

Formulation of *Salacca zalacca* Fruit Peel and *Citrus nobilis* Peel Extract as an Alternative for Environmentally Friendly Tissue Paper

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ABSTRAK

Tissue paper is commonly used as a water substitute for cleaning, made from pulp with cellulose as the primary raw material. *Salacca zalacca* peel contains cellulose that can serve as an adsorbent capable of absorbing heavy metals in wastewater. With a cellulose content of 25.8483%, *Salacca zalacca* peel holds great potential as a raw material for producing environmentally friendly tissue paper. This study focuses on formulating *Salacca zalacca* peel waste with the addition of aromatherapy from *Citrus nobilis* peel extract to create eco-friendly tissue. The objectives of this research are to (1) identify the formulation process, (2) determine the best formulation, and (3) evaluate the quality of the eco-friendly tissue produced. The research uses a true experimental method, and data analysis includes organoleptic tests, tissue paper quantity tests, and biodegradability tests. The findings indicate that the best formulation is achieved with a 70% NaOH concentration, resulting in good physical quality tissue, characterized by a smooth texture, pale yellowish-brown color, and a dominant citrus scent. From a biodegradability perspective, all samples showed excellent degradation rates, confirming their environmentally friendly nature. This research contributes to sustainable environmental practices by offering an alternative to traditional wood-based tissue paper. Utilizing agricultural waste such as *Salacca zalacca* peel not only reduces the pressure on forest resources but also minimizes environmental pollution. The incorporation of natural aromatherapy further enhances the product's eco-friendly credentials, promoting a sustainable approach to tissue production that aligns with global efforts to reduce deforestation and encourage the use of renewable materials. In conclusion, the study demonstrates the feasibility of using *Salacca zalacca* peel and *Citrus nobilis* peel extract, combined with corn husk, as raw materials for producing eco-friendly tissue paper.

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1. INTRODUCTION

Tissue paper is a soft, absorbent, and disposable product that has become an essential part of modern life due to its convenience and practicality (Syarifuddin & Hamzah, 2019). It is commonly used as a substitute for water in cleaning tasks, making it indispensable in households, public facilities, and even industries. However, the widespread use of tissue paper has raised significant environmental concerns, particularly regarding deforestation and excessive natural resource consumption. The tissue paper industry is heavily dependent on wood as the primary raw material, and this reliance has led to unsustainable logging practices, contributing to habitat destruction, biodiversity loss, and increased carbon emissions. According to the Indonesian Green Youth Coalition (Koalisi Pemuda Hijau Indonesia), tissue production, which began using tree bark as a pulp source around the 1880s, has continued to rely on wood for over a century (Jangga et al., 2022).

Despite the industry's growth and technological advancements, wood remains the dominant raw material for tissue production, with substantial environmental impacts. The increasing global demand for

tissue paper has accelerated the depletion of forest resources, particularly in tropical regions like Indonesia, which is one of the world's largest tissue producers. As forests are cleared for timber, the loss of trees diminishes natural carbon sinks, exacerbating climate change. Additionally, deforestation disrupts ecosystems, threatens wildlife habitats, and decreases the planet's overall biodiversity. These concerns underline the urgent need for alternative, eco-friendly raw materials for tissue paper production. The integration of organic waste, particularly agricultural by-products, into the manufacturing process is a promising approach to addressing these environmental challenges while promoting sustainable development (Phiri et al., 2024; Singh et al., 2021).

One such alternative is the utilization of fruit peel waste, which is typically underutilized and can cause environmental problems when left unmanaged. In Indonesia, the region of Turi, located in Sleman, Yogyakarta, is a well-known center for *Salacca zalacca* (snake fruit) cultivation. However, the waste generated from *Salacca zalacca* peels is often left to accumulate, posing a local environmental challenge due to improper disposal. This study also highlights the broader potential of utilizing

various salak fruit wastes, such as seeds and peels, with peels being the most commonly used due to their high cellulose content, making them ideal for eco-friendly applications (Cheok et al., 2016). By converting this agricultural waste into a raw material for tissue production, there is the potential to not only mitigate waste accumulation but also reduce dependence on wood-based materials for tissue manufacturing (Chan et al., 2021; Gupta et al., 2024). The cellulose content in *Salacca zallacca* peels, approximately 25.8483%, makes them a viable alternative for producing pulp, the main component of tissue paper. Cellulose fibers derived from this source can produce soft, absorbent tissue, suitable for everyday use and comparable to traditional wood-based tissue paper.

