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QUALITY EVALUATION OF SALAK PEEL TEA UNDER VARIOUS DRYING TEMPERATURES AND DURATIONS

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ABSTRACT

Salak peel, commonly discarded as agricultural waste, contains bioactive compounds that can be developed into functional food products, such as herbal tea. The quality of this tea is significantly influenced by the drying process, particularly in terms of temperature and drying duration. This study investigated the effects of different drying temperatures and durations on the sensory and nutritional characteristics of salak peel tea. Drying was carried out at three temperature levels (60, 70, and 80°C) combined with six drying durations (2, 4, 6, 8, 10, and 12 h). Sensory attributes, including color, aroma, and taste, were evaluated, and the data were analyzed using factorial ANOVA, followed by Duncan's multiple range test at a 5% significance level. The findings revealed that temperature and drying time significantly affected the sensory quality of the salak peel tea. The optimum conditions were observed at 70°C for 4 h, producing scores of 3.8, 3.76, and 3.5 for color, aroma, and taste, respectively. Proximate analysis of the best treatment indicated a moisture content of 3.85%, ash of 5.77%, protein of 0.55%, fat of 0.06%, and carbohydrate of 89.77%. These results suggest that drying at 70°C for 4 h is the most suitable treatment for producing salak peel tea with desirable sensory characteristics and proximate composition.

Keywords: Salak peel; drying method; organoleptic

INTRODUCTION

Indonesia has a high potential for local fruit production. Salak (*Salacca zalacca*) is an indigenous fruit of Indonesia and a major horticultural commodity. Salak comes from the palm family, where the fruit grows in clusters at the base of the tree, covered with reddish-brown scales that resemble snakes; hence, the name snake fruit (Saleh et al., 2018a). The fruit is egg-shaped, with white, firm flesh and a sweet, slightly sour, and astringent taste (Suica-Bunghez et al., 2016). This fruit is underutilized but is rich in carbohydrates, dietary fiber, and antioxidants, which vary slightly depending on the variety (Mazumdar et al., 2019). The fertile soil of Kalimantan is ideal for salak cultivation, resulting in highly productive harvests. This is especially true in Balikpapan, East Kalimantan, which serves as a major hub for the cultivation of fruits.

According to 2025 data from BPS-Statistics Balikpapan City, salak production reached 109,641 quintals, driven primarily by the North Balikpapan District, salak production reached 109,641 quintals, with the largest contributor being the North Balikpapan District. This production has increased significantly compared to the previous year, when it was only 47,902 quintals (BPS, 2025). The greater the volume of salak fruit harvested, the greater the quantity of salak peels produced (Kusdarini et al., 2025). As long as the consumer only focuses on using the fruit flesh, the peel is discarded directly into the environment as waste. The whole salak fruit has an edible portion of 56-65%, while 35-44% is considered waste, with 10-14% being the peel (Surbakti and Barus, 2022). Instead of allowing salak peels to become agricultural waste, they can be transformed into valuable products.

By-products, such as fruit peels, contain high levels of bioactive compounds. Research on salak (*Salacca zalacca*) peel has mainly focused on phytochemical identification rather than processing optimization. Studies

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related to the drying of salak peel remain limited, even though drying is a crucial step in the production of herbal tea and greatly influences the product quality (Kowalska et al., 2017). To date, there is no established agreement on the most appropriate drying method or optimal conditions, such as temperature and drying duration, to effectively retain phenolic compounds and antioxidant activity in salak peel tea (Girsang et al., 2021). Moreover, the effects of drying parameters on the functional stability and sensory characteristics of salak peel tea have not been systematically evaluated, particularly in relation to its radical scavenging potential and health-related properties (Tan et al., 2020). Research on salak (*Salacca zalacca*) peel has primarily focused on phytochemical identification rather than processing optimization. Studies related to the drying of salak peel remain limited, even though drying is a crucial step in the production of herbal tea and greatly influences the product quality. Furthermore, the antioxidant activity of the peel was recorded at 229.27 ± 6.35 µg/mL, highlighting its potential as a functional ingredient (Čepková et al., 2021). This gap highlights the need for targeted drying optimization studies to support the development of salak peel as a functional tea product and enhance its utilization as an agricultural by-product.

