

# Analysis on Microstructural Features and Tensile Properties of Acrylic-Coated Banana-Polyester Synthetic Leather

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Banana fiber, synthetic leather, acrylic coating, polyester fiber, tensile strength, microstructure

## Abstract

The increasing demand for sustainable and eco-friendly materials has led to a growing interest in synthetic leather alternatives. This study explores the use of banana fiber combined with polyester (BF-PE) as a sustainable alternative, bonded and coated with eco-friendly acrylic binders. The research addresses the challenge of improving adhesion and tensile properties between banana fibers and acrylic binders to enhance durability and mechanical performance. Nonwoven BF-PE fabric was coated using acrylic solutions with two dilution ratios: 50% acrylic and 50% water (A50W50) and 80% acrylic and 20% water (A80W20). Samples were subjected to compression pressures of 2 kPa, 4 kPa, and 6 kPa to study the effects of binder concentration and pressure on mechanical and microstructural properties. Results showed that the A50W50 sample at 4 kPa compression exhibited the most balanced characteristics for synthetic leather applications, with a tensile strength of 1.063 MPa and a Young's Modulus of 21.817 MPa. This combination provided flexibility, strength, and a smooth surface finish. The findings demonstrate that acrylic-coated banana-polyester fabrics are promising sustainable alternatives to conventional synthetic leathers. They offer environmental and economic benefits, aligning with global efforts to reduce dependence on non-renewable resources and promote sustainable material development.

## 1. Introduction

The demand for synthetic leather has significantly increased over the last few decades, driven by the automotive, furniture, and fashion industries. However, the reliance on synthetic fibers and inorganic coatings such as polyurethane (PU) and polyvinyl chloride (PVC) raises environmental concerns. Traditional synthetic leather, primarily made from petroleum-based plastics, contributes significantly to environmental pollution due to its non-biodegradable nature and toxic chemical processes [1][2]. Research has demonstrated that natural fibers, such as banana fiber, offer a viable solution by providing biodegradable and renewable alternatives that enhance mechanical properties [3]. Moreover, the synthetic leather market is experiencing growth, driven by rising consumer awareness of animal rights and environmental concerns [4].

Natural fibers, like banana fiber, showed great potential, but their use with acrylic coatings for synthetic leather was not fully explored. A notable challenge lies in balancing the contrasting properties of hydrophobic polyester (PE) and the hydrophilic banana fiber. Polyester fibers resist water, providing durability and environmental stability, while banana fibers, with their strong water affinity, enable better interaction with the acrylic coating. These opposing properties present an opportunity to create a composite material that balances water resistance and coating adhesion. One key issue in research was not fully understanding how acrylic coatings impacted the material's strength and structure when combined with natural fibers. Additionally, the effects of different manufacturing processes, such as the ratio of acrylic to water and compression pressures, on the material's overall performance were not well-understood. This gap in knowledge provided an opportunity to study how these factors affected the final product and its suitability for commercial use.

A big challenge in making synthetic leather was achieving the right amount of coating penetration, which affected both the structure and surface of the material. When acrylic coatings were applied in different mixes, uneven penetration could occur, leading to differences in strength and structure. The hydrophilic nature of banana fibers could enhance coating penetration, while the hydrophobic nature of polyester fibers could limit it, resulting in uneven distribution of the coating. The thickness of the coating mix and the pressure used to apply it were important factors in how deeply the coating went into the fabric and how much stayed on the surface. Understanding how different ratios of coating and pressures affected both the inside and outside of the synthetic leather was key to improving its performance and durability.

