Eksergi
Chemical Engineering Journal
Vol 22, No. 3. 2025

ISSN: 1410-394X
e-ISSN: 2460-8203

Production of Fragrance Tag (Paper-Based Air Fresheners) from Agarwood Powder Waste (*Aquilaria malaccensis*)

Reni Yuniarti, Elfira Wardani Putri, Abror Sida Mubin, Feerzet Achmad*

Department of Chemical Engineering, Faculty of Industrial Technology, Institut Teknologi Sumatera, South Lampung, Lampung, 35365, Indonesia

Article history:

Submitted 4 July 2025
Revision 29 July 2025
Accepted 30 July 2025
Online 1 August 2025

ABSTRACT: Agarwood is a non-timber forest product known for its distinctive fragrance. Its processing generates powder waste that is often undervalued and underutilized, despite containing aromatic compounds with potential for value-added products such as fragrance tags. This study aimed to determine the optimal composition of agarwood powder and waste paper, assess the effects of NaOH treatment on product characteristics, and evaluate economic feasibility. The process involved preparing agarwood and HVS paper waste, treating with or without NaOH, producing pulp at ratios of 75:25, 50:50, and 25:75 (% w/w), and adding essential oil. Results showed that NaOH treatment significantly improved physical and sensory properties such as color brightness, grammage, and tensile strength but reduced thickness, absorbency, and scent longevity. Material ratio also influenced performance: 25:75 (% w/w) with NaOH yielded the best color and tensile strength, while 75:25 without NaOH showed the highest thickness, absorbency, and scent stability up to day 5. Economic analysis indicated feasibility, with a break-even point of 181 units, a return cost ratio (RCR) of 1.44, and a payback period of 2.27 months.
Keywords: agarwood; fragrance tag; naoh; paper; powder waste

1. Introduction

Agarwood (*Aquilaria malaccensis*) is one of the most economically valuable non-timber forest products (NTFPs), formed as a result of microbial infection in the heartwood of the tree, which leads to the production of a distinctive aromatic resin (Du et al., 2022; Fauziah et al., 2022). This resin emits a fragrant scent that is widely utilized across various sectors, including the cosmetics industry, religious practices, traditional medicine, and handicrafts (Shivanand et al., 2022). In Indonesia, agarwood-producing trees are found throughout Sumatera, Kalimantan, Sulawesi, and Papua, with A. malaccensis recognized as the primary species yielding high-quality agarwood (Lee et al., 2018; Yuniarti et al., 2023). However, during the processing of agarwood, waste in the form of wood powder is generated. This by-product still contains aromatic compounds and lignocellulose, yet it is often underutilized.

Agarwood powder waste (APW) is a by-product of agarwood processing, primarily derived from the sapwood (gubal) and kemedangan parts of the tree (Gusmailina & Sumadiwangsa, 2020). Scraping or crushing the wood produces a brown to dark-colored powder, depending on its resin content (Pang et al., 2024). Although commonly used as incense fuel or simply discarded, this waste holds significant potential for conversion into value-added products, as it still contains aromatic compounds and lignocellulosic materials (Achmad et al., 2022).

Lignocellulose is composed of cellulose, hemicellulose, and lignin (Batubara et al., 2021), with cellulose serving as the primary raw material in paper production, while lignin must be removed through a delignification process to ensure paper quality (Deivy et al., 2021; Edahwati et al., 2014; Susanti, 2021). One widely used method is soda pulping with NaOH solution, which effectively breaks down lignin and hemicellulose bonds and opens the fiber structure to increase cellulose accessibility (Suhendri et al., 2025). The delignification reaction using NaOH is shown in Figure 1. Moreover, agarwood powder also contains aromatic resin, mainly composed of sesquiterpenes and chromones, which contribute to its distinctive and valuable scent (Yang et al., 2021).

The high resin content, particularly in high-quality powder, further enhances its potential as a base material for aromatic products such as fragrance tags and cellulose-based scented papers used as air fresheners for rooms, vehicles, or closets. These products require physical characteristics such as high absorbency and adequate tensile strength, making material selection and chemical treatment essential aspects of the manufacturing process. With this approach, underutilized APW can be transformed into an environmentally friendly and commercially valuable

* Corresponding Author: +62 812-2012-6389
Email address: feerzet.achmad@tk.itera.ac.id

alternative raw material, aligning with the principles of sustainability and the circular economy.

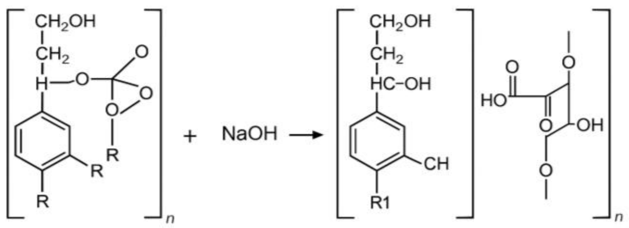


Figure 1. Lignocellulose Breakdown Reaction (Deivy et al., 2021)

Various studies have explored the development of alternative paper using non-wood biomass waste such as empty oil palm fruit bunches (EFB), coconut husks, young coconut fibers, sugarcane bagasse, wood waste, and recycled HVS paper through the soda pulping method using NaOH solution (Safrizal et al., 2022; Sutanti et al., 2024). This process is generally conducted at temperatures ranging from 100 °C to 145 °C, with NaOH concentrations ranging from 6% to 15% and varying cooking durations. Studies involving oil palm empty fruit bunches and recycled HVS paper with NaOH treatment have demonstrated promising physical characteristics, which may be comparable to agarwood waste (Safrizal et al., 2022). However, none have specifically explored the use of APW, which contains both lignocellulose and a unique aromatic resin profile, as a dual-function raw material that contributes both structural and aromatic properties.

