Indonesian Journal of Halal Research
E-ISSN: 2657-0165
P-ISSN: 2656-3754

ARTICLE

Indonesian Journal of HALAL RESEARCH

Feasibility Study of Halal Brushes Made from Natural Fibers of the Pandanaceae Family for Sustainable Development

Jumrodah Jumrodah[1], Atin Supriatin[2]*, Sardimi Sardimi[3], Yuyun Maryuningsih[4] Andi Wahyudi[5]

Abstract: *This study evaluates Pandanus tectorius, Pandanus amaryllifolius, and Pandanus helicopus fibers as alternative raw materials for brush manufacturing by assessing their mechanical properties and user-perceived suitability. The research involved the experimental preparation of pandan fibers using varying NaOH (sodium hydroxide) concentrations and mechanical testing covering tenacity, elongation, fineness, and coefficient of variation in accordance with SNI 08-1112-1989 standards. Subsequently, brush prototypes were fabricated from the three fiber types and evaluated for suitability by 21 business operators. Data were collected via questionnaires and interviews covering five aspects: utility, comfort, flexibility, safety, and aesthetics. The results indicate that all brush samples were rated from suitable to highly suitable for use, with Pandanus helicopus showing the best overall performance in comfort, flexibility, and safety. Analysis indicates that alkali solution concentration and Pandan variety significantly improved fiber fineness and flexibility through partial delignification ($p<0.05$). Nevertheless, fiber tensile strength (tenacity) remained stable, with no loss of structural integrity ($p>0.05$). These findings show that fibers from Pandanus tectorius, Pandanus amaryllifolius, and Pandanus helicopus have significant potential as sustainable, halal-compliant materials for brush production, supporting the development of eco-friendly, halal-certified production tools.*

Keywords: *feasibility study; food production equipment; halal brush; pandanaceae fibers; plant-based materials*

e-mail: jumrodah@uin-palangkaraya.ac.id[1], atin.supriatin@uin-palangkaraya.ac.id*[2], sardimi@uin-palangkaraya.ac.id[3], yuyunmaryuningsih2014@gmail.com[4]. andi.wahyudi@ubd.edu.bn[5].
*Corresponding Author

Received: April 18, 2026	Accepted: August 31, 2026	Published: August 31, 2026

How to cite this article (APA 7th Edition Reference Style): Jumrodah, J., Supriatin, A., Sardimi, S., Maryuningsih, Y., & Wahyudi, A. (2026). Feasibility study of halal brushes made from natural fibers of the pandanaceae family towards the creative economy and sustainable development. *Indonesian Journal of Halal Research*, *8*(2).), 155–170. https://doi.org/10.15575/ijhar.v8i2.55485

[1]*Department of Biology, Universitas Islam Negeri Palangka Raya, Jl. G. Obos, Komplek Islamic Centre Palangka Raya, Central Kalimantan, 73112, Indonesia.* [2]*Department of Madrasah Ibtidaiyah Teacher Education Universitas Islam Negeri Palangka Raya, Jl. G. Obos, Komplek Islamic Centre Palangka Raya, Kalimantan Tengah, 73112, Indonesia* [3]*Department of Islamic Education Management, Universitas Islam Negeri Palangka Raya, Jl. G. Obos, Komplek Islamic Centre Palangka Raya, Central Kalimantan, 73112, Indonesia.* [4]*Department of Biology Education, Universitas Islam Negeri Siber Syekh Nurjati Cirebon, Jl. Perjuangan Majasem Kota Cirebon, West Java, 45135, Indonesia.* [5]*Sultan Hassanal Bolkiah Institute of Education, Universiti Brunei Darussalam, Bandar Sri Begawan, BE1410, Brunei Darussalam.*

1. Introduction

The large Muslim population in Indonesia influences people's halal lifestyle choices in determining products and services. In 2025, the global Muslim population is projected to reach approximately 2.06 billion, or 25.16% of the world's total population (United Nations, 2024; Zurlo, 2025). This estimate aligns with a Pew Research Center report indicating that the Muslim population reached approximately two billion, or 25.6% of the global population, by 2020 (Pew Research Center, 2025). This undoubtedly affects the need for halal products, domestically and internationally. Not limited to food and pharmaceuticals, the demand extends to non-food products, such as services, cosmetics, clothing, and equipment. This includes the tools used in the production of processed products, such as food and beverages, making their halal status an important consideration. A critical production tool in this regard is the brush.

Brushes are essential tools in the production of dry and wet foods. Therefore, brush raw materials must be halal to prevent contamination of processed products. Consequently, increasing demand for halal products in society will intensify competition between halal and non-halal product manufacturers. This has become a concern for the government, leading to the issuance of Law No. 33 of 2014 on Halal Product Assurance, which aims to protect consumers when selecting and determining halal products. Furthermore, this regulation ensures that consumers, especially Muslims, are protected from non-halal products. The rapid advancement of science and technology in the food and non-food sectors enables the engineering of products using raw materials whose halal status is uncertain. This highlights the need for greater scrutiny and regulation of product ingredients to maintain halal integrity.

Brushes available on the market are generally made from animal hair (including pig, horse, goat, and camel), human hair, synthetic fibers, or silicone. Additionally, plant-based fibers such as pineapple fiber are used, but their availability is very limited. Some food production brushes found on the market are labeled "boar bristle" or "pig/boar hair." These brands originate from China and use pig bristles as their raw material (commonly, HS code 05021000). Statistics Indonesia (BPS) reported that, in 2020, 27,625 kg of pig bristles were imported into Indonesia, a figure that rose significantly to 154,450 kg in 2021. Meanwhile, imports totaled at 84,301 kg in 2023 and 41,625 kg in 2024, with import values of USD 488,059 and USD 347,870, respectively (BPS-Statistics Indonesia, 2025). This data shows the ongoing importation of pig-derived bristles and hair (pig, hog, and boar) into Indonesia. However, using animal hair brushes in food production raises concerns about halal status because of potential points of impurity. These concerns are grounded in Surah Al-Baqarah (2:173) of the Qur'an and Indonesian Ulema Council (MUI) Fatwa No. 2/Munas VI/MUI/2000. This underscores the importance of developing plant-based materials as a potential non-porcine alternative for bristle brush applications.

Investigations in several markets in Central Kalimantan, particularly Palangka Raya, found no food-production brushes made from plant fibers, including those from the Pandanaceae family. Meanwhile, the Pandanaceae family is widely found in swamp areas or along the banks of the Sebangau River in Central Kalimantan. Natural fibers from the Pandanaceae family remain underutilized by the community, despite their physical, chemical, and biological durability, as well as their hardness and flexibility, making them suitable for the textile industry (A'in et al., 2024; Herlina et al., 2018; Nurmeilisa et al., 2024; Sunarya et al., 2024). Plant fibers have several advantages: they are a renewable raw material source, environmentally friendly due to their biodegradability, and capable of absorbing significant amounts of CO_2 while also possessing excellent physical and mechanical properties. Additionally, plant fibers have great potential for further development (Elfaleh et al., 2023). Pandanaceae habitats, particularly *P. helicopus*, are predominantly found in rivers or swamps and function as zinc (Zn) accumulator plants (A'in et al., 2024; Sulistiyarto, 2019). Although its Zn absorption capacity is classified as low, its ability to absorb Zn from water bodies helps maintain water quality (Lukas et al., 2021; Mardiyaningsih & Aini, 2014). Additionally, Pandanaceae can be used as a raw material for paper and pulp production (Herlina et al., 2018). *P. tectorius* is commonly found in tropical coastal ecosystems. It is well adapted to coastal forest vegetation and helps to mitigate coastal erosion (Hsu et al., 2023). Beyond its ecological role, it contains bioactive compounds that exhibit antioxidant and anticancer properties (Do, Bui, et al., 2025; Do, Nguyen, et al., 2025). *P. amaryllifolius* is an erect or trailing shrub characterized by prop roots. Its leaves are commonly used as a natural coloring agent and flavoring in cooking. Additionally, the leaves contain bioactive compounds such as phenolics, flavonoids, alkaloids, and terpenoids that can function as antioxidants, antimicrobials, and anti-inflammatory agents (Do, Nguyen, et al., 2025; Wahyuni et al., 2024). Pandan leaf fibers can also be used in composite materials for electronic product casings (Elfaleh et al., 2023; Nurmeilisa et al., 2024; Nuryati et al., 2021). Based on these findings, natural fibers from the Pandanaceae family have

significant potential as a non-food raw material, particularly for industrial applications, providing sustainable economic value. However, the management of Pandanaceae resources has not yet been optimized. In fact, it is often considered an invasive plant, as its roots and stems can obstruct river flow along crucial water transportation routes (A'in et al., 2024; Rachma, Risca et al., 2017; Suryani et al., 2020).