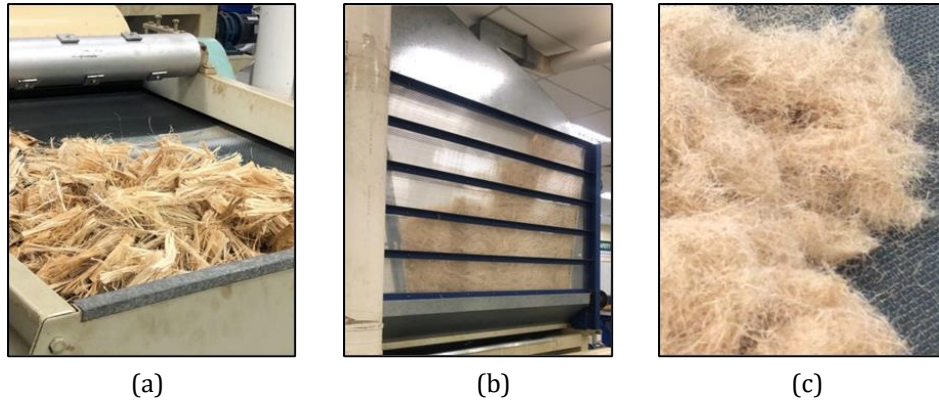
The main goal of the study was to examine how different ratios of acrylic to water and varying compression pressures affected the tensile strength, Young's Modulus, and overall mechanical properties of acrylic-coated banana-polyester leather fabric. The study also aimed to look at the fabric's structure under a microscope to understand how these factors influenced its design. This research provided valuable information on how to optimize the production of synthetic leather with natural fibers, leading to more sustainable and high-performing alternatives.

The importance of this study was in its ability to improve the manufacturing process of acrylic-coated banana-polyester leather. It ensured that the coating penetrated well into the material while leaving a thicker layer on the surface. By addressing the hydrophilic-hydrophobic interactions of banana and polyester fibers, the study sought to achieve an optimal balance between coating penetration and surface coverage. By improving these production steps, the study aimed to make the deeper binder penetration in base fiber increase frictional force among fibers and thus increasing the synthetic leather tensile strength. These findings were instrumental in gaining knowledge on the optimization of binder and fiber compositions, particularly in understanding how these components affect the Young's Modulus of the leather. Ultimately, the study aimed to support the growing demand for high-quality, eco-friendly synthetic leather in the market.

## 2. Methodology

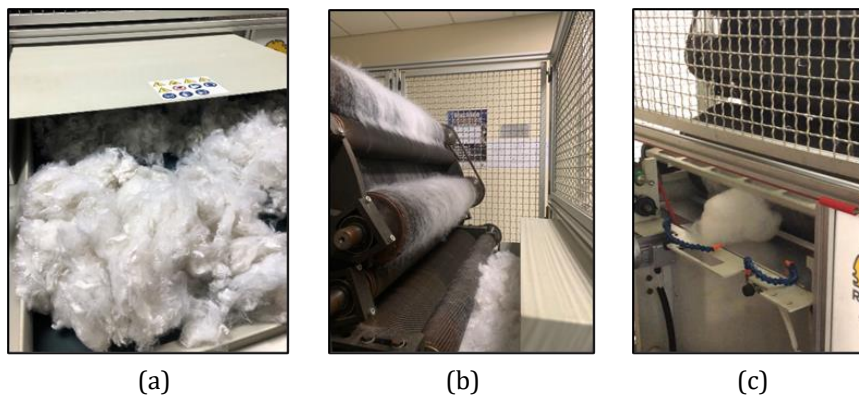
### 2.1 Sample preparation

The materials of the sample consist of 2kg of banana fiber (BF) from the cavendish species, 600g of polyester fiber (PE) with 6 denier of the thickness and SMAR-968 acrylic waterproof coating which were all the materials from the Bambusoideae Technology Sdn. Bhd. UTHM. First, BF and PE were opened using the needle punching nonwoven machine and carding machine respectively. The fiber opening for BF were separated the clumped fiber manually using hand at the conveyor of the opening machine, then the fiber was fed through the chute feeder to ensure a further separation into fine fibers and repeated the process to get the finer of BF. Figure 1 shows the process fiber opening of banana fiber.



**Fig. 1:** The process fiber opening of banana fiber (a) The raw banana fibers at the opening machine; (b) The loosen banana fibers at the chute feeder; (c) The banana fiber after the fiber opening