In contrast to previous research, this study introduces a novel approach by integrating APW with recycled HVS paper to develop fragrance tags that function not only as paper-based products but also as natural air fresheners. The presence of sesquiterpenes and chromones in APW offers natural fragrance retention, setting it apart from other lignocellulosic waste materials. To date, no studies have reported the formulation of aromatic paper products through a simple soda pulping process that preserves the signature scent of agarwood while achieving desirable mechanical properties. Thus, this study contributes an innovative perspective by combining aromatic and structural functions in a single biodegradable product, marking a clear advancement over existing research on paper-based air fresheners.

Moreover, this work supports broader sustainability objectives by converting two types of waste, agarwood powder and recycled paper, into a value-added product suitable for micro and small enterprises (MSMEs) and the creative industry. Future exploration of this concept can lead to the development of other lignocellulosic waste-based products with specific functionalities, contributing to material innovation and zero-waste design strategies.

2. Materials and Methods

2.1 Materials

The primary materials used were APW and HVS paper waste (HPW) as sources of lignocellulosic fiber. Supporting materials included tapioca flour (Rose Brand, food grade) as a natural adhesive, distilled water (Brataco, 99.5%) as a solvent, agarwood essential oil (100%) as the aromatic agent, and absolute ethanol (Merck, 96%) as the diluting solvent for the essential oil. For the pretreatment process, a sodium hydroxide (NaOH) solution at a concentration of 11% w/v was prepared from solid NaOH pellets (Merck, 98%) and used to break down lignin and soften the agarwood powder prior to pulping.

2.2 Equipment

A 60-mesh screen (wooden frame, 14.8 cm × 21 cm) was used as the primary tool for forming paper sheets. The supporting equipment included a digital scale (Taffware Digipounds, ±0.01 g) for material weighing, a grinder (OSSEL, 600 W) for homogenizing the pulp mixture, and scissors for cutting and shaping the finished sheets. Plastic buckets (20 L) were used for mixing, and sponges (Scotch-Brite, 3M) were employed to absorb excess water from the wet sheets. The drying process utilized an electric drying oven (Advance AOV-500 900 W) and a tampah (traditional bamboo tray) for air-drying. Sheet dimensions were measured using a stainlesssteel ruler (±0.1 cm) and a digital caliper (Mitutoyo, ±0.01 mm) for thickness. We stirred the pulp mixture with a plastic spatula and ensured accurate liquid measurements with measuring cups and drip pipettes (Eppendorf, 0.1–10 mL). Lastly, solid ballast weights (approximately 2–3 kg) were applied to compact the paper sheets and remove residual water during the pressing process.

2.3 Methods

2.3.1 Raw Material Preparation

A total of 50 g of a mixture comprising APW and HPW was prepared based on predetermined formulation ratios (Table 1). Approximately 200 mL of hot water was added to the APW, followed by the addition of 20 g of solid NaOH. The mixture was stirred until homogeneous and left to stand for 2 hours to allow for the delignification process. After soaking, the APW mixture was thoroughly rinsed with clean water and filtered using a fine-mesh sieve to remove residual NaOH.

Table 1. Composition ratios

Sample Code	APW (%)	HPW (%)	Total Mass (g)
A1	25	75	50
A2	50	50	50
A3	75	25	50

ISSN: 1410-394X
e-ISSN: 2460-8203

Meanwhile, HPW was manually cut into approximately 0.5 cm pieces using scissors, then blended with 300 mL of water to produce recycled paper pulp. The pretreated APW and HPW pulp were then combined in a container and mixed thoroughly until a uniform pulp mixture was obtained.

2.3.2 Paper Making and Drying

The prepared pulp was mixed with 50 g of tapioca flour and 3 liters of water, then stirred until homogeneous. The mixture was then molded into paper sheets using a 60-mesh screen (wooden printing frame). Water from the surface of the wet paper sheets was removed by pressing with a sponge. The sheets were carefully lifted from the screen and further compressed using solid ballast to reduce moisture. Drying was performed using an oven at 150 °C for approximately 2 hours until the sheets were completely dry.

2.3.3 Fragrance Tag Production

Dried paper sheets were cut into various desired sizes and perforated at the top to allow for hemp rope installation. Agarwood essential oil was prepared by dissolving 1 mL of oil in absolute ethanol at a ratio of 30:70 (% v/v). The solution was sprayed evenly onto the surface of the paper sheets. Finally, the fragrance tags were packed in air-resistant plastic packaging to maintain scent stability and product quality. The resulting product, fragrance tags made from APW and HPW, was then ready for use.

2.4 Testing and Analysis

2.4.1 Characteristics of the Fragrance Tag

a) Color Test

The color test was conducted using a sensory evaluation method in accordance with SNI 01-2346-2006. The sensory evaluation of paper color was conducted using a descriptive test method. Panelists were asked to categorize the samples into five predetermined color groups: (1) predominantly white, (2) white with slight light brown tint, (3) light brown, (4) dark brown, and (5) white with slight dark brown tint. A total of 54 untrained but willing panelists participated in the assessment. To ensure consistency, observations were carried out under standardized lighting conditions between 09:00 AM and 04:00 PM. Each panelist evaluated paper samples with dimensions of 7 cm × 5 cm. The final color classification of each sample was determined based on the majority vote among the panelists to increase objectivity (Badan Standarisasi Nasional, 2006).