Pandanaceae fibers are suitable for the textile industry because of their physical, chemical, and biological durability, as well as their hardness and flexibility. (A'in et al., 2024; Elfaleh et al., 2023; Nurmeilisa et al., 2024; Soeprijanto et al., 2021). These properties align with the key indicators of a viable brush for food production, including being halal, strong, resistant to breakage or shedding, free from harmful chemicals, flexible or non-shrinking, and free from hazardous microorganisms (Elfaleh et al., 2023). Plant fibers, specifically pandan, offer distinct advantages over synthetic fibers: they are strong, biodegradable, and non-abrasive (Batoro et al., 2015; Nuryati et al., 2021). Furthermore, pandan fibers have low density, making them ideal raw materials for food-topping brushes because they are pliable, flexible, and eco-friendly (A'in et al., 2024; Jacky et al., 2019; Nurmeilisa et al., 2024; Suryani et al., 2020). This aligns with UN Sustainable Development Goal 12: This aligns with UN Sustainable Development Goal 12: Responsible Consumption and Production, which aims to protect, the objective is to ensure that the production and use of goods to meet human needs involve the wise use of natural resources, waste minimization, the avoidance of hazardous materials, and the prevention of adverse impacts on the environment and human health; in other words, human needs are met and quality of life improves, while the consumption of resources and hazardous materials, as well as the generation of waste and pollution, are minimized during the production process (UNESCO, 2017). Processing Pandanaceae plant fibers as raw material for halal brushes aligns with SDG 12, as the utilization of pandan fiber, a plant-based material, supports the use of renewable resources. The production process includes raw material procurement, fiber processing using sodium hydroxide (NaOH), washing, drying, brush manufacturing, and waste disposal. The materials are categorized as non-hazardous. Furthermore, the use of NaOH can reduce carbon emissions. This view is supported by Alcivar-Bastidas et al. (2024), who found that in abaca fiber processing, the recirculation of NaOH solution remains effective for up to eight cycles, yielding consistent TGA, SEM, and tensile strength data while achieving a 25% reduction in carbon footprint compared to conventional processing methods.

2. Materials and Methods

2.1. Sample preparation

Natural fibers of the Pandanaceae family were collected and prepared by separating the fibers from the leaf strands. The extracted fibers were then processed and designed into halal brushes to be used as prototypes in this study. The preparation aimed to ensure the fibers met the basic physical requirements for use as food-production tools. Three types of Pandanaceae fibers were used: *P. tectorius*, *P. amaryllifolius*, and *P. helicopus*, as each possesses distinct characteristics. *P. tectorius* fibers are generally coarser and denser, providing good absorbency and structural strength, which makes them suitable for applications requiring higher durability. *P. amaryllifolius* fibers are relatively softer and more flexible, with moderate strength, allowing for balanced performance between comfort and functionality. In contrast, *P. helicopus* fibers are finer and more slender, resulting in a smoother texture, higher flexibility, and better inter-fiber bonding, which enhances comfort and reduces shedding.

The sampling site for *P. tectorius* was in Kotawaringin Timur, specifically at Ujung Pandaran. The Sampling of *P. amaryllifolius* was collected in Barito Selatan Regency, while *P. helicopus* samples were collected in Palangka Raya City. The collected Pandanaceae leaf samples were neither too old nor too young. Local community information estimated their age at two years.

The method for producing pandan fiber was: 1) The leaves were cut into 30 cm lengths to facilitate the separation of fibers from the leaf skin and lignin. The portion of the leaf used in this study was limited to the 60 cm section starting from the base, as this area is thicker than the tip. 2) The cut leaves were boiled for three hours at 80°C. This process softened the leaves, making fiber separation easier. The boiling time and temperature were based on research by Hidayat (2008), which indicated that an effective boiling duration for softening leaves is three hours at temperatures between 75°C and 85°C. 3) The boiled leaf sections were then soaked in water within a sealed container for seven days to allow for decomposition, making it easier to detach the leaf skin from the fibers. 4) Next, the leaves were manually scraped until the fibers and leaf skin were completely separated. The separated fibers were soaked in an NaOH (sodium hydroxide) solution to facilitate the removal of residual wax or lignin adhering to the fibers and to reduce fiber surface roughness. This treatment was expected to yield fibers

of higher quality and strength, as well as greater resistance to bacterial or microbial attack (Elfaleh et al., 2023; Nuryati et al., 2021). The NaOH solution was applied at three concentration levels (2.5%, 5%, and 7.5%) alongside a control treatment (0%), with a soaking time of two hours. 5) Afterward, the fibers were washed under running water and soaked in clean water for three days, with the water changed every six hours. This step was performed to remove any residual NaOH that may still adhere to the fibers. Finally, the fibers were rinsed with clean water and air-dried at room temperature.

2.2. Procedure

This study employed two methods: an experimental approach to producing pandan fibers and a feasibility test of pandan fibers processed into brushes. The experimental work was conducted at the UIN Palangka Raya laboratory. Analysis of fiber strength, fineness, and elongation based on the SNI 08-1112-1989 standard was performed at the STT Tekstil Bandung laboratory. The feasibility test for the brushes was carried out in Palangka Raya and Cirebon, involving 21 business owners as respondents. The 21 respondents were given three brushes made from natural fibers of *P. tectorius*, *P. amaryllifolius*, and *P. helicopus*, with a 5 % NaOH concentration; the prepared brushes were distributed to the participants and used as production tools for two weeks, specifically for tasks such as applying toppings to bakery products and baking processes. Following the trial period, respondents completed a feasibility questionnaire and participated in follow-up interviews covering five assessment criteria. Research subjects were selected through purposive sampling based on the characteristics of food business operators ranging from snack producers to those making main courses who use brushes in their production processes. The collected data were then compiled for further analysis.

2.3. Data Collection

The data collection process comprised two stages. The experimental phase used a factorial design with NaOH treatments at concentrations of 2.5%, 5%, and 7.5%, plus a 0% control, during the production of *P. tectorius*, *P. amaryllifolius*, and *P. helicopus* fibers. The resulting fibers were tested for strength, fineness, and elongation in accordance with SNI 08-1112-1989. The subsequent data collection stage involved a feasibility assessment of the produced pandan fiber brushes, engaging 21 business practitioners. The research sample consists of vendors selling snacks such as satay, cookies, various grilled foods, cakes, and martabak, whose production process involves using a brush to apply toppings or seasonings. The instrument used in this stage was a feasibility assessment questionnaire structured around five key aspects: utility, comfort, flexibility, safety, and aesthetics. To ensure reliability and relevance, the instrument was validated by experts before implementation, with revisions made based on their feedback. In addition to the questionnaire, an interview guide was used to gain deeper insights into the participants' experiences using the brushes.

