Journal of Academia Vol. 12, Issue 2 (2024) 186 – 194

PHYSICAL AND MECHANICAL PROPERTIES OF PINEAPPLE BIO-LEATHER

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Abstract

Bio-leather, or vegan leather, is a range of materials that imitate the characteristics and look of regular animal leather but are crafted from eco-friendly and sustainable sources. These substances are frequently made with plant-derived components, agricultural leftovers, or advanced laboratory cultivation methods. However, the physical and mechanical properties of bio-leather made from pineapple skin fibre is yet to be explored. Therefore, the research objective of this study is to assess the material's tear resistance, stiffness, and ability to withstand water impact penetration. Various samples containing different amounts of pineapple skin fibre were created to investigate how it affects the quality of the bio-leather. In this research, pineapple skin, xanthan gum, cinnamon powder and lemon juice were used as the materials to create three samples with different weight of pineapple fibre. Specifically, 50g, 100g and 150g of pineapple skin were utilised, along with 30g of cinnamon powder, and 150ml of lemon juice for each sample. All samples were tested for flexibility, tensile strength and water impact penetration. It is found that the increasing amount of pineapple skin fibres in the leather increases the strength up to 167.26 N and reduces the water penetration by 44.54% with low flexibility.

Keywords: pineapple skin fibre, bio-leather, eco-friendly leather, sustainable textile

Article History:- Received: 26 July 2024; Revised: 22 August 2024; Accepted: 29 August 2024; Published: 31 October 2024

Introduction

Pineapple (*Ananas comosus*) is a tropical fruit that is popular for its distinct aroma and sweet flavour. It is known as a flavourful fruit because it contains a variety of volatile chemicals in small amounts and complex mixtures (Ali et al., 2020). Pineapple is primarily grown in tropical and subtropical areas due to its moderate environment and rainfall distribution. The crop can bear fruits at an early stage after flowering, allowing yield production all year (Shamsudin et al., 2020). The pineapple business has grown rapidly in terms of the use of pineapple food-based processing goods and waste around the world (Mohd Ismail et al., 2018). Pineapple waste such as leaves has been used in the textile industries and very few research works are reported on the exploration of this kind of fibres for making flexible composite material such as leather (Basak et al., 2022).

Bio-leather becomes the main focus in the current study as an attempt to substitute traditional leather. Traditional leather in general is produced across the globe from the skin of animals (Patil & Athalye, 2023). The animals are hunted and killed only for their skin to be removed and used in animal-based leather making industries. If the hunting happens extensively, then it has a major effect on the environment like deforestation and water overuse, or worse, this can lead to animal extinction (Patil & Athalye, 2023). Additionally, animal killing for fur and leather products for the related industry has led to unethical critique within the fashion sector (Moralde & Octavo, 2022). According to People for the Ethical Treatment of Animals (PETA), approximately around 1 billion animals are globally killed for leather trade each year (PETA, 2024). Therefore, to reduce the excessive pineapple skin waste and minimise animal cruelty in the leather making industry, bio-leather has started to be used to make the environment more sustainable. Due to its sustainable features, bio-leather is easy to decompose and most likely, safe for the earth (Kefale et al., 2023).

Bio-leather is a sustainable biomaterial that comes from natural sources like plants and microorganisms (Kim et al., 2021). The physical and mechanical properties are among the important attributes to be investigated to ensure its usefulness in the related field. A number of research have been conducted in the last few decades to replace traditional leather with bio-leather substitutes which help to reduce the amount of natural product waste as it is biodegradable and environmentally friendly. The basic sources for bio-leather include natural latex, pineapple, mushroom, jellyfish, and bacterial cellulose (Kim et al., 2021). Bio-leather also exhibits better tensile strength and flexibility compared to cow leather (Vinay, 2022), as well as has a substantially lower level of toxicity to humans and a smaller carbon footprint (Bai et al., 2022). Pineapple fibre can be made into leather owing to its excellent fibre strength and some past studies mentioned that the leather made of pineapple has comparable or better properties than traditional or other bio-leather (Duangsuwan et al., 2023; Sureshkumar et al., 2012). Furthermore, pineapple leather, a by-product of pineapple skin, can be repurposed and used to make a variety of goods, including coats, handbags, shoes, and more, resulting in the creation of a flexible leather-like film from pineapple waste.