Complementary evidence from herbal tea studies, such as that reported by Wickramarachchi et al. (2017), has demonstrated that drying temperature and duration significantly influence the nutritional composition and sensory quality of herbal teas. The longer the duration and the higher the temperature, the greater the effect on the characteristics of the resulting tea (Smith et al., 2024). This study investigated the effects of different drying temperatures and durations on the sensory and nutritional characteristics of salak peel tea. The quality of the salak peel tea was evaluated using organoleptic tests based on color, aroma, and taste. Proximate analysis was performed to evaluate the nutritional composition and overall quality of the tea. Collectively, these findings support the rationale of the present study, indicating that optimization of drying temperature and time is essential for enhancing visual quality.

MATERIALS AND METHOD

Materials

Ripe fruits of *Salacca zalacca* were sourced from local farmers at KM 21, Balikpapan City, East Kalimantan, Indonesia. Only fruits with intact peels and free from visible defects were selected. The outer skin was separated manually and used as raw material. Distilled water was used for cleaning, and food-grade filter paper was used for tea bag preparation. Analytical grade chemicals were used for proximate analysis.

Experimental Design and Data Analysis

A factorial experiment was conducted to evaluate the effects of drying temperature and time on the salak peel tea. The treatments consisted of three temperature levels (60, 70, and 80 °C) combined with six drying durations (2, 4, 6, 8, 10, and 12 h), each performed in triplicate. Sensory evaluation, comprising color, aroma, and taste, was conducted using a five-point hedonic scale, and nutritional attributes were determined according to standard procedures. Data were analyzed using two-way ANOVA, and mean separation was performed using Duncan's test at a 5% significance level. The treatment combination with the highest sensory acceptance was further analyzed for its proximate composition following AOAC standard methods.

Methods

Fresh salak (*Salacca zalacca*) fruits were sourced directly from local farmers in Balikpapan, East Kalimantan. The peels were manually removed, thoroughly rinsed with running water, and allowed to drain at ambient temperature for approximately 10 min before weighing. Subsequently, the peels were cut into uniform pieces with a thickness of 2–3 mm and dimensions of approximately 2 × 3 cm to ensure consistent drying behavior.

The prepared peel samples were placed evenly in a single layer on stainless steel drying trays, with a loading of approximately 200 g per tray and a spacing of 2–3 mm between individual pieces to facilitate uniform air distribution. Drying was performed in an electric cabinet-type food dehydrator equipped with forced convection. The samples were dried at 60, 70, and 80 °C

for drying durations of 2, 4, 6, 8, 10, and 12 h. Each treatment was performed in three independent replicates, following the experimental design (Rachmadani et al., 2025). This temperature range was selected based on prior hot-air drying studies on salak fruit and peel products, which demonstrated that drying temperature plays a critical role in moisture reduction, drying kinetics, and product quality. Upon completion of drying, the samples were cooled to room temperature for 30 min and then stored in airtight, food-grade containers until further analysis.

Analysis

Hedonic Evaluation

A sensory evaluation was conducted to assess the consumer acceptance of salak peel tea in terms of color, aroma, and taste. Twenty-five untrained panelists, recruited from undergraduate students at Institut Teknologi Kalimantan, participated in the test. **S**ensory evaluation was conducted in a quiet, well-ventilated room under controlled neutral lighting, with panelists isolated in individual booths to prevent interaction. Tea samples were prepared under standardized conditions by brewing 2 g of dried salak peel powder in 200 mL of hot water (95 °C for 5 min) and served in coded cups labeled with randomized three-digit numbers to ensure blind testing of the samples. Each panelist independently evaluated all samples and scored them using a five-point hedonic scale ranging from 1 (dislike very much) to 5 (like very much) (Djaafar et al., 2024). The scores were recorded for each attribute, and mean values were calculated to determine the most preferred sample, which was selected for proximate analysis.

Proximate Analysis

A procedure to quantify the major nutritional fractions, including moisture, ash, crude protein, crude fat, and carbohydrates (by difference), was conducted according to the Official Methods of Analysis of AOAC International (AOAC, 2006). Moisture and ash were determined gravimetrically, crude protein was measured using the Kjeldahl nitrogen method, crude fat was obtained by Soxhlet extraction with a non-polar solvent, and carbohydrate was calculated as the remaining portion after subtracting the other components from 100%.

Moisture content

Moisture content was determined gravimetrically by drying approximately 5 g of the ground sample in a hot-air oven at 105 °C until a constant weight was achieved. The moisture content was calculated based on the weight loss relative to the initial mass.

Ash content

Ash content was determined using the gravimetric method. Approximately 2–3 g of the sample was placed in a pre-weighed crucible, charred, and then incinerated in a muffle furnace at 550 °C until a light-colored ash was obtained. The remaining residue was weighed, and the ash percentage was calculated based on the original sample mass.