b) Thickness Test

The thickness of the paper samples was measured using a caliper. Measurements were taken on all four sides of each sample. The average thickness (cm) was calculated using Equation (1):

$$Average\ thickness = \frac{\sum \text{Measurement values}}{\text{total number of measurement}} \quad (1)$$

c) Grammage Test

The grammage test was conducted in accordance with SNI 14-0439-1998. The final weight value was determined by averaging the two weighing results using Equation (2):

$$average\ weight = \frac{weight\ 1 + weight\ 2}{2} \quad (2)$$

Subsequently, the grammage (in g/m²) was calculated using Equation (3):

$$Grammage = \left(\frac{weight\ of\ paper\ (g)}{surface\ area\ (cm^2)}\right) \times 10^4 \quad (3)$$

d) Absorbency Test

The absorbency test was based on the RSNI3 ISO 535:2023 standard (Badan Standarisasi Nasional, 2023). The water absorbency was calculated using Equation (4):

$$Cobb_{30} = \frac{(W_2 - W_1)}{A} \times 10^4 \quad (4)$$

Where:
W_1 = initial weight (g)
W_2 = final weight after 30 s (g)
A = surface area (cm²)

e) Scent Longevity

The scent longevity was assessed over 7 consecutive days using a subjective scoring method to evaluate fragrance intensity each day using (1): very weak, (2) weak, (3) moderate, (4) strong, and (5) very strong. The evaluation was conducted in a closed room measuring 3 × 4 meters with minimal air circulation to prevent external interference that could accelerate scent loss. Panelists maintained a consistent distance of approximately 1 meter from the fragrance tag during each assessment session. The assessments were conducted at the same time each day to ensure consistency. The room temperature was maintained between 23 °C and 27 °C, and relative humidity was kept at around 80–89% to minimize evaporation caused by environmental fluctuations.

f) Tensile Strength Test

Tensile strength was measured using a Universal Testing Machine (UTM) Zwick Roell Z250SR, following the SNI ISO 1924-2:2016 standard (Badan Standarisasi Nasional, 2023). The tensile strength was calculated using Equation (5):

$$Tensile\ strength(Mpa) = \frac{Force(N)}{Cross\text{−}sectional\ area(mm^2)} \quad (5)$$

2.4.2 Economic Feasibility Analysis

To assess the economic feasibility of fragrance tag production from agarwood powder and recycled HVS paper, both variable and fixed costs were identified and calculated. The variable costs include consumable materials used per production cycle (Table 2), while fixed costs refer to one-time investments in equipment and tools required for the manufacturing process (Table 3).

Table 2. Variable Costs

Component	Unit Price (IDR)	Unit
Tapioca	8,000	500 g
Perfume	4,000	1 ml
Absolute	22,500	500 ml
NaOH	50,000	1 kg
Hemp rope	12,000	10 meters
Agarwood powder	60,000	2 kg
HVS paper waste	1,200	2 kg
Packaging	1,200	50 pcs
Total variable cost per batch (IDR)		417,500
Production frequency 2 batches per month (IDR)		835,000

a) Break Even Point (BEP)

BEP was calculated in two forms. BEP (unit) using Equation (6) (Novelia et al., 2024):

$$BEP = \frac{Total\ fixed\ cost}{(Selling\ price\ per\ unit - total\ variable\ cost\ per\ unit)} \quad \textbf{(6)}$$

BEP (sales value) using Equation (7).

$$BEP = \frac{Total\ fixed\ cost}{1-\left(\frac{variable\ cost\ per\ unit}{selling\ price\ per\ unit}\right)} \quad \textbf{(7)}$$

b) Return Cost Ratio (RCR)

RCR was calculated using Equation (8) (Kurniawan A. et al., 2023):

$$RCR = \frac{Total\ revenue}{Total\ production} \quad \textbf{(8)}$$

c) Payback Period (PP)

The payback period was calculated using Equation (9) (Ibad et al., 2022):

$$PP = \frac{Revenue}{Net\ profit} \quad \textbf{(9)}$$

All cost and revenue data used in the above calculations were obtained during this research.

Table 3. Fixed Costs

Component	Unit Price (IDR)	Unit
Storage box	68,000	500 g
Paper mold	45,000	1 ml
Digital scale	100,000	500 ml
Scissors	35,000	1 kg
Hole punch	25,000	10 meters
Mixing basins	15,000	2 kg
Total fixed cost per batch (IDR)		553.000

3. Results and Discussion

3.1 The Effect of NaOH and APW Ratio Variation on Fragrance Tag Color

The color sensory test involved 54 panelists to assess the visual appearance of the fragrance tag based on five color categories, namely dominant white, white with a little light brown, light brown, dark brown, and white with a little dark brown. Figure 2 presents the results of the color test on the fragrance tags.

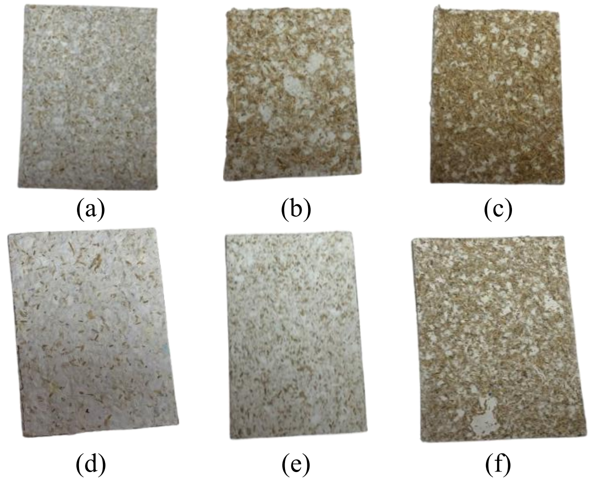


Figure 2. Color Test Results without NaOH, (a) 25%:75%, (b) 50%:50%, and (c) 75%:25%; with NaOH, (d) 25%:75%, (e) 50%:50%, and (f) 75%:25%.

The results showed that the addition of NaOH produced a brighter and more even color due to the delignification process that reduced the lignin content of natural dyes. Fragrance tags without NaOH tend to be darker in color and inhomogeneous. At an APW to HPW ratio of 25:75 (% w/w) without NaOH, the color that appears is white with a little light brown (75.9%), while the 75:25 ratio produces a dark brown color (75.93%). With the addition of NaOH, the color became lighter; the 25:75 ratio showed a dominant white color (74.07%), while the 75:25 ratio produced a light brown color (48.15%).