Therefore, the objective of this study is to investigate the physical properties, tearing strength, stiffness and water impact penetration of leather made from pineapple skin fibre. Furthermore, this study is conducted to utilize pineapple skin for leather production with different amounts of pineapple skin used in each sample. The research seeks to examine the physical characteristics of bio-leather, with a specific emphasis on pineapple skin leather. Researchers can evaluate its suitability as a sustainable substitute for traditional animal leather by analysing its durability, flexibility, physical strength and more characteristics. Pineapple skin leather provides a sustainable alternative aligned with Sustainable Development Goal (SDG) 12 of the United Nations, lessening the environmental effects linked to traditional leather manufacturing in the future (Eisen et al., 2024; Linnea Harris, 2022).

Methods

Materials Preparation

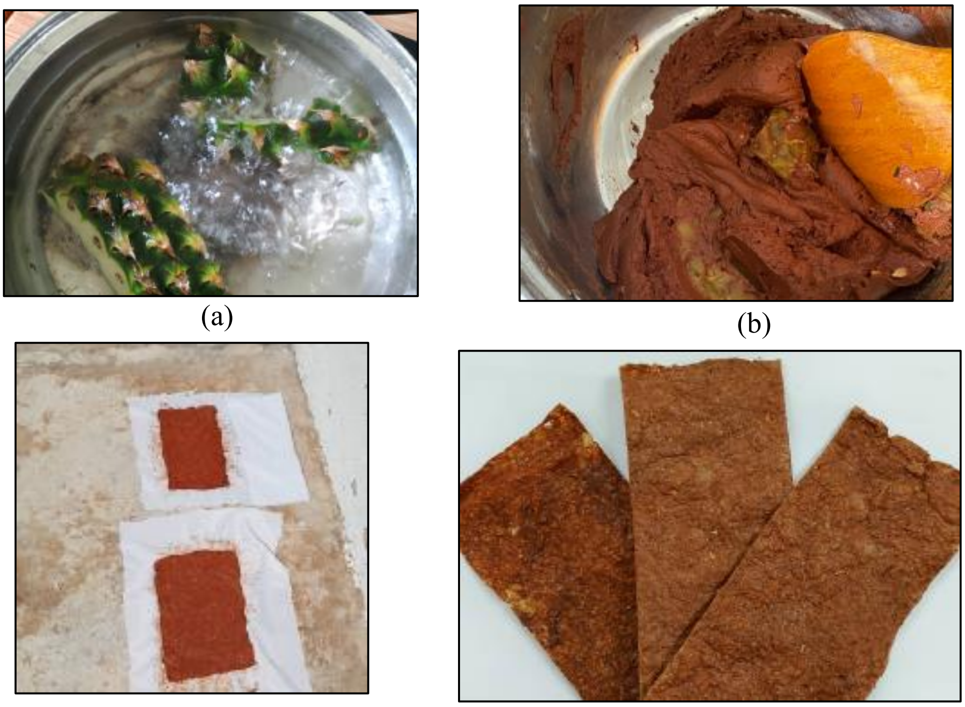
Three different samples were prepared; Sample A, B and C. A quantity of 1 kg of pineapple skin was collected from the domestic waste with the mixture of pineapple variation and maturity. Table 1 shows the amount of materials that have been used in the study for sample A, B, and C respectively.

Table 1. List of materials

Materials	Weight of ingredients (g)		
	Sample A	Sample B	Sample C
Pineapple skin	50	100	150
Xanthan gum	20	20	20
Lemon juice	150	150	150
Cinnamon powder	30	30	30

Leather Formation

The steps of the leather formation are illustrated in Figure 1 (a – c). 50 g of pineapple skin was washed and cut before being brought to cooking process. Subsequently, the pineapple skin was cooked at 100°C and kept on low heat without boiling until the substance became soft. Next, the mixture was blended with fresh lemon juice and cinnamon. The purpose of adding these materials was for their antimicrobial properties which could minimise the unpleasant odour and to prevent the formation of mould in the puree mixture (Al-qudah et al., 2018; Soliman & Badeaa, 2002). Xanthan gum was then added into the mixture as a thickening agent. The leather puree was spread onto polyester fabric evenly and left until completely dehydrated under the sun.



(a) (b)

(c) (d)

Figure 1. Leather formation. (a) Pineapple skin boiling, (b) leather puree mixing, (c) leather puree spreading, (d) dried pineapple leather

Leather Evaluation

The leather samples were evaluated for the weight, thickness, stiffness, tensile strength and water impact penetration.

Weight and thickness

The weight of the samples was measured using weighing balance according to Malaysia Standards (Malaysian Standard, 2015b). Apart from that, the leather thickness was measured which correlates to MS ISO 5084-2003 by using thickness gauge (Malaysian Standard, 2015a).