Moreover, the structural characteristics of *Salacca zallacca* peel fibers align with the requirements for tissue production. According to (Wang & Zhao, 2021), ideal raw materials for tissue paper should have a high alpha-cellulose content (above 40%), low lignin content (less than 25%), and minimal moisture and ash content. Although the cellulose content in *Salacca zallacca* peel is slightly lower than that of wood, it presents a sustainable alternative,

especially when integrated with other natural additives to enhance its properties (Chan et al., 2021; Wang & Zhao, 2021). By utilizing agricultural waste as a raw material, this approach contributes to the circular economy, reduces the environmental footprint of tissue production, and supports local economies by providing value-added uses for waste products.

In addition to the cellulose content, the aesthetic and sensory qualities of tissue paper are important for consumer acceptance. Tissue paper is often infused with fragrance to enhance its appeal for cleaning and personal hygiene purposes. However, the processing of *Salacca zallacca* peels with chemical agents does not naturally yield a pleasant scent. To address this, essential oils extracted from the peel of *Citrus nobilis* (Siam orange) offer a natural and sustainable solution. Essential oils are known for their aromatic properties and can be extracted through methods like maceration, which involves soaking the plant material in organic solvents (Fischer et al., 2008). The resulting oil from *Citrus nobilis* peel is rich in limonene, providing a fresh and invigorating citrus aroma that can be used to infuse tissue paper, making it more appealing to consumers while

avoiding synthetic chemicals. This research is important because it offers a sustainable alternative to wood-based tissue production by utilizing agricultural waste, such as *Salacca zalacca* peels, reducing deforestation and environmental pollution. It aligns with global sustainability goals by promoting renewable materials and supporting the circular economy.

This research aims to (1) investigate the formulation process for producing eco-friendly tissue paper from *Salacca zalacca* peel and *Citrus nobilis* essential oil, (2) identify the optimal formulation based on physical and sensory properties, and (3) evaluate the biodegradability and environmental sustainability of the resulting tissue product. This study contributes to the growing field of sustainable materials science by exploring innovative uses for agricultural waste and aligning with global efforts to reduce deforestation and promote the use of renewable, eco-friendly materials. By integrating waste materials into tissue production, this research supports sustainable environmental practices and highlights the potential of circular economy models to reduce waste, conserve natural resources, and minimize the environmental

impact of consumer products (Singh et al., 2021).

2. LITERATURE REVIEW

2.1. *Salacca zalacca* Peel Waste

Salacca zalacca, commonly known as snake fruit, produces peel waste that has been underutilized despite its significant potential as a raw material for eco-friendly products. The peel of *Salacca zalacca* contains several key components, most notably cellulose, which is a critical element in tissue paper production. Cellulose is a polysaccharide that provides the structural integrity necessary for producing pulp-based products like tissue paper. According to research by (Sholihah & Tarmidzi, 2022).

Salacca zalacca peel contains approximately 25.8483% cellulose, making it a viable candidate for an alternative raw material in tissue production. Additionally, the peel contains hemicellulose, lignin, and other organic compounds, which further contribute to its potential as a pulp substitute. Studies have indicated that cellulose derived from agricultural waste, such as fruit peels, can significantly reduce environmental impact by minimizing the need for wood-based pulp and decreasing waste accumulation (Lidya et al., 2023).

The use of agricultural waste like *Salacca zalacca* peel aligns with circular economy principles, where waste materials are repurposed into valuable products. This not only addresses the issue of waste management but also reduces the carbon footprint associated with traditional tissue production, which relies heavily on deforestation. Furthermore, *Salacca zalacca* peel's natural fibrous structure allows for the creation of soft, biodegradable tissue paper. Utilizing this waste also aligns with the zero-waste goal of sustainable practices, reducing the reliance on raw forest materials and contributing to environmental conservation efforts (Wang & Zhao, 2021).