Crude protein

Protein content was analyzed using the Kjeldahl method. The sample was digested in concentrated sulfuric acid with a catalyst until clear, followed by the distillation and titration of the released ammonia. The nitrogen content was determined and converted to crude protein using a 6.25 factor.

Crude fat

Fat content was determined using Soxhlet extraction. A known weight of dried sample was wrapped in filter paper and placed in an extraction thimble, and extracted with petroleum ether for 6–8 h. After solvent removal, the extract was dried and weighed, and the percentage of fat was calculated.

Carbohydrate (by difference)

The carbohydrate content was estimated by difference using the following formula:

$$\% \text{ Carbohydrate} = 100 - (\% \text{ Moisture} + \% \text{ Ash} + \% \text{ Protein} + \% \text{ Fat})$$

RESULTS AND DISCUSSION

Salak Peel Tea

The product obtained in this study was salak peel tea powder, a functional herbal tea derived from the dried peel of salak fruit (*Salacca zalacca*). This powder is produced by washing, slicing, and drying the peels, followed by milling them into a fine powder. The resulting product retains desirable sensory characteristics, such as color, aroma, and taste, as well as nutritional components.

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The effects of different drying conditions on the quality of the best salak peel tea powder are illustrated in Figure 1.

(a) (b)

Figure 1. Salak peel tea powder with treatments (a) 70°C for 4 hours and (b) 60°C for 12 hours

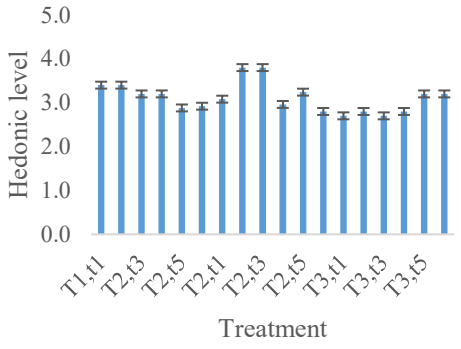
The following figure illustrates the salak peel tea powder produced under optimal treatment, representing the best combination of drying temperature and time. Among the treatments, the sample dried at 70 °C for 4 h was selected as the optimal condition. Although there was no significant difference in sensory scores compared to the sample dried at 60 °C for 12 h, the shorter drying time at 70 °C makes this treatment more efficient while still producing a product with acceptable quality using sensory evaluation.

Hedonic Evaluation

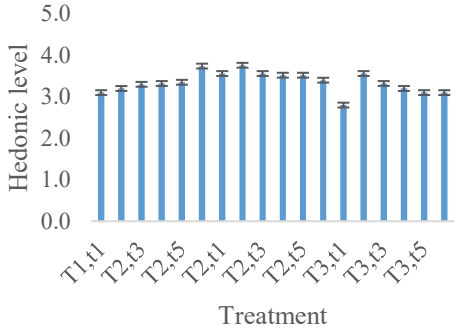
Color

The resulting product retained desirable sensory attributes. Specifically, color evaluation revealed that drying at 70 °C for 4 h produced the most visually appealing tea, characterized by a uniform brown hue that was preferred by the panelists**.** Color evaluation indicated that tea dried at 70 °C for 4 and 6 h exhibited a uniform brown appearance with high panelist acceptance, yielding hedonic scores of 4.92 and 4.85, respectively. There is no significant difference between these two treatments ($p > 0.05$); however, both treatments differed significantly from the other drying conditions (Figure 2a.). However, this treatment was not significantly different from drying at 70 °C for 6 h, suggesting that the shorter 4-hour duration is more efficient while still maintaining acceptable color quality.

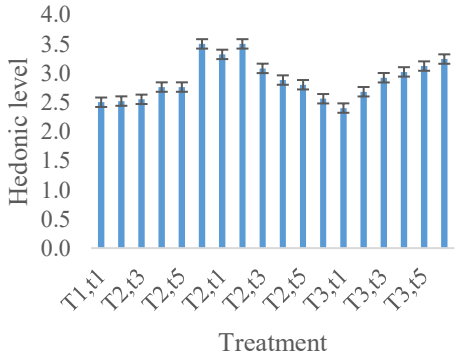
Higher temperatures or longer drying periods tended to excessively darken the tea, whereas shorter drying times resulted in a lighter color that was less attractive. Sensory evaluation was conducted to determine consumer preferences for salak peel tea based on color, aroma, and taste. Color and sensory quality are pivotal attributes in herbal tea development, and extensive research has established that drying parameters significantly influence these characteristics (Mao et al., 2024).