Stiffness test

Three tests were conducted for each sample to determine their mean flexibility or curvature using a Stiffness Tester. To conduct the test, the machine was standardized with the standard method of ASTM D1388 (ASTM International, 2023).

Tensile strength test

Every sample needs to be tested in five experiments, with each sample trimmed to dimensions of 8 x 4 inches before testing. Next, the tool was adjusted to operate at a speed of 300 m/s and a gauge length of 100 using the ISO 13934 standard procedure (International Standard, 2013), while the sample was placed between clamps measuring 1 x 1 inch. The sample was subjected to tension until it fractured, and the force and elongation at the point of failure were recorded.

Water impact penetration test

All three samples underwent water impact penetration testing with a Water Impact Penetration Tester. Initially, the water impact test was conducted with the standard method of AATCC TM42 (AATCC, 2017). Next, both the blotting paper and the pineapple skin leather were cut to a size of 15 x 15 cm, weighed, and then placed on a glass base to achieve a smooth, wrinkle-free surface. Next, the hoop was positioned on the spray tester stand. The tester's funnel was filled with 50 mL of distilled water and sprayed until empty, a process that should be completed in 1 minute. The weight of the moisture absorbed by the blotting paper was determined following the spraying by subtracting the weight of blotting paper before and after. The same procedure was carried out on the two remaining samples to calculate the fabric's total water resistance rating.

Results and Discussion

Weight and Thickness

Table 2 below shows the weight and thickness of the pineapple skin leather. According to the results in Table 2, sample C records the heaviest in weight whereas sample A is the lightest. The thickest leather is sample C measuring 2.643 mm and the thinnest leather is sample A measuring 1.327 mm. Based on the results, the thickness of the leather could affect the weight of the sample. Therefore, the more pineapple skin added to the sample, the heavier the sample is.

Table 2. Weight and thickness

Sample	Leather Weight (g/m^2)	Average Thickness (mm)
A	586.75	1.327
B	762.04	2.473
C	1088.71	2.643

Stiffness

In the stiffness test conducted, sample A shows better bending and flexibility compared to the other samples, with a bending length of 4.75 cm in the front and 5.25 cm in the back. Based on Figure 2, sample B measures 6.75 cm in the front and 6.65 cm in the back. Sample C possesses little flexibility, with measurements of 6.90 cm on its front surface and 6.70 cm on its back surface.

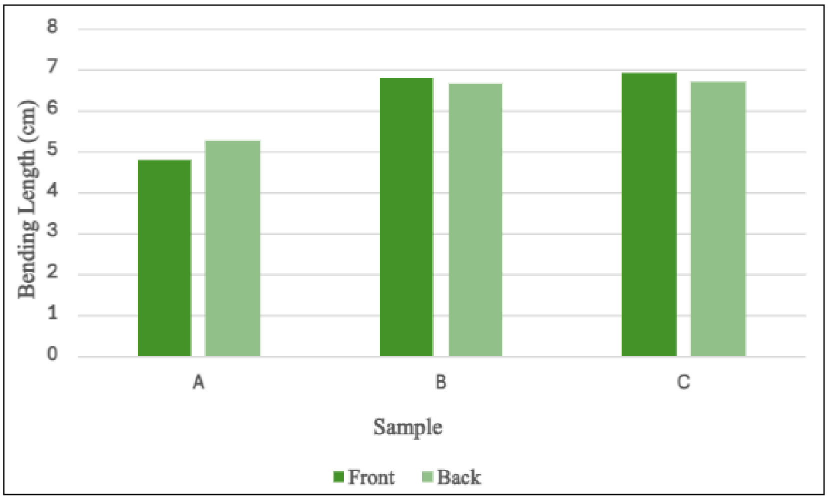


Figure 2. Bending length

Figure 3 displays the bending stiffness of the pineapple skin leather. The bar graph shows that sample C has a flexural rigidity of 751.21 mg.cm, ranking as the most rigid, while sample A has the lowest rigidity at 278.71 mg.cm. The increased bending length and enhanced flexural rigidity generally result in reduced flexibility. The amount of pineapple skin in the samples affects both the flexibility and bending. Samples with higher amounts of pineapple skin exhibit reduced flexibility.