The higher the ratio of APW, the more intense the color produced, both with and without NaOH. This study shows that in addition to chemical treatment, the composition of the material greatly affects the intensity of the final color (Prasetia et al., 2022). Color also serves as an indicator of visual quality and consumer preference, so these results are important for formulation optimization and production processes (Yuliyanto et al., 2022).

3.2 The Effect of NaOH and APW Ratio Variation on Fragrance Tag Thickness

Paper thickness is one of the key parameters affecting the absorbency, mechanical strength, and visual appearance of the fragrance tag. The thickness test showed that samples without NaOH treatment exhibited greater thickness (Figure 3), with the highest value of 0.21 cm observed at a 75:25 (% w/w) ratio, compared to 0.13 cm for the 25:75 ratio with NaOH. This is attributed to the presence of intact lignocellulosic structures, which form coarse fibers and aggregates that increase volume (Wijayanti et al., 2024). In contrast, NaOH treatment facilitates delignification, softening the fibers and promoting a finer, more evenly distributed fiber network, resulting in lower and more consistent thickness values (Puspitasari et al., 2022).

ISSN: 1410-394X
e-ISSN: 2460-8203

An increasing proportion of APW also consistently led to greater thickness, due to higher solid content enriching the fiber matrix (Khasanah et al., 2017). However, the untreated samples showed greater standard deviation in thickness (±0.008–0.019 cm) compared to NaOH-treated ones (±0.003–0.020 cm), indicating fiber inhomogeneity caused by manual sheet forming (P. G. Putri et al., 2022). Thickness plays an important role in both absorbency and mechanical durability; thicker sheets tend to retain more liquid and withstand deformation. Nevertheless, achieving uniform fiber distribution remains a challenge in manual production processes (Apriani & Hasanah, 2023).

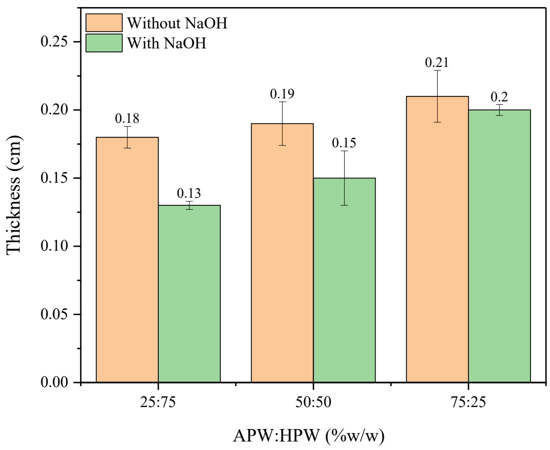


Figure 3. Thickness Test Result

3.3 The Effect of NaOH and APW Ratio Variation on Fragrance Tag Grammage

The grammage test was conducted to evaluate the mass per unit area (g/m²), which affects the absorbency and mechanical strength of the fragrance tag. The results indicated that NaOH treatment increased grammage (Figure 4), with the highest value recorded at 482.29 g/m² for the 25:75 (%w/w) ratio, compared to 416.67 g/m² without NaOH. This increase is attributed to fiber delignification and swelling, which enhanced inter-fiber bonding and improved mass retention (Sridach, 2010).

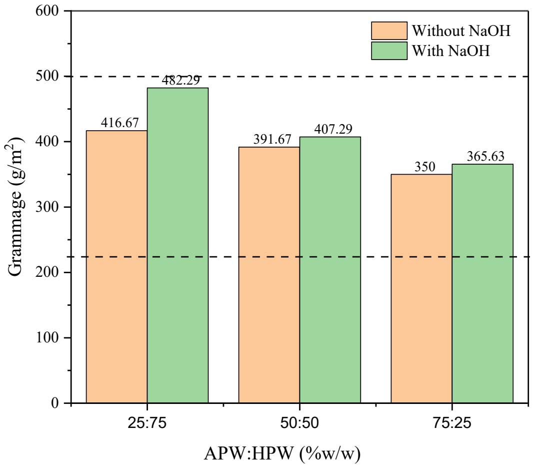


Figure 4. Grammage Test Result

Grammage was also influenced by the APW: HPW composition, where higher proportions of HPW resulted in higher grammage due to its greater density compared to agarwood powder. In addition, the manual sheet-forming method using sponges led to uneven pulp distribution, contributing to variation among samples (Tarigan et al., 2013). Despite minor fluctuations due to environmental factors such as temperature and humidity, all samples fell within the standard grammage range of 225–500 g/m², as specified in SNI 0123:2008, thus qualifying them as duplex board materials suitable for commercial applications such as packaging (F. Putri et al., 2023).

3.4 The Effect of NaOH and APW Ratio Variation on Fragrance Tag Absorbency

The paper absorbency test was conducted to measure the ability of the paper surface to absorb liquids. This test was conducted using the Cobb30 method. The fragrance tag without the addition of NaOH has a higher absorbency, with the highest value at a ratio of 25:75 (% w/w) of 597.91 g/m², compared to 539.58 g/m² for the sample with NaOH at the same ratio. The addition of NaOH causes a decrease in porosity due to the delignification process, which makes the fibers finer and tighter, thus reducing the ability to absorb liquids (Mufridayati et al., 2013). Figure 5 presents the results of the absorbency on the fragrance tags.