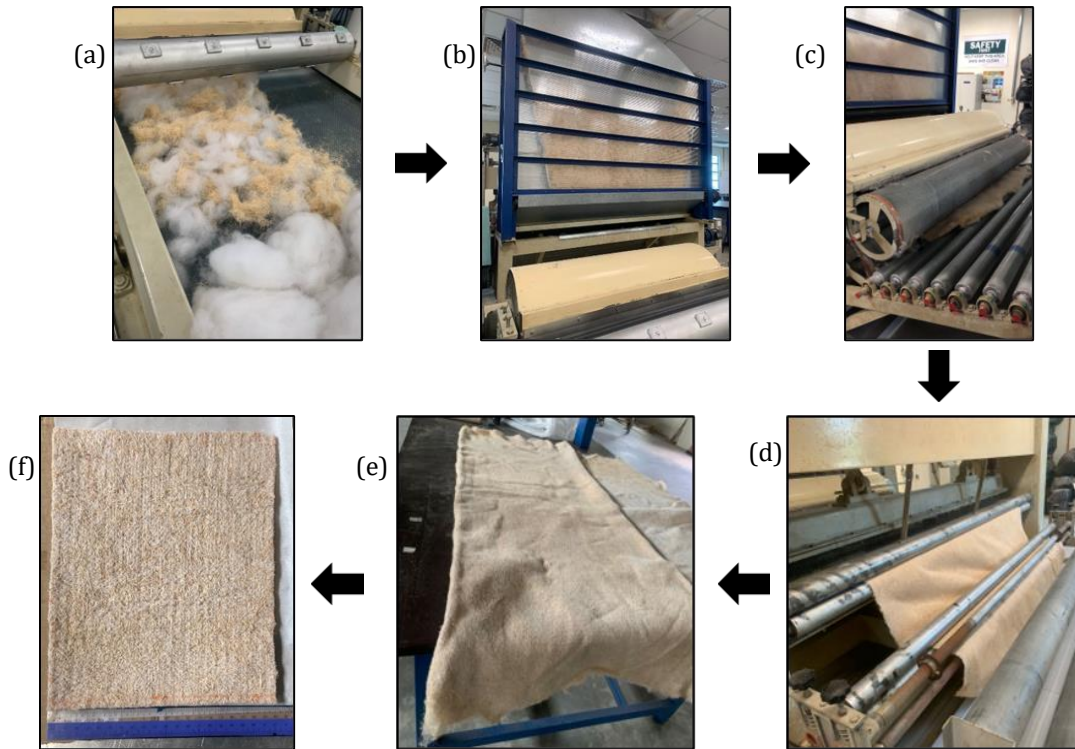
The PE fiber processing involved three phases: feeding, carding, and collection. Raw polyester fibers were opened and prepared in the feeding unit, then combed and aligned by rollers in the carding stage to ensure uniformity and cleanliness. Finally, the processed fibers were transformed into a thin, consistent web in the collection stage, emphasizing the importance of precise machinery in achieving industrial-quality standards. Figure 2 displays the process of opening polyester fiber.



**Fig. 2:** The process fiber opening of polyester fiber (a) Fiber at feeding unit; (b) Carding process; (c) Polyester web collection

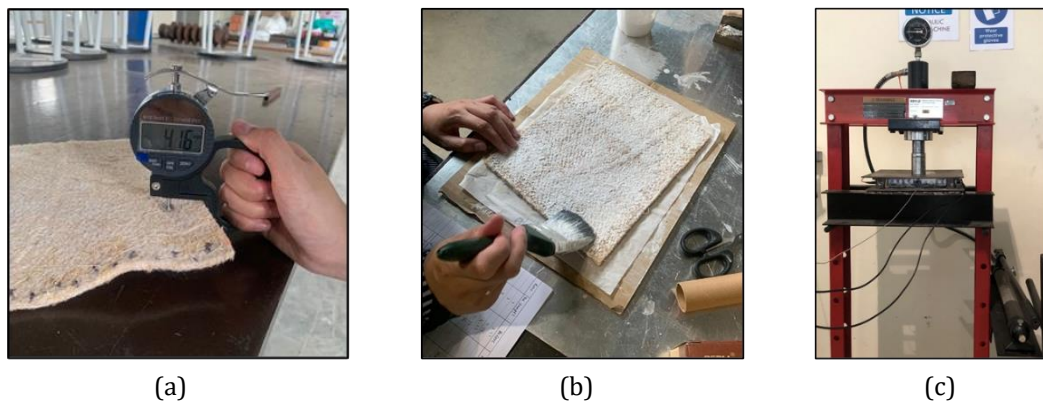
## 2.2 Sample fabrication

The BF-PE nonwoven fabric was produced using a needle-punching process with a 70% banana fiber and 30% polyester fiber blend. The process began with an opening machine that loosened, mixed, and prepared the fibers, followed by a chute feed to ensure even distribution to the carding machine. The carding machine aligned and formed the fibers into a continuous web, which was then needle-punched in two stages. The first stage used barbed needles to mechanically entangle the fibers into a cohesive fabric, and the second stage involved additional needle punching to create a dense, compact structure with enhanced strength and stability. The final nonwoven fabric was cut into 25 cm x 20 cm pieces for use. Figure 3 demonstrates the process of BF-PE nonwoven fabric.