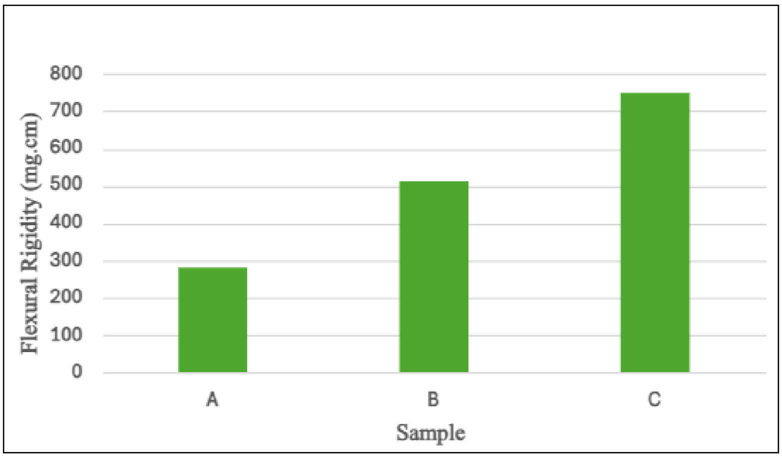


Figure 3. Flexural rigidity

Tensile Strength

The grab test was the method utilized for the tensile strength test. Based on Table 3 data, sample C displays the longest breaking time at 2.23 seconds, while sample A has the shortest breaking time at 1.21 seconds. The grab test force is measured in Newton (N) with sample C requiring a maximum force of 167.26 N to break the leather, compared to sample A which only needs 58.31 N. Furthermore, sample C has the highest elongation at break at 10.70%, while sample A has the lowest at 5.84%.

Table 3. Tensile strength

Sample	Breaking Extension (mm)	Breaking Time (s)	Grab Test Force (N)	Breaking Elongation (%)
A	4.09	1.21	58.31	5.84
B	5.80	1.72	131.53	8.29
C	7.49	2.23	167.26	10.70

Sample C possesses the highest tensile strength in contrast to sample A, which has the lowest tensile strength as indicated by Figure 4. The primary factor leading to these outcomes is the varying amount of pineapple utilized in each specimen. Moreover, as shown in Figure 5, there is a strong correlation between the weight of the fibres and their tensile strength, indicating that the greater the quantity of pineapple skin in the leather has contributed to the greater tensile strength. This finding is in agreement with past research which used pineapple leaf fibres for bio-leather making (Duangsuwan et al., 2023). The result in this study indicates that the increment of the fibre content has added to the tensile strength, where the pineapple fibre serves as reinforcement within the structure.

