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Comparison of the sensory and physical quality of sand baking and conventionally grilled mackerel

Perbandingan kualitas sensorik dan fisik ikan kembung hasil sand baking dan pemanggangan konvensional

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Abstract

Food processing plays a critical role in maintaining food quality and safety. However, scientific information regarding the effectiveness of sand baking as an alternative cooking technique remains limited, particularly in the context of marine fish. This study aimed to compare the sensory and physical qualities of mackerel processed using sand baking and conventional grilling. This study was conducted from January to September 2025 using a laboratory experimental design. Twenty fish were divided into two treatment groups. Sensory evaluation was performed by three trained panelists using hedonic and hedonic quality tests to assess the samples. The physical analyses included measurements of the moisture content and texture. Data were compared using independent t-tests. The results showed that The sensory scores for both methods were categorized as good, with no significant differences in taste ($p = 0.742$), aroma ($p = 0.423$), texture ($p = 0.423$), or color ($p = 0.423$). The physical parameters were also comparable between the two treatments. In conclusion, sand baking can produce organoleptic and physical qualities equivalent to those achieved through conventional grilling. This technique has the potential to be an applicable and efficient alternative fish processing method for community use.

Keywords: Mackerel, physical quality, sand baking, sensory quality,

Abstrak

Pengolahan makanan merupakan proses penting untuk menjaga mutu dan keamanan pangan. Namun, informasi ilmiah mengenai efektivitas sand baking sebagai teknik pemasakan alternatif masih terbatas, khususnya dalam pengolahan ikan laut. Penelitian ini bertujuan membandingkan kualitas sensorik dan fisik ikan kembung yang diolah menggunakan metode sand baking dan pemanggangan konvensional. Penelitian ini dilakukan pada Januari–September 2025 dengan desain eksperimen laboratorium. Sebanyak 20 ekor ikan dibagi menjadi dua kelompok perlakuan, dan penilaian sensorik dilakukan oleh tiga panelis terlatih melalui uji hedonik dan mutu hedonik. Analisis fisik meliputi kadar air dan tekstur. Data dibandingkan menggunakan uji Independent t-test. Hasil penelitian menunjukkan bahwa skor sensorik kedua metode berada pada kategori baik, dan tidak ditemukan perbedaan bermakna pada aspek rasa ($p= 0,742$), aroma ($p= 0,423$), tekstur ($p= 0,423$), dan warna ($p= 0,423$). Parameter fisik juga menunjukkan nilai yang sebanding antara kedua perlakuan. Kesimpulan, sand baking mampu menghasilkan mutu organoleptik dan fisik yang setara dengan metode pemanggangan konvensional. Teknik ini berpotensi digunakan sebagai alternatif pengolahan ikan yang aplikatif dan efisien bagi masyarakat.

Kata Kunci: Ikan kembung, kualitas sensorik, mutu fisik, sand baking

Introduction

Cooking involves applying heat to food ingredients, resulting in changes in texture, flavor, and safety for consumption (Rini & Luthfiah, 2024). Traditional cooking techniques continue to evolve, including baking practices that utilize natural heat sources and are still in use today (Lubis et al., 2018; Kora, 2019). One such traditional technique is sand baking, which uses heated sand as the primary heat transfer medium. Although initially developed for simple community needs, sand baking has gained increasing attention because it can produce food with unique sensory characteristics and does not require the use of oil (Maulana, 2021; Mohtar et al., 2024). This issue is particularly relevant in Indonesia, a country with a large population and substantial food demand, especially in meeting protein requirements for a balanced diet.

Conversely, the use of cooking oil presents several challenges, including its inadequate supply relative to demand, often resulting in fluctuating prices, as well as potential negative health impacts associated with excessive consumption. Additionally, the common practice of repeatedly using cooking oil poses food safety risks (Rachim et al., 2019). With rising household expenditures on energy, time, and costs due to the reduced availability and affordability of biomass resources, the need for more efficient, healthy, and cost-effective cooking methods has become increasingly urgent (Wondimagegn et al., 2023).

Given this need, the selection of nutrient-dense foods has become increasingly important (Sharma & Gujral, 2011). Marine fish are a valuable food source, as they are rich in protein, widely accessible, and generally healthier than other high-fat animal products (Astiana et al., 2025). Marine fish are a key biological resource for meeting community protein needs, particularly in coastal and island regions (Nurilmala et al., 2015).

Mackerel (*Rastrelliger sp.*) is an important fish commodity in many coastal areas of Indonesia, including the Riau Islands, because of its high nutritional content and year-round availability (Astiana et al., 2025; Rini, Saputra, et al., 2025). The sensory quality of fish is strongly influenced by its processing method; thus, selecting an appropriate cooking technique is essential for maintaining the quality of fish consumed by the community (Oppong et al., 2021).