(a)



(b)



(c)

Figure 2. Effect of drying temperature and duration on the hedonic score of salak peel tea taste. Color (a), aroma (b), taste (c).

This study demonstrated that variations in drying temperature significantly altered the color profile of Tencha, with certain settings yielding more desirable visual qualities than others. Similarly, Su et al. (2025) highlighted that drying temperature not only affects the sensory properties of Lichuan black tea, including aroma and taste, but also modulates its bioactive components. These findings revealed that initial drying temperatures played a crucial role in shaping both the biochemical composition and volatile profile of Lishui wild black tea, further underscoring the importance of precise thermal control during processing.

Complementary evidence from herbal tea studies, such as that by Wickramarachchi et al. (2017), confirmed that both temperature and drying duration significantly influenced the nutritional and sensory qualities of Moringa oleifera tea. Collectively, these studies provide strong support for the current investigation, suggesting that optimizing temperature and drying time is essential for improving the visual appeal, nutritional integrity, and consumer acceptance of salak peel tea.

Aroma

Sensory evaluation revealed that drying temperature and duration significantly affected the acceptability of salak peel tea. Samples processed at 60 °C for 12 h had a hedonic score of 3.74, indicating a satisfactory level of panelist approval. A similar result was observed at 70 °C for 4 h, with a score of 3.76, showing that both treatments were well received. Statistical analysis showed no significant difference between the two treatments ($p > 0.05$), suggesting that both drying conditions were similarly well-accepted by the panelists (Figure 2b.). These findings suggest that extended drying at a lower temperature and shorter drying at a slightly higher temperature can produce nearly equivalent outcomes in terms of sensory quality. From a technological perspective, the 70 °C for 4 h treatment may be more efficient, as it maintains high acceptance while considerably reducing processing time and energy requirements.

Recent evidence from studies on herbal and tea products further corroborates the findings of this study. Luo et al. (2025) observed that different drying methods significantly modified the aroma profiles of large-leaf green tea (*Assamica*), and that hot-air drying produced aroma components identified by HS-SPME-GC-MS that were both richer and more preferred in sensory evaluation. Similarly, Bimo et al. (2025) demonstrated that drying at 60 °C for shorter durations enhanced the floral and sweet notes of rose tea while preserving consumer acceptance, even though color intensity decreased under longer drying times or higher temperatures. These parallels suggest that in salak peel tea, as in these teas, moderate temperatures and balanced drying times yield optimal aroma and sensory appeal without compromising visual qualities.

Taste

The taste assessment showed that drying salak peel tea at 60 °C for 12 h resulted in a hedonic score of 3.5, indicating that the product was moderately well accepted in terms of flavor. A similar score of 3.5 was also obtained for the treatment at 70 °C for 4 h, suggesting that the panelists perceived both samples to have comparable palatability. Statistical analysis revealed no significant difference between these two treatments ($p > 0.05$); however, their scores were significantly higher than those of the other drying treatments ($p < 0.05$), demonstrating a superior flavor acceptance (Figure 2c.). This outcome demonstrates that a longer drying process at lower temperatures or a shorter process at higher temperatures can equally preserve desirable taste attributes. Considering processing efficiency, the 70 °C for 4 h condition is advantageous, as it provides the same sensory acceptance level while reducing drying duration.

These results suggest that longer low-temperature drying and shorter moderate-temperature drying are equally effective in preserving desirable taste characteristics of the rice. Comparable outcomes have been reported in studies on other herbal teas. Latarissa et al. (2022) found that drying duration significantly influenced the chemical profile and sensory properties of nutmeg peel tea, where extended drying enhanced certain flavor attributes. Similarly, Bimo et al. (2025)

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demonstrated that drying rose petals at 60 °C for shorter times produced a balanced floral aroma and pleasant taste, whereas higher temperatures reduced flavor acceptability. Bahar et al. (2025) reported that phytochemical composition and subtle differences in taste perception of mixed herbal teas were directly influenced by the drying temperature applied. Together, these findings reinforce the present study, showing that careful adjustment of both temperature and time is essential to optimize the flavor quality of the salak peel tea.

Luo et al. (2025) showed that drying methods significantly altered the aroma and taste profiles of large-leaf green tea, highlighting that controlled hot-air drying better retained pleasant sensory attributes compared to pan-fired techniques. Zhao et al. (2025) further demonstrated that processing methods had a decisive role in determining the flavor of rose herbal tea, where low temperature drying preserved floral and sweet notes more effectively. In addition, Jin et al. (2023) reported that different drying methods strongly influenced the metabolite composition of tea, which was directly associated with differences in taste and overall flavor perception. These findings align with those of the current study, emphasizing that both drying time and temperature must be carefully optimized to achieve a balanced taste and consumer acceptance in salak peel tea.