**Fig. 3:** The process of BF-PE nonwoven fabric (a) Fiber opening; (b) Fiber mixing; (c) Carding process; (d) Needle punching process; (e) The BF-PE nonwoven fabric; (f) A 25cm x 20 cm of BF-PE nonwoven fabric

The BF-PE nonwoven fabric samples (25 cm x 20 cm) were coated with SMAR-968, an elastic acrylic waterproof coating, using two ratios: A50W50 terms for 50% acrylic, 50% water and A80W20 stands for 80% acrylic, 20% water. Before coating, fabric thickness was measured for uniformity using thickness gauges from model MITUTOYO. The acrylic mixtures were evenly brushed onto the fabric, with A50W50 ensuring a lighter layer and A80W20 providing a thicker coating for enhanced waterproofing. Each sample was wrapped in baking paper and plastic wrap to prevent sticking, then compressed between clean metal plates using a hydraulic press under specific pressures which were 2 kPa, 4 kPa and 6 kPa on each sample. The samples remained compressed for 48 hours to ensure proper curing. Thickness measurements before and after coating evaluated the effect on sample dimensions, with the process parameters summarized in Table 1 for reference.



**Fig. 4:** (a) Measure the thickness of the fabric; (b) Process of applying the coating with a brush; (c) The sample between two metal plates on the hydraulic press machine

**Table 1:** The process parameter on sample

Ratio	Compression pressure (kPa)
A50W50	2
	4
	6
A80W20	2
	4
	6

The needle-punching process was chosen for fabricating banana-polyester (BF-PE) nonwoven fabric due to its ability to mechanically entangle fibers without adhesives or thermal bonding. This technique enhances fiber interlocking, improving tensile strength, flexibility, and durability. Unlike woven fabrics, needle-punched nonwovens offer a uniform and stable structure, ideal for synthetic leather alternatives [9]. The selection of A50W50 and A80W20 coating ratios was based on their potential to enhance fabric characteristics while ensuring practical application and drying efficiency. The A50W50 ratio enables moderate penetration, which keeps the material flexible and cost-effective, then A80W20 enhances surface durability and water resistance. These selections are consistent with previous studies [5], which explored water-based coatings for hydrophobic enhancement, and focused on the importance of balancing coating efficacy with the integrity of the fabric [6]. Compression pressures of 2 kPa, 4 kPa, and 6 kPa were chosen based on studies that examined their effects on the structure of nonwoven fabrics and the penetration of coatings. Research indicated that compression pressure has a significant impact on the properties of synthetic leather, affecting uniformity, flexibility, and finish [7]. This study applies similar variations in pressure to optimize coating penetration and replicate the characteristics of synthetic leather.

### 2.3 Tensile test

The tensile properties of the acrylic-coated BF-PE synthetic leather samples, including tensile strength and Young's Modulus, were evaluated using a Universal Tensile Testing Machine (UTM) model LR30KPlus AMETEK at UTHM Pagoh, following ASTM D5035 standards. Samples measured 150 mm x 25 mm with a 100 mm gauge length, and a total of 30 samples were tested, with 5 samples per compression pressure for each coating ratio. The UTM operated at 50 mm/min, and samples were carefully aligned and clamped to ensure accurate results. The machine was calibrated, and sample data were input into the system to monitor parameters such as tensile force, stress, strain, and breaking point in real time. The test continued until the samples fractured, and the data collected provided insights into the material's strength, ductility, and stress-handling capabilities, aiding in assessing its suitability for various applications.

### 2.4 Microstructure

The bonding quality between the acrylic coating and the BF-PE nonwoven fabric was analyzed to evaluate performance and durability under varying compression pressures (2 kPa, 4 kPa, and 6 kPa). Microstructural observations were conducted using the Olympus BX53M microscope in the Materials Science Laboratory. Small samples were securely placed on the microscope stage, and the microstructure was brought into view using coarse and fine focus adjustments with the 5x magnification. Light intensity and aperture diaphragm settings were fine-tuned to enhance contrast and brightness, ensuring clear visualization on the connected computer screen for detailed analysis. This process helped assess the impact of compression pressure on adhesion and material properties.