2.4. Instrument Validation

The questionnaire regarding the suitability of the pandan fiber brush was validated by three experts: one botanist, one linguist, and one bakery professional. Instrument validation did not involve halal, materials, or food safety experts because the raw materials used are on the positive list consisting of natural fibers of the Pandanaceae and NaOH specifically Caustic Soda Flakes/Solid from PT. SULFINDO ADIUSAHA and already holds halal certification ID No. ID00410000260360422. The purpose of validation is to determine whether the questionnaire is suitable for data collection.

Validation analysis was conducted using the Gregory method. The instrument covered: 1) Utility: a. The brush is easy to use; b. The brush has good absorbency; c. The brush is effective to use. 2) Comfort: a. The brush has a soft surface; b. The brush is comfortable to use. 3) Flexibility: a. The brush is flexible and elastic; b. The brush does not break easily; c. The brush does not shed easily; d. The brush is not easily flammable. 4) Safety: a. The brush is odorless; b. The brush does not discolor; c. The brush does not stick to food. 5) Aesthetics: a. The brush is aesthetically pleasing; b. The brush is neatly made; c. The handle is clean and attractive. The calculation results yielded a Content Validity coefficient of 0.933 (CV > 0.70). Thus, the product evaluation instrument for this brush was deemed highly valid and suitable for use in research data collection.

2.5. Data Analysis

A quantitative analysis of the strength and flexibility of pandan fibers was conducted by analyzing test results based on SNI 08-1112-1989 standard, followed by an ANOVA test. Meanwhile, the suitability of the pandan fiber brush was evaluated using a descriptive qualitative approach, employing a formula to calculate the suitability percentage (Sugiyono, 2017), as shown in Equation (1). These results were

interpreted using the suitability criteria in Table 1, which classifies the product from "Highly not Feasible" to "Highly Feasible" based on percentage scores adapted from Riduwan and Akdon (2013).

$$Score = \frac{total\ obtained\ score}{N \times highest\ weight\ of\ total\ score} \times 100 \quad (1)$$

Table 1. Feasibility Assessment Criteria

No	Assessment (%)	Qualification
1	80 < N ≤ 100	Highly Feasible
2	60 < N ≤ 80	Feasible
3	40 < N ≤ 60	Moderately Feasible
4	20 < N ≤ 40	Not Feasible
5	0 < N ≤ 20	Highly Not Feasible

3. Results and Discussion

3.1. Material Characteristics of Natural Fibers of the Pandanaceae

NaOH is a basic compound that is highly soluble in water and a strong base capable of complete ionization. Test data conducted in accordance with SNI 08-1112-1989 indicated that all three types of pandan fibers became finer and stronger after treatment than fibers obtained without NaOH soaking. Based on laboratory evaluations using SNI 08-1112-1989, *P. tectorius*, *P. amaryllifolius*, and *P. helicopus* were deemed suitable as raw materials for brush bristles. Consequently, the researchers recommended trying these three species as sources of plant-based brush fibers, offering an eco-friendly alternative that supports sustainable development. Fibers from these three pandan species are abundant in Kalimantan but have not yet been optimally used as raw materials for plant-based brushes.

Soaking fibers in various concentrations of NaOH solution yields fibers with distinct characteristics. Control fibers (0% concentration) are stiff, coarse, and pure white. Fibers soaked in a 2.5% NaOH solution become stiffer and coarser and turn brown. Fibers soaked in a 5% NaOH solution become somewhat flexible and smooth and turn dark brown. Meanwhile, fibers soaked in a 7.5% NaOH solution become even more flexible and smooth, turning an even darker shade of brown.

The fibers were evaluated based on tenacity (gf/tex), fineness (Tex), and elongation (%), as summarized in Figures 1-3. These parameters are essential for determining the strength, consistency, and flexibility of fibers as raw materials for halal brush production, as they directly influence durability, breakage resistance, and performance (Herlina et al., 2018). The NaOH soaking method, regardless of concentration, requires more time and extensive washing to remove residual solution. However, an advantage of using the NaOH solution is that the resulting fibers are cleaner because it dissolves non-cellular components, and the non-cellulose components decompose easily. The final product requires only drying. Several types of pandan grow abundantly in Kalimantan, including *P. helicopus*, *P. amaryllifolius*, and *P. tectorius*. The primary requirements for brush bristles are strength, elasticity, and softness. The strength of pandan fibers stems from their lignin and cellulose content. Cellulose provides tensile strength through covalent bonds between the constituent sugar units (Elfaleh et al., 2023; Herlina et al., 2018; Qomarudin, 2023). High cellulose content contributes to the fiber's flexibility.

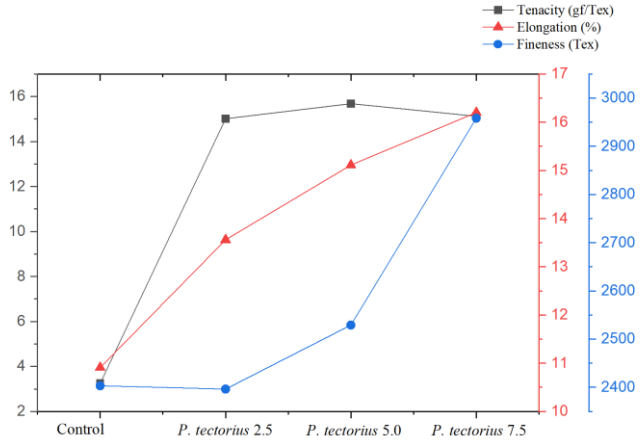


Figure 1. Effect of treatment concentration on the physical properties of *P. tectorius* fibers, including tenacity, elongation, and fineness.

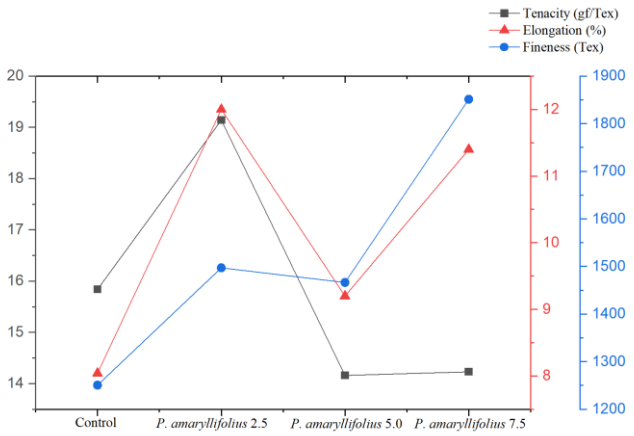


Figure 2. Effect of treatment concentration on the physical properties of *P. amaryllifolius* fibers, including tenacity, elongation, and fineness.

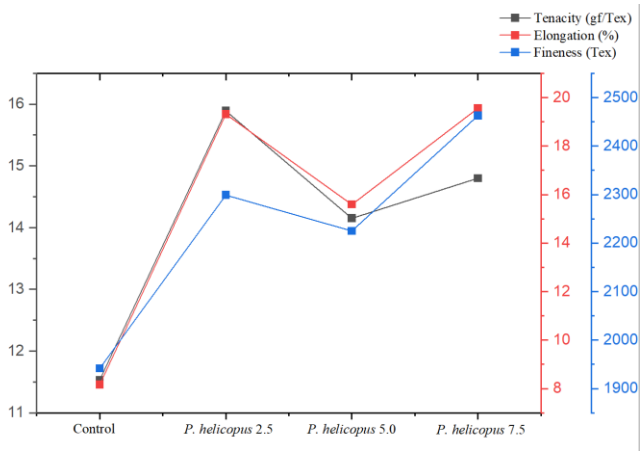


Figure 3. Effect of treatment concentration on the physical properties of *P. helicopus* fibers, including tenacity, elongation, and fineness.

