et al., 2018; Gouyo et al., 2020). Together, these characteristics contributed to panelists' positive acceptance of the product's appearance.

In terms of taste, the pie offered a balanced flavor profile, combining the sweetness of salak jam with the savory notes from the oat-based crust. Frying oat-based dough has been reported to produce a nutty savory flavor with a mild, distinctive sweetness (Zhang et al., 2023). The filling, made from the salak pondoh variety, provided a naturally dominant sweetness with slight sour and astringent taste (Djaafar et al., 2024; Faizah & Ilyas, 2022). Using local fruit as pie fillings highlights the potential of diversifying pastry products by incorporating local resources, echoing other fruit-based pie innovations such as durian pies and milk pies with dragon fruit (Ananda et al., 2025; Kemalawaty et al., 2025). Furthermore, the decision to retain cinnamon while eliminating nutmeg preserved the familiar spiced flavor typical of pies, while ensuring the distinctive taste of salak to remained prominent. These combined qualities likely explain the relatively higher consumer acceptance for the taste attribute.

Both aroma and texture received slightly lower acceptance, although still within the "like slightly" and "like" categories. For aroma, the fruity note of the salak jam filling was generally perceived as refreshing and contributed positively to the panelists' preference. However, some panelists noted that the distinctive fruit aroma was rather mild, giving the overall aroma a somewhat flat impression. This may explain why panelists' acceptance of aroma was not as strong as appearance and taste, reinforcing previous findings that aroma plays an important role as a key determinant in food preference (Mesurolle et al., 2013). Other studies highlight that strong fruity notes in processed products such as jams can increase sweetness perception, mask undesirable odors, and strengthen overall sensory appeal (Hastuti et al., 2025; Palupi et al., 2021; Xiao et al., 2021). In this case, optimizing the intensity of the salak aroma—whether through formulation adjustments or processing techniques—could help improve overall sensory performance.

Lastly, in terms of texture, the pie offered a combination of a crispy crust and small fruit

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chunks that created a pleasant mouthfeel. The decision not to fully smooth the salak filling, but instead retain small pieces, gave a variation of texture compared to a homogenic, puree-like mixture. This adjustment was made in the second trial and appeared to enhance both expert and panelists' perception of texture. However, the substitution of oat flour contributed to a denser and more fibrous crust compared to conventional wheat flour, since oat flour tends to absorb more liquid and yields a firmer structure (Astiz et al., 2022; Wei et al., 2024). To achieve the desired form and texture, a greater proportion of oat flour (270 grams) was also required compared to the amount of wheat flour in the original base formulation (170 grams). While this characteristic may have limited panelists' acceptance of the texture attribute, it also highlights the nutritional advantages of oat flour, which contains higher levels of protein and dietary fiber (Astiz et al., 2022; Krochmal-Marczak et al., 2020). Balancing these sensory trade-offs with nutritional benefits remains an important consideration for future product refinement.

4. CONCLUSIONS

This study demonstrated that fried pies with oat flour-based crust can be formulated using three principal ingredients—oat flour, butter, and ice water—in a proportion of 270 grams, 113 grams, and 75 grams, respectively, which corresponds to a 3,6:1,5:1 ratio (or approximately 4:2:1). The filling, prepared from salak pondoh, butter, brown sugar, salt, water, and cinnamon, achieved an optimal fruit-to-sugar proportion of 400 grams and 80 grams, or a 5:1 ratio. Sensory evaluation with 30 untrained panelists indicated an overall acceptance level between "slightly like" and "like" categories, with appearance and taste emerging as the dominant attributes. The salak-like appearance and the air-frying method contributed to the visual appeal of the product, while the combination of sweet salak jam and savory oat-based crust provided a balanced flavor. These two attributes can serve as focal points for product development and marketing strategies, while also reinforcing the potential for the use of local ingredients in the diversification of internationally-inspired snack products.

The findings strengthen the literature on local resource utilization in food product innovation and fusion cuisine by demonstrating how visual appeal and flavor balance shape consumer acceptance. They also extend research on cereal-based substitutions in pastry products, showing that full substitution using oat flour is technically feasible within a fried-pie format. Furthermore, the use of air-frying as the cooking method broadens knowledge of healthier preparation alternative for snack products without compromising the baseline qualities necessary for positive consumer acceptance.

This study, however, is not without limitations. The sensory evaluation relied on a relatively small sample of untrained panelists, which may limit the generalizability of the findings. The testing environment was also not fully controlled due to laboratory constraints, which may have introduced bias. Moreover, the study did not quantify compositional or process-related outcomes (e.g., fat uptake, moisture loss, or texture parameters), did not provide nutritional analysis, did not compare air-frying with conventional methods such as deep-frying or oven-baking, and did not assess shelf life, packaging performance, or scalability.

Future research is therefore recommended to explore these areas. Studies involving larger and more diverse consumer groups, compositional and nutritional profiling, and controlled comparisons across different cooking methods would strengthen the understanding of both sensory and health-related characteristics. Investigating shelf life, product packaging, and industrial scale production would also help determine commercial feasibility. Such efforts will provide a more comprehensive and robust understanding of how snack products based on oat substitution and local fruits like salak pondoh can represent healthier innovations that align

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with both evolving market preferences and contemporary healthy lifestyle initiatives.

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