Dual-Action Preservatives: Improving Palm Sugar (Arenga pinnata Merr) Quality Using a Natural and Chemical Additive Combination

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Abstract. Traditional palm sugar production faces a major challenge due to the rapid fermentation of palm sap, which is caused by microbial contamination. The resulting decline in sap quality significantly affects the final quality of the palm sugar. This study aimed to evaluate the effectiveness of a combination of natural preservatives and sodium metabisulfite in improving palm sugar quality. Specifically, the research focused on identifying the optimal type and concentration of natural preservatives and their interaction with sodium metabisulfite to maintain product quality. The results showed that a combination of 1.5% clove leaves and 0.2% sodium metabisulfite (p3k1) was identified as the most effective treatment. This optimal treatment yielded a moisture content of 6.361%, an ash content of 1.530%, and a reducing sugar content of 5.600%. Based on the Indonesian National Standard (SNI) for palm sugar, these three parameters met the quality standard. However, the recorded sucrose content of 54.180% was still below the minimum SNI standard of 77.0%.

Keywords: natural preservatives, palm sugar, quality, sodium metabisulfite.

Introduction

Palm sugar (Arenga pinnata), a traditional Indonesian food product, holds significant economic value. It is favored as a natural sweetener due to its unique flavor, caramel aroma, and richer nutritional profile, including a higher mineral content compared to sugarcane sugar. However, palm sugar faces a primary challenge related to its quality stability, which tends to deteriorate during storage. This degradation is attributed to several factors: microbial activity, non-enzymatic browning reactions, and physicochemical changes such as clumping, discoloration, and flavor degradation (Murni, Selviana, & Rochmawati, 2020).

The main factors contributing to this quality decline are the high reducing sugar content and relatively high moisture content in the product, which create an ideal environment for microbial growth and accelerate chemical reactions. To address this issue, various preservation methods have been developed. One of the most common and effective methods is the use of sodium metabisulfite ($Na_2S_2O_5$). This chemical compound acts as a dual-purpose preservative and antioxidant, effectively inhibiting microbial growth and slowing down browning reactions. Its effectiveness stems from the release of sulfur dioxide (SO_2), which possesses potent antimicrobial properties (Ilie-Mihai, Ion, & van Staden, 2022).

The widespread use of sodium metabisulfite in the food industry, including in the production of palm sugar, is a strategic effort to maintain quality and extend shelf life. Nevertheless, the use of sodium metabisulfite raises concerns regarding food safety. Strict regulations on its maximum permissible use are enforced by various standards, including the Indonesian National Agency of Drug and Food Control (BPOM), which sets a maximum limit of 40 mg/kg, due to its potential to trigger allergic reactions or health issues in individuals sensitive to sulfites. This situation is compounded by a growing consumer preference for products with a "clean label" or those with minimal synthetic preservatives. Reports from field studies indicating that some local palm sugar products contain sodium metabisulfite levels above the safe limit further emphasize the urgency of transitioning to safer and more sustainable preservation methods (Murni, Selviana, & Rochmawati, 2020).

In response to these challenges, both research and the food industry are shifting toward natural preservatives. Various plant extracts, such as cloves, turmeric, and ginger, have been identified to contain bioactive compounds like eugenol, curcumin, and gingerol, which possess significant antimicrobial and antioxidant properties. The use of natural preservatives not only offers a safer solution for consumers but also enhances the product's value, aligning with the market's demand for healthier and natural food options. Studies have shown that materials like mangosteen peel extract, clove leaves, and betel leaves have significant potential in extending the shelf life of palm sugar products (Musita & Saptaningtyas, 2017).

For instance, in research demonstrated that clove and ginger extracts in soy milk were more effective in extending shelf life and suppressing microbial growth than a single chemical preservative (Arekemase & Babashola, 2019). This efficacy is consistent with findings from other studies confirming the antimicrobial effects of spice extracts against various harmful pathogens, including *Salmonella*, *E. coli*, and *Shigella* (Ebrahimi, Jalali, & Ziaolhagh, 2023).