The treated *P. tectorius* fibers exhibited improved mechanical performance compared with the control (Figures 1-3). The control sample recorded a tenacity of 3,25 gf/tex. Treatment increased tenacity to 15.01 gf/tex at 2.5%, 15.68 gf/tex at 5%, and 15.12 gf/tex at 7.5%. Representing improvements of approximately 32.6% and 38.5%, respectively, relative to the control. Elongation also increased from 10.91% in the control to 13.56%, 15.11%, and 16.20% at 2.5%, 5%, and 7.5%, respectively. The fineness values were 2403.32 tex for the control, 2396.36 tex at 2.5%, 2529.16 tex at 5%, and 2958.4 tex at 7.5%. The lower fineness value at 2.5% indicates a slightly finer fiber, whereas the subsequent increase in tex suggests greater linear mass at higher treatment concentrations. The 7.5% treatment produced the highest elongation, indicating reduced uniformity. Overall, the *P. tectorius* results suggest that moderate treatment concentrations improve tenacity and elongation while maintaining more favorable structural consistency than the highest treatment level.

A distinct concentration-dependent response was observed in the *P. amoryllifolius* fibers (Figure 2). The control exhibited a tenacity of 15.84 gf/tex, which increased to 19.14 gf/tex at 2.5%, corresponding to an increase of approximately 20.8%. Tenacity subsequently decreased to 14.16 and 14.23 gf/tex at 5% and 7.5%, respectively. Elongation increased from 8.04% in the control to 12.00% at 2.5%, then of 9.20% and 11.40% at 5% and 7.5%, respectively. Fineness also varied with treatment concentration, with values of 1250.76 tex for the control, 1497.07 tex at 2.5%, 1466.4 tex at 5%, and 1851.33 tex at 7.5%. Testing of Pandanaceae fibers was conducted using the SNI 08-1112:1989 method, utilizing fiber bundles rather than individual elementary fibers. Samples were prepared with a specimen length of 30 cm, using 10 g of fiber material. The recorded figures represent linear density values ranging from 1,250 to 2,960 tex, indicating the mass per unit length of the extracted fiber bundles. Higher tex values indicate greater mass per unit length, suggesting coarser or heavier fiber bundles. The 2.5% treatment therefore produced the highest tenacity. However, the highest elongation was observed in the 7.5% treatment. The decline in tenacity and increase in tex at 5% suggest that higher treatment intensity may alter the fiber structure and linear mass, although the underlying mechanism should be interpreted

cautiously without supporting morphological or chemical evidence.

P. helicopus fibers showed a pronounced improvement in strength and extensibility following treatment (Figure 3). Tenacity increased from 11.53 gf/tex in the control to 15.89 gf/tex at 2.5%, representing an increase of approximately 37.8%. Tenacity then decreased to 14.15 gf/tex at 5% and slightly increased to 14.80 gf/tex at 7.5%. Elongation increased substantially from 8.16% in the control to 19.31% at 2.5%, then to 15.59% at 5% and 19.56% at 7.5%. Fineness values were 1941.52 tex for the control, 2298.76 tex at 2.5%, 2224.92 tex at 5%, and 2462.88 tex at 7.5%. The reduction in tex at 2.5% and 5% indicates finer fibers than the control, whereas the increase to 21.212 tex at 7.5% indicates greater linear mass at the highest treatment concentration. The 2.5% treatment produced the highest tenacity, while the 7.5% treatment produced the highest elongation.

The results of the two-way ANOVA (without interaction) regarding the variables NaOH Treatment (Control, 2.5% NaOH, 5% NaOH, 7.5% NaOH) and Pandan Variety (*P. tectorius, P. amaryllifolius, and P. helicopus*) are presented in Table 2.

Table 2. Two-Way ANOVA Test Results

Parameter	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value	*p-value*	Note (α=0.05)
Fineness (Tex)	NaOH Treatment	486,153.5	3	162,051.2	18.66	0.0019	Significant
	Pandan Variety	2,321,993.0	2	1,160,996.5	133.71	0.000011	Highly Significant
	Residual (Error)	52,096.5	6	8,682.8	-	-	-
Tenacity (gf/tex)	NaOH Treatment	6,486.0	3	2,162.0	2.00	0.2163	Not Significant
	Pandan Variety	2,456.0	2	1,228.0	1.13	0.3824	Not Significant
	Residual (Error)	6,501.7	6	1,083.6	-	-	-
Elongation (%)	NaOH Treatment	80.30	3	26.77	5.24	0.0410	Significant
	Pandan Variety	63.26	2	31.63	6.20	0.0347	Significant
	Residual (Error)	30.62	6	5.10	-	-	-

ANOVA results indicate that NaOH concentration (0–7.5%) and pandan variety significantly influenced fiber fineness ($p<0.05$) and elongation percentage ($p<0.05$), with pandan variety as the dominant factor contributing most to variation in finenes ($F=133.71$; $p=0.000011$). Mechanistically, increasing the alkali concentration selectively removes non-cellulosic components such as lignin and hemicellulose (delignification); this process triggers the separation of fiber bundles into finer individual fibers and loosens polymer chains, thereby markedly enhancing fiber flexibility and elasticity.

Conversely, neither the NaOH treatment nor the pandan variety differences significantly affected tensile strength (tenacity, $p>0.05$), as all value variations remained within the range of random error. This suggests that alkali modification within the 0–7.5% concentration range does not compromise the crystalline structure of the cellulose core, which bears the fiber's primary mechanical load. These findings confirm that alkali treatment effectively improves the morphological fineness and flexibility of pandan fibers without compromising tensile strength.

NaOH treatment within this concentration range effectively increases specific surface area and elasticity without compromising the integrity of the cellulose core crystals. Consequently, this treatment has been shown not to alter strength but rather to enhance fiber fineness and elongation at break. Cellulose in pandan fibers provides tensile strength to the cells; higher cellulose content increases flexibility. *P. tectorius* contains approximately 54.37% α-cellulose, 21.57% hemicellulose, and 12.15% lignin (Hossain et al., 2024). *P. helicopus* has a lignin content of 31.67% and a cellulose content of 27.06% (Herlina et al., 2018). Diyana et al. (2021) reported that *P. amaryllifolius* has a lignin content of 18.64% and a cellulose content of 48.79%. The high lignin content, combined with its extractive properties, imparts significant cell wall rigidity and high thermal stability to the plant. Consequently, brushes made from this material are flexible and fineness resistant, confirming the viability of pandanus fibers as a raw material for brush manufacturing. Making it suitable as a raw material for food-grade brushes.

The tensile strength and flexibility of these pandan fibers stem from the synergistic role of these polymers, where cellulose provides structural rigidity to the cell, while lignin is a complex binding agent that strengthens intercellular adhesion (Elfaleh et al., 2023). Cellulose provides tensile strength to the cell due to the strong covalent bonds between the sugar units that constitute it; higher cellulose content results in greater flexibility (A'in et al., 2024; Herlina et al., 2018; Mardiyaningsih & Aini, 2014; Nurmeilisa et al., 2024; Purwanto & Munawaroh, 2010; Qomarudin, 2023; Suryani et al., 2020). Using

pure cellulose as a filler is a method of modifying synthetic polymers to produce composites with superior mechanical and physical properties (A'in et al., 2024; Nuryati et al., 2021; Zulkifli et al., 2018).

Lignin and cellulose content determine the tensile strength, fineness, and elongation of pandan leaves. Tensile testing is essential for assessing a specimen's strength under load until the point of failure. Fineness is also important because it influences the physical characteristics of the brush bristles; the same applies to elongation, since elastic and flexible brushes offer optimal performance. The sampling of Pandanaceae leaves is a crucial factor in determining fiber quality; high-quality fiber is obtained from leaves that are neither too old nor too young (Amalia et al., 2021). This opinion is reinforced by Hartini et al. (2022), indicate that Pandanus fibers aged approximately 24-26 months have potential for use as fiber material due to a relatively good combination of maximum strength and elasticity.