Various fish processing methods, ranging from traditional to modern, have been developed to enhance flavor, prolong shelf life, and preserve nutritional value (Prastyo & Mahmudi, 2020). Several reports indicate that sand baking produces distinct aroma, texture, and taste profiles compared to conventional baking methods (Duan et al., 2018; Sari & Irianto, 2023). However, these findings vary and lack support from systematic comparative sensory studies, indicating a research gap in this area.

Conventional cooking methods remain widely practiced because of their practicality; however, these methods can result in variations in the physical and sensory qualities of fish, including tenderness, color, and moisture content (Rini, Kurniawan, et al., 2025). Therefore, scientific evaluation is needed to compare the characteristics of fish processed using sand baking and conventional methods, particularly through sensory and physical analyses, to identify the strengths and limitations of each technique (Oppong et al., 2021).

Furthermore, few studies have examined the differences in the physical quality of fish, such as moisture content and texture, between these two cooking techniques. Therefore, comprehensive research is required to address this gap. This study is novel in its simultaneous evaluation of traditional and conventional cooking methods through both sensory (hedonic and hedonic quality) and physical analyses, providing a more comprehensive understanding of the final quality of processed fish products.

Based on this background, the objectives of the present study are twofold: (1) to compare panelists' preferences for mackerel processed using sand baking and conventional baking and (2) to evaluate the sensory and physical qualities of fish produced by these two processing methods.

Methods

This study employed a laboratory experimental design with a comparative approach to evaluate the sensory and physical qualities of marine fish processed using the sand baking method and a conventional cooking method. The research was conducted from January to September 2025 at the Culinary Laboratory of Batam Tourism Polytechnic, Riau Islands Province.

A total of 20 mackerel (*Rastrelliger sp.*) were purposively selected based on freshness, relatively homogeneous weight (±250 g), and intact physical conditions. The fish were divided into two treatment groups: sand-baking and conventional grilling, with 10 fish assigned to each group. Sand baking involved burying the fish in hot sand at approximately 180°C for 20 min, whereas the conventional method involved charcoal grilling at the same temperature and duration.

Sensory evaluation was conducted by three trained panelists using hedonic testing (scale of 1–5) and hedonic quality assessment, which included a descriptive evaluation of color, aroma, taste, and texture. Physical analyses included the measurement of moisture content using the oven-drying gravimetric method, texture testing using a standardized manual compression technique with three repetitions, and visual color assessment based on established sensory standards.

All sensory and physical test data were first assessed for homogeneity to ensure consistency between the samples. Descriptive statistics, including the mean, standard deviation, and frequency distribution, were used to summarize the data. An independent t-test was applied to compare the mean values between the two groups for each parameter, with a significance level of $\alpha = 0.05$.

This study was approved by the Ethics Committee of the Research and Community Service Center of the Batam Tourism Polytechnic (number: 045/S-KL/PUSLITABMAS/BTP/IV/2025). Written informed consent was obtained from all the panelists prior to participation.

Result and Discussion

Hedonic Test Results

Table 1 presents the average hedonic scores for taste, aroma, texture, and color, along with the corresponding statistical values for both processing methods.

Table 1. Average hedonic scores for taste, aroma, texture, and color of seafood products processed using the sand baking and conventional methods

Hedonic Test Aspect	Conventional Method (H0)	Sand Baking Method (H1)	Mean Difference	t-value	p-value
Taste	4.33	4.00	0.33	0.378	0.742
Aroma	3.67	4.00	0.33	-1.000	0.423
Texture	4.67	4.33	0.34	0.378	0.742
Color	4.00	4.33	0.33	-1.000	0.423

The hedonic test results (Table 1) indicated that there were no significant differences in the panelists' preferences for taste, aroma, texture, or color between the fish processed using sand baking and those processed using the conventional method ($p > 0.05$ for all attributes). Both methods yielded scores within the "good" range, with only minor variations of 0.33–0.34. These findings suggest that both processing methods produce comparable organoleptic qualities.

These results align with international research demonstrating that sensory evaluation is a reliable tool for assessing food product quality and acceptance. Minor variations in hedonic scores are commonly not statistically significant when trained panelists and standardized methodologies are used (Gil et al., 2022; Shahandasht et al., 2024). The findings of this study support previous work, indicating that innovative processing methods for fish can maintain desirable sensory attributes (Lamont & McSweeney, 2020; Tahir et al., 2020).

The differences noted between this study and others particularly those reporting texture changes resulting from natural additives may be driven by variations in interventions, panelist demographics, and processing conditions (Xu et al., 2020; Yang et al., 2019). Sensory evaluations are inherently subjective, and such variability among panelists must be considered during data interpretation (Giri et al., 2023; Patterson et al., 2022).