Despite the proven effectiveness of sodium metabisulfite, research on the efficacy of natural preservatives specifically for palm sugar remains limited. This study, therefore, aims to evaluate the effectiveness of a dual-action preservative system combining natural additives with sodium metabisulfite in improving palm sugar quality. The specific objectives are: to identify the most effective natural preservative; to determine the optimal concentration of the natural preservative; and to evaluate the interaction between the natural preservative and sodium metabisulfite in enhancing the quality of palm sugar. Ultimately, a comparative analysis of the effectiveness of these two types of preservatives is crucial to determine the extent to which natural ingredients can replace or reduce the reliance on synthetic preservatives without compromising product quality.

Methods

The primary materials used were palm sap, sodium metabisulfite ($Na_2S_2O_5$), calcium hydroxide ($Ca(OH)_2$), mangosteen peel powder, clove leaves powder, and betel leaf powder. Standard chemicals for laboratory analysis were also used. The equipment included essential instruments such as a pan, pipettes, burettes, beakers, Erlenmeyer flasks, analytical scales, a pH meter, a stirrer, a refractometer, and other relevant instruments for physicochemical testing.

The study employed a quantitative approach with an experimental design. A factorial Randomized Block Design (RBD) was used with two factors. The first factor (p) was the type of natural preservative, with three levels: p_1 (mangosteen peel powder), p_2 (betel leaf powder), and p_3 (clove leaves powder). The second factor (k) was the concentration of the natural preservative, with two levels: k_1 (1.5%) and k_2 (4.5%). The combination of these two factors resulted in six experimental treatments, each replicated three times, for a total of 18 experimental units.

The study was executed in two main stages: (1) preliminary stage: the process of preparing the natural preservative powders from the collected materials; (2) research stage: the application of the preservative combinations to the palm sap, followed by the analysis of quality parameters of the resulting palm sugar product. The analysis included measurements of moisture content, ash content, reducing sugar content, and sucrose content.

Result and Discussion

Water Content

The primary principle in palm sugar production is the dehydration process, which involves reducing the water content of the palm sap until it reaches a solid consistency. This process is fundamentally achieved through the heating or boiling of the sap to evaporate the water. Consequently, the sap undergoes concentration and subsequently crystallizes into solid palm sugar (Prasmatiwi, Evizal, & Zahra, 2022).

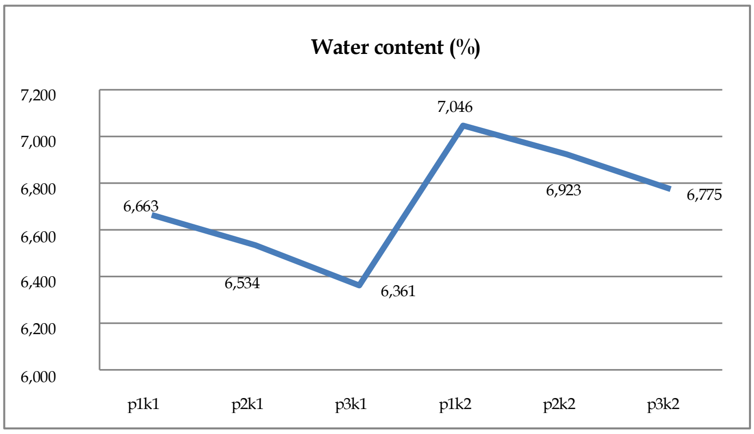

Figure 1. Water content of palm sugar

Figure 1 illustrates the water content (%) in the palm sugar products. All treatments yielded water content values below 10%, which is the maximum limit according to the Indonesian National Standard (SNI) for palm sugar. This indicates that all tested preservative combinations were effective in maintaining water content within an acceptable commercial range. The lowest water content was consistently observed in treatments using clove leaf powder, particularly at the 1.5% concentration (p_3k_1) with a value of 6.361%. Treatments with a higher natural preservative concentration (4.5%) tended to yield slightly higher water content, with the highest value of 7.046% recorded for p_1k_2 (mangosteen peel powder 4.5% + 0.2% $Na_2S_2O_5$).