## 3. Results and Discussion

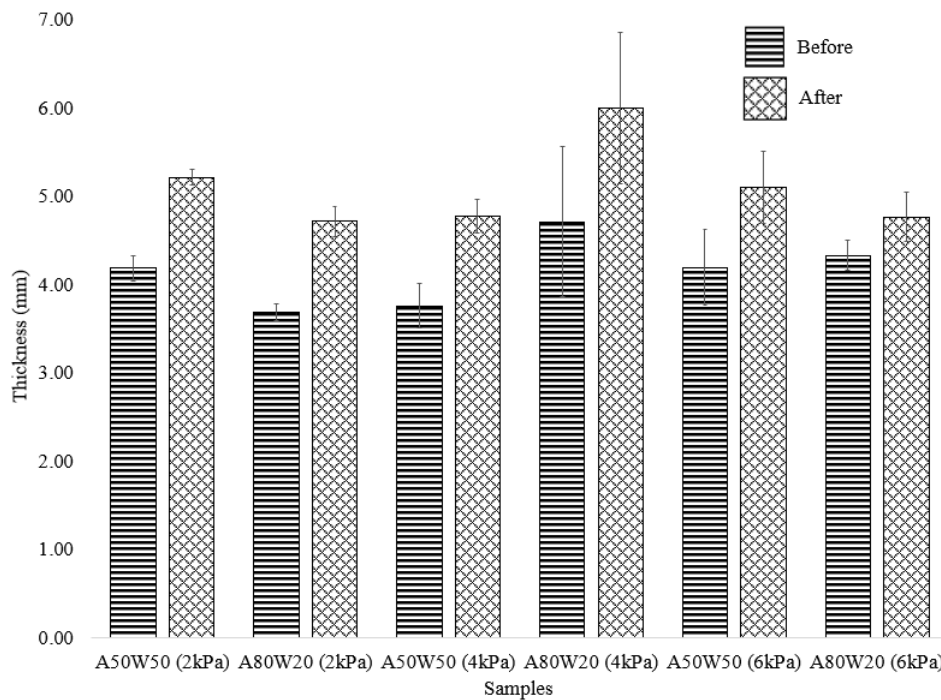
### 3.1 Thickness of the samples

The study analyzed the coating thickness of BF-PE nonwoven fabrics using two acrylic coating ratios, A50W50 and A80W20, at three compression pressures (2 kPa, 4 kPa, and 6 kPa). Results showed that coating thickness increased across all samples post-coating, with variations influenced by coating viscosity, penetration behavior, and compression pressure. A50W50 exhibited consistent thickness changes, while A80W20 showed the greatest thickness increase at 4 kPa but with higher variability, likely due to uneven coating penetration and retention.

This suggests that intermediate pressures may allow more acrylic to remain on the surface, whereas higher pressures promote uniform penetration. However, variability in fabric structure, coating application, and measurement methods may have influenced the results. These findings highlight the importance of optimizing coating ratios and compression pressures to achieve desired thickness and uniformity for specific applications, with potential limitations in controlling coating penetration under varying conditions. Table 2 shows the thickness of the samples and Figure 5 shows the graph of the thickness of samples before and after coating when compression pressure applied.

**Table 2:** The thickness of the samples

Sample code	Compression pressure (kPa)	Before (mm)	After (mm)
A50W50	2	4.19	5.22
	4	3.76	4.78
	6	4.20	5.10
A80W20	2	3.69	4.72
	4	4.71	6.00
	6	4.33	4.77



**Fig. 5:** The graph of the thickness of samples before and after coating when compression pressure applied

### 3.2 Mechanical properties of the samples

Table 3 presented the findings regarding the mechanical properties of acrylic-coated BF-PE synthetic leather samples. This study investigated the tensile strength and Young’s Modulus of the samples (A50W50 and A80W20) under varying compression pressures (2 kPa, 4 kPa, and 6 kPa).