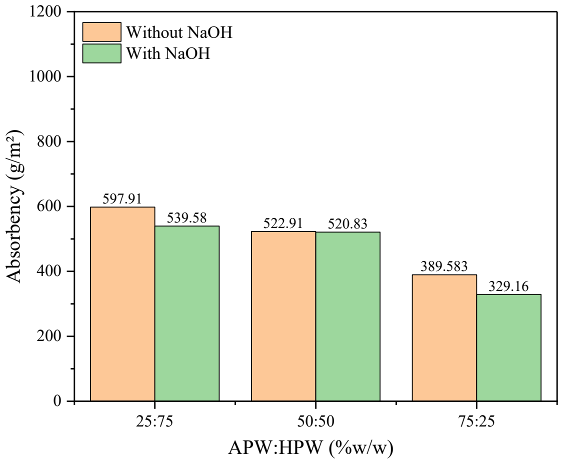


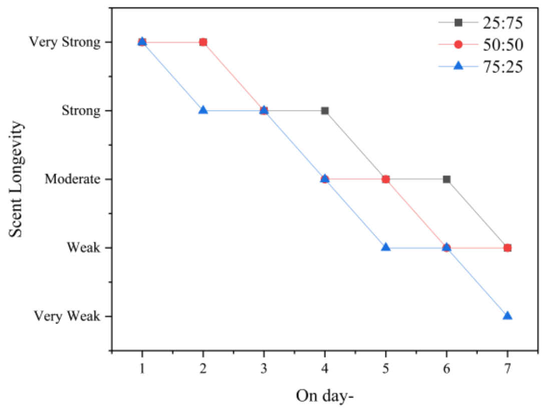
Figure 5. Absorbency Test Result

The variation of the APW:HPW ratio also has an effect: the higher the agarwood powder content, the higher the absorbency due to its short and more porous fiber structure. Conversely, a high ratio of HPW decreases the absorbency because the fibers are longer and tighter. This result is in line with the theory that fiber length affects the absorption area (Sutanti et al., 2024). While high absorbency can support scent absorption, excess water absorption decreases the physical strength of the paper, making it more prone to damage. Therefore, a balance between absorbency and mechanical strength is needed to produce an optimal fragrance tag (Munashifah et al., 2018).

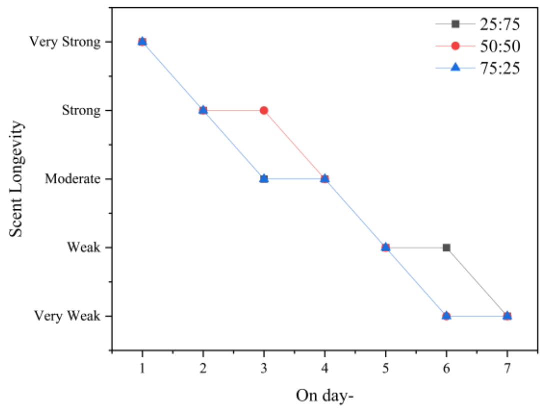
3.5 The Effect of NaOH and APW Ratio Variation on Fragrance Tag Scent Longevity

The scent longevity test was conducted over a 7-day period to evaluate the fragrance stability of the tags after application of agarwood essential oil. The sample without NaOH treatment and at a 25:75 (% w/w) ratio exhibited the best scent longevity, detectable up to the fifth day. In contrast, the shortest scent lifespan was observed in the NaOH-treated sample with a 75:25 ratio, with fragrance detectable only until the second day.

This difference is attributed to the tighter fiber structure caused by delignification in the NaOH-treated samples, which reduces porosity and limits the gradual release of essential oil (Pratama et al., 2024). Conversely, the untreated samples retained a more open structure, allowing for greater oil absorption and a slower, sustained release of scent (Atmaka et al., 2016). Figure 6 presents the results of the fragrance tag scent longevity.



(a)



(b)

Figure 6. Fragrance Tag Scent Longevity Test Results (a) Without NaOH and (b) With NaOH

The raw material ratio also played a significant role. The 25:75 composition provided an optimal balance between the aromatic characteristics of APW and the absorbent nature of HPW (Sundari et al., 2020), resulting in a porous yet structurally stable sheet ideal for controlled scent release (Sutanti et al., 2024). In addition to absorbency, physical properties such as thickness, grammage, and elasticity contributed to scent longevity. Thicker, more elastic sheets retained more oil and maintained a stable hanging position, enhancing fragrance dispersion (Ardiani et al., 2020).

3.6 The Effect of NaOH and APW Ratio Variation on Fragrance Tag Tensile Strength

The tensile strength test was conducted to assess the mechanical strength of the fragrance tag against the tensile force before breaking, using a Universal Testing Machine (UTM). This parameter is important to ensure the physical durability of fragrance tags during use. Based on the test results (Figure 7), fragrance tags with the addition of NaOH showed higher tensile strength values compared to those

ISSN: 1410-394X
e-ISSN: 2460-8203

without NaOH. At a ratio of 25:75 (%w/w), the tensile strength value reached 6.16 MPa, decreasing to 4.55 MPa at a ratio of 50:50 and 0.80 MPa at a ratio of 75:25. In contrast, fragrance tags without NaOH showed a sharp decrease, which was 3.35 MPa at the 25:75 ratio and only 0.93 MPa for the other two ratios.

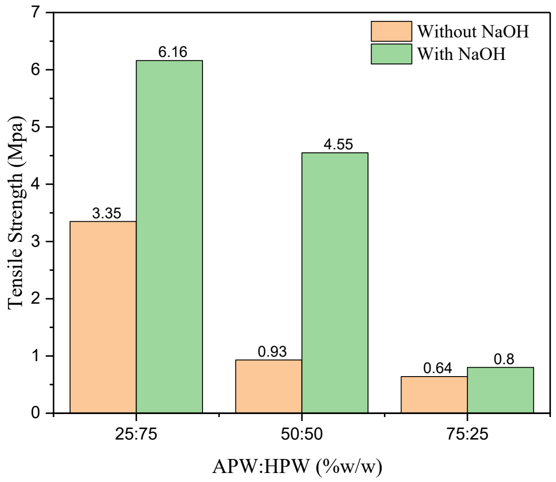


Figure 7. Tensile Strength Test Result

The addition of NaOH increases tensile strength through the delignification process, which helps dissolve lignin and improve the bond between fibers. The fibers become smoother and denser, forming a stronger and more flexible network. This finding is supported by previous studies showing a positive correlation between NaOH concentration and increased tensile strength (Safrizal et al., 2022; Selvia, 2018).