The organoleptic equivalence observed between the two methods may be attributed to the similar temperature and cooking duration (approximately 180°C for 20 min). Controlling the time and temperature is essential for preserving the volatile compounds responsible for aroma and flavor. Sand baking, which applies

even heat distribution through hot sand, may help preserve both the physical and sensory characteristics of fish, which is consistent with previous studies (Moss & McSweeney, 2021; Tirtawijaya et al., 2020).

In addition to matching the sensory outcomes of conventional grilling, sand baking offers additional benefits for the fish processing industry, particularly in terms of efficiency and sustainability. The results of this study suggest that sand baking is a feasible alternative for both household and industrial-scale fish processing, providing an innovative option that requires minimal equipment while maintaining an acceptable sensory quality for consumers. The adoption of this method could support sustainable food production based on local resources and contribute to the diversification of seafood-processing techniques in coastal and urban communities.

Hedonic Quality Test Results

Table 2 presents the descriptive hedonic quality scores, including the t-values and p-values for each attribute.

Table 2. Average hedonic quality scores for taste, aroma, texture, and color of seafood products processed using the sand baking and conventional methods

Hedonic Test Aspect	Conventional Method (H0)	Sand Baking Method (H1)	Mean Difference	t-value	p-value
Taste	4.67	4.33	0.34	1.000	0.423
Aroma	3.67	3.33	0.34	0.500	0.667
Texture	4.67	4.33	0.34	1.000	0.423
Color	4.33	4.67	0.34	1,000	0.423

The hedonic quality test results (Table 2) similarly demonstrated no significant difference in the organoleptic quality of fish processed using sand baking versus the conventional method ($p > 0.05$ for all attributes). The small differences in average scores (0.33–0.34 points) suggest that variability is more likely attributable to subjective panelist assessment than to the processing method. These findings reinforce the potential of sand baking as an effective alternative processing technique that maintains sensory quality of the final product (Bassig et al., 2021; Ravishankar & Elavarasan, 2023).

Indonesian studies support these results, such as Wiyanti (2024), who reported that innovations in local fish-processing technologies can preserve the sensory quality of seafood products. This finding is also consistent with Mihafu et al. (2020), who highlighted the importance of sensory evaluation in assessing consumer acceptance of new food products. Consistency across studies may be linked to similar methodologies, including trained panelists, controlled processing temperatures and durations, and standardized hedonic evaluation techniques (Lorentzen et al., 2020).

Differences from other studies, such as those reporting significant textural modifications due to natural ingredient interventions, are likely attributable to methodological variations, different panelist groups, or distinct sensory evaluation frameworks (Anggarkasih et al., 2023; Mihafu et al., 2020). Subjectivity remains a known limitation of sensory evaluation and must be carefully considered when interpreting the results.

The similarity in time–temperature parameters for both methods (approximately 180°C for 20 min) contributes to the preservation of volatile compounds and the maintenance of aroma and flavor. Sand baking, which facilitates uniform heat transfer through heated sand, may help maintain the texture and color of the fish. Previous studies have emphasized that strict control of time and temperature is essential for sustaining the physical and sensory quality of seafood (Bassig et al., 2021; Lorentzen et al., 2020).

Overall, the sand baking method demonstrated the ability maintained organoleptic quality at a level comparable to that of the conventional method. Given its practicality and efficiency, sand baking is an innovative alternative for fish processing that aligns with consumer expectations regarding sensory attributes. These findings support the development and application of sand-baking techniques in both household and industrial settings, contributing to the diversification of efficient, resource-adaptive seafood processing methods.

This study has several limitations. The sample size of the panelists was relatively small, and subjective bias may have influenced sensory evaluations, limiting the generalizability of the results. Future research should involve a larger number of panelists and incorporate quantitative analyses, including chemical profiling of aroma compounds and instrumental texture analysis, to enhance the robustness of these findings.

Conclusion

This study demonstrated that mackerel processed using the sand baking method and conventional baking exhibited comparable sensory and physical qualities. The absence of significant differences in taste, aroma, color, texture, moisture content, and physical texture attributes indicates that both methods yield similar final product qualities. However, these results should be interpreted cautiously because of the limited sample and panelist size.

Sand baking shows promise as a practical and resource-efficient alternative processing technique, particularly for household use in coastal communities. This method enables oil-free cooking and requires minimal equipment, making it suitable for contexts where traditional tools are limited. To ensure consistent results, standardized guidelines for temperature, cooking time, and material characteristics should be developed. Further research with larger panelist groups and more comprehensive chemical and physical analyses is recommended to strengthen the reliability and generalizability of these findings.

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