2.2. *Citrus nobilis* Peel Extract

The peel of *Citrus nobilis*, commonly known as Siam orange, is rich in essential oils, making it a valuable source for natural fragrance and antimicrobial properties. The essential oils, predominantly composed of limonene, myrcene, and linalool, are known for their strong aromatic qualities and are widely used in personal care and cleaning products. Limonene, in particular, comprises up to 90% of the oil's composition and is responsible for the characteristic citrus scent. Limonene is also known for its eco-friendly nature, as it can be easily extracted through non-invasive

techniques like maceration (Fischer et al., 2008).

The addition of *Citrus nobilis* peel extract to tissue paper not only enhances the fragrance but also improves its antimicrobial properties, making it suitable for personal hygiene use. Studies have shown that essential oils derived from citrus peels possess strong antibacterial and antifungal activities, which further increase the hygienic value of products incorporating these natural extracts (Fischer et al., 2008; Silalahi et al., 2022). Moreover, using natural extracts from fruit peels instead of synthetic fragrances reduces the environmental impact of chemical production, aligning with sustainable practices in product development. By incorporating such natural resources, tissue products can be made safer for daily use, while also reducing their carbon and chemical footprints (Singh et al., 2021; Thomas et al., 2023).

2.3. Environmentally Friendly Tissue Paper

The production of environmentally friendly tissue paper necessitates compliance with several critical factors, most notably biodegradability, minimal resource extraction, and eco-friendly additives. Tissue paper is considered environmentally sustainable when it meets criteria such as being derived from renewable resources, exhibiting high biodegradability, and avoiding harmful

chemicals during production. Tissue papers produced from agricultural waste like *Salacca zalacca* peel meet these criteria by reducing the reliance on forest-based pulp and supporting waste minimization (Bala et al., 2023; Duguma et al., 2023). Moreover, agricultural waste often provides natural biodegradability, a critical factor for reducing landfill waste.

In this study, three tests were employed to assess the tissue paper's environmental sustainability: the organoleptic test, the tissue count test, and the biodegradability test. The organoleptic test evaluates the sensory attributes of the tissue, including texture, color, and scent. For tissue to be considered eco-friendly, it must not only function well but also offer a pleasing sensory experience, particularly when infused with natural extracts like *Citrus nobilis*. The tissue count test measures the yield of tissue sheets per formulation, with higher yield formulations contributing to more efficient resource use. Lastly, the biodegradability test is essential in determining how quickly and completely the tissue decomposes in natural environments. According to research, tissues derived from fruit peel waste have demonstrated superior biodegradability compared to wood-based products, breaking down within a shorter timeframe and contributing less to pollution (Kamsiati et al., 2017; Vigneswari et al., 2024).

In summary, the use of *Salacca zalacca* peel and *Citrus nobilis* peel extract in tissue paper production not only satisfies the conditions for environmentally friendly products but also promotes the sustainable utilization of waste materials, contributing to a reduced environmental footprint.

3. METHOD, DATA, AND ANALYSIS

The research method employed is a true experimental design, which allows for the manipulation of variables to test hypotheses and observe the effects of those manipulations under controlled conditions. This approach ensures high internal validity and is suitable for identifying cause-and-effect relationships (Furtak et al., 2012). In this experiment, the focus is on testing and analyzing the raw materials at the initial stage of the tissue production process. The tools and materials used in this study are selected to facilitate the extraction and processing of cellulose from the peels of *Salacca zalacca* and *Citrus nobilis*, among others, to produce eco-friendly tissue paper.

The apparatus includes standard laboratory equipment essential for the treatment and processing of raw materials. A screen sablon is used for filtering and straining the pulp, while a blender is employed to homogenize the mixture, ensuring a consistent pulp texture. A

large basin serves as a container for soaking or processing large quantities of materials, while an oven is utilized for drying the prepared tissue at controlled temperatures. Personal protective equipment such as rubber gloves is used for handling chemicals, ensuring safety. A tripod and Bunsen burner provide heating during chemical reactions, and an analytical balance, ensures precise measurements of chemical reagents. Other essential tools include knives for cutting the peels, a mortar and pestle for crushing materials, and 500 ml beakers for holding chemical solutions. Aluminum foil covers containers during processes that require protection from contamination, and dropper pipettes facilitate the precise addition of small amounts of reagents.

The materials used in the study include distilled water (aquades) as a solvent, and varying concentrations of sodium hydroxide (NaOH) (60%, 70%, and 80%) are used for the delignification process, which breaks down lignin to extract cellulose from the plant material (Wang & Zhao, 2021). Hydrogen peroxide (H₂O₂) at 5% is applied as a bleaching agent to lighten the color of the tissue paper, and 70% ethanol is used for purification purposes (Lestari & Kartika sari, 2016).