Material composition also had a significant effect. A higher ratio of HPW resulted in greater tensile strength due to its longer and thick-walled fibers compared to agarwood powder, which has short and weak fibers (Paskawati et al., 2010). Therefore, a high proportion of HPW increased the tensile strength, while the predominance of agarwood powder decreased it (Sundari et al., 2020).

Overall, the tensile strength of fragrance tags was determined by the combination of material ratio and chemical treatment. The use of NaOH and increasing the proportion of HPW gave the best results in terms of mechanical resistance. A high tensile strength value indicates that the fragrance tag is more resistant to tearing and physical damage when used (Safrizal et al., 2022).

3.7 Fragrance Tag Economic Feasibility Analysis

Based on the calculations, the total monthly production cost was Rp1,388,000, comprising Rp553,000 in fixed costs and Rp835,000 in variable costs, for a production capacity of 200 units per month. At a selling price of Rp10,000 per unit, gross revenue reached Rp2,000,000 with a net profit of Rp612,000 per month.

The break-even point (BEP) was calculated at 181 units or Rp1,807,190 in sales revenue, indicating that any sales beyond this threshold generate profit (Novelia et al., 2024). The return cost ratio (RCR) was 1.44, meaning that each Rp1 spent on production yields Rp1.44 in revenue, confirming economic feasibility (Kurniawan A. et al., 2023). Meanwhile, the payback period (PP) was 2.27 months, reflecting a relatively short investment return time.

Therefore, the production of fragrance tags from waste-derived materials is not only environmentally friendly but also economically viable, with strong potential for scaling up at household and SME levels (Ibad et al., 2022).

4. Conclusions

Based on the results, it can be concluded that the addition of NaOH has a significant effect on the physical and sensory characteristics of fragrance tags. This treatment increased color brightness, grammage, and tensile strength but reduced thickness, absorbency, and scent longevity due to decreased fiber porosity as a result of the delignification process. In addition, the variation in ingredient ratio also had a significant impact on product performance. The 25:75 (% w/w) ratio without NaOH gave the best results in terms of absorbency and scent longevity, while the 25:75 ratio with NaOH produced the brightest color and highest tensile strength.

From an economic perspective, this business proved to be feasible to develop with a break-even point (BEP) of 181 units, a Return Cost Ratio (RCR) value of 1.44, and a Payback Period of 2.27 months. This shows that the production of fragrance tags from APW and HPW is not only environmentally friendly but also financially promising.

While the findings are promising, this study was limited by its small production scale, limited scent variants, and short evaluation duration. Future studies should address these limitations and explore more specific improvements, such as enhancing aroma stability, optimizing drying conditions, and conducting a life cycle analysis (LCA) to assess long-term environmental impact. Furthermore, future research may also focus on refining the printing process, developing longer-lasting scent formulations, and expanding the application of waste-based products in MSME and creative industry contexts.

Acknowledgments
The authors would like to thank the agarwood farmer MSMEs in Lampung for providing the agarwood powder used in this research.

Statement
During the preparation of this manuscript, the authors used ChatGPT-4o and Quillbot in order to improve the English language and proofread the text. The graphics in this manuscript were created using the OriginLab application. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Reni Yuniarti: Supervision, Conceptualization, Validation, Writing – review & editing. **Elfira Wardani Putri:** Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. **Abror Sida Mubin:** Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. **Feerzet Achmad**: Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

References

Achmad, Z., Arsa, A. K., Alfitamara, B., & Virgiandini, A. (2022). Renewable Energy from Pyrolysis of Pine Wood with Zeolite Catalyst. *Eksergi*, *19*(1), 1. https://doi.org/10.31315/e.v19i1.4564

Apriani, R., & Hasanah, S. F. (2023). Pengaruh Penambahan Pulp Bambu sebagai Blending Material dengan Variasi Freeness terhadap Sifat Fisik dan Optik Kertas Coklat. *Seminar Nasional Rekayasa, Sains Dan Teknologi*, *3*(1), 156–164. https://repository.itsb.ac.id/id/eprint/958

Ardiani, S., Rahmayanti, H., & Akmalia, N. (2020). The Study of Paper Capillarity with a Simple Technique. *Publipreneur Polimedia: Jurnal Ilmiah Jurusan Penerbitan Politeknik Negeri Media Kreatif*, *8*(1), 34–47. https://doi.org/10.46961/jip.v8i1.55

Atmaka, W., Manuhara, G. J., Destiana, N., Kawiji, K., Khasanah, L. U., & Utami, R. (2016). Karakterisasi Pengemas Kertas Aktif dengan Penambahan Oleoresin dari Ampas Pengepresan Rimpang Temulawak (Curcuma xanthorrhiza Roxb). *Reaktor*, *16*(1), 32–40. https://doi.org/10.14710/reaktor.16.1.32-40

Badan Standarisasi Nasional. (2006). Petunjuk Pengujian Organoleptik dan atau Sensori 01-2346-2006. In *BSN (Badan Standarisasi Nasional)*. https://drive.google.com/file/d/0B-ODhmdmLK-3T3ltMXphQW1idjQ/view?resourcekey=0-stXOVRpw4cOJO3kFE4rxpw