The low water content in the palm sugar products is strongly correlated with a controlled reducing sugar content. Reducing sugars (glucose and fructose) are highly hygroscopic, meaning they readily absorb moisture from the environment. By effectively controlling the level of reducing sugars, the palm sugar is prevented from absorbing moisture, thereby maintaining a low water content. This result is also a direct outcome of an optimized cooking process. The active compounds in the preservatives, both sodium metabisulfite and natural extracts, can influence the boiling point or viscosity of the palm sap, which in turn contributes to a more efficient moisture reduction.

The consistent reduction in water content observed in the p_3k_1 treatment (1.5% clove leaves powder + 0.2% $Na_2S_2O_5$) demonstrates a synergistic effect between the preservatives and the heating process. This synergy either accelerates water evaporation or stabilizes the sugar matrix, yielding a denser and drier product. This synergistic action is primarily due to the bioactive compound eugenol, which is abundant in clove leaves and possesses potent antimicrobial properties. Eugenol inhibits the growth of microorganisms responsible for sap fermentation, a process that can produce water as a byproduct. By suppressing this fermentation, eugenol directly contributes to the lower water content. Thus, the combination of sodium metabisulfite and eugenol from cloves not only inhibits microbial growth but also prevents product degradation that could generate moisture, collectively maintaining a low and stable moisture content. This low moisture content is crucial for a product's shelf life as it inhibits microbial growth and reduces the risk of spoilage during storage.

Ash Content

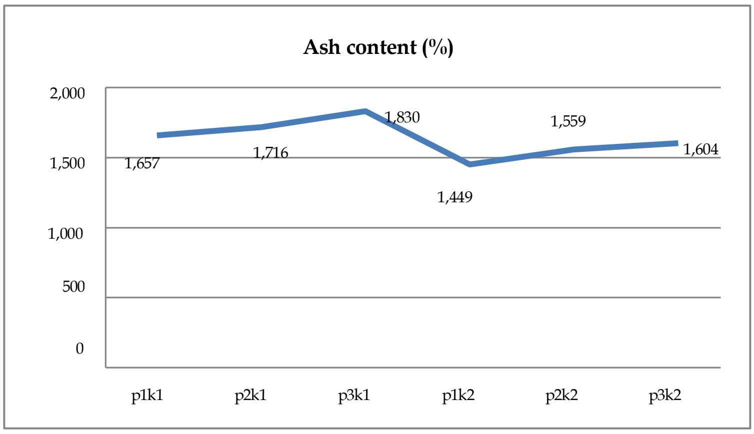

Figure 2. Ash content of palm sugar

The ash content (%) in the palm sugar values remained below the 2% maximum limit stipulated by the Indonesian National Standard (SNI). This result confirms that the processing methods and preservative combinations were effective in producing palm sugar with acceptable levels of minerals and inorganic residues. The lowest ash content was achieved with the higher concentration of natural preservatives, specifically in treatment p_1k_2 (mangosteen peel powder 4.5%+0.2% $Na_2S_2O_5$) at 1.449%. Conversely, the highest ash content (1.830%) was found in treatment p_3k_1 (clove leaves powder 1.5%+0.2% $Na_2S_2O_5$).

Ash content is a crucial quality parameter for palm sugar, influenced primarily by the mineral content of the palm sap and the processing methods (Fitri, Asyik, & Sadimantara, 2024). Minerals can be broadly classified into two types: organic minerals, such as malic, oxalic, and acetic acids, and inorganic minerals, which include phosphates, carbonates, chlorides, sulfates, and nitrates (Zuliana, Widyastuti, & Hadi, 2016).

Variations in the ash content of palm sugar are primarily attributed to differences in the mineral composition of the palm sap and environmental factors such as weather. The addition of preservatives during the cooking process also contributes to the final ash content, as each type of natural preservative (mangosteen peel, betel leaf, and clove leaf powder) contains a distinct composition of minerals and bioactive compounds. These bioactive compounds, such as tannins and polyphenols, can interact with the natural minerals in the palm sap, influencing the ash fraction of the final product. Furthermore, the high-temperature cooking process can induce chemical changes in minerals and organic compounds. The interaction between the preservatives and heat may trigger reactions that alter the mineral forms, which is reflected in the lower ash content observed in certain treatments.