The results indicated that A80W20 performed better at 2 kPa and 6 kPa due to its higher acrylic binder content, which enhanced rigidity and load distribution. These findings aligned with research on waterborne acrylic resins, which highlighted their ability to improve stress distribution and adhesion properties, especially in compositions with higher acrylic content [8]. However, A80W20’s tensile strength decreased significantly at 4 kPa due to limited flexibility and uneven penetration, suggesting that moderate pressure was less effective for this composition.

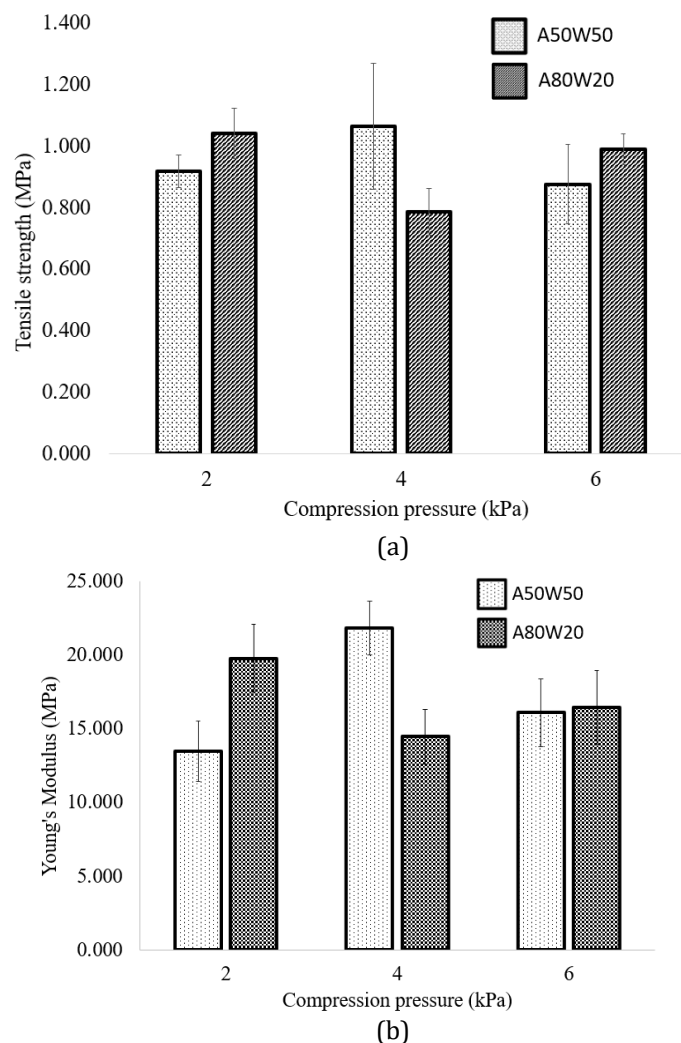
Conversely, A50W50 exhibited its highest tensile strength at 4 kPa, which was attributed to its balanced acrylic-water ratio. This balance facilitated optimal bonding between fibers, enabling enhanced stress distribution and flexibility. This result was consistent with studies on nonwoven composites, which emphasized the role of

moderate pressure in achieving uniform fiber bonding and improved load distribution [9]. Young's Modulus analysis revealed that A50W50 achieved optimal stiffness at 4 kPa but showed increased variability at higher pressures, while A80W20 displayed more consistent but less predictable stiffness changes across all pressures.

These findings highlighted the significant influence of coating ratios and compression pressures on the mechanical properties of the fabric. A50W50 excelled in flexibility and adaptability at medium pressures, while A80W20 performed better in rigidity at lower pressures. Limitations such as variability in coating uniformity, manual application techniques, and fabric inconsistencies may have affected the results. These outcomes underscored the importance of precise manufacturing methods to optimize coating processes and achieve a balance between flexibility and stiffness for specific applications. Applications such as protective gear, which required elasticity, may have benefited from A50W50, while load-bearing materials requiring rigidity may have benefited from A80W20. Figure 6 illustrates the graph of the mechanical properties of the samples.

**Table 3:** The mechanical properties of samples

Sample code	Compression pressure (kPa)	Tensile strength (MPa)	Young's Modulus
A50W50	2	0.917	13.461
	4	1.063	21.817
	6	0.875	16.007
A80W20	2	1.040	19.747
	4	0.786	14.441
	6	0.989	16.443



**Fig. 6:** The graph of the mechanical properties of the samples (a) Tensile strength; (b) Young's Modulus

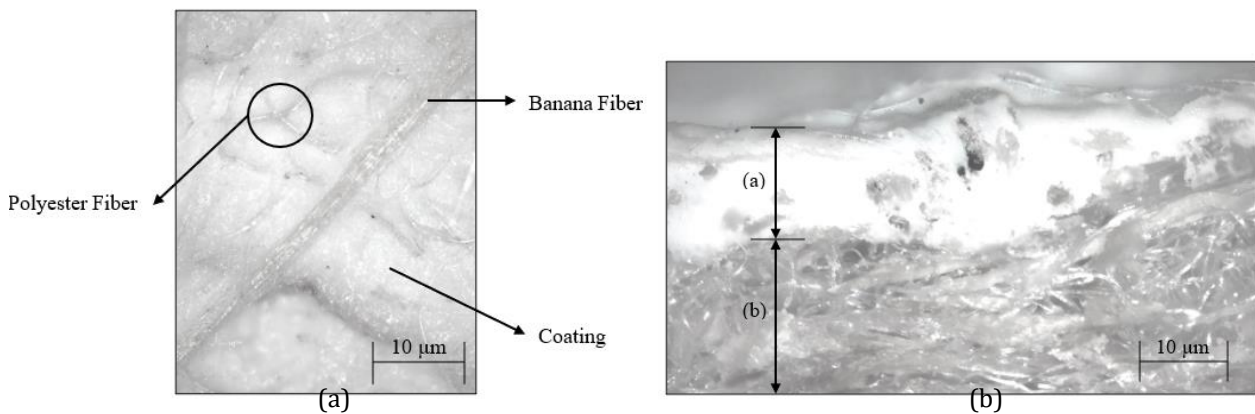
### 3.2 Microstructure of the samples

This study analyzed the microstructure of acrylic-coated BF-PE synthetic leather samples to evaluate their potential as synthetic leather alternatives, focusing on fiber arrangement, coating uniformity, and compression effects. The microstructure revealed distinct characteristics: banana fibers appeared coarse and irregular due to their natural origin, while polyester fibers were thinner and smoother, reflecting their synthetic nature. The acrylic coating formed a protective layer, enhancing durability and water resistance.

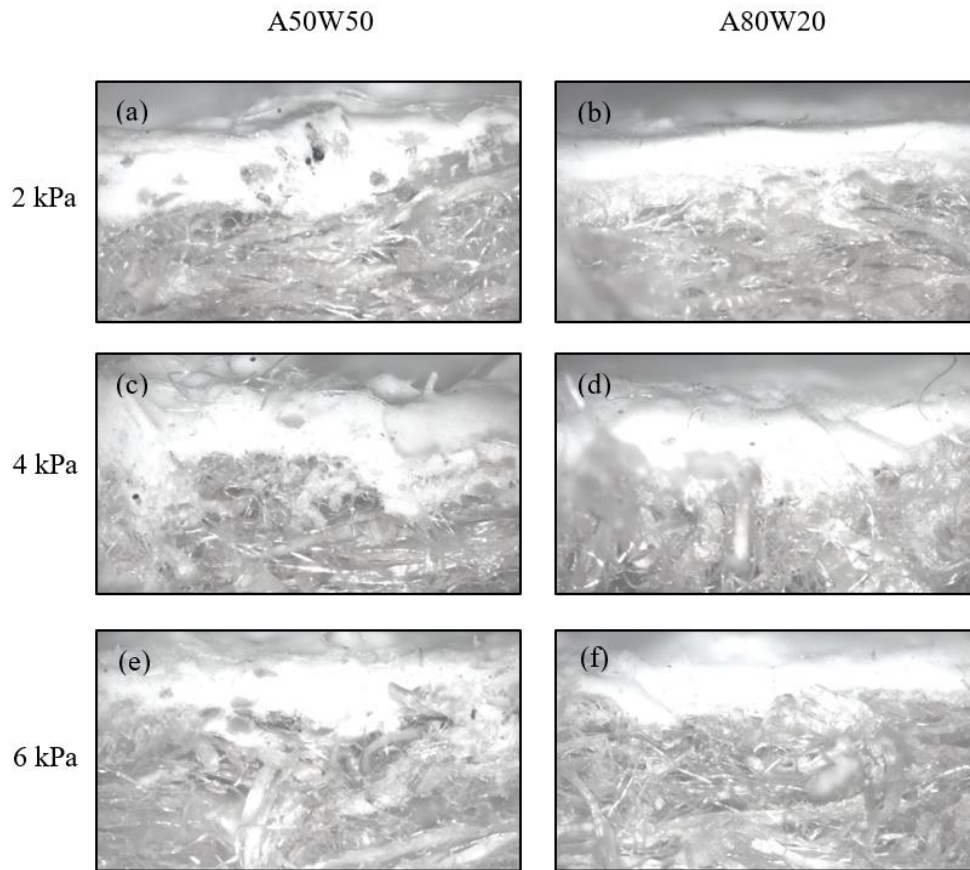
At 2 kPa, A50W50 and A80W20 demonstrated minimal coating penetration, preserving flexibility with moderate tensile strength and stiffness. At 4 kPa, A50W50 achieved optimal structural stability due to improved fiber packing and adhesion, as confirmed by microstructure analysis, which showed uniform coating penetration and fiber bonding. This result aligns with research [10] on coated fabrics which underscores the importance of moderate coating penetration to ensure strong adhesion and uniform fiber bonding. In contrast, at 4 kPa, A80W20 exhibited surface accumulation and reduced cohesion, leading to decreased performance. Excessive penetration, as highlighted in this study, can compromise flexibility, while insufficient penetration reduces adhesion.

At 6 kPa, A80W20 benefited from fiber compaction, which improved bonding and tensile strength but maintained less rigidity. However, excessive compression in A50W50 reduced thickness, tensile strength, and elasticity, indicating diminishing structural integrity under higher pressures. These findings align with insights from *Advances in Coated Fabrics for Civil Engineering* which emphasize the importance of uniform coating layers for durability and stress resistance [11]. Even distribution of coatings enhances mechanical performance, as observed in A50W50 at 4 kPa was confirmed.

Limitations included variations in coating application and fiber uniformity, which impacted consistency and material performance. These findings have significant implications for optimizing fabrication processes, as precise control of compression pressure and coating ratios is essential for tailoring the material's mechanical and structural properties for specific applications, such as flexible fabrics for dynamic uses or rigid materials for load-bearing purposes.



**Fig. 7:** (a) the microstructure the top surface of the sample; (b)(a) The top layer is acrylic coating; (b) The bottom layer is BF-PE nonwoven fabric



**Fig. 8:** The microstructure of A50W50 and A80W20 sample under different compression pressure

#### 4. Conclusion

In conclusion, this study investigated how different ratios of acrylic coating to water and varying compression pressures influence the mechanical characteristics and microstructure of acrylic-coated BF-PE synthetic leather. The results indicated that the combination of A50W50 at a compression pressure of 4 kPa exhibited the highest performance, achieving peak tensile strength (1.063 MPa) and Young's Modulus (21.817 MPa) due to its balanced flexibility and rigidity. Analysis of the microstructure further revealed that increased compression pressures enhanced both surface uniformity and fiber-coating adhesion, resulting in improved wear resistance. From an industrial perspective, these findings highlight the potential of acrylic-coated BF-PE synthetic leather offering durability and mechanical reliability suitable for automotive interiors, upholstery, and fashion applications. The use of water-based acrylic coatings aligns with sustainable manufacturing practices, reducing the reliance on petroleum-based materials and minimizing environmental impact. Additionally, the use of banana fibers derived from agriculture waste to encourage resource efficiency and support industries in areas with high banana production which contributes to a circular economy. By optimizing processing parameters, this study provides valuable insights for scaling up production while maintaining eco-friendly practices. By optimizing processing parameters, this study provides valuable insights for scaling up production while maintaining eco-friendly practices. By optimizing processing parameters, this study provides valuable insights for scaling up production while maintaining eco-friendly practices. The integration of bio-based materials in engineered textiles not only enhances product sustainability but also opens new opportunities for industries seeking greener alternatives without compromising performance.

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#### Conflict of Interest

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

## Author Contribution

Muhammad Farid Shaari helped supervise and consult the project. Syaidatul Qaisha Noor Azmi contributed to sample preparation. Nurathirah Nadiah Mohd Faisal performed the experiments and analysis data, drafted the manuscript with consultation with Muhammad Farid Shaari.

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