Talcum powder is added to the formulation to improve the texture of the tissue paper, enhancing its softness. The primary raw

materials include the peels of snake fruit (*Salacca zalacca*), Siam orange (*Citrus nobilis*), and corn husk (*Zea mays*), which serve as the sources of cellulose. These organic materials are rich in fibers that, when processed properly, can provide the foundation for biodegradable tissue paper.

This experimental design is structured to ensure precise manipulation of the variables, making it possible to assess the viability of fruit peels as an alternative raw material for tissue production, contributing to sustainable environmental practices (Fischer et al., 2008). By comparing the effects of different concentrations of chemicals on the cellulose extraction process, this study aims to optimize the formulation for producing high-quality, eco-friendly tissue paper.

3.1. Preparation of Siam Orange (*Citrus nobilis*) Peel Extract

The first step in the extraction process involves thoroughly cleaning the Siam orange peels (*Citrus nobilis*) to remove any dirt or residues. The cleaned peels are then subjected to air drying, ensuring they are completely moisture-free, which prevents microbial growth during the extraction process. Once the peels are fully dried, they are cut into small pieces and pulverized using a blender to increase the surface area for optimal extraction. The

resulting extract is then used in three different variations: 5 mL, 8 mL, and 10 mL, depending on the formulation requirements.

The next phase involves soaking the orange peel fragments in ethanol. Ethanol is widely used as a solvent in essential oil extraction due to its polarity, which allows it to dissolve both hydrophobic and hydrophilic compounds, making it ideal for extracting volatile oils and other bioactive compounds from plant materials (David et al., 2019; Dong et al., 2015). The mixture is placed in a sealed glass jar and allowed to sit for three days to maximize the release of essential oils from the peel. After this period, the mixture is filtered to separate the liquid extract from the solid residues, yielding the essential oil-rich extract, which can be used as a fragrance or additive in the tissue production process.

3.2. Tissue Paper Production Process

The production of tissue paper from *Salacca zalacca* and corn husk (*Zea mays*) fibers begins with the initial cleaning of the raw materials using running water to remove dirt and impurities. Following this, the *Salacca zalacca* peels are boiled in solutions of sodium hydroxide (NaOH) with varying concentrations of 60%, 70%, and 80%. The NaOH acts as a delignification agent, breaking down the lignin structure and facilitating the

extraction of cellulose fibers (Rahayu et al., 2022).

This boiling process is carried out for approximately two hours to ensure optimal softening of the peels and the release of cellulose. For the papermaking process, approximately 100 grams of *Salacca zalacca* peels and 50 grams of corn husks are required to produce a batch of tissue paper, depending on the desired thickness and quality of the final product.

Simultaneously, the corn husks undergo a similar boiling process under the same conditions. After the boiling is complete, both the salak peels and corn husks are thoroughly rinsed under running water to remove any residual NaOH. The *Salacca zalacca* peels are then ground using a blender to produce a fibrous pulp, making it easier to blend and mold the fibers into tissue paper. Next, the pulp undergoes a bleaching process using a 5% hydrogen peroxide (H₂O₂) solution. Hydrogen peroxide is commonly used as an eco-friendly bleaching agent, which oxidizes chromophores in the plant material, resulting in a whiter and more visually appealing product (Lestar & Kartika Sari, 2016). This bleaching process lasts for two hours, and talcum powder is added during this stage to enhance the texture and softness of the final product.

The pulp from the corn husks and *Salacca zalacca* is mixed in water to form a homogeneous blend. The mixture is then poured onto a screen sablon for manual molding and compression into thin layers. The thin pulp layers are spread evenly across the screen to ensure a uniform thickness and texture. Once the molding process is complete, the pulp is dried in an oven at a controlled temperature of 80°C for 1.5 hours. The drying process solidifies the tissue structure and removes any residual moisture. The result is three different samples of tissue paper with varying properties due to the different NaOH concentrations used in the delignification process. These samples undergo further testing to evaluate their physical properties, including texture, fragrance absorption, and biodegradability.