A low ash content is positively correlated with product purity. The decrease in ash content observed in treatments with a higher concentration of natural preservatives (4.5%) suggests a specific interaction between the natural additives and sodium metabisulfite with the minerals in the sap. This combination may be more effective at controlling reactions that produce mineral or inorganic residues. Specifically, the lowest ash content was recorded in the p1k2 treatment (4.5% mangosteen peel powder + 0.2% sodium metabisulfite), indicating a synergistic effect between mangosteen peel powder and sodium metabisulfite that effectively enhances the purity of the palm sugar product.

Reducing Sugar Content

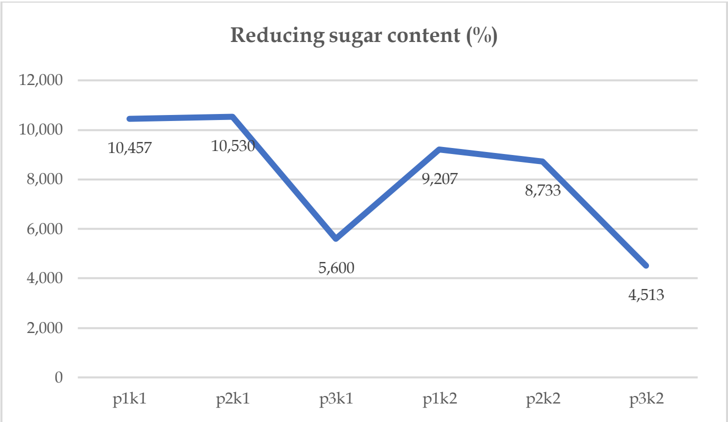

Figure 3. Reducing sugar content of palm sugar

Figure 3 presents data on the reducing sugar content (%) of the palm sugar for all treatments. The results show that all treatments, except for p_1k_1 and p_2k_1, yielded reducing sugar levels within the quality standard set by the Indonesian National Standard (SNI), which is a maximum of 10%. This indicates that the tested preservative combinations were generally effective in controlling the hydrolysis of sucrose into reducing sugars during the processing. The data also reveals a clear trend: treatments with a higher concentration of natural preservatives (k2) tended to produce lower reducing sugar levels compared to those with a lower concentration (k1). The lowest reducing sugar content was achieved in the p3k2 treatment (4.5% clove leaves powder + 0.2% $Na_2S_2O_5$) with an average value of 4.513%. Conversely, the highest value, 10.530%, was recorded in the p2k1 treatment (1.5% betel leaf powder + 0.2% $Na_2S_2O_5$), which slightly exceeded the SNI limit.

These findings suggest that increasing the concentration of natural preservatives, particularly clove leaves powder, is effective in suppressing the formation of reducing sugars. The control of reducing sugar content has a positive impact on product quality, as a low level can prevent the product from becoming hygroscopic, thereby enhancing the stability and shelf life of the palm sugar (Syska, Nuroniah, & Ropiudin, 2023). Furthermore, reducing sugar content plays a vital role in the non-enzymatic browning process of the sap and influences the product's sweetness, given that glucose and fructose have a lower sweetness intensity than sucrose (Klau, Ngginak, & Nge, 2019). This is consistent with the finding that a lower reducing sugar value leads to higher quality palm sugar, as it affects the product's hardness, color, and flavor (Naufalin, Yanto, & Sulistyaningrum, 2013). This premise is supported by research from (Turnip, Ginting, Martgrita, & Aditia, 2025), which states that mangosteen bark extract effectively inhibits microbial growth and slows down pH reduction, which indirectly preserves sugar content and suppresses the formation of reducing sugars.