3.2. Feasibility Results of Halal Brushes

Before the questionnaire was administered to respondents, it underwent expert validation; Subsequently, further analysis was conducted. The calculation results yielded a Content Validity coefficient of 0.933 (CV > 0.70). Consequently, the product evaluation instrument for this brush was deemed highly valid and suitable for use in research data collection.

The feasibility test of halal brushes made from natural fibers of the Pandanaceae family involved 21 business owners in Palangka Raya and Cirebon. The assessment was based on five aspects: utility, comfort, flexibility, safety, and aesthetics. Table 3 shows that all brush samples are classified as "Feasible" to "Highly Feasible."

Table 3. Feasibility Data Results of Halal Brushes Made from Plant Fibers of the Pandanaceae Family

No	Indicator	Sub Indicator	Max Score	Assessment Percentage		
				P.tectorius	P. amaryllifolius	P.helicopus
1.	Utility	The brush is easy to use	4	96% (Highly Feasible)	89% (Highly Feasible)	94% (Highly Feasible)
		The brush has good absorbency	4	93% (Highly Feasible)	79% (Feasible)	81% (Highly Feasible)
		The brush is effective for use	4	96% (Highly Feasible)	100% (Highly Feasible)	82% (Highly Feasible)
2.	Comfortable	The brush has a soft surface	4	94% (Highly Feasible)	92% (Highly Feasible)	96% (Highly Feasible)
		The brush is comfortable to use	4	79% (Feasible)	96% (Highly Feasible)	99% (Highly Feasible)
3.	Flexibility	The brush is flexible and elastic	4	77% (Feasible)	95% (Highly Feasible)	94% (Highly Feasible)
		The brush is not easily broken	4	77% (Feasible)	79% (Feasible)	87% (Highly Feasible)
		The brush does not shed easily	4	77% (Feasible)	98% (Highly Feasible)	87% (Highly Feasible)
		The brush is not easily flammable	4	98% (Highly Feasible)	77% (Feasible)	89% (Highly Feasible)
4.	Safety	The brush is odorless	4	77% (Feasible)	93% (Highly Feasible)	100% (Highly Feasible)
		The brush does not change color	4	95% (Highly Feasible)	79% (Feasible)	100% (Highly Feasible)
		The brush does not stick to food	4	79% (Feasible)	96% (Highly Feasible)	96% (Highly Feasible)

No	Indicator	Sub Indicator	Max Score	Assessment Percentage		
				P.tectorius	P. amaryllifolius	P.helicopus
5.	Aesthetic	The brush is aesthetic	4	95% (Highly Feasible)	79% (Feasible)	98% (Highly Feasible)
		The brush is neat	4	79% (Feasible)	95% (Highly Feasible)	83% (Highly Feasible)
		The handle is clean and attractive	4	79% (Feasible)	98% (Highly Feasible)	96% (Highly Feasible)

Table 3 shows that *P. helicopus* had the lowest score, at 81 %, and was therefore classified as highly Feasible. These findings indicate that natural Pandanaceae fibers meet the essential criteria required for food production tools, particularly in terms of functionality and safety. The high feasibility ratings suggest that these brushes are viable alternatives to conventional brushes, which are often made from animal hair and may raise halal concerns (Jumiono, 2022; Nashirun, 2020; Nurohma et al., 2019).

3.3. Comparative Analysis by Feasibility Aspects

The comparative analysis of halal brushes made from Pandanaceae fibers was based on five key aspects: utility, comfort, flexibility, safety, and aesthetics.

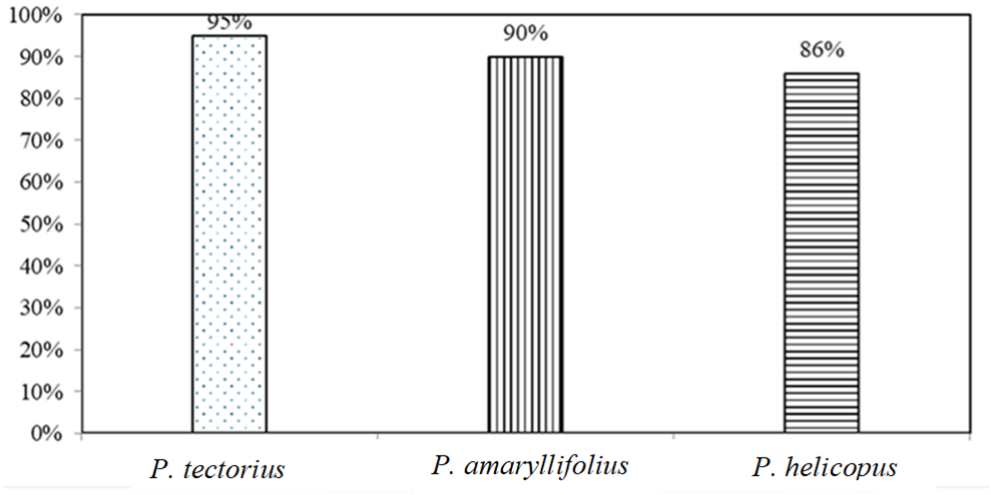


Figure 4. Percentage comparison of brushes based on the utility aspect.

As shown in Figure 4 on the utility aspect, the *P. tectorius* sample achieved the highest score (95%), followed by *P. amaryllifolius* (90%) and *P. helicopus* (86%). Respondents indicated that the *P. tectorius* brush has denser bristles, which enhance absorbency and effectiveness in applying food ingredients. This finding supports the argument that optimal fiber maturity enhances tensile strength It can be used optimally in the food production process, effectively applying toppings to food products (Suryani et al., 2020).

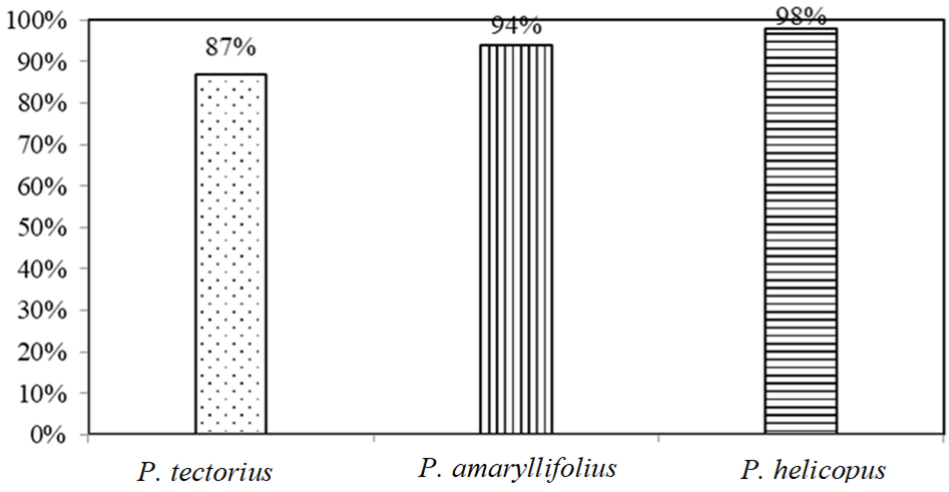


Figure 5. Percentage comparison of brushes based on comfortability aspect.

In terms of comfort, Figure 5 shows that the *P. helicopus* sample obtained the highest score (98%), followed by P. *amaryllifolius* (94%) and *P. tectorius* (87%). The *P. helicopus* brush was perceived as softer and more comfortable due to its finer fiber structure, allowing more even distribution of food toppings. This characteristic is closely related to the fibers' slender diameter, which enhances comfort and application precision (Inaku et al., 2023).