The data analysis for this research involves three primary tests: organoleptic, quantitative production, and biodegradability assessments. The organoleptic test evaluates the tissue samples' physical attributes—specifically, texture, color, and smell—using a panel of assessors to gather sensory perceptions. This method is essential for understanding consumer preferences regarding the product's tactile qualities and aroma, particularly the impact of *Citrus nobilis* extract on enhancing the tissue's fragrance (Mahajan et al., 2020). The

quantitative production test focuses on measuring the quantity of tissue paper produced from various formulations of *Salacca zalacca* peel and corn husk with differing NaOH concentrations. The number of tissue sheets generated is counted and visually represented using diagrams, which provide insights into the production efficiency and optimal material ratios (Ghofur et al., 2020; Koul et al., 2022). Lastly, the biodegradability test assesses the tissue's decomposition capabilities by burying samples in soil for two days. The percentage of biodegradation is calculated based on the weight difference before and after burial, utilizing the formula:

$$\begin{aligned} \text{Biodegradability (\%)} \\ &= \frac{W_1 - W_0}{W_0} \times 100\% \end{aligned}$$

This evaluation is crucial for determining the environmental impact of the tissue, with higher biodegradability percentages indicating an eco-friendlier product (Vigneswari et al., 2024). Together, these tests comprehensively assess the physical properties and environmental sustainability of the produced tissue paper, contributing to the development of eco-friendly alternatives in the market.

4. RESULT AND DISCUSSION

This research focuses on determining the optimal formulation for producing environmentally friendly tissue paper made from *Salacca zalacca* peel combined with essential oil extracted from *Citrus nobilis* peel. The researchers opted to incorporate a portion of corn husk (*Zea mays*) to enhance pulp yield and binding properties. The tissue samples were subjected to variations during the boiling process using sodium hydroxide (NaOH) concentrations of 60%, 70%, and 80%. Each sample exhibited distinct characteristics during testing, which facilitated the identification of the best formulation. The researchers

conducted several evaluations of the sample outcomes, including physical observations, quantification of the produced tissue sheets, and assessments of biodegradability to determine the samples' decomposition rate in soil. This comprehensive approach aims to contribute to the development of sustainable alternatives in tissue production while addressing environmental concerns.

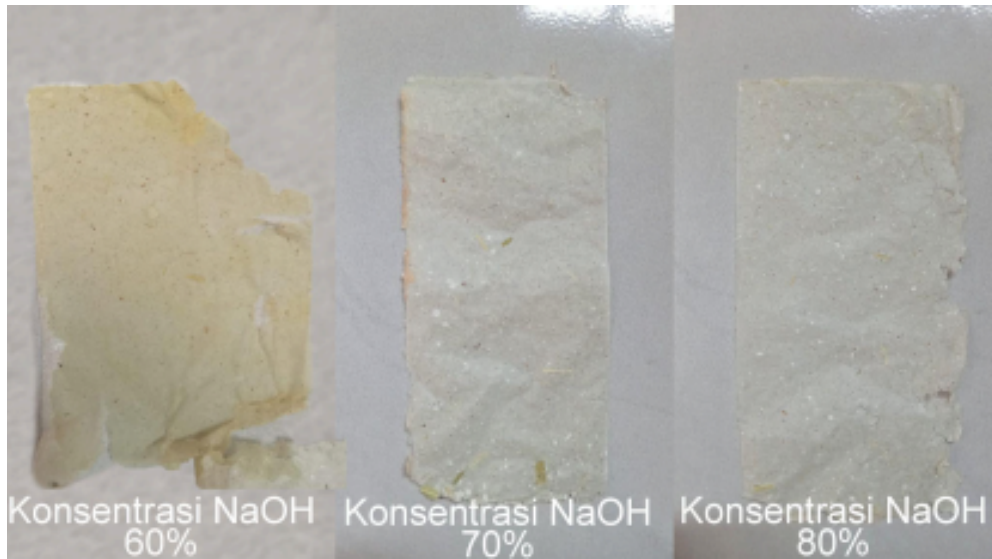
4.1. Organoleptic Test

The organoleptic test involved observing three parameters: texture, color, and aroma of the environmentally friendly tissue paper.