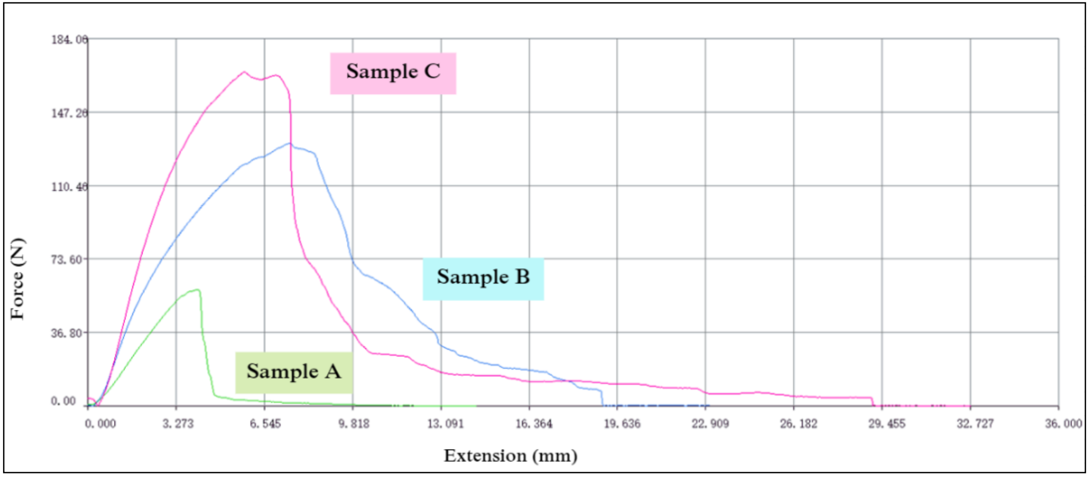


Figure 4. Tensile strength

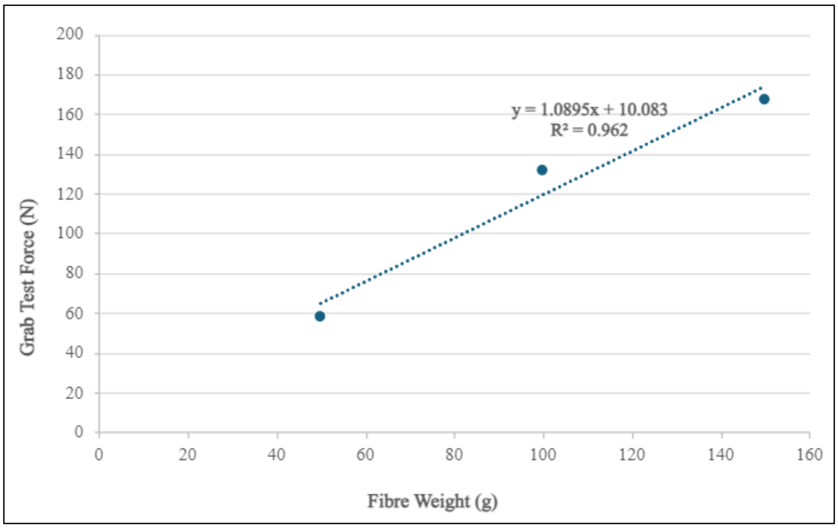


Figure 5. Correlation between fibre weight and tensile strength

Water Impact Penetration

According to Figure 6, sample A has the highest amount of water penetration at 12.28% due to its lower pineapple skin fibre content in comparison to sample B and C, with the amount of water penetrated at 7.96% and 6.81% respectively. It has been demonstrated that the greater the presence of pineapple skin fibre in the leather, the lesser the likelihood of it being penetrated with water. It is possible that the inclusion of higher fibre content has improved the hydrophilic properties. However, the moisture has been absorbed and locked in the leather, and limited the water penetration due to the thicker and more compact structure in sample C. This specific leather characteristic is similar to suede leather which is known to be porous and absorbent (Kaliappa et al., 2010).

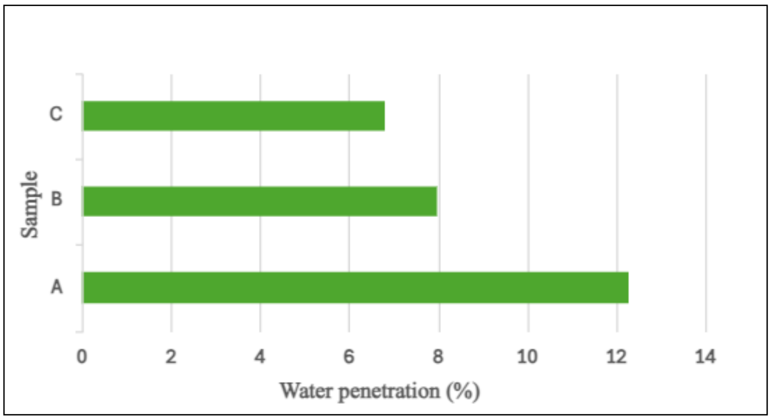


Figure 6. Water impact penetration

Conclusion

Pineapple skin leather expresses magnificent high durability, flexibility and water resistance properties. It has been shown that the more pineapple skin fibre added to the leather, the stronger, stiffer, and low water penetration it has. Therefore, the physical properties of the produced bio-leather show high levels of strength and lower water penetration. However, the leather lacks in flexibility and stiffness. Hence, this produced bio-leather is recommended and suitable for non-apparel applications such as upholstery like sofa cushion bases and automotive like car seat covers. Further research and developments can be made in order to improve and enhance the bio-leather properties such as the flexibility and stiffness for the leather where it can be used for various applications making the bio-leather a greater alternative for traditional leather.

For future research endeavours in the field of pineapple skin bio-leather, several areas can be explored to improve its properties and overall quality. Researchers can focus on finding ways to enhance the durability of pineapple skin bio-leather. This could involve experimenting with different treatment methods, additives, or processing techniques to strengthen the material's structure and resistance to wear and tear. Moreover, pineapple skin bio-leather might have inherent odours due to the organic nature of its components. Finding effective ways to eliminate or minimise any unpleasant smells could make it more appealing for commercial use. Research efforts can be dedicated to making pineapple skin bio-leather more biodegradable and environmentally friendly by reducing the power consumption in pineapple skin leather production. Hence, future research and development should focus on enhancing its durability, flexibility, water resistance, and expanding its applications across various industries.

Acknowledgement/Funding

The authors would like to acknowledge the Academic Affairs Division of Universiti Teknologi MARA Cawangan Negeri Sembilan for funding the material purchase, and providing the research facilities and exceptional support during the completion of this study.

Author Contribution

NAS Norisam, PS Shaharuddin, AS Kamal Azman and FN Mat Sani carried out the literature search, experimental works, analysing and drafting the manuscript. E Nasir conceptualised the central research idea, advising the results analysis and manuscript editing.

Conflict of Interest

The authors agree that this manuscript was made in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with any parties.

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