Proximate Analysis

Proximate composition analysis was performed to assess the nutritional profile of the sample, focusing on moisture, ash, protein, fat, and carbohydrate levels (Table 1). The findings revealed that the sample contained a low level of moisture (3.85 ± 0.026%), which is advantageous for product stability and shelf life, as reduced water content can suppress microbial activity. The ash value was recorded at 5.77 ± 0.039%, indicating the presence of considerable amounts of mineral components. Protein was relatively scarce (0.55 ± 0.001%), indicating that the material is not a major protein contributor. Meanwhile, the fat content reached 3.85 ± 0.001%, which enhanced the flavor and texture.

Table 1. Proximate analysis of salak peel tea

Chemical characteristics	Content (%)
Moisture content	3.85 ± 0.03
Ash content	5.77 ± 0.04
Protein content	0.55 ± 0.00
Fat content	0.06 ± 0.00
Carbohydrate	89.77 ± 0.07

Carbohydrates dominated the composition, accounting for 89.77 ± 0.065%, highlighting the sample as an energy-rich source of carbohydrates. In general, the product is characterized by minimal moisture, appreciable mineral content, and carbohydrates as the predominant constituent. The proximate composition of the dried salak peel tea, characterized by low moisture (3.85 ± 0.026 %) and high carbohydrate content (89.77 ± 0.065 %) with modest ash, protein, and fat, aligns with the nutrient profile typically associated with salak-derived products.

Salacca zalacca fruit is known to have high moisture and carbohydrate content with low protein and fat content, a pattern reflected in its edible fruit composition and potentially in peel-derived products, indicating the carbohydrate-rich nature typical of salak materials (Saleh et al., 2018b). The proximate composition of salak peel tea in this study, which showed a predominance of carbohydrates (89.77%) along with low protein and fat content, aligns with the patterns reported for other herbal teas. For example, a study on *Asystasia gangetica* herbal tea found carbohydrates to be the major nutrient, while protein and fat were detected only at minimal levels (Okolo et al., 2022). Similarly, proximate analysis of fruit tea infusions from Manipur, India, demonstrated that carbohydrates were the principal component, with protein and lipid fractions contributing marginally to the overall composition (Devi et al., 2022). In another study, herbal blends of hibiscus and ginger were evaluated, and although fat levels were relatively low, they played a role in enhancing sensory attributes such as aroma and mouthfeel (Sunday et al., 2024). Moreover, research on composite formulations of *Cymbopogon citratus*, *Lippia multiflora*, and *Ganoderma lucidum* confirmed that low

moisture content is crucial for improving shelf stability and reducing microbial risks in herbal teas (Dzah, 2015). These findings collectively reinforce the observation that plant-based herbal teas are typically rich in carbohydrates, with minor contributions from proteins and fats, and that moisture control is a critical factor for product stability.

Furthermore, community and product development studies highlight the feasibility and market interest in salak peel tea as an antioxidant-rich herbal beverage, reinforcing its potential position in health-oriented markets and local entrepreneurship contexts (Saputri et al., 2024). Finally, the presence of significant phytochemicals such as phenolics and flavonoids in salak peel indicates additional *functional benefits* that complement the proximate nutritive profile, supporting nutritional positioning beyond basic macroanalysis and enhancing its appeal in the functional beverage market (Girsang et al., 2022).

CONCLUSION

These findings indicate that processing temperature and drying duration play a decisive role in shaping the sensory quality of salak peel tea. Treatment at 70 °C for 4 h provided comparable acceptance to 60 °C for 12 h, but with greater efficiency in terms of time and energy use. Nutritional evaluation showed that carbohydrates were the major component, accompanied by low protein and fat contents, while mineral presence was reflected in the ash value. The reduced moisture content further supports the longer shelf stability. When these nutritional and sensory characteristics are viewed alongside existing literature reporting antioxidant and bioactive compounds in salak peel, the product shows potential to be positioned as a functional beverage derived from agricultural byproducts. However, the present study did not directly measure bioactive compounds or antioxidant activity, nor did it involve consumer-based sensory testing, which limits the strength of these functional claims. Therefore, future research should focus on quantifying bioactive components, evaluating antioxidant stability during drying, and conducting broader consumer acceptance studies to more fully support the functional and commercial potential of salak peel tea.

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