Sucrose Content

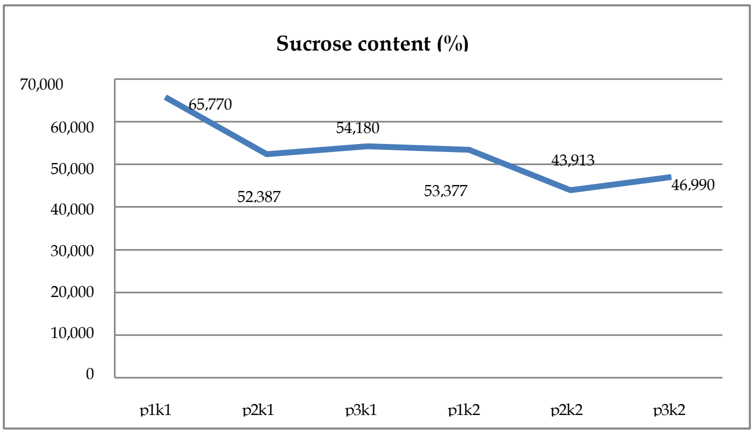

Figure 4. Sucrose content of palm sugar

The minimum Indonesian National Standard (SNI) of sucrose content is 77.0%. The highest value was p_1k_1 treatment (1.5% mangosteen peel powder+0.2% $Na_2S_2O_5$), with an average of 65.770%. Conversely, the lowest value of 43.913% was obtained from the p_2k_2 treatment (4.5% betel leaf powder+0.2% $Na_2S_2O_5$). This consistent pattern across all tested natural preservatives reveals that treatments with a lower concentration of natural additives (k_1) tended to produce higher sucrose content compared to high-concentration treatments (k_2).

This significant decrease in sucrose content can be attributed to several mechanisms. Palm sugar is primarily composed of sucrose, which can undergo hydrolysis into reducing sugars (glucose and fructose) during processing. This hydrolysis can be accelerated by acidic conditions (low pH) or enzymatic activity from microorganisms. An increase in the concentration of natural preservatives, especially those containing acidic compounds, has the potential to lower the pH of the palm sap, thus triggering hydrolysis. Although these preservatives possess antimicrobial properties, a concentration that is too high may not be sufficient to suppress the specific enzymes that catalyze sucrose hydrolysis. The interaction between natural preservatives and sodium metabisulfite could also be antagonistic toward sucrose stability, even if it is synergistic in inhibiting microbial growth. Furthermore, the cooking process itself, which involves high temperatures and a relatively long duration, can be a primary trigger for sucrose hydrolysis, especially if the pH is not properly controlled.

Optimal Sample Selection

Table 1: The mean values for each analysis and sample

Treatment	Water content (%)	Ash content (%)	Reducing Sugar Content (%)	Sucrose content (%)
p_1k_1	6,663	1,657	10,457	65,770
p_2k_1	6,534	1,716	10,530	52,387
p_3k_1	6,361	1,830	5,600	54,180
p_1k_2	7,046	1,449	9,207	53,377
p_2k_2	6,923	1,559	8,733	43,913
p_3k_2	6,775	1,604	4,513	46,990

Selection of the best treatment was carried out by scoring each quality parameter following the Indonesian National Standard (SNI). The aim was to identify the treatment with the most optimal combination of values. Based on the analysis of physicochemical parameters, all experimental treatments successfully met the Indonesian National Standard (SNI) quality standards for moisture content, ash content, and reducing sugar content. However, no treatment was able to reach the minimum standard for sucrose content (min. 77.0%).

Through a scoring analysis that prioritized the proximity of parameter values to the Indonesian National Standard (SNI), the best treatment was $\mathbf{p_3k_1}$ (1.5% clove leaves powder + 0.2% $Na_2S_2O_5$). This treatment demonstrated the most optimal and balanced performance, yielding the lowest moisture content and stable reducing sugar content, which are important indicators for product stability and shelf life. Although the sucrose content in this treatment did not meet the SNI standard, its value was competitive compared to other treatments.

Conclusion

Dual-action preservatives, which are a combination of natural and chemical additives, have been proven effective in improving the quality of palm sugar. This is reflected in the results of a study designed to evaluate the effect of these preservative combinations on palm sugar quality. The most optimal treatment, a combination of 1.5% clove leaf powder and 0.2% sodium metabisulfite ($\mathbf{p_3k_1}$), yielded palm sugar with a moisture content of **6.361%**, an ash content of **1.530%**, and a reducing sugar content of **5.600%**. These results successfully met the Indonesian National Standard (SNI) for all three parameters. Nevertheless, no treatment was able to achieve the minimum SNI standard for sucrose content, which is set at **77.0%**. These findings indicate that a dual-action preservative approach can be a promising strategy for maintaining the quality of palm sugar.

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