Mechanical and Physical Characterization of Chemically Treated Pineapple Leaf Fibre/Polyester Biocomposites

By

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DECLARATION

I declare that this thesis entitled "Mechanical and Physical Characterization of Chemically Treated Pineapple Leaf Fibre/Polyester Bio composites" is the results of my own research except as cited in the references.

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Mechanical And Physical Characterization of Chemically Treated Pineapple Leaf Fibre/Polyester Bio composites.

ABSTRACT

The rising demand for environmentally friendly materials has motivated study into the improvement of natural fibres as reinforcing agents in polymer composites. Hence, pineapple leaf fibres (PALF), derived from agricultural waste, were introduce into polyester polymer to improve their properties. The experiment was conducted to explore mechanical and physical qualities of NaOH treated PALF reinforced unsaturated polyester (UPE) resin bio-composites. A detailed experimental study was conducted by immersing the PALF into various NaOH concentration viz. 0, 2, 4, 6 and 8% for 3-hour soaking time. The PALF-UPE bio composites with 10:90 (w/w) composition ratio were fabricated using compression moulding at 100 ^{0}C. Prior to mechanical and physical characterization, the PALF-UPE bio composites were prepared into appropriate specimen according to ASTM D5083 and D570, respectively. The functional categories of both treated and untreated PALF-UPE bio composites were characterised using Fourier transform infrared spectroscopy (FTIR) suggested that all alkali-treated PALF samples underwent lignin and hemicellulose removal to varying degrees. The tensile properties results show that, 2% of NaOH concentration producing the most optimum tensile strength and modulus at 22.8 and 620 MPa, respectively. It was determined that NaOH-treated PALF-UPE bio composites had greater tensile strength and reduced water absorption than untreated PALF.

Pencirian Mekanikal Dan Fizikal bagi komposit Bio Serat/Poliester Daun Nanas Dirawat Secara Kimia.

ABSTRAK

Permintaan yang semakin meningkat untuk bahan lestari telah mendorong penyelidikan ke dalam peningkatan gentian semula jadi sebagai agen penguat dalam komposit polimer. Oleh itu, gentian daun nanas (PALF), yang berasal daripada sisa pertanian, telah dimasukkan ke dalam polimer poliester untuk memperbaiki sifatnya. Eksperimen telah dijalankan untuk menyiasat sifat mekanikal dan fizikal biokomposit resin poliester tak tepu (UPE) yang dirawat dengan NaOH. Kajian eksperimen terperinci telah dijalankan dengan merendam PALF ke dalam pelbagai kepekatan NaOH iaitu. 0, 2, 4, 6 dan 8% untuk masa rendaman 3 jam. Komposit bio PALF-UPE dengan nisbah komposisi 10:90 (b/b) telah difabrikasi menggunakan pengacuan mampatan pada 100 ^{0}C. Sebelum pencirian mekanikal dan fizikal, komposit bio PALF-UPE telah disediakan ke dalam spesimen yang sesuai mengikut ASTM D5083 dan D570, masing-masing. Kumpulan berfungsi kedua-dua komposit bio PALF-UPE yang dirawat dan tidak dirawat telah dicirikan menggunakan spektroskopi inframerah transformasi Fourier (FTIR) mencadangkan bahawa semua sampel PALF yang dirawat alkali menjalani penyingkiran lignin dan hemiselulosa pada tahap yang berbeza-beza. . Keputusan sifat tegangan menunjukkan bahawa, 2% kepekatan NaOH menghasilkan kekuatan tegangan dan modulus yang paling optimum pada 22.8 dan 620 MPa, masing-masing. Telah ditentukan bahawa komposit bio PALF-UPE yang dirawat NaOH mempunyai kekuatan tegangan yang lebih besar dan mengurangkan penyerapan air daripada PALF yang tidak dirawat.

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LIST OF ABBREVIATIONS

NaOH	Sodium Hydroxide
UPR	Unsaturated Polyester Resin
FTIR	Fourier Transform Infrared Spectroscopy
PLF	Pineapple Leaf Fibre
PMC	Polymer Matrix Composite
TS	Thickness Swelling

LIST OF SYMBOLS

%	Percentage
h	Hours
MPa	Megapascal
GPa	Gigapascal
Wt%	Percentage of weight
g	gram
°C	degree Celsius

CHAPTER 1

INTRODUCTION.

1.1 Background of Study.

A bio composite is a composite material created by mixing two or more distinct materials where at least one component is derived from renewable biological sources. The matrix for bio composites is often made from biobased or fossil-fuel resources, additionally to natural fibres like the flax plant, hemp fibre, bamboo, or a coir and kenaf, which are commonly used as reinforced components. The biopolymer matrix derived from a resource that can be produced again, such as maize starch or soy protein, and serves as the binding agent for the natural fibres. (Radoor et al., 2020). Because they are manufactured from materials that can be recycled and are reusable, bio-composites are environmentally benign and sustainable. Bio-composites have several of benefits over conventional materials, including better thermal and acoustic insulation, sustainability, lightweight, strength, and adaptability (Akter et al., 2022). Although there are some possible drawbacks to employing bio-composites, their environmental advantages and sustainability make them a desirable option for a variety of applications.

Natural fibres are adaptable and environmentally friendly materials that come from minerals, plants, or animals. These materials, including cotton, hemp, jute, silk, wool, and linen, have been employed for many purposes over the years. They have their unique features such as biodegradable properties nontoxicity, recycling, and light. Nguyen and Nguyen (2022) Natural fibres are more energy and carbon efficient than synthetic equivalents, making them more environmentally friendly. They also offer comfort and durability and are hypoallergenic. Natural fibres are still prized for their environmental friendliness, aesthetic appeal, and connection to nature, whether they are used in fashion, home textiles, or industrial applications. Their continued appeal serves as evidence of the materials' classic beauty and usefulness.

The term "pineapple leaf fibre" describes the organic plant fibres made from the leaves of pineapple plants, also referred to as Ananas comosus in science (Asim et al., 2015). The pineapple plant's long, narrow leaves, which are generally abandoned after the fruit is picked, are used to extract these fibres. These leaves can be treated to remove the fibrous material rather of being thrown away. The fibres are extracted by severing them from the stalk or central vein of the leaf. The non-fibrous parts of the leaves are stripped off either manually or mechanically to obtain the fibres. The resulting fibres are then washed, dried, and put through additional processing for a variety of uses.

Because of its outstanding durability, chemical resistance, and adhesive qualities, polymer resin is a versatile substance widely employed throughout industries (Takeichi and Furukawa, 2012). Because of its moldability, it can be formed into a variety of shapes, making it important in manufacturing and product development processes. Next, a thermoset resin is a form of polymer that cures by undergoing a chemical reaction, resulting in a stiff and irreversible solid state. It cannot be remelted or reformed, unlike thermoplastics. Thermoset resins are suitable for composites, adhesives, coatings, and electrical insulators due to their great strength in mechanics, heat resistance, and chemical stability. Among many commercially available resins, unsaturated polyesters show an excellent category because of their exceptional mechanical qualities and corrosion resistance. (Bartoli et al., 2019).

The application for specific chemical substances to affect the qualities, composition, or behaviour of a material or substance is referred to as chemical therapy. It is common in many industries, including manufacturing, water treatment, and agriculture. Chemical treatments include a variety of operations such as cleaning, surface modification, corrosion prevention, preservation, and material performance enhancement (Bledzki et al., 2008). These treatments frequently entail the use of chemicals such as acids, solvents, coatings, inhibitors, or additives, and are performed to achieve desired effects or improvements in the targeted material or system. A popular chemical treatment for fibre reinforced polymer bio composites is sodium hydroxide (NaOH), a strong alkaline material. In the case of pineapple leaves treatment, NaOH is employed in a retting process to remove unwanted substance for fibre or textile manufacture. NaOH degrades non-cellulosic components, allowing long, strong fibres to be extracted from the leaves.