Badan Standarisasi Nasional. (2023). Kertas dan Karton - Cara Uji Daya Serap Air- Metode Cobb. *Badan Standarisasi Nasional*, *RSNI3 ISO*. https://theadiokecenter.wordpress.com/wp-content/uploads/2010/06/1293_sni-0499-2008-kertas-dan-karton.pdf

Batubara, R., Wirjosentono, B., Siregar, A. H., Harahap, U., & Lubis, S. M. (2021). Chemical content and fiber dimension of agarwood branches (Aquilaria malaccensis Lamk). *IOP Conference Series: Earth and Environmental Science*, *912*(1). https://doi.org/10.1088/1755-1315/912/1/012025

Deivy, A. P., Anwar, K., Alfi, A., & Yusniwati. (2021). Delignification of Lignocellulosic Biomass. *World Journal of Advanced Research and Reviews*, *12*(2), 462–469. https://doi.org/10.30574/wjarr.2021.12.2.0618

Du, T., Dao, C., Mapook, A., Stephenson, S. L., Elgorban, A. M., Al-rejaie, S., Suwannarach, N., Karunarathna, S. C., & Tibpromma, S. (2022). Diversity and Biosynthetic Activities of Agarwood Associated Fungi. *Diversity*, *14*(3), 1–17. https://doi.org/https://doi.org/10.3390/d14030211

Edahwati, L., Suci, D., & Siswati, D. (2014). Penurunan Lignin Kulit Buah Kopi dengan Metode Organosolve Reduction of Lignin from Coffee Husk using Organosolve Method. *Eksergi*, *11*(2), 7–10. https://doi.org/ /10.31315/e.v11i2.364

Fauziah, D. R., Satria, A. W., & Yuniarti, R. (2022). Studi kinetika ekstraksi minyak gaharu dengan kombinasi fermentasi. *Jurnal Integrasi Proses*, *11*(2), 34–39. https://doi.org/http://dx.doi.org/10.36055/jip.v11i2.14640

Gusmailina, & Sumadiwangsa, S. (2020). The enhancement of added value of agarwood by diversification product. *IOP Conference Series: Earth and Environmental Science*, *591*(1). https://doi.org/10.1088/1755-1315/591/1/012022

Ibad, I., Nangameka, Y., & Sari, S. (2022). Analisis Kelayakan Usaha Produksi Ikan Kering Asin Di Situbondo. *Prosiding Nasional Universitas Abdurachman Saleh SItubondo*, 364–370. https://www.studocu.id/id/document/universitas-terbuka/bahasa-indonesia/2480-206-12302-1-10-20221126/111408781

Khasanah, L. U., Atmaka, W., Kurniasari, D., Kawiji, K., Praseptiangga, D., & Utami, R. (2017). Karakterisasi Kemasan Kertas Aktif dengan Penambahan Oleoresin Ampas Destilasi Sereh Dapur (Cymbopogon citratus). *Agritech*, *37*(1), 60. https://doi.org/10.22146/agritech.17011

Kurniawan A., E., Hasid, Z., & Busari, A. (2023). Analisis Pendapatan Usaha Pengolahan Ikan Asin pada Usaha Rumah Tangga di Bontang Kuala, Kalimantan Timur. *Jurnal Galung Tropika*, *12*(2), 159–168. https://doi.org/10.31850/jgt.v12i2.1107

Lee, S. Y., Turjaman, M., & Mohamed, R. (2018). Phylogenetic relatedness of several agarwood-producing taxa (Thymelaeaceae) from Indonesia. *Tropical Life Sciences Research*, *29*(2), 13–28. https://doi.org/10.21315/tlsr2018.29.2.2

Mufridayati, Humaidi, S., & Simbolon, T. R. (2013). Pembuatan dan Karakterisasi Kertas dari Campuran Seratt Jambul Nanas dan Serat Jerami Padi. In *Universitas Sumatera Utara*. https://repositori.usu.ac.id/handle/123456789/77595

Munashifah, Z., Kasjono, H. S., & Suwerda, B. (2018). Pemanfaatan Kertas Bekas, Serabut Kelapa (Socos nucifera) dan Kulit Singkong (Manihot utilissima)

Untuk Pembuatan Kertas Daur Ulang. *Jurnal Teknologi Kesehatan (Journal of Health Technology)*, *14*(2), 65–70. https://doi.org/10.29238/jtk.v14i2.372

Novelia, K., Rikoles, L., Fret, D. I., & Elsa, R. (2024). Analisis Break Even Point (BEP) Sebagai Alat Perencanaan Laba Pada Usaha Gorengan KUD Kota Sorong. *Jurnal Manuhara : Pusat Penelitian Ilmu Manajemen Dan Bisnis*, *2*(2), 291–304. https://doi.org/10.61132/manuhara.v2i2.791

Pang, S., Zhao, W., Zhang, Q., Tian, Z., Wu, D., Deng, S., Zhang, P., Li, Z., Liu, S., Yang, B., Huang, G., & Zhou, Z. (2024). Aromatic components and endophytic fungi during the formation of agarwood in Aquilaria sinensis were induced by exogenous substances. *Frontiers in Microbiology*, *15*(August), 1–20. https://doi.org/10.3389/fmicb.2024.1446583

Paskawati, Y. A., Susyana, Antaresti, & Retnoningtyas, E. S. (2010). Pemanfaatan Sabut Kelapa Sebagai Bahan Baku Pembuatan Kertas Komposit Alternatif. *Jurnal Widya Teknik*, *9*(1), 12–21. https://doi.org/10.33508/wt.v9i1.1293

Prasetia, R., Purbawati, P., & Halikianoor, H. (2022). Uji Organoleptik Kertas Komposit Berbahan Kertas Bekas dan Ampas Kelapa (Cocos nucifera L.). *Journal of Sustainable Transformation*, *1*(1), 16–21. https://doi.org/10.59310/jst.v1i1.8

Pratama, N. R., Indriyani, & Lisani. (2024). Pengaruh natrium Hidroksida (NaOH) Terhadap Mutu Fisik Kemasan dari Limbah Kulit Kopi Arabika (Coffea arabica l). *Syntax Literate: Jurnal Ilmiah Indonesia*, *8*(4), 1–8.