Table 1. Organoleptical Test Results

Parameter	Tissue Yield Samples with Variations in NaOH Concentration		
	60%	70%	80%
Texture	Rough	Smooth	Smooth
Color	Yellowish brown	Faint yellowish brown	Faint green
Odor	Dominant citrus odor	Dominant citrus odor	Still strong NaOH odor

Figure 1. Sample of tissue making results



According to the observation results, the texture of the tissue made with a 60% sodium hydroxide (NaOH) concentration was coarse, whereas those with 70% and 80% concentrations were smooth. This is related to the concentration of NaOH used during boiling; NaOH serves to remove non-cellulosic components that hinder hydrogen bonding between cellulose molecular chains (Le Moigne & Navard, 2010). Thus, it was found that higher concentrations of NaOH lead to a finer texture in the resulting tissue.

The second parameter, color, revealed that the tissue with a 60% NaOH concentration exhibited a brownish-yellow hue, predominantly influenced by

The third parameter assessed was aroma. The samples with 60% and 70% NaOH concentrations were predominantly scented with the essential oil extracted from *Citrus nobilis*, while the sample with 80% NaOH still emitted a strong NaOH odor, even after spraying with the same dosage of citrus oil. This suggests that the effectiveness of the essential oil in masking the chemical smell is reduced at higher NaOH concentrations, which may require further optimization to enhance the

the *Salacca zalacca* peel. In contrast, the tissue with a 70% NaOH concentration appeared as a faded yellow-brown, while the 80% NaOH concentration resulted in a pale green tissue. The differences in coloration can be attributed to the bleaching process with hydrogen peroxide (H_2O_2) and the characteristics of the pulp obtained from varying NaOH concentrations. Specifically, the 80% NaOH concentration yielded a very smooth pulp, leading to a reduction in the dominant dark brown color of the salak peel, especially when combined with the greenish corn pulp and H_2O_2 bleaching (Lestari & Kartika Sari, 2016).

sensory properties of the tissue (Le Moigne & Navard, 2010). Overall, these findings underscore the importance of optimizing the formulation and processing conditions to improve the sensory attributes of the tissue paper, making it more appealing for consumer use while still being environmentally friendly.

Of the three parameters, the best concentration is the 70% NaOH concentration, as it produces the best overall quality tissue. This

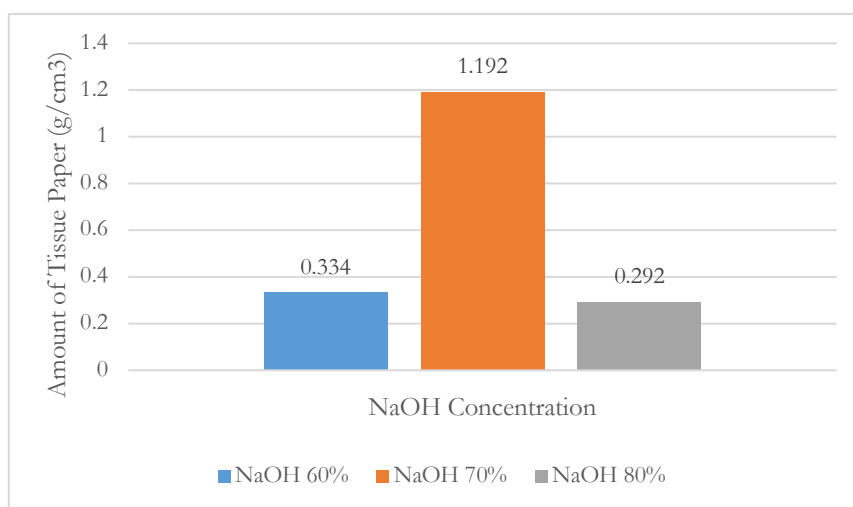
formulation yields a smooth texture, a faded yellow-brown color, and a dominant citrus aroma, making it ideal for use as an eco-friendly kitchen tissue. The 70% NaOH concentration strikes an optimal balance between effective delignification and desirable tissue properties. It softens the *Salacca zalacca* peels and breaks down lignin, exposing cellulose fibers that create a smooth and fine texture. The faded yellow-brown color indicates effective delignification without over-bleaching, while hydrogen peroxide further lightens the tissue. The dominant citrus aroma from *Citrus nobilis* essential oil enhances the tissue's appeal, masking chemical smells and making it more pleasant for consumer

use. This combination of texture, color, and fragrance makes the 70% NaOH formulation the ideal choice for eco-friendly kitchen tissue.