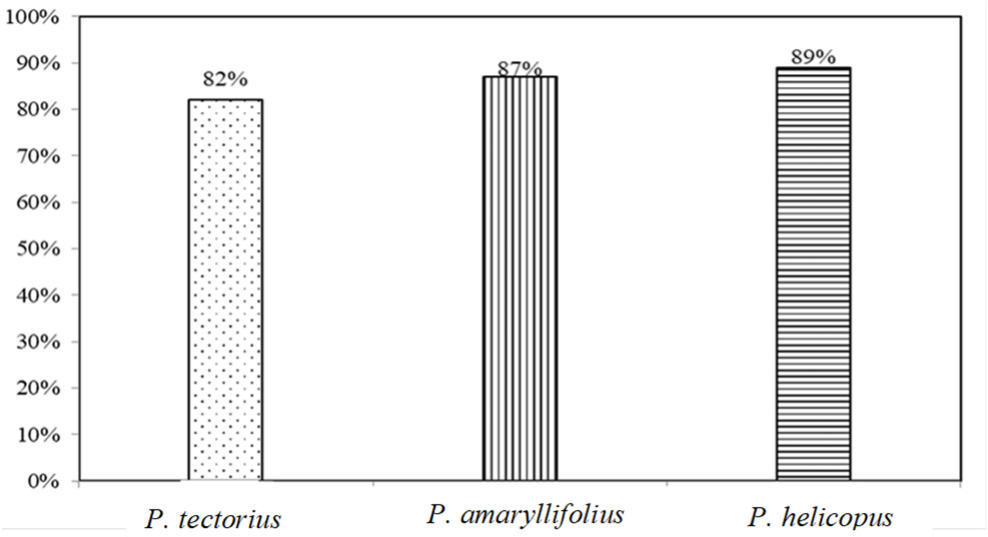


Figure 6. Percentage comparison of brushes based on the flexibility aspect

Similarly, Figure 6 shows that the P. helicopus sample achieved the highest score (89%), followed by P. amaryllifolius (87%) and P. tectorius (82%). Interview findings reveal that *P. helicopus* fibers are more elastic, resistant to breakage, and less prone to shedding during use. These properties are attributed to the structural characteristics of the slender fibers, which interweave effectively and improve durability (Qomarudin, 2023; Soeprijanto et al., 2021).

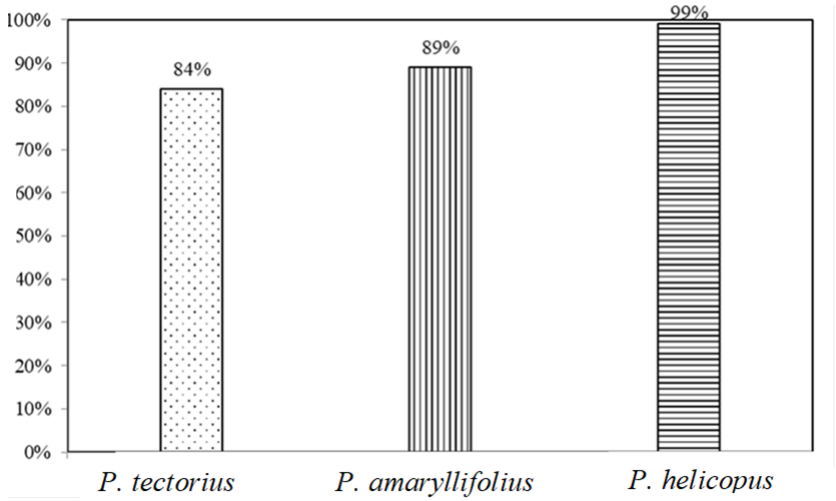


Figure 7. Percentage comparison of brushes based on safety aspect

Regarding safety, Figure 7 shows that the *P. helicopus* sample again obtained the highest score (99%), followed by P. *amaryllifolius* (89%) and *P. tectorius* (84%). Respondents reported that *P. helicopus* fibers do not readily detach or adhere to food, ensuring cleanliness and reducing the risk of contamination. This aspect is critical, as the use of inappropriate or non-halal tools may compromise the integrity of food products (Nurmeilisa et al., 2024; Tugon et al., 2023). This data was corroborated during interviews with respondents, who confirmed that the brushes used did not contaminate the food products; the bristles did not shed, nor did the brushes alter the food's color or impart any odor other than that of the food itself. Furthermore, using brushes made from plant-based fibers instilled greater confidence, as the raw materials were on the "positive list" of approved substances, unlike the brushes previously purchased from a local building materials store.

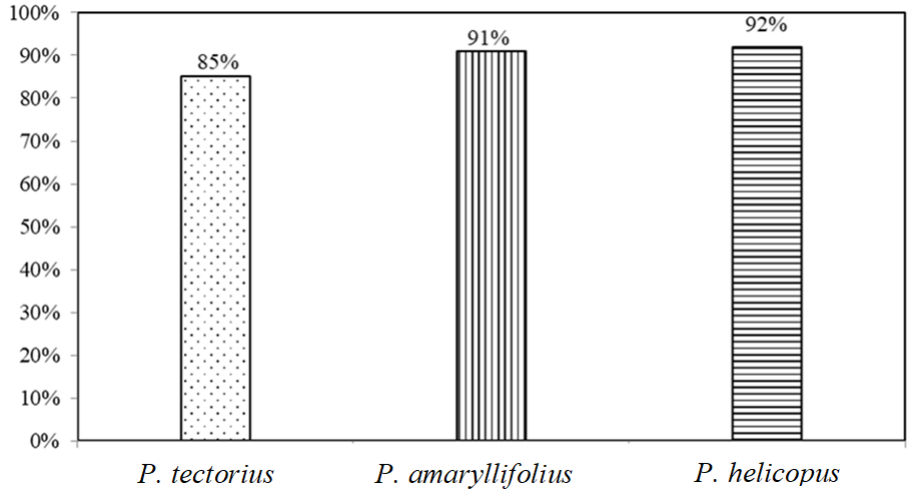


Figure 8. Percentage comparison of brushes based on aesthetic aspect

Finally, the aesthetic aspect illustrated in Figure 8 indicates that the *P. helicopus* sample achieved the highest score (92%), followed closely by *P. amaryllifolius* (91%) and *P. tectorius* (85%). The P. helicopus brush appears cleaner, with neatly arranged bristles, and the brush handle looks clean and attractive.

These results also support the feasibility findings discussed in Table 2 and Table 3, a good food brush does not necessarily need to be strong, soft, or highly stretchable. It should strike the right balance among these factors and be tailored to the specific needs of the production process. If it is too hard or stiff, it may be uncomfortable to use for applying toppings, whereas a brush that is too soft or weak with low stretchability lacks the necessary flexibility.

3.4. User Evaluation and Practical Feedback

User evaluation through questionnaires and interviews revealed that the halal brushes made from Pandanaceae fibers are generally well accepted by business owners. Respondents highlighted several advantages, including good absorbency, cleanliness, minimal fiber shedding, and comfortable wooden handles. For instance, one respondent stated, "*The brush absorbs the topping well and spreads it evenly, similar to the brushes we usually use.*" Another participant noted, "*The brush is clean and does not leave fibers on the food, which is very important for us.*" These findings confirm that the developed brushes meet practical requirements for food production tools.

However, several respondents suggested improvements, particularly regarding brush size and fiber thickness. Some users found the brushes too small and less efficient than conventional tools, requiring more time to apply. One business owner commented, "*The brush works well, but the size is too small, so it takes longer when applying toppings in large quantities.*" Another respondent added, "*The fibers are a bit too thin, making the brush feel less strong compared to the ones we usually use.*" This feedback indicates the need for further product optimization to enhance usability.