Puspitasari, M., Nandari, W. W., & Hadi, F. (2022). Perbandingan Penggunaan Aktivator NaOH dan KOH pada Pembuatan Karbon Aktif dari Kulit Singkong (Manihot utilissima). *Jurnal Eksergi*, *19*(2), 58–62.

Putri, F., Meidinariasty, A., & Yerizam, M. (2023). Pemanfaatan Limbah Ampas Tebu dan Alang-Alang pada Pembuatan Kertas Karton dengan Proses Pulping Organosolv. *Jurnal Pendidikan Tambusai*, *7*(3), 22060–22068. https://mail.jptam.org/index.php/jptam/article/download/10030/8121/18737

Putri, P. G., Ningtyas, K. R., & Agassi, T. N. (2022). Pembuatan Kertas Komposit Berbahan Baku Tandan Kosong Kelapa Sawit dan Serabut Kelapa. *Daun: Jurnal Ilmiah Pertanian Dan Kehutanan*, *9*(2), 112–118. https://doi.org/10.33084/daun.v9i2.4213

Safrizal, D., Herry, M., Rahmadhani, N. C., & Satriananda, S. (2022). Pembuatan Kertas Komposit Dari Tandan Kosong Kelapa Sawit (Elaeis Guineensis) Dan Limbah Kertas HVS. *Jurnal Sains Dan Teknologi Reaksi*, *20*(01), 1–8. https://doi.org/10.30811/jstr.v20i01.3234

Selvia, A. (2018). Pengaruh Konsentrasi NaOH dan Waktu Hidrolisis terhadap Kadar Selulosa pada Daun Nanas. *Jurnal Teknik Kimia*, *24*(1), 28–31. https://doi.org/10.36706/jtk.v24i1.424

Shivanand, P., Arbie, N. F., Krishnamoorthy, S., & Ahmad, N. (2022). Agarwood—The Fragrant Molecules of a Wounded Tree. *Molecules*, *27*(11), 1–23. https://doi.org/10.3390/molecules27113386

Sridach, W. (2010). the Environmentally Benign Pulping Process of Non-Wood Fibers. *Suranaree J. Sci. Technol*, *17*(2), 105–123. https://www.thaiscience.info/journals/Article/SJST/10890500.pdf

Suhendri, S., Evelyn, E., Setiadi, T., & Ristianto, H. (2025). Optimization of Palm Frond Pulping Using a Soda-Anthraquinone Process in a Circulating Digester: A Sustainable Approach. *Eksergi*, *22*(1), 48–57. https://doi.org/10.31315/vzzf1t33

Sundari, E. M., Suhendra, & Apriani, W. (2020). Uji Kekuatan Tarik Kertas Daur Ulang Campuran Ampas Tebu, Serabut Kelapa, dan Kertas Bekas. *Aplikasi Mekanik & Energi (AME) Ilmiah Teknik Mesin*, *6*(1), 28–33. https://doi.org/10.32832/ame.v6i1.2871

Susanti, A. (2021). Pembuatan dan Karakterisasi Biodegradable plastic Berbasis Campuran Pati dan Selulosa Dari Limbah Jagung. *Eksergi*, *18*(2), 49. https://doi.org/10.31315/e.v18i2.5341

Sutanti, S., Oktaviananda, C., Handhayani, E. T. U., & Orxellina, E. S. (2024). Pembuatan Kertas Seni Dari Kombinasi Limbah Serbuk Kayu Sengon dan Ampas Tebu dengan Sizing Agent Carboxy Cellulose (CMC) menggunakan Metode Soda Pulping. *Jurnal Ilmiah Teknik Kimia*, *8*(2), 98–105.

Tarigan, D. ., Manis, S., & Perdinan, S. (2013). Pembuatan dan Karakteristik Kertas dengan Bahan Baku Tandan Kosong Kelapa Sawit. *Saintia Fisika*, *5*(1), 1–4. https://doi.org/10.33084/daun.v9i2.4213

Wijayanti, R., Yusmita, L., & Putra, F. A. (2024). Kajian Perbedaan Konsentrasi Naoh Pada Pembuatan Kertas Terhadap Penerimaan Panelis Kertas Seni Dari Mensiang. *Menara Ilmu*, *18*(2), 58–67. https://doi.org/10.31869/mi.v18i2.4958

Yang, L., Yang, J. L., Dong, W. H., Wang, Y. L., Zeng, J., Yuan, J. Z., Wang, H., Mei, W. L., & Dai, H. F. (2021). The characteristic fragrant sesquiterpenes and 2-(2-phenylethyl)chromones in wild and cultivated "qi-nan" agarwood. *Molecules*, *26*(2), 1–12. https://doi.org/10.3390/molecules26020436

Yuliyanto, Y., Rollastin, B., & Hasdiansah, H. (2022). Efek Perendaman Serat Gaharu terhadap Pengujian Tarik dan Pengujian Impak Sebagai Bahan Komposit. *Jurnal Dinamika Vokasional Teknik Mesin*, *7*(2), 146–151. https://doi.org/10.21831/dinamika.v7i2.53102

Yuniarti, R., Achmad, F., Sanjaya, A., & Yusupandi, F. (2023). Sosialisasi peningkatan produksi dan pengembangan diversifikasi produk turunan gaharu. *TeknoKreatif: Jurnal Pengabdian Kepada Masyarakat*, *3*(2), 25–35. https://doi.org/https://doi.org/10.35472/teknokreatif.v3i2.1134