4.2. Tissue Paper Quantity Test

In the tissue paper quantity test, the researcher weighed each printed sample on a 20 x 30 cm screen, and the results were interpreted in a diagram showing the average weight of the tissue pulp.

Figure 2. Tissue paper quantity test



Based on the results from the diagram, it was found that the tissue made with a NaOH concentration of 70% produced a greater amount of tissue paper or pulp compared to the other concentrations. The tissue with a 60% concentration yielded less pulp, resulting in a rough texture due to incomplete binding, as not all materials formed into pulp fibers.

Conversely, the tissue produced with an 80% NaOH concentration also resulted in a lower pulp yield; the high concentration of NaOH caused the pulp to become finer and more pliable, which negatively affected the tear strength of the tissue.

These findings align with previous studies that emphasize the importance of optimal

NaOH concentrations in the pulping process. (Fernando et al., 2022; Rousu et al., 2002) highlighted that adjusting the concentration of NaOH is crucial for achieving a balance between the quantity and quality of pulp produced. An inadequate concentration may lead to coarse tissue, while an excessive concentration could weaken the pulp structure. (Le Moigne & Navard, 2010) noted that a higher NaOH concentration tends to create softer pulp but at the cost of reduced strength, indicating that the right concentration is essential for producing high-quality tissue paper. Additionally, (Chan et al., 2021; Koul et al., 2022) pointed out that the effectiveness of agricultural waste in producing eco-friendly paper can vary significantly based on processing conditions, including chemical treatments.

Their findings further support the need to optimize NaOH concentration to maximize both the yield and the mechanical properties of the resulting tissue paper.

4.3. Biodegradability Test

The biodegradability test was conducted by burying the three tissue samples in soil located at the Rooftop Laboratory of Science Education, FMIPA, Universitas Negeri Yogyakarta, for two days to observe their decomposition capability. The soil conditions used for the degradation test were dry and barren, with a few plants growing in the surrounding area. Prior to burial, each sample was weighed to record its initial weight (W_0), and after two days of burial, the samples were reweighed to obtain the final weight (W_1).

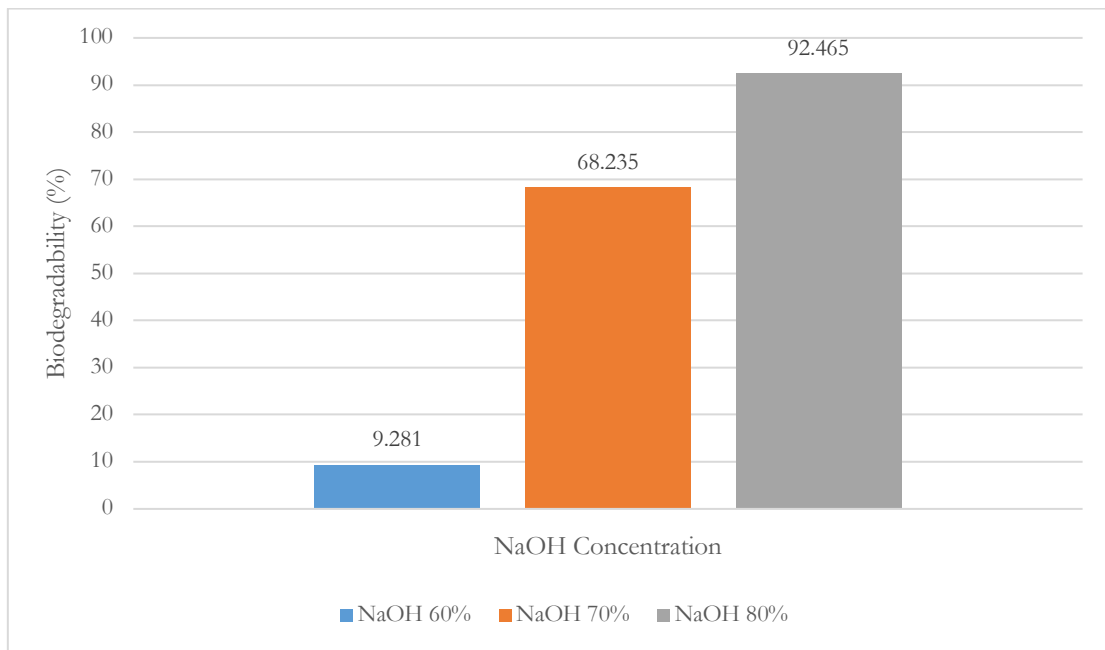
Figure 3. Tissue paper initial weight (W_0)



Figure 4. Tissue paper final weight (W_1)



Figure 5. Biodegradability test result



The results from the biodegradability test, after burying the samples for two days, revealed that the higher the NaOH concentration, the greater the degradation rate. The tissue sample with 60% NaOH concentration had the lowest degradation rate at 10%, while the sample with 80% NaOH showed the highest degradation rate at 90%. This is influenced by the thickness

of the tissue produced; the 80% NaOH concentration resulted in the thinnest tissue, making it more easily decomposable. The overall degradation rate observed across all samples was favorable, indicating that within two days, the samples demonstrated significant biodegradation, supporting the conclusion that these tissues are environmentally friendly.

This outcome aligns with findings by (Le Moigne & Navard, 2010; Wang & Zhao, 2021), which highlighted that higher NaOH concentrations enhance the breakdown of cellulose fibers, contributing to increased biodegradability in pulp-based products. According to (Rahayu et al., 2022), thinner tissues with minimal lignin and hemicellulose content degrade more rapidly in soil environments, making them suitable for environmentally friendly applications. The fast degradation observed in all samples underscores the potential for these tissues as a sustainable alternative to conventional products.

5. CONCLUSION AND SUGGESTION

Based on the research conducted, the following conclusions were drawn:

1. Tissue Material Formulation: This study successfully demonstrated that the use of *Salacca zalacca* peel waste and *Citrus nobilis* peel extract, along with a high-cellulose material such as corn husk, can serve as effective raw materials for producing environmentally friendly tissue. This combination of materials produces sufficient pulp for tissue production with good characteristics.
2. Effect of NaOH Concentration: Among the three NaOH concentration variations (60%, 70%, and 80%), the best formulation was achieved with a 70% concentration. The tissue produced with 70% NaOH concentration exhibited optimal physical qualities, including smooth texture, faded yellowish-brown color,

and a dominant citrus scent, making it suitable for kitchen tissue use.

3. Pulp Quantity and Quality: The pulp quantity test showed that tissue with 70% NaOH concentration generated more pulp compared to other concentrations. This resulted in denser tissue and greater production efficiency.
4. Biodegradability: All tissue samples demonstrated good biodegradability during the soil test over two days, confirming that the tissues produced are environmentally friendly. Although tissue with 80% NaOH concentration exhibited the highest degradation rate, the tissue with 70% NaOH concentration balanced both physical quality and ease of degradation.

Based on the research findings regarding the production of environmentally friendly tissue from *Salacca zalacca* peel waste and *Citrus nobilis* peel extract, the following suggestions are made to enhance future research and practical applications:

1. Optimization of Pulp Production: Future research should explore the use of other natural cellulose-rich materials alongside corn husk, such as banana fiber or bamboo, to further optimize the pulp yield. This could lead to higher-quality tissue production and provide additional sustainability benefits by utilizing various agricultural wastes.
2. Scaling Up Production: While the laboratory-scale process has proven successful, future studies should focus on scaling up the production process. Investigating industrial techniques for pulping and tissue manufacturing could reveal new challenges and solutions, such

as the energy efficiency of large-scale NaOH usage or the integration of renewable energy sources into production.

3. Enhancement of Biodegradability: Although all samples demonstrated good degradation rates, further studies could focus on extending the biodegradation testing period and exploring how different environmental conditions (e.g., soil types, temperature, and moisture levels) influence the breakdown of the tissue. This would provide a more comprehensive understanding of the tissue's behavior in diverse waste management scenarios.
4. Broader Applications: The tissue produced with 70% NaOH concentration showed promising

qualities for kitchen use. However, the development of other tissue products, such as facial tissue or toilet paper, should be considered. Additional testing on factors like absorbency, strength, and softness could expand the potential applications of the environmentally friendly tissue.

5. Further Organoleptic Testing: To refine the sensory characteristics of the tissue, it is suggested that further organoleptic testing be conducted with a larger group of participants. This would provide a broader range of feedback on texture, color, and scent preferences, aiding in the formulation of a product that meets diverse consumer needs.

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