To verify the halal status of brushes made from pandan fibers, further testing is required involving fiber production without the use of chemicals. The pandan fibers could be produced mechanically using a specially designed fiber-making machine. Additionally, brush production should consider the handle material, which must be sourced from wood included on the positive list, as well as adhesives, colorants, and binding agents that are certified halal. Furthermore, the research sample should be more diverse, extending beyond micro enterprises to include larger business operators that use these brushes in production processes and households.

Most of the business owners reported that they previously used synthetic or silicone brushes or a brush purchased from a local building materials store, the halal status of whose raw materials remains questionable. The introduction of halal brushes made from natural fibers increased their confidence in maintaining product halalness. As expressed by one respondent, "Using this brush makes me more confident that my products are halal because the material is natural." This perception is important in strengthening consumer trust and aligns with findings by Azam (2016), Pratama et al. (2023), Sari et al. (2019), and Nashirun (2020), who state that religiosity significantly influences the intention to use halal non-food products.

The sustainable processing of natural plant fibers offers not only economic benefits, such as increased community income, but also ecological advantages by protecting the environment from contamination by hazardous substances and preserving biodiversity (Alcivar-Bastidas et al., 2024).

4. Conclusion

Based on data from questionnaires and interviews, a halal brush made from natural fibers of the Pandanaceae family is feasible. In terms of utility, the *P. tectorius* sample achieved the highest percentage (95%). However, for comfort, flexibility, safety, and aesthetics, the *P. helicopus* sample scored higher compared to the other two samples, that is *P. tectorius* and *P. amaryllifolius*. Additionally, a halal brush made from natural *Pandanaceae* fibers is highly suitable for food production, including bakery and grilling applications. The brush fibers are flexible, durable, and resistant to shedding, allowing for efficient absorption and even distribution of toppings. Furthermore, the brush is made from natural fiber included on the positive list and poses no critical issues regarding ingredients of questionable Halal status, thereby boosting business owners' confidence in selling their food products. For future improvements, it is recommended that the brush size be increased, and additional fibers be incorporated to enhance its durability and firmness. Further testing is required regarding the halal status of brushes made from *Pandanaceae* plant fibers.

Based on the ANOVA results, the alkali solution concentration and Pandan variety significantly improved fiber fineness and flexibility through partial delignification ($p<0.05$). Nevertheless, fiber tensile strength (tenacity) remained stable, with no loss of structural integrity ($p>0.05$).

Future research is expected to include samples from various culinary businesses that use brushes in their production processes, extending beyond small-scale operators to encompass medium- to large-scale enterprises and households to ensure a diverse dataset is obtained.

CRediT Authorship Contribution Statement

Jumrodah: Writing – original draft, Formal analysis. **Atin Supriatin:** Writing – review & editing, Writing – original draft, Formal analysis, Methodology. **Sardimi:** Writing – review & editing, Methodology. **Yuyun Maryuningsih**: Writing – review & editing, Writing – original draft, Formal analysis, Methodology. **Andi Wahyudi**: Writing-review & editing, Formal analysis, Visualization.

Acknowledgments

The author expresses gratitude to all parties involved in this research. Special thanks are extended to UIN Palangka Raya for the financial support that enabled the successful completion of this study. Appreciation is also given to UIN Siber Syekh Nurjati Cirebon as the collaboration team, whose contributions helped bring this research to completion.

References

A'in, L. N., Jumrodah, & Supriatin, A. (2024). Potential utilization of rasau fiber (Pandanus helicopus) as an alternative non-food industry material towards a creative economy. *BIOLINK (Jurnal Biologi Lingkungan Industri Kesehatan)*, *10*(2), 196–209. https://doi.org/10.31289/biolink.v10i2.11195

Alcivar-Bastidas, S., Petroche, D. M., Ramirez, A. D., & Martinez-Echevarria, M. J. (2024). Characterization and life cycle assessment of alkali treated abaca fibers: The effect of reusing sodium hydroxide. *Construction and Building Materials*, *449*, 138522. https://doi.org/10.1016/j.conbuildmat.2024.138522

Amalia, L., Sontani, F. D., & Nurkamilah, S. (2021). Kajian etnobotani tumbuhan cangkuang (Pandanus furcatus Roxb.) di masyarakat adat Kampung Pulo Garut. *Journal Civics & Social Studies*, *5*(2), 158–167. https://doi.org/10.31980/civicos.v5i2.1324

Azam, A. (2016). An empirical study on non-Muslim's packaged halal food manufacturers: Saudi Arabian consumers' purchase intention. *Journal of Islamic Marketing*, *7*(4), 441–460. https://doi.org/10.1108/JIMA-12-2014-0084

Batoro, J., Indriyani, S., & Rahardi, B. (2015). Etnobotani masyarakat lokal, struktur anatomi jenis pandan (Pandanaceae) bermanfaat di Jawa Timur. *Research Journal of Life Science*, *2*(2), 133–144. https://doi.org/10.21776/ub.rjls.2015.002.02.7

BPS-Statistics Indonesia. (2025). *Statistik Perdagangan Luar Negeri Indonesia Impor 2024* (D.

S. Distribusi (ed.); 42nd ed., Vol. 42). Badan Pusat Statistik.

Diyana, Z. N., Jumaidin, R., Selamat, M. Z., Alamjuri, R. H., & Md Yusof, F. A. (2021). Extraction and characterization of natural cellulosic fiber from Pandanus amaryllifolius leaves. *Polymers*, *13*(23), 4171. https://doi.org/10.3390/polym13234171

Do, H. G., Bui, T. N. Le, Nguyen, T. T. M., Nguyen, T. T. T., Nguyen, H. D., Hoang, L. T. A., Nguyen, N. T., & Nguyen, T. D. (2025). Optimization of the extraction conditions and evaluation of bioactivities of the phenolic enrichment from Pandanus amaryllifolius leaves. *Journal of Analytical Methods in Chemistry*, *2025*(1). https://doi.org/10.1155/jamc/5256388

Do, H. G., Nguyen, H. D., Tran, T. T. P., Le, T. H., Nguyen, T. U., Nguyen, T. L., Nguyen, T. T. T., Hoang, L. T. A., Nguyen, N. T., & Nguyen, T. D. (2025). Optimization of phenolic- and saponin-enriched extraction from Pandanus tectorius fruit using Box–Behnken design and evaluation of their bioactivities. *Journal of Analytical Methods in Chemistry*, *2025*(1). https://doi.org/10.1155/jamc/5539843

Elfaleh, I., Abbassi, F., Habibi, M., Ahmad, F., Guedri, M., Nasri, M., & Garnier, C. (2023). A comprehensive review of natural fibers and their composites: An eco-friendly alternative to conventional materials. *Results in Engineering*, *19*(July), 101271. https://doi.org/10.1016/j.rineng.2023.101271

Hartini, D., Pinandita, L. R., & Mubarak, P. N. (2022). Tensile strength analysis of sea pandan leaves (Pandanus tectorius) fiber reinforced epoxy composite. *Vortex*, *3*(2), 108. https://doi.org/10.28989/vortex.v3i2.1242

Herlina, Istikowati, W. T., & Fatriani. (2018). Analisis kimia dan serat pandan rasau (Pandanus helicopus) sebagai alternatif bahan baku pulp kertas. *Jurnal Sylva Scienteae*, *01*(2), 150–159.