In this study, hand lay-up and compression moulding processes were employed to make pineapple leaf fibre (PLF). reinforced unsaturated polyester resin (UPR). A multifaceted strategy is needed to get around limitations in the physical and mechanical properties of such bio composites so one of the solutions is by application of chemical treatment such as NaOH. The primary goal of this research is to evaluate the impact of NaOH chemical treatment on the physical and mechanical properties of PLF reinforcement UPR bio-composites.

1.2 Problem Statement.

The pursuit for environmentally acceptable and sustainable materials has led to the research of natural fibres as reinforce in polymer composites. Pineapple leaf fibre (PLF) have demonstrated amazing ability among these fibres due to its renewable and biodegradable nature. PLF can form bio-composites with increased mechanical and physical qualities when coupled with unsaturated polyester (UPR), a frequently used polymer matrix. However, the full potential of PLF/UPR bio-composites has not yet been realised, and improvements to their characteristics are required for greater commercial viability. (Rowell, 1998). Natural fibre integration in polymer matrices is a well-established practise for producing composite materials with higher strength, stiffness, and lower environmental impact than typical synthetic composites. Pineapple leaves are a substantial and largely underutilised byproduct of the pineapple industry, making them an appealing target for fibre extraction and subsequent composite manufacturing. Unsaturated polyester (UPR) resins are widely utilised in a variety of sectors due to their superior mechanical qualities, corrosion resistance, and cost-effectiveness. (Rowell, 1998) Despite the inherent benefits of PLF/UPR bio-composites, numerous obstacles prevent their widespread use. Unmodified PLF has poor adhesion to the UPR matrix, resulting in weak interfacial bonding and a reduction in the composite's overall mechanical performance. Furthermore, the hydrophilic characteristic of PLF might cause moisture absorption, leading in dimensional instability and mechanical property loss over time. (Asim et al., 2015). The main objective of this research is to produce Pineapple Leaf Fibre (PLF) reinforced Unsaturated Polyester (UPR) bio-composites and investigate the impact of sodium hydroxide (NaOH) chemical treatment on their mechanical and physical properties. The suggested study attempts to overcome the current constraints and improve the overall performance of the bio-composites.

To achieve stated goal, the research will take a systematic approach. PLF will first be isolated from pineapple leaves using an appropriate mechanical extraction process. To make composite specimens, the UPR resin will be manufactured, and varied weight fractions of PLF will be disseminated in the UPR matrix. A selection of these specimens will be chemically treated with NaOH to change the fibre surface. (Kalia & Kaith, 2011). The produced PLF/UPR bio-composites, as well as NaOH-treated variations, will go through a variety of mechanical tests, including tensile, flexural, and impact testing. The data will be compared to see whether the chemical treatment improved mechanical qualities. Alam et al. (2015) Furthermore, physical parameters such as moisture absorption and dimensional stability will be assessed to comprehend the effect of NaOH treatment on these features.

This study aims to prepare for the creation of outstanding durability, environmentally friendly materials that can replace traditional synthetic composites in a range of applications, decreasing the environment's imprint and encouraging a circular economy exploring the environmental effects of NaOH chemical treatment on the mechanical and physical properties of PLF/UPR bio-composites. (Duc et al., 2014)

1.4 Objectives.

1) To investigate the physical characteristics, specifically water absorption and thickness swelling, chemically treated pineapple leaf fibre/polyester bio composites compared to untreated counterparts.

2) To assess the effect of chemical treatment on the mechanical properties of pineapple leaf fibre/polyester bio composites by measuring tensile strength.

1.5 Scope of study

Bio composite based PLF/UPR will expand its exploration. Using pineapple leaf fibres (PLF) as bio composite materials helps reduce PLF waste in a variety of ways. It eliminates the demand for landfill space and reduces environmental contamination by converting trash into profitable products. The use of NaOH chemical treatment can help to solve the problem of weakening the connections between fibre and matrix of polymers phases. NaOH treatment eliminates non-cellulosic components from the fibre surface, improving its compatibility with the polymer matrix. This treatment improves interfacial adhesion, allowing for efficient stress transfer and enhancing the composite material's mechanical qualities.

1.6 Significant of study

The researchers wanted to make bio composites out of pineapple leaf fibre (PLF) and unsaturated polyester (UPR) and see how NaOH chemical treatment affected their mechanical and physical qualities. The study aimed to determine how the treatment influenced the performance and properties of PLF/UPR bio composites. Because of its qualities, pineapple leaf fibre (PLF) has great potential. It is abundant, renewable, and biodegradable, making it a sustainable material. PLF has a high mechanical strength, low density, and good thermal characteristics, making it appropriate for bio composites, textiles, packaging, and paper manufacture. Furthermore, PLF can be used as a value-added by-product of pineapple cultivation, helping to promote sustainable agriculture and waste management practises.

CHAPTER 2

LITERATURE REVIEW

2.1 Polymer matrix composite (PMC)

Polymer matrix composite (PMC) is a widely recognised composite material with appealing characteristics like a relatively low density, outstanding stiffness, high breaking strength, and robust corrosion and chemical resistance. (Refaai et al., 2022). Generally, as matrices for polymer composites, thermoset polymers have (Epoxy resins, polyester resins, vinyl esters, bismaleimide, and polyamides) and thermoplastic (polyesters, polypropylene, polyphenylene sulphide (PPS), polyether ether ketone (PEEK), and liquid crystal polymers) are employed. (Radoor et al., 2020). Because of their remarkable features like high tensile strength, high modulus also, a relatively low percentage of expansion during heating, and chemical inertness, fibre reinforcements are often utilised to enhance the efficiency of PMC. (Radoor et al., 2020). However, because synthetic fibre is expensive and non-biodegradable, researchers are looking for an alternate material. As a result, there has been an increasing tendency in recent years of replacing natural fibre for traditional synthetic fibres to reinforce the matrix of polymers since it reduces environmental challenges and the depletion of fossil resources. Composites have applications in a wide range of industries, from automobiles to more complicated fields such as aerospace and electronics. Radoor et al. (2020).

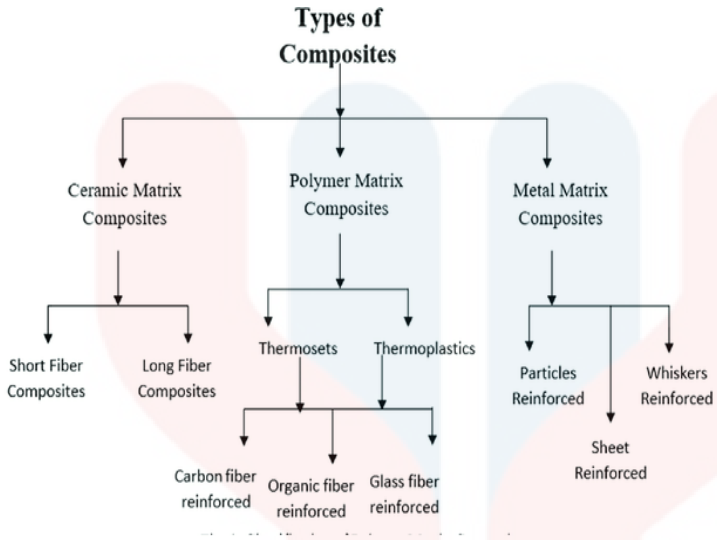

Figure 2.1: Classification of Polymer Matrix Composites. Radoor et al. (2020)

2.1.1 Bio-composite

An appealing possibility could be the use of construction materials consisting of renewable resources, such as natural fibres incorporated in biopolymers (so-called bio composites) and involving economically and environmentally acceptable manufacturing procedures (U. Riedel et al., 2012). Bio-composites made with local and sustainable resources are extremely sustainable; manufacturing ecology, environmental effectiveness, and ecologic chemistry are driving the development of innovative materials, products, and processes. Bio composites have seen substantial growth in the household sector, building supplies, aerospace manufacturing, electronic devices, and vehicles has occurred during the last decade, although use in other industries remains minimal.

