MULTIDISCIPLINARY APPLIED RESEARCH AND INNOVATION
e-ISSN: 2773-4773

MARI

Vol. 5 No. 1 (2024) 1-7
https://publisher.uthm.edu.my/periodicals/index.php/mari

Plant Fibres as the Sustainable Alternatives for Textile and Non-Textile Applications

Aiman Firzana Lokman, Alia Maisarah Abu Talib, Norhazimah Abdul Halim*

Department of Science and Mathematics, Centre for Diploma Studies,
University Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author: norhazimah@uthm.edu.my
DOI: https://doi.org/10.30880/mari.2024.05.01.001

Article Info

Received: 01 September 2023
Accepted: 10 December 2023
Available online: 31 January 2024

Keywords

Banana Fiber, Soft, Distilled Water, Sodium Hydroxide

Abstract

Cotton fibre has been heavily utilized in the clothing sector due to its excellent strength, comfort, and durability qualities. However, it also has some negative effects on the environment, necessitating a replacement with a more environmentally friendly fibre like banana fibre. The textile industry relies heavily on fibers, an essential material derived from both natural and fossil resources. Hence, the conversion of agricultural waste into fibres is a sustainable and marketable solution to reduce environmental pollution, taking into account the current supply and future demands. Banana fibre is a good-quality, naturally occurring, readily obtainable fibre that has low density, the right stiffness, and good mechanical strength. This study investigates the possibility of banana fibre as a cotton fibre replace in the textile industry. Banana fibres were softened using traditional techniques, such as boiling in distilled water for several minutes and soaking in sodium hydroxide at different concentrations ranging from 1% to 10%. The resulting fibers were blended with polyester cotton at a 10:90 ratio. By incorporating natural fibres into cotton, the resulting fabric gains enhanced strength, durability, and wrinkle resistance. Blending also improves moisture management, making the textile more breathable and comfortable. The softening treatment, especially at higher concentrations showed an increasing in fibre structure porosity.

1. Introduction

The textile company can offer banana farmers an additional source of revenue rather than letting banana trees go to waste. This helps to lessen the environmental impact due to textile industries. Natural fibre industry can provide employment opportunities to millions of people, mostly to farmers and cottage industries which might give more profit to them [1]. Additionally, using cellulose fibre from agricultural and forestry waste has several benefits, including being recyclable, environmentally friendly, and even a free source of raw material. Banana fiber can be used to create and utilize as raw material for industry in a range of products like handcrafted papers, ropes, mats, and woven garments [2]. Due to its wide availability, affordable production costs, and high level of disposable nature, banana fiber is a material of great interest. Fibre made from bananas has many benefits over synthetic fibre, including being lightweight, corrosion-resistant, low density, non-toxic, and having high specific strength, high toughness, and high stiffness. It is also biodegradable and eco-logical [3]. In addition, banana fibre can also reduce the demand for cotton in textile production, and at the same time, all environmental problems caused by the use of cotton can be reduced.

The fibre was extracted from the banana pseudo manually and then allowed to air dry. Extracted banana fibres were cut into small pieces that were used for softening process treatment. Sodium hydroxide is used to soften banana fibers followed by boiling and soaking in distilled water at a certain time. Bleaching is done for the removal or lightening of the colored materials. Bleaching is carried out chemically using sodium hypochlorite before blending the fibres with polyester cotton and spinning them into yarn.

In this study, banana pseudostem was used as the raw material for textiles. The main objective of this study is to produce textiles from banana fibres using different process treatments and compare the results between each type of softening method used. This study also determines the characteristics of the textile produced from this plant fibre. Lastly, the feasibility of banana fibre as a new raw material for textile production was investigated. Banana fibres were obtained from banana pseudostem. Banana fibres were treated with sodium hydroxide (NaOH) for softening purposes and different concentrations of sodium hypochlorite (NaOCl) for the bleaching process. After those treatments, banana fiber characteristics were studied via fibre-burning test.

2. Materials and Methods

Banana pseudo-stems were obtained from several areas in Batu Pahat and the cotton used is polyester cotton.

2.1 Fibre Softening

Generally, banana fibres are treated with NaOH for softening purposes. Banana fibre was divided into five parts and each part was weighed approximately 20 g using a weighing scale. The NaOH is weighted with different masses and it was put in each three of 2000 ml beakers which are 20 g, 100 g, and 200 g respectively. NaOH of mass 20 g, 100 g, and 200 g were placed into three different beakers before being added with distilled water up to 2000 ml mark scale, each. The three parts of fibre that have been weighed earlier are put into the three beakers that have the NaOH solution. Following that, 20 g of banana fibre was placed into each solution. Each beaker is stirred once in a while using a glass rod for 90 minutes. Next, the other two 2000 ml beakers are filled with distilled water (DI) until it reaches 2000 ml. The fibre that had been weighed was put into these two beakers, one of these beakers was left for 90 minutes, and the other beaker was boiled using a stirring hot plate with a temperature of 100 °C for 90 minutes. All the fibres were ensured to be soaked and each beaker was stirred once in a while using a glass rod for 90 minutes. All the fibres were rinsed using DI after 90 minutes. Then, the fiber from each beaker is dried in the oven at 60 °C for 24 hours. Finally, all five samples are weighed after they are completely dry, and each weight is recorded. A comparison was made to single out the better treatment in terms of feel, weight loss, and strength loss as tabulated in Table 1.

2.2 Fibre Bleaching for Yarn Preparation

Mostly, NaOCl is used to treat banana fiber for bleaching purposes. In this study, the same concentration of NaOCl is used to bleach all five samples prepared in the previous step. Next, 250 ml of NaOCl was put into each 1 L beaker and DI was added until it reached the 1 L mark. The softened fiber is immersed into each beaker and left for 2 hours. Each sample was soaked into a 1 liter of homogeneous solution containing DI and 250 ml of NaOCl for two hours and each beaker was stirred once in a while using a glass rod to get effective color bleaching. After two hours, the fiber was taken out and it was dried under the sunlight until it was totally dry. The obtained banana fibres were blended with polyester cotton in 10:90 blend ratios at the opener machine.

2.3 Fibre Burning Test

In this test, a microscope was used to observe the structure before and after burning. The initial structure of each type of softened fibre was observed using a microscope before the burning test and the initial structure was photographed. Next, approximately 3 g of treated fibre from each type of softened fiber was taken to burn in a fume hood for 5 minutes using a crucible, Bunsen burner, and tongs. Make sure to burn this fibre in the fume hood to prevent the release of hazardous substances into the general laboratory space. At the same time, each type of treated fiber was compared by the smell, color, and shape of the ash, and the speed at which the fibres burn down must also be given attention. Finally, the fibre structure after burning was observed under a microscope and was recorded.

3. Results and Discussion

The analysis results are discussed in detail as in the following sub-topics.

Multidisciplinary Applied Research and Innovation Vol. 5 No. 1 (2024) p. 1-7

3.1 Softening Treatment Properties

Softening banana fibre using different concentrations of NaOH can affect the weight loss of the fibre. When banana fibre is treated with NaOH, it undergoes a process called mercerization, which leads to swelling and structural changes in the fibre. The concentration of NaOH used in the treatment has an impact on the extent of weight loss. Table 1 reports the comparison of all the softening treatments in terms of feel, weight loss, and strength loss.

Table 1 *Effect of various softening treatments on the properties of banana fibre*

No.	Condition	Subjective analysis	Weight loss (%) $\frac{before - after}{before} \times 100$
1	1% NaOH	Slight less harsh feel	7.09
2	5% NaOH	Medium soft feel	13.21
3	10% NaOH	Soft feel	25.16
4	Boiling in DI	Medium soft feel	4.92
5	Soaked in DI	Slight less harsh feel	1.79

Table 1 shows the result of softening banana fibre using different concentrations of NaOH and distilled water that give various effects in terms of feel, weight loss, and strength loss. Based on Table 1, the feel of the fibre on each concentration of chemicals is different. With a low concentration of NaOH, the feel of the softened banana fibre may not significantly change. There may be some softening and increased flexibility, but the overall feel may remain relatively similar to untreated fibre. As the concentration of NaOH increases, the softened banana fibre may feel noticeably softer and more pliable. The fibre structure undergoes swelling and may become more supple to the touch. At high NaOH concentrations, the softened banana fibre can become extremely soft and flexible. The fibre structure undergoes significant swelling and may have a gel-like feel, with reduced stiffness and increased pliability. Boiling the banana fibre with DI can result in a softer feel compared to untreated fibre. The heat and agitation during boiling help break down some components of the fibre, leading to increased flexibility and pliability. Soaking the banana fibre in DI can also result in a softer feel, although the softening process may be slower compared to boiling. The water gradually penetrates the fibre, causing it to swell and become more pliable over time.

Based on the result above, the percent of the weight loss is directly proportional to the concentration of NaOH and the percent of the weight loss boiled in distilled water is higher than the fibre soaked in DI. When banana fiber is treated with a low concentration of NaOH, the weight loss may be minimal. The fibre may undergo some degree of swelling and softening, resulting in a slight weight reduction due to the removal of impurities or superficial components. However, the structural changes and weight loss would be relatively minor. As the concentration of NaOH increases, the weight loss of the banana fibre is likely to be more significant. The higher concentration of NaOH leads to more extensive swelling and breakage of hydrogen bonds within the fibre, resulting in greater weight reduction. The fibre becomes softer, and there may be some dissolution or removal of non-cellulosic components, contributing to weight loss. With a high concentration of NaOH, the weight loss of banana fibre can be substantial. The increased concentration causes significant swelling and disruption of the fiber structure. The NaOH may penetrate deeper into the fibre, leading to increased removal of impurities, hemicelluloses, and other non-cellulosic components. This can result in notable weight loss [5]. Boiling the fibre with distilled water may cause some weight loss. The heat and prolonged exposure to water can lead to the removal of impurities and non-cellulosic components from the fibre, resulting in a weight reduction. Soaking the fibre with DI may cause minimal weight loss. While some impurities may be removed from the surface, the weight reduction is generally less significant compared to boiling.

In addition, softening banana fiber with distilled water helps preserve its natural characteristics. DI does not introduce any chemical changes or alter the fibre's composition, allowing it to retain its original properties such as color, texture, and strength. NaOH is a chemical substance that requires proper handling, storage, and disposal to ensure safety and minimize environmental impact. Using distilled water avoids the use of chemicals, making it a more environmentally friendly option. Banana fibre can be sensitive to chemical treatments, especially at higher concentrations of NaOH. Excessive exposure to NaOH can lead to over-swelling, weakening the fibre structure, and causing potential damage. Softening with DI reduces the risk of structural damage and maintains the integrity of the fibre. Distilled water is generally more readily available and cost-effective compared to NaOH, which may require additional procurement, storage, and handling considerations. Distilled water has limited ability to induce significant softening or swelling of the fibre, especially if the objective is to modify its properties for specific applications. In such cases, a chemical treatment like NaOH may be necessary to achieve the desired softness or improved processability of the fibre.

3.2 Fibre Blending for Yarn Preparation

After fibre bleaching, banana fiber is blended with cotton fiber in 10:90 blend ratios as shown in Fig. 1. Blending banana fibre with cotton allows for diversification of the raw material used in yarn production. By incorporating banana fibre, which is a non-traditional and renewable fibre, the dependency on cotton as the sole raw material is reduced. This diversification helps alleviate the demand pressure on cotton and creates alternative options for yarn production [4]. Blending banana fibre with cotton allows for the utilization of a smaller percentage of cotton in the yarn composition. This reduction in cotton consumption can contribute to the conservation of cotton resources.

By blending it with cotton, the overall yield and utilization of available fiber resources can be improved. This helps optimize the use of both cotton and banana fibres and minimizes waste in the production process. Blending banana fibre with cotton aligns with sustainability goals and reduces the environmental impact of yarn production. Banana fibre is a natural, renewable, and biodegradable material, and incorporating it into yarn reduces the reliance on synthetic fibers. This shift towards more sustainable and eco-friendly practices supports the growing demand for environmentally conscious products. Blending banana fibre with cotton offers unique product offerings in the textile market. It allows for the creation of yarn with distinct characteristics, such as added strength, improved softness, and enhanced moisture absorption. This differentiation in product properties can open up new market segments, attract environmentally conscious consumers, and foster innovation within the textile industry.

Overall, blending banana fibre with cotton to make yarn provides opportunities to diversify fibre resources, reduce cotton consumption, promote sustainability, and drive market differentiation. These factors collectively contribute to managing cotton demand and creating more sustainable and versatile options for yarn production.

Fig. 1 *Blended fibre of cotton and banana fibre*

3.3 Fibre Burning Test

In fibre burning test, approximately 5 g of each sample was used. Through this test, various changes and characteristics were observed when conducting a burning test on banana fibre with different concentrations of softening treatments. From the data in Table 2, 10% concentration of NaOH is shorter than 5% and 1% concentration of NaOH in terms of ignition time. Higher concentrations of NaOH, such as 10%, may lead to a shorter ignition time compared to lower concentrations like 1%. This means that the fibres treated with a higher concentration of NaOH may ignite more quickly when exposed to a flame while lower concentrations might delay ignition. Higher concentrations of NaOH generally increase the chemical reactivity between the treatment and the fibre. This enhanced reactivity can facilitate faster heat generation and combustion initiation, leading to a shorter ignition time. Higher concentrations of the NaOH also improve the thermal conductivity of the fibre. This means that heat is more efficiently transferred throughout the fibre, increasing the overall temperature and promoting faster ignition. The higher concentration of the softening treatment can accelerate the chemical processes occurring during combustion. It can promote faster decomposition of the fibre, release of volatile compounds, and subsequent ignition of these volatile components, thereby reducing the overall ignition time. Boiling the fibres may potentially result in a shorter ignition time compared to soaking in DI. The process of boiling can modify the fiber structure and remove certain components that can affect ignition. Boiling the fibres in DI helps remove water-soluble impurities and substances that may inhibit combustion or contribute to a higher ignition temperature. This enhanced porosity allows for better air circulation and improved oxygen availability during the burning process. As a result, the fibres are more easily ignited, leading to a shorter ignition time. Table 2 shows the result of the banana fibre burning test for fibre that undergo different concentrations of softening treatment for all fibre samples.

Table 2 *Fibre burning test properties in 5 minutes*

No.	Condition	Ignition Time (minutes)	Flame Spread (minutes)	Residue formation
1	1% NaOH	4.3	3.8	Less
2	5% NaOH	3.5	2.8	Moderate
3	10% NaOH	2	1	Greater
4	Boiling in DI	2.5	2	Greater
5	Soaked in DI	4.8	3.5	Moderate

Based on Table 2, a 10% concentration of NaOH is faster than a 5% and 1% concentration of NaOH in terms of flame spread. With higher concentrations of NaOH, the flame spread along the banana fibres may be faster compared to lower concentrations. This is because the higher concentration of NaOH may promote better combustion and facilitate the spread of the flame. Higher concentrations of NaOH typically enhance the chemical reactivity between the treatment and the fibre. The higher concentration of the softening treatment can modify the fibre's surface and structure, creating favorable conditions for combustion. This modification may involve removing or breaking down certain components that can act as barriers to flame propagation. Higher concentrations of the softening treatment can increase the availability of combustible components within the fibre. These components, such as cellulose and lignin, can serve as fuel for the flame. With a higher concentration, there is a greater abundance of fuel, leading to faster flame spread. The softening treatment, especially at higher concentrations, can alter the fibre structure, increasing its porosity [6]. This enhanced porosity improves air and oxygen flow to the combustion zone. With better oxygen accessibility, the flame can be sustained and spread more rapidly along the fibres. Boiled fibres may have a faster flame spread compared to fibers soaked in DI. Boiling can alter the fibre surface, making it more susceptible to combustion and facilitating the spread of the flame. Boiling the fibres in distilled water can increase the porosity of the fibres. This enhanced porosity improves the flow of air and oxygen within the fibre, providing a more favorable environment for combustion and enabling faster flame propagation. Boiled fibres may retain more moisture compared to fibers soaked in DI. The presence of moisture can lower the ignition temperature and act as a heat sink, promoting faster combustion and flame spread. The higher moisture content in boiled fibres contributes to their faster flame spread compared to soaked fibres.

Based on the data above, a 10% concentration of NaOH is greater than 5%, and a 1% concentration of NaOH in terms of residue formation. Higher concentrations of NaOH can result in greater residue formation after the burning test. This means that fibres treated with a higher concentration of NaOH may leave behind more residue or ash compared to lower concentrations. The residue composition may also differ, with higher concentrations potentially leaving more substantial ash. The higher concentration of NaOH can improve the overall combustion efficiency of the fibres. This means that a larger proportion of the fibre material is converted into gaseous products and residue during the burning process. The specific softening treatment used and its concentration can affect the composition of the residue formed. Higher concentrations may promote the formation of specific compounds or minerals that contribute to a larger residue mass. The higher concentration may alter the decomposition pathways and produce more substantial residue during the burning process. Boiled fibres may leave behind more significant residue compared to fibers soaked in DI. The boiling process can result in the breakdown of fibres and the formation of charred residue or ash. Boiling the fibres in distilled water helps remove volatile components present in the fibers, such as volatile organic compounds (VOCs) and water-soluble impurities. The removal of these volatile components during boiling leaves behind a higher concentration of non-volatile components, resulting in greater residue formation during the burning process. During combustion, these non-volatile components contribute to the formation of residue or ash, resulting in greater residue formation in boiled fibres.

Table 3 *The microscopic image sample*

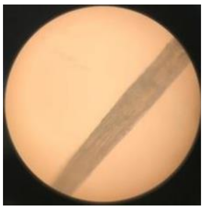
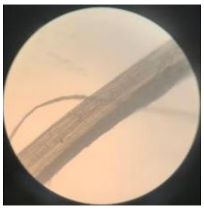
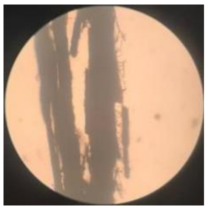
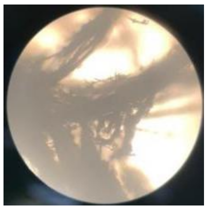
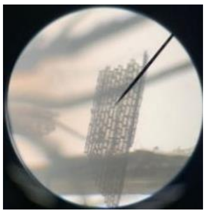
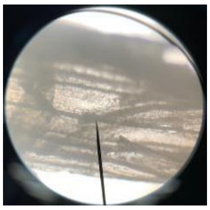
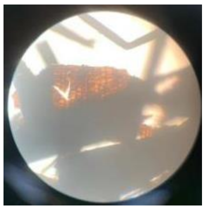
No.	Condition	Before	After
1	1% NaOH		
2	5% NaOH		
3	10% NaOH		
4	Boiling in DI		
5	Soaking in DI		

Table 3 shows the structure of the banana fibres before and after burning. The structure of the banana fibres can be observed at a microscopic level. Higher concentrations of NaOH, such as 10%, may lead to more noticeable changes in the fibre structure. These changes can include increased degradation, breakage, or disintegration of the fibres. Lower concentrations, like 1%, may result in milder or less apparent structural modifications. The surface of the banana fibres treated with different concentrations of NaOH can exhibit variations under the microscope. Higher concentrations, such as 10%, may cause more pronounced surface modifications, including increased roughness, etching, or changes in surface morphology. Lower concentrations may have less noticeable effects on the fibre surface. The morphology of the banana fibers, including their shape, diameter, and cross-sectional characteristics, can be observed. Higher concentrations of NaOH may alter the fibre morphology to a greater extent, potentially leading to thinner or fragmented fibres.

4. Conclusion

In this study, it is shown that the mixture of DI and NaOH can be effective in softening certain types of fibres by removing impurities and enhancing the fabric's flexibility. Blending fibre with cotton can provide numerous advantages in terms of fabric performance and comfort. By incorporating natural fibers into cotton, the resulting fabric gains enhanced strength, durability, and wrinkle resistance. Blending also improves moisture management, making the textile more breathable and comfortable. Blended fabrics can also exhibit improved colorfastness and offer a more cost-effective alternative to pure cotton textiles. The specific benefits of a fibre blend will vary depending on the types and proportions of fibres used, as well as the intended application of the textile. Overall, blending fibres with cotton allows for the creation of fabrics that combine the desirable qualities of both materials, resulting in versatile, durable, and comfortable textiles.

Acknowledgement

The authors would like to thank the Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Aiman Firzana Lokman, Alia Maisarah Abu Talib, Norhazimah Abdul Halim;* ***data collection:*** *Aiman Firzana Lokman, Alia Maisarah Abu Talib, Norhazimah Abdul Halim;* ***analysis and interpretation of results:*** *Aiman Firzana Lokman, Alia Maisarah Abu Talib, Norhazimah Abdul Halim;* ***draft manuscript preparation:*** *Aiman Firzana Lokman, Alia Maisarah Abu Talib, Norhazimah Abdul Halim. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Sangamithirai, K., & Vasugi, N. (2020). Banana fibre – A potential source of sustainable textiles. Journal of Applied Horticulture, 22(2), 133–136. https://doi.org/10.37855/jah.2020.v22i02.24

[2] Patel, B. Y., & Patel, H. K. (2022). Retting of banana pseudostem fibre using Bacillus strains to get excellent mechanical properties as biomaterial in textile & fiber industry. Heliyon, 8(9), e10652. https://doi.org/10.1016/j.heliyon.2022.e10652

[3] Advances in materials processing and manufacturing applications. (2021). In Springer eBooks. https://doi.org/10.1007/978-981-16-0909-1

[4] Subagyo, A., & Chafidz, A. (2020). Banana Pseudo-Stem Fiber: Preparation, characteristics, and applications. In IntechOpen eBooks. https://doi.org/10.5772/intechopen.82204

[5] Universiti Teknologi MARA, Negeri Sembilan. (n.d.). Physical properties of banana pseudo-Stem woven fabric treated with softening agent / Wan Syazehan Ruznan . . . [et al.] - UiTM Institutional Repository. https://ir.uitm.edu.my/id/eprint/41443/

[6] Liu, H., You, L., Jin, H., & Yu, W. (2013b). Influence of alkali treatment on the structure and properties of hemp fibers. Fibers and Polymers, 14(3), 389–395. https://doi.org/10.1007/s12221-013-0389-8