Hidayat, P. (2008). Teknologi pemanfaatan serat daun nanas sebagai alternatif bahan baku tekstil. *Teknoin*, *13*(2), 31–35. https://doi.org/10.20885/.v13i2.795

Hsu, C.-H., Fang, W.-T., Chiu, H.-K., Kao, W.-C., & Huang, T.-S. (2023). Coastal forest structure survey and associated land crab population in Suao Dakenggu community, Yilan, Taiwan. *Diversity*, *15*(4), 515. https://doi.org/10.3390/d15040515

Inaku, C., Yusuf, M., & Praktisi, S. (2023). Formulasi dan uji efek lilin aromaterapi minyak atsiri daun pandan wangi (Pandanus amaryllifolius Roxb.) terhadap immobility time mencit (Mus musculus) jantan yang dibuat stres. *JOPS (Journal Of Pharmacy and Science)*, *6*(2), 132–142. https://doi.org/10.36341/jops.v6i2.3363

Jacky, Putri, D. A., & Azizah, M. (2019). Uji aktivitas anti bakteri ekstrak etanol daun pandan wangi (Pandanus amaryllifolius Roxb) terhadap bakteri penyebab diare. *Jurnal Kesehatan Saelmakers Perdana*, *2*, 91–98.

Jumiono, A. (2022). Identifikasi titik kritis kehalalan bahan hewani dan produk turunan hewan. *Jurnal Ilmiah Pangan Halal*, *4*(2), 51–58. https://doi.org/10.30997/jiph.v4i2.9909

Lukas, Hastari, B., Ardianor, & Gumiri, S. (2021). Diversity of riparian plants of black water ecosystem in the Sebangau River of Central Kalimantan Indonesian. *IOP Conference Series: Earth and Environmental Science*, *744*(1), 012040. https://doi.org/10.1088/1755-1315/744/1/012040

Mardiyaningsih, A., & Aini, R. (2014). Pengembangan potensi ekstrak daun pandan (Pandanus amaryllifolius Roxb) sebagai agen antibakteri. *Pharmaciana*, *4*(2), 185–192. https://doi.org/10.12928/pharmaciana.v4i2.1577

Nashirun. (2020). Makanan halal dan haram dalam persfektif Al Qur'an. *Halalan Thayyiban: Jurnal Kajian Manajemen Halal Dan Pariwisata Syariah*, *3*(2).

Nurmeilisa, Jumrodah, & Supriatin, A. (2024). The potential of sea pandan (Pandanus tectorius) fiber as a non-food industry material towards sustainable development. *EKsakta: Berkala Ilmiah Bidang IPA*, *25*(01), 99–110.

Nurohma, A., Firanti, F., Yogi, Y., & Pujiono, E. (2019). osialisasi pemilihan kuas halal dengan sasaran pelaku usaha warung makanan Desa Balunijuk. *Prosiding Seminar Nasional*

Penelitian & Pengabdian Pada Masyarakat, *3*, 36–38. https://journal.ubb.ac.id/index.php/snppm/article/view/1308

Nuryati, N., Ningsih, Y., Huzairi, H., & Irawan, C. (2021). Karakterisasi fisik komposit plastik polyethylene terephthalate (PET) berbasis serat alam daun pandan laut (Pandanus tectorius) dan aplikasinya sebagai bahan baku casing pada produk elektronik. *Buletin Profesi Insinyur*, *4*(2), 58–61. https://doi.org/10.20527/bpi.v4i2.101

Pew Research Center. (2025). *How the global religious landscape changed from 2010 to 2020*. https://www.pewresearch.org/religion/2025/06/09/how-the-global-religious-landscape-changed-from-2010-to-2020/

Pratama, A. A. N., Hamidi, M. L., & Cahyono, E. (2023). The effect of halal brand awareness on purchase intention in indonesia: the mediating role of attitude. *Cogent Business & Management*, *10*(1). https://doi.org/10.1080/23311975.2023.2168510

Purwanto, Y., & Munawaroh, E. (2010). Etnobotani jenis-jenis Pandanaceae sebagai bahan pangan di Indonesia. *Berk. Penel. Hayati Edisi Khusus: 5A (97–108), 2010*, *5A*(1).

Qomarudin, Q. (2023). Extraction of Pandanus amaryllifiolus Roxb.: A review of methods and the influencing factors. *Advances in Food Science, Sustainable Agriculture and Agroindustrial Engineering*, *6*(1), 72–87. https://doi.org/10.21776/ub.afssaae.2023.006.01.7

Rachma, Risca, A., Hendrian, & Azrianingsih Rodiyati. (2017). The analysis of Pandanus relationship of Purwodadi Botanical Garden collections based on morphological character and molecular marker (trnL and trnL-F). *Research Journal of Life Science*, *4*(2), 129–141.

Riduwan, & Akdon. (2013). *Rumus dan data dalam analisis statistika untuk penelitian: Administrasi pendidikan, bisnis, pemerintahan, sosial, kebijakan, ekonomi, hukum, manajemen, kesehatan* (B. Alma (ed.)). Alfabeta.

Sari, D. K., Suziana, N. A., & Games, D. (2019). Exploring the effects of an Islamic branding strategy for non-food products in Indonesia. *International Journal of Islamic Marketing and Branding*, *4*(2), 131. https://doi.org/10.1504/IJIMB.2019.104544

Soeprijanto, S., Fajar, N., Eva, P., Ningrum, O., & Hamzah, A. (2021). Produksi serat kasar dari limbah daun nanas melalui ekstraksi mekanik di Desa Satak Kabupaten Kediri. *Jurnal Pengabdian Kepada Masyarakat*, *5*(3). https://doi.org/10.12962/j26139960.v5i3.80

Sugiyono. (2017). *Metode penelitian kuantitatif, kualitatif, dan R&D* (26th ed.). Alfabeta.

Sulistiyarto, B. (2019). Kandungan logam seng (Zn) pada rasau (Pandanus helicopus) dan bakung air (Hanguana malayana) di Sungai Sebangau, Kalimantan Tengah. *Jurnal Ilmu Hewani Tropika*, *8*(1), 31–35. https://unkripjournal.com/index.php/JIHT/article/view/144

Sunarya, D., Mukti, H., & Sunandar, A. (2024). Ethnobotany of Dayak medicinal plants in Kayu Ara village, Landak regency as a learning resource. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *10*(3), 748–760.

Suryani, C. L., Wahyuningsih, T. D., Supriyadi, S., & Santoso, U. (2020). The potential of mature pandan leaves as a source of chlorophyll for natural food colorants. *Jurnal Teknologi Dan Industri Pangan*, *31*(2), 127–137. https://doi.org/10.6066/jtip.2020.31.2.127

Tugon, T. D. A., Larasati, R. D., Adnan, S., Sucimilawati, E., Agustiani, F. S., & Jaswir, I. (2023). Characterization of banana peel pectin (Musa acuminata Colla) as a potential halal pharmaceutical excipient. *Indonesian Journal of Halal Research*, *5*(1), 41–52. https://doi.org/10.15575/ijhar.v5i1.21285

UNESCO. (2017). *Education for sustainable development goal*. https://www.unesco.org/en/articles/education-sustainable-development-goals-learning-objectives

United Nations. (2024). *World population prospects 2024*. https://population.un.org/wpp/

Wahyuni, D. K., Nuha, G. A., Atere, T. G., Kharisma, V. D., Tari, V. S., Rahmawati, C. T., Murtadlo, A. A. A., Syukriya, A. J., Wacharasindu, S., Prasongsuk, S., & Purnobasuki, H. (2024). ntimicrobial potentials of Pandanus amaryllifolius Roxb.: Phytochemical

profiling, antioxidant, and molecular docking studies. *PLoS ONE*, *19*(8), 1–20. https://doi.org/10.1371/journal.pone.0305348

Zulkifli, Z., Hermansyah, H., & Mulyanto, S. (2018). Analisa kekuatan tarik dan bentuk patahan komposit serat sabuk kelapa bermatriks epoxy terhadap variasi fraksi volume serat. *JTT (Jurnal Teknologi Terpadu)*, *6*(2), 90. https://doi.org/10.32487/jtt.v6i2.459

Zurlo, G. A. (2025). *Referensi World Religion Database 2025*. 2025–2026.

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.

© 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY SA) license (https://creativecommons.org/licenses/by-sa/4.0/).