2.2 Matrix for Bio composites

2.2.1 Introduction

Generally, matrix can be divided into thermoplastic and thermosets. Thermoplastics have advantages like reuse, yet thermosets provide the toughness needed for other applications. (Duc et al., 2014). Thermosetting plastics and thermoplastics are both polymer matrix used in wide ranges of applications. However, when they are exposed to heat, their behaviour changes. After curing, thermoplastics may dissolve when exposed to heat, whereas thermoset plastics maintain their shape and remain solid when exposed to heat. Thermoset is a form of polymer that, once cured or hardened, cannot be remelted, or reshaped using heat. It is the opposite of a thermoplastic, which can be melted and reformed multiple times without undergoing any significant chemical change. Crosslinking, a chemical process that involves the production of covalent links between polymer chains, is used to create thermosetting polymers. This crosslinking is responsible for thermosets' distinct features, which include great strength, rigidity, and durability to temperatures, chemicals, and conductivity to electricity. (Dhinakaran et al., 2020)

2.2.2 Thermoset

Thermoset resins are excellent for composites, adhesives, coatings, and electrical insulators due to their great strength in mechanics, thermal resistance, and chemical resistance. Sun Longfeng et al. (2020). Once a thermoset material is molded or cured, it undergoes a chemical reaction that irreversibly transforms it into a solid, three-dimensional structure. This process is often facilitated by the addition of a curing agent or a combination of heat and pressure. The resulting material retains its shape and cannot be melted or reshaped by heating, making it suitable for applications that require stability and durability. Common examples of thermoset materials include epoxy resins, phenolic resins, melamine formaldehyde, polyurethane, and unsaturated polyester resin (UPR). Among several commercially available resins, UPR stands out due to its superior their great strength in mechanics and resistance to corrosion, as well as its reduced cost. (Duc et al., 2014) It is suitable for many uses due to its great heat resistance and dimensional stability. The resulting thermoset possesses high transparency, good toughness, and the potential for self-healing. (Sun Longfeng et al.,2020)

2.2.3 Unsaturated Polyester Resin

Unsaturated Polyester Resin (UPR) surpasses other biodegradable polymers due to a variety of inherent benefits. For starters, its outstanding longevity, as seen by its great strength and stiffness, distinguishes it in applications that require long-term structural integrity. (Islam et al., 2019). UPR's adaptability allows for easy adaptation to fulfil unique requirements across several industries, increasing its usefulness. Furthermore, UPR is more resistant to environmental stressors such as moisture, UV light, and temperature variations than many biodegradable options. This robustness provides long-term performance under difficult situations, extending its lifespan. Furthermore, UPR's cost-effectiveness makes it economically viable for enterprises seeking dependable yet affordable solutions, which contributes to its widespread use. Its interoperability with traditional processing techniques like moulding and casting simplifies manufacturing operations and increases productivity. Despite lacking inherent biodegradability, UPR's durability, adaptability, resilience to environmental variables, cost-effectiveness, and ease of processing makes it preferred in applications that value lifespan and performance. (Islam et al., 2019). In contrast to biodegradable materials, which can decay quickly in certain situations, UPR provides long-lasting performance without sacrificing quality or functionality. This makes it ideal for applications where biodegradability is not a top priority, such as automobile components, construction materials, and marine constructions. (Islam et al., 2019). The flexibility to customise UPR formulations to individual performance needs emphasises its appropriateness for a wide range of applications, bolstering its advantage over other biodegradable alternatives. Overall, UPR stands out as a dependable, cost-effective, and adaptable material that provides unrivalled benefits in a wide range of industrial applications. the choice of thermoset material for a particular application depends on a careful evaluation of the required properties, compatibility with the environment and chemicals involved, processing requirements, cost considerations, and availability of materials. (Islam et al., 2019). While UPR may be suitable for some applications involving sodium hydroxide characterization, other thermoset materials could also be considered based on specific needs and preferences.

2.3 Natural Fibre for Bio composites

2.3.1 Introduction

Natural fibres are increasingly being used as reinforcing components in petroleum, thermoplastics, and thermosets. In terms of cost, density, acceptable properties, ease of separation, improved energy recovery, and biodegradability, these natural fibres outperform traditional reinforcing fibres such as fibreglass and carbon. They also reduce processing machine wear and health concerns. (Cheung et al., 2009). Natural fibres appear to be the most outstanding components at the forefront of material research, offering as a viable and abundant replacement for the costly and not renewable synthetic fibre. The classification of natural fibre shown in Figure: 2.2

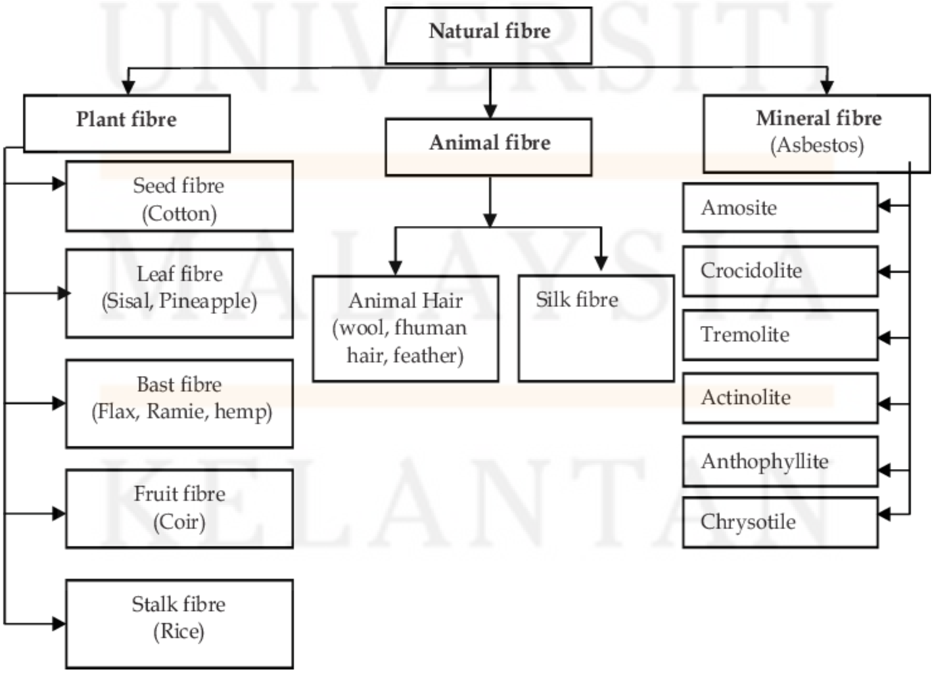

Figure 2.2: Classification of natural fibre

Figure 2.2 displays the varieties of reinforcing natural fibres that are employed today. Numerous studies have been conducted on natural fibre reinforced composites such as kenaf fibre, oil palm fibre, vegetable fibre, coconut fibre, and pineapple leaf fibre.

Figure 2.3: The types of reinforcing natural fibres. (Nurazzi et al.,2021)

2.3.2 Pineapple Leaf Fibre

Plant fibres are appealing because they are abundant and have features like as biodegradability and low density that aid in the creation of high specific strength composite structures. According to the literature, pineapple (Ananas comosus) (PLF), which are classified as waste from agriculture, have shown potential for polymers reinforcement. (Gaba et al., 2021). PLF has played a key part in most plastic fibres and forcing because it is affordable, has superior properties to other natural fibres, and supports agricultural-based industries. PLF is a multicellular and lignocellulose material recovered from the leaves of the Bromeliaceae plant Ananas cosomus through. PLF has a ribbon-like structure and is bonded together by lignin and pentosan-like chemicals, which increase the fibre's strength. (Kengkhetkit & Amornsakchai, 2012). According to Gaba et al. (2021), PLF consists of around 80 percent cellulose, between

6 and 12 percent hemicellulose, and 5 to 12 percent lignin. The most abundant component of PLF is cellulose, which comes in two forms: crystalline and amorphous. The amorphous phase is composed of randomly distributed cellulose and hemicellulose, both have a negligible effect on the fibre's structural and mechanical stiffness. As a result, multiple studies have shown that removing the amorphous phase via hydrolysis results in more organised crystalline areas, with the goal of increasing fibre stiffness. PLF, according to multiple researchers, has enhanced the properties of several composites. The next sections will go through of the most important mechanical qualities, such as tensile, flexural, and impact properties.

2.4 Chemical Treatment.

2.4.1 Introduction

The extraction technique, plant growing location, environment, plant age, and plant character all have an impact on the structure and chemical components of biofibre. The primary disadvantages of natural fibre are its low mechanical strength, poor dimension stability, and significant moisture absorption, high swelling, incompatibility with the hydrophobic polymer matrix, and low temperature resistance. These limits can be alleviated through a variety of chemical and physical treatments. Researchers frequently use acetylation and benzoylation treatment procedures to change natural fibres. In the acetylation treatment method, a less polar acetyl group (C6H5CO) is applied at the surface of natural fibre, while during the benzoylation treatment procedure, a benzoyl group (C6H5CO) is introduced. Benzoyl (C6H5C=0) in benzoyl chloride reduces the hydrophilic character of the treated fibre, it enhances interfacial adhesion and thermal stability. (Bledzki et al., 2008). Chemical treatments are typically employed to decrease the hydrophilic nature of the fibre. However, Surface treatments influence not just the fibre's surface but also its strength, resulting in better fibre-matrix adhesion. (Aravindh et al., 2022). It removes non-cellulose elements from fibres such as cellulose, waxy substance, and oily substances, promotes ionisation of cellulose hydroxyl molecules to alkoxide, and reduces hydroxyl group content on fibre surfaces. The impact of chemical treatments on the characteristics of PLF and PLF-reinforced composite polymers is investigated, and numerous chemical treatments and their roles are detailed. Alkaline therapy (NaOH) is the most used chemical treatment due to its effectiveness and inexpensive cost. (Siakeng et al., 2020)

2.4.2 Sodium hydroxide

The more common chemical method for modifying the surface of natural fibres is an alkaline treatment using sodium hydroxide (NaOH) (Kalia & Kaith, 2011). Alkali treatment with NaOH can improve the bonding and characteristics of natural fibres by removing pectin, lignin, and hemicellulose and roughening the fibre surface. For henequen fibre, alkali treatment with NaOH increased mechanical interlocking as well as interaction between fibre and matrix. Furthermore, one of treating natural fibre with an alkaline (NaOH) solution is one of the chemical treatments that may enhance the mechanical properties of natural fibre reinforced polymer composites. The use of NaOH can result in a reduction in spiral angle and a rise in cellulose chain molecular orientation. Alkali treatments often provide a rougher fibre topography, which might improve fibre matrix adherence in a composite by offering additional mechanical interlocking sites. Because it is the most cost-effective approach for treating natural fibre, alkali (NaOH) is the most employed method. This study's chemical treatment (NaOH) The goal of this study was to improve the mechanical characteristics of short pineapple leaf fibre (PLF).

2.4.3 Extraction and Alkali Treatment of PLF

Alkali treatment of cellulosic fibres, commonly known as mercerization, is a common process employed by some researchers to produce high-quality fibres to strengthen polymer matrix. Alkaline treatment improves the external roughness of the fibres, eliminates the lignin waxy substance, and oils from the cell walls of the fibres, and disturbs hydrogen bonding in the network structure. (Li et al., 2007). Pineapple leaf fibres' quality and properties are greatly influenced by the extraction and processing technique used to obtain them. Fibre length, cleanliness, and strength are impacted by factors like the decortication procedure, cleaning procedures, and drying processes. Techniques for extraction and processing must be effective and controlled if high-quality fibres with desired qualities will be generated. The number of fibres from pineapple leaves that are included into composite materials or goods impacts how they perform. In general, more fibre improves strength and stiffness, but it can also affect cost and processability. Depending on the application and the required balance between performance and pragmatic concerns, different fibre contents are optimum.

2.4.4 Retting of Pineapple Leaves

Little bundles of scraped pineapple leaves are immersed in a water tank during the retting process. Materials in the water tank are checked with a finger on a regular basis to confirm that the fibre has been loosened and that it can extract several chemical elements such as pentosans, cellulose, fats and waxy substance, ash content, waste nitrogen, and gelatine. The fibres are mechanically separated after the retting process by washing in pond water. Extracted fibres are air dried while hanging. Not only are the techniques simple, but they also create more fibre with less fibre than previous methods. Wet ball milling is the slower of the two mechanical grinding procedures studied, but it produces PLF with more elementary fibres. Asim et al. (2015)

2.5 The Effect of Different Chemical Treatments on PLF on Bio Composites

The mechanical characteristics of hemp fibre-reinforced composite manufacturing were investigated by Kobayashi et al (2014) and the hemp fibre has been chemically processed to promote solubility between fibre and matrix. Climate/natural/environmental changes influenced the mechanical and physical characteristics of natural and synthetic fibres, according to the researchers. As a result, chemicals such as acetyl, an alkaline substance and siloxane were used to treat the surface of the hemp fibre. Alam et al. (2015) The tensile strength of new composites constructed from untreated kenaf, treated kenaf, sisal fibre, and a rope made from jute was investigated. They discovered that kenaf and jute fibre have higher tensile strengths than jute rope. Similarly, treated fibre had stronger water absorption properties than untreated fibre.

Bledzki et al. (2008) found that acetylated treated flax fibre had great tensile, flexural, and thermal stability. FT-IR spectroscopy showed the chemical interaction between the cross-linker and the cellulose functional group. Experiment results show that CNT coated cellulose fibre has better functionality and thermal stability. The stress transmission capacity of the fibre improves because of micro void exclusion, and the surface of the fibre becomes more uniform. They discovered that the kenaf and jute fibres outperform jute rope in terms of strength at tensile stress. Similarly, treated fibre had more water absorption than untreated fibre. Furthermore, the PLF were alkali treated using different NaOH concentrations.

Bio composites were made using alkali treated and untreated PLF reinforced with a polypropylene (PP) matrix. PLF/PP bio composites' tensile properties and water absorption were investigated. (S. Gnanasekaran et al., 2021). The thermal stability of a bio composite comprising 8% alkali treated PLF is high, with a maximum breakdown temperature of 270 °C, representing a 7.17% improvement over untreated PLF. This bio composite also displayed increased tensile strength (116 MPa), representing a 43% improvement over the untreated PLF/PP (66 MPa) bio composite, as well as lower water absorption (6% versus 21% for the untreated bio composite). As a result, by reducing the lignin and hemicellulose content, alkali treated PLF can improve its characteristics and increase its compatibility with fibre and polymer. S. Gnanasekaran et al (2021).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

Sodium hydroxide (NaOH), Agropark UMK Jeli provided pineapple leaves harvested from the pineapple plant. The raw pineapple leaf (PLF) taken from Agropark UMK Jeli was manually separated from the leaves, rinsed with distilled water, and dried in an oven at 80°C for 24 hours.

3.2 Methods.

3.3 Sample Preparation

Cutting, sifting, internal mixing, compression moulding, and machining procedures were used to create varied fibre compositions. Using the traditional method of water retting. Matured pineapple plant leaves were steeped in water for four weeks to soften them and allow for easy fibre isolation. This approach encouraged microorganisms such as fungus and bacteria to breakdown the hemicellulose cement matrix, freeing the fibre bundle and improving fibre separation. The isolated fibres were deionized water washed and air-dried. (Gaba et al., 2021)

Figure 3.1: Sample preparation fibre

3.5 Pineapple Leaf Fibre Treatment

The pineapple leaf fibres were treated in a NaOH solution at ambient temperature (27-29°C) with concentrations ranging from 2%, 4%, 6%, and 8%. Each set of pineapple leaf fibres was treated for 3 hours. Following that, the treated fibres were thoroughly rinsed with water to remove any residual NaOH that had adhered to the fibres. The fibres were then dried using hot air after a final washing cycle with distilled water. Finally, the fibres were precisely cut into lengths of 140 mm, ready for the composite moulding process. This methodology assures that the chemical treatment and processing of pineapple leaf fibres follow the same protocols as coir fibres, allowing for comparative examination in research or application contexts.

3.5 Fabrication of Composite Specimens

Produced with a mould was used to make the material that was composite size 300 mm×300 mm×3 mm. Hand layup was used for moulding, which is the most basic method of composite production. The mould was placed under atmospheric conditions to prepare for the fabrication of a composite material. Wax was applied to the bottom and upper surfaces of the walls and mould and left to cure. The wax was applied to the mould to facilitate removal and to create a good surface finish for the plates. Slim plastic sheets were used at the bottom and top surface of the cast laminate to obtain a fine and homogenous surface finished product. The temperature. The material is heated to 100 degrees Celsius for 5 minutes in the hot press machine, followed by a 5-minute cooling period.

3.6 Fibre Characterization Techniques

3.6.1 Fourier Transform Infrared Spectroscopy (FTIR)

Fourier Transform Infrared Spectroscopy (FTIR) is a technique for analysing and identifying chemical substances based on their infrared absorption spectra. Its was used to analyse the absorbance, chemical chain present, functional group, and peaks. FTIR spectra was recorded in range of 4000-400 cm-1 in absorbance mode. FTIR analysis at varying NaOH concentrations (0%, 2%, 4%, 6%, 8%). The sample was repeated for each NaOH concentration.

3.7 Mechanical properties

3.7.1 Tensile Test

Tensile strength was determined using an ASTM-C1557 universal tensile test machine and the ASTM-C1557 technique. The objective is to evaluate essential mechanical parameters such as the yield strength, the final tensile strength, and elongation. Tensile tests measure a material’s capacity to endure stretching forces and provide useful information for engineering and production applications. Tensile tests were carried out with the aid of a computerised universal testing machine. The crosshead moved at a rate of 5 mm/min. Tensile strength was given in MPa.

3.8 Physical Properties

3.8.1 Water Absorption

One of the most significant physical tests is water absorption. The ASTM570 procedure was employed to assess the composite's water absorption. To test the absorption capacity of the specimen composite, a sample was created with distilled water as a medium. The percentage of water absorption was calculated by subtracting the final and starting weights before and after 24 hours in the water bath. Tests were repeated until the ratio of water absorptive achieved stability by Ayalew and Wodag (2022). The calculation based on equation:

$$\text{Water absorption (\%)} = \frac{W_1 - W_o}{W_o} \times 100\%$$

Wo = The weight of sample before submersion in distilled water

W1 = The weight of sample after submersion in distilled water

Equation 3.1: Calculation of water absorption.

Figure 3.2: Samples of bio composites during water absorption test.

3.8.2 Thickness swelling

The water soak technique thickness swelling (TS) (American Society for Testing and Materials 1994) is used to evaluate the dimensional stability of wood composites panel materials. Radzi et al. (2019) Thickness swelling is the rise in thickness of a material, often wood-based panels, when exposed to moisture. It happens when a substance absorbs water, causing individual fibres or particles to swell and expand in thickness. The swelling properties' thickness was determined using the water immersion time test. Increasing the SPF content reduced the water absorption and swelling thickness of the RF/SPF hybrid composites. (Radzi et al., 2019). The calculation based on equation:

$$\text{Thickness swelling (\%)} = \frac{t_1 - t_o}{t_o} \times 100\%$$

t_o = The thickness of sample before submersion in distilled water

t_1 = The thickness of sample after submersion in distilled water

Equation 3.2: Calculation of thickness swelling

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Mechanical Properties

The mechanical characterisation of chemically treated pineapple leaf fibre/polyester bio composites was examined using a tensile test. Figures 4.1-4.3 show the results of tensile tests for tensile strength, tensile modulus, and elongation break.

4.1.1 Tensile Strength

Figure 4.1 show the data on tensile strength of pineapple leaf fibre-UPE bio-composites treated with various concentrations of NaOH (sodium hydroxide) provides crucial insights into the influence of chemical treatment on the material's mechanical performance. Tensile strength is a fundamental parameter representing the maximum stress a material can withstand before breaking, making it a critical factor for applications where structural integrity is paramount.

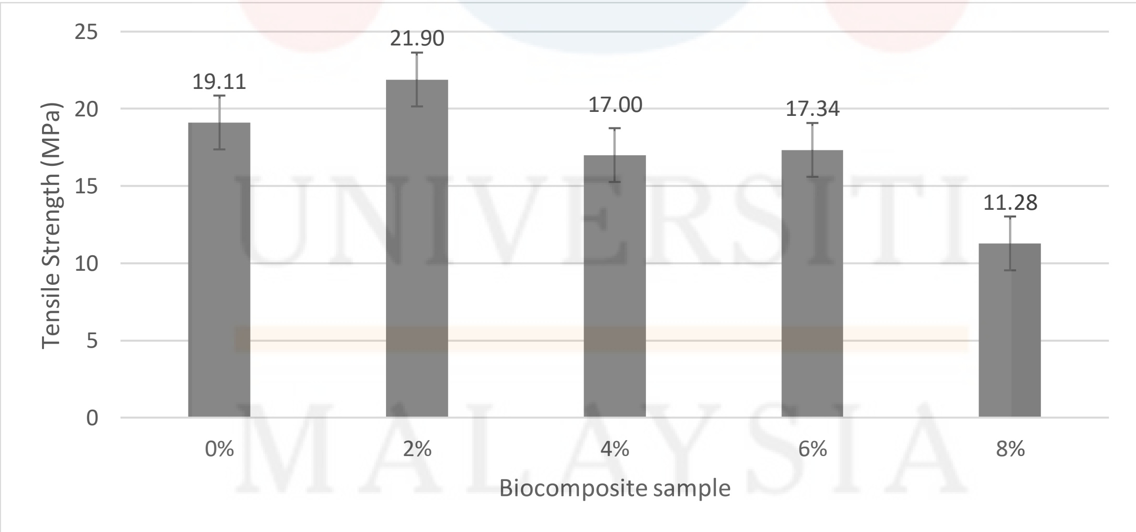

Figure 4.1: Tensile strength of untreated and treated pineapple leaf fibre-UPE bio-composites.

The untreated samples, characterized by 0% NaOH concentration, exhibit a tensile strength of 19.11 MPa, serving as the baseline for evaluating the impact of NaOH treatment. As the NaOH concentration increases to 2%, there is a notable increase in tensile strength to 21.90 MPa, suggesting that the introduction of a mild chemical treatment enhances the material's ability to withstand stress, thereby improving tensile strength. probably due to an optimal balance between effective fibre alteration and little damage. While NaOH treatments can improve fibre-matrix interaction, excessive exposure at this concentration may cause fibre breakdown or reduced adhesion, leading in a loss in tensile strength. Research by Kobayashi et al.

Fortunately, as the NaOH concentration rises to 4%, tensile strength decreases significantly, decreasing to 17.00 MPa. This decline shows that higher NaOH concentrations cause structural changes in pineapple leaf fibres, which may have a negative impact on the material's tensile strength. The drop at 4% concentration may be due to a trade-off between chemical alteration and the fibres' inherent mechanical properties, emphasising the delicate balance required in optimising tensile strength through NaOH treatment.

The pattern of decreasing tensile strength continues at 6% NaOH concentration, with an additional reduction to 17.34 MPa. This discovery suggests that the material becomes more prone to breaking under stress at this concentration, possibly due to the chemical treatment's ongoing impact on the fibre structure. The complex response at 6% emphasises the significance of carefully considering concentration-dependent effects while attempting to maximise tensile strength.

The highest concentration of sodium hydroxide studied, 8% NaOH, results in a significant drop in tensile strength to 11.28 MPa. This unexpected drop shows that, at this concentration, the chemical treatment causes specific structural changes that reduce the material's tensile strength.

High NaOH concentrations can induce excessive breakdown of fibres. This degradation can cause a loss of structural integrity and diminish the overall strength of the fibres (Oushabi et al., 2017). The decline at 8% concentration emphasises the importance of fully understanding concentration-dependent effects and the possibility of nonlinear reactions in the material's mechanical behaviour. Research by Sathish et al. (2020) also demonstrated that, when the percentage of sodium hydroxide was increased to 10%, deterioration on the properties was observed owing to the damage of fibers at increased concentration.

Finally, the tensile strength data for pineapple leaf fibre bio-composites treated with different NaOH concentrations demonstrate the complex link between chemical treatment and the material's ability to withstand stress. Lower concentrations improve tensile strength, however larger concentrations may result in trade-offs and unanticipated results. This knowledge is critical for customising bio-composites to satisfy specific mechanical criteria for a wide range of applications, including load-bearing structures and materials with high tensile strength. Further research into the precise impacts of various NaOH concentrations on fibre qualities could illuminate the underlying mechanisms, leading treatment conditions optimisation for achieving targeted mechanical properties in pineapple leaf fibre/polyester bio composites.

4.1.2 Tensile Modulus

Figure 4.2 shows tensile modulus data for pineapple leaf fibre bio-composites at various NaOH (sodium hydroxide) concentrations provide useful insights into how chemical treatment affects the material's mechanical properties. Tensile modulus is a fundamental characteristic in analysing the stiffness and rigidity of a material, providing crucial information for situations where structural integrity is paramount.

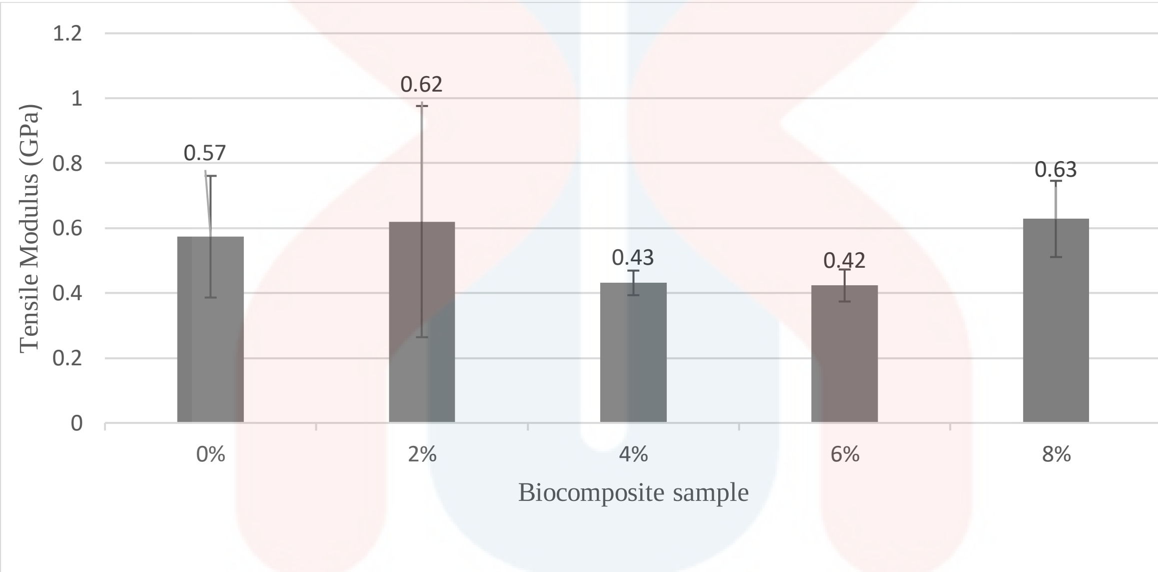

Figure 4.2: Tensile modulus of untreated and treated pineapple leaf fibre-UPE bio-composites.

The untreated samples, with 0% NaOH content, have a tensile modulus of 0.57 GPa, which serves as a baseline for assessing the effect of NaOH treatment on pineapple leaf fibre. As the concentration of NaOH increases to 2%, the tensile modulus increases slightly, reaching 0.62 GPa. This implies that applying a moderate chemical treatment has a visible effect on increasing the material's stiffness while without considerably reducing its overall tensile strength.

However, as the NaOH concentration increases to 4%, the tensile modulus decreases significantly, decreasing to 0.43 GPa. This decline implies that higher concentrations of NaOH cause structural changes in pineapple leaf fibres, potentially resulting in a decrease in stiffness.

The drop at 4% concentration could be attributed to a trade-off between chemical alteration and the fibres' inherent mechanical capabilities, highlighting the complexities of the interaction between NaOH treatment and tensile modulus.

The maximum concentration investigated, 8% NaOH, results in a considerable rise in tensile modulus to 0.63 GPa. This means concentration of NaOH did not influence the stiffness properties and can resist the most deformation under stress. This unexpected increase indicates that, at this concentration, the chemical treatment causes unique structural changes that increase the material's stiffness, potentially compensating for the reported drop at 4% and 6%. This emphasises the need of understanding concentration-dependent effects and the possibility of nonlinear reactions in the material's mechanical behaviour.

These concentrations achieve an appropriate equilibrium, increasing the stiffness and resistance to deformation of the material as compared to untreated samples (Panyasart et al., 2014), revealing the efficiency of regulated chemical treatments in reinforcing pineapple leaf fibre/polyester bio composites.

In conclusion, the findings on tensile modulus for pineapple leaf fibre bio-composites treated with different NaOH concentrations highlight the complex interaction between chemical treatment and material stiffness. The results indicate that lower concentrations contribute to benefits, whereas larger concentrations may result in trade-offs and unanticipated outcomes. Understanding these concentration-dependent effects is critical for designing bio-composites to suit specific mechanical requirements for a wide range of applications, including structural components and flexible materials. More research might investigate the underlying processes of these effects, offering a more complete knowledge of the connection between NaOH treatment and the tensile modulus of pineapple leaf fibre-UPE bio-composites.

4.1.3 Elongation at Break

Figure 4.3 shows different values of elongation at break of untreated and treated pineapple leaf fibre reinforced UPE bio-composites (2%, 4%, 6% and 8%). Elongation at break is an important statistic that measures the material's capacity to deform before fracture, providing information about its ductility and flexibility.

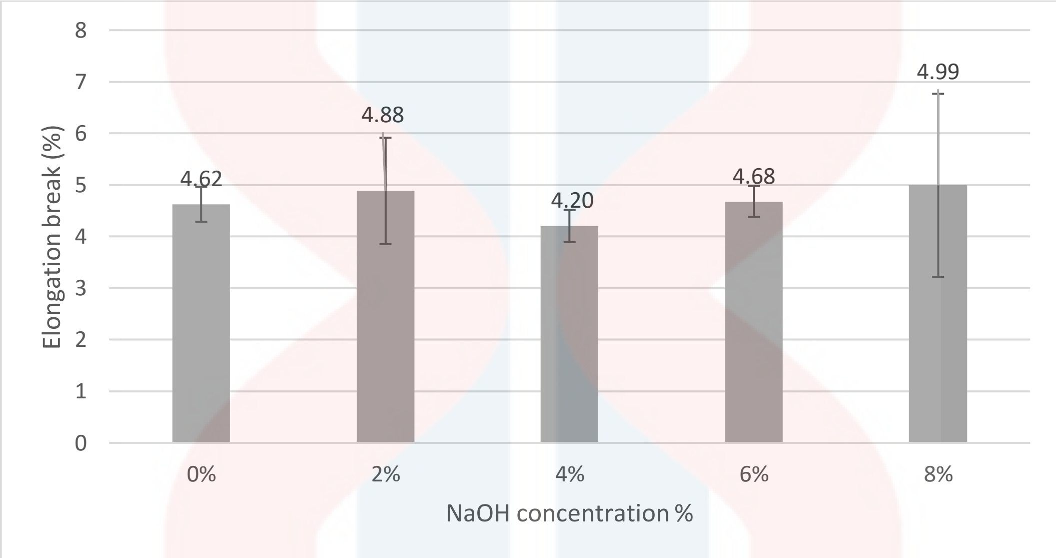

Figure 4.3: Elongation at break of untreated and treated pineapple leaf fibre-UPE bio-composites.

The untreated samples, with 0% NaOH content, had an elongation at break of 4.62%. This baseline measurement serves as a reference point for evaluating the effect of NaOH treatment on the material's mechanical properties. As the NaOH concentration climbs to 2%, there is a minor but noticeable increase in tensile elongation at break, reaching 4.88%. This increase shows that adding a mild chemical treatment improves the material's flexibility slightly while maintaining its total tensile strength.

However, a notable tendency unfolds as the NaOH concentration rises further. At 4%, elongation at break decreases to 4.20%. This reduction implies that a higher concentration of NaOH causes structural changes in the pineapple leaf fibres, which may affect the material's ductility. The decrease in elongation at this concentration could indicate a trade-off between chemical alteration and the fibres' inherent mechanical qualities.

Interestingly, at 6% NaOH concentration, the tendency reverses, and elongation at break increases to 4.68%. This shift suggests a complex interplay of variables, demonstrating that the effect of NaOH treatment on elongation is not linear. The 6% rise can be due to certain chemical alterations that improve the material's flexibility, decreasing the detrimental impacts seen at 4%.

At the highest concentration studied, 8% NaOH, tensile elongation at break further increases to 4.99%. This suggests that, despite the higher concentration of the chemical treatment, the material retains or even surpasses its ductility compared to the untreated samples. The 8% concentration may induce unique structural changes that positively influence the material's mechanical behaviour, emphasizing the importance of understanding the intricate relationship between chemical treatment and mechanical properties.

In conclusion, the data on elongation at break for pineapple leaf fibre bio-composites treated with NaOH concentrations reveals important information about how chemical treatment affects material flexibility. The findings show NaOH's subtle impact on elongation, with lower concentrations resulting in improvements and larger concentrations necessitating careful consideration of potential trade-offs. Understanding these interactions is critical for adapting bio-composites to specific mechanical needs for a wide range of applications, including building, textiles, and packaging. Further research could delve into the underlying processes of these effects, allowing for a more comprehensive knowledge of the connection between chemical treatment and mechanical behaviour of pineapple leaf fibre-UPE bio composites.

4.2 Fibre Characterization Techniques

4.2.1 Fourier Transform Infrared Spectroscopy (FTIR)

Figure 4.4 presented characterization techniques of FTIR pineapple leaf fibre-UPE bio-composites untreated and treated with various concentrations of NaOH (sodium hydroxide) over a variety of bonds from 4000-400 cm-1. Figure 4.4 shows the concentration of NaOH increases, the strength of the peak at 1716 cm- 1, which corresponds to the carbonyl (C=O) stretching vibration of ester groups, decreases. This implies that the NaOH treatment partially hydrolyzes the ester bonds in the polyester matrix. Peaks at 1266 cm-1 and 1100 cm-1 correspond to the C-O stretching vibrations of cellulose and hemicellulose, respectively, and decrease in intensity as NaOH concentration increases. Aravindh et al. investigated FTIR researcher revealed the elimination of functional groups in the fibres.

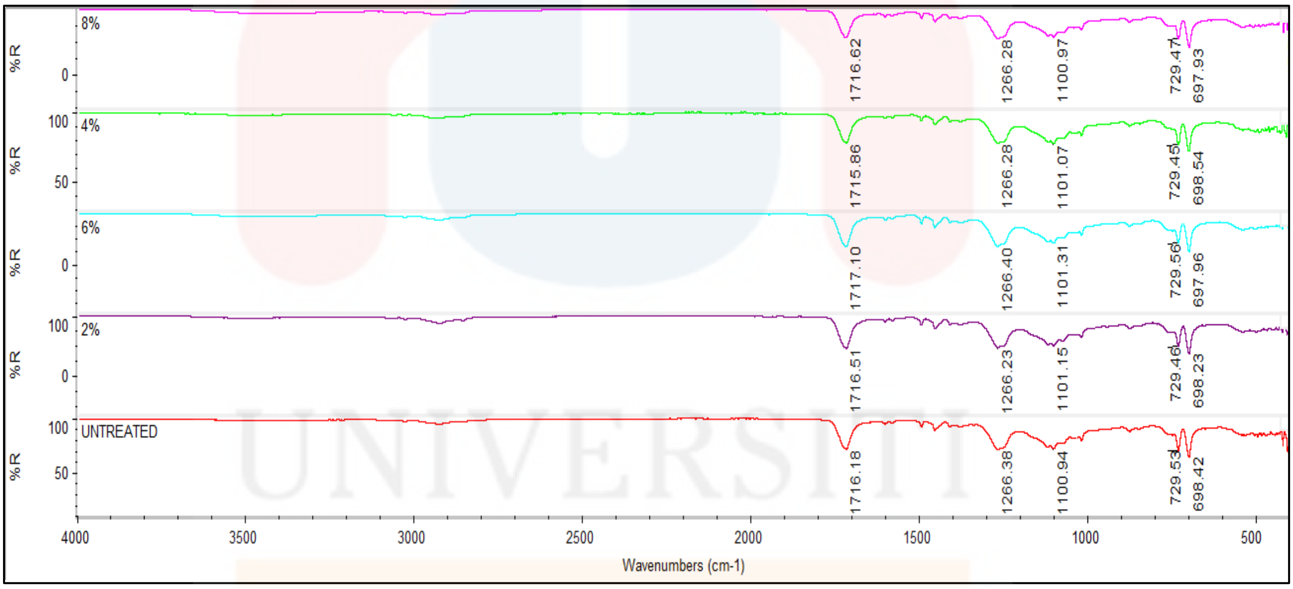

Figure 4.4: FTIR plot of untreated PLF, 2%, 4%, 6%, and 8% concentrations NaOH treated PLFs. The bands at ~4000 and ~400 cm−1 are affected by NaOH.

The peak at 1716 cm-1 for untread indicates the presence of a carbonyl group. Peaks at 1266 cm-1 and 1101 cm-1 suggest the presence of C-O stretching vibrations. Additionally, peaks at 730 cm-1 and 698 cm-1 correspond to bending vibrations of the Na-O bond. A single strong band at ~730 cm−1 which corresponds to C–O stretching of lignin is observed in the untreated PLF. This indicates that the NaOH treatment is removing some cellulose and hemicellulose from the pineapple leaf fibres. The NaOH treatment has no appreciable effect on the peak at 730 cm-1, which represents cellulose's C-H bending vibration. This shows that NaOH treatment has no effect on cellulose's crystalline structure. Following the treatment, the characteristic lignin peaks disappeared, and new peaks formed, demonstrating the mercerization action of the NaOH on the lignocellulosic fibre.

Characterization using FTIR of a 6% concentration of NaOH exhibits similar peak wavenumbers as the untreated sample but its higher peaks than other sample . The peak at 1717 cm-1 still suggests the presence of a carbonyl group. Peaks at 1266 cm-1 and 1101 cm-1 remain indicative of C-O stretching vibrations. Additionally, the peaks at 730 cm-1 and 698 cm-1 persist, corresponding to bending vibrations of the Na-O bond.

Aravindh et al. (2022) claimed that the isolated fibres were mercerized using 5% NaOH. FTIR analysis demonstrated the elimination of hemicellulose, lignin, wax, and other surface-related contaminants from the fibres. As NaOH treatment removes lignin from the fibres, the intensity of the peak at 698 cm-1 will likely diminish. It has the potential to change the hydrogen bonding network within the fibres, hence indirectly influencing the peak intensity. Other functional groups in the samples may also contribute to the intensity at 698 cm-1, making it challenging to distinguish the unique contribution of C-H bending in lignin.

4.3 Physical Properties

4.3.1 Water Absorption

Figure 4.5 shows the average percentage water absorption characteristics of pineapple leaf fibre-UPE bio-composites treated with different concentrations of NaOH (sodium hydroxide) during various time periods (24, 48, 72, 96, and 110 hours). This investigation gives insight into the effect of NaOH concentration on the material's hydrophilic or hydrophobic character, offering useful information for applications where moisture resistance is crucial.

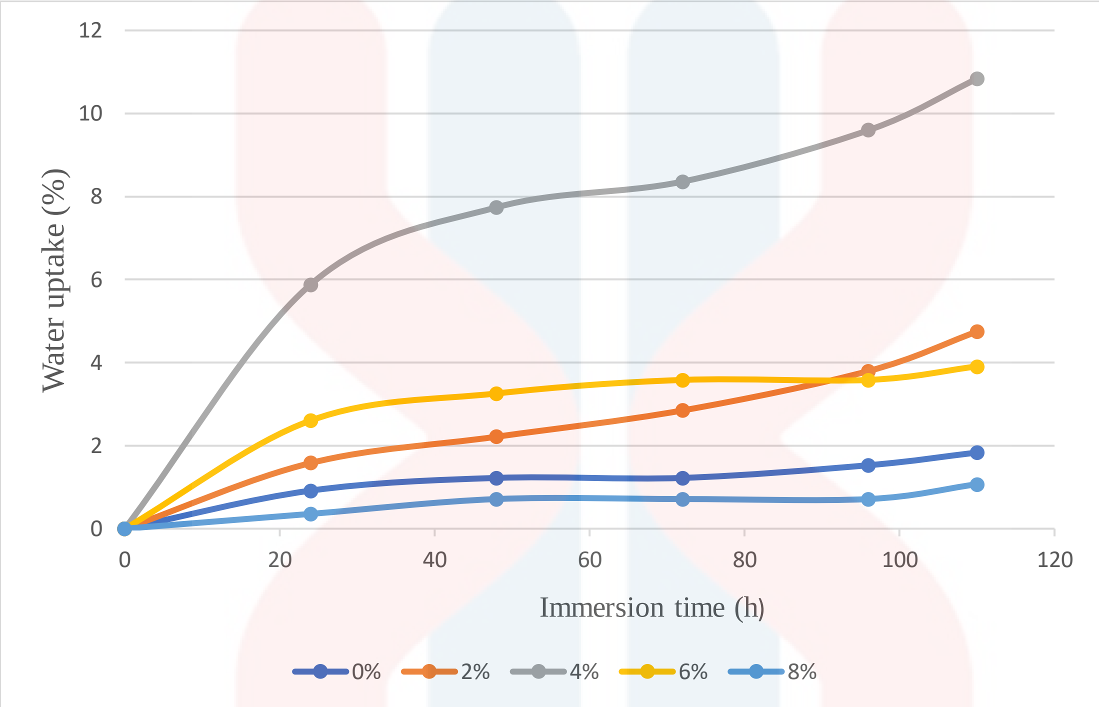

Figure 4.5: Water absorption for untreated and treated pineapple leaf fibre-UPE bio-composites.

Untreated samples absorb 0.92% of water during the first 24 hours, establishing the baseline for the hydrophilicity of bio-composites. Water absorption increases with increasing NaOH concentrations, peaking at 5.88% at 4% NaOH. This shows that the alkaline treatment alters the pineapple leaf fibres, making them more hydrophilic. However, a notable tendency emerges as the NaOH concentration rises. Water absorption lowers to 2.61 % at 6% NaOH and 0.36% at 8%. This decrease implies that increasing NaOH concentrations cause hydrophobic changes in the fibres, reducing their affinity for moisture absorption.

Examining the follow-up time periods reveals dynamic patterns in water absorption. In the 48-hour timeframe, treated samples, notably at 4% NaOH concentration, have a peak water absorption of 7.74%, outperforming untreated samples. This peak is followed by a slow reduction over time, with the lowest water absorption measured at 0.71% in 72 hours, which corresponds to an 8% NaOH concentration. This low water absorption is likely due to the modifications induced by the alkaline treatment, making the fibres more hydrophobic and less prone to absorbing moisture.

The trends persist at 96 hours and 110 hours, with 4% of treated samples indicating ongoing water absorption. In contrast, treated samples, particularly those containing 8% NaOH, regularly outperform others, with the lowest water absorption percentages at both time intervals. This long-lasting effectiveness demonstrates the long-term influence of hydrophobic changes caused by increasing NaOH concentrations. Study by Aravindh et al. (2022) claimed that, in the same way, treated fibre has better water absorption qualities than untreated fibre. The amount of reinforcement was increased from 10% to 50% by weight for the alkali treatment, which involved the use of NaOH (sodium hydroxide).

The 8% NaOH concentration is the most effective in reducing water absorption, demonstrating its potential for producing bio-composites with improved moisture resistance. This concentration's lower water absorption (0.36 % in 24 hours) compared to the highest absorption at 4% concentration (5.88 %) demonstrates its efficacy in preventing water intrusion. The underlying chemical properties of the NaOH treatment at various doses require further investigation to determine the specific alterations to the observed water absorption behaviour.

In conclusion, the higher of water absorption is 10.84 % in 4% concentration of NaOH and the lowest of water absorption is 1.07 % in 8% concentration of NaOH. The 8% NaOH concentration's decreased water absorption (1.07 %) may be due to its chemical characteristics, which limit its capacity to absorb water when compared to the 4% concentration (10.84 %). The water absorption properties of pineapple leaf fibre bio-composites are closely related to the NaOH concentration utilised during treatment. The concentration-dependent transition from hydrophilic to hydrophobic behaviour has important consequences for the material's applicability in a variety of applications, highlighting the significance of tailoring NaOH treatment to specific performance requirements. More investigation into the molecular mechanisms behind these alterations will surely lead to the development of bio-composites with optimised moisture resistance qualities.

4.3.2 Thickness Swelling

The data presented shows the thickness swelling behaviour of pineapple leaf fibre bio-composites exposed to various NaOH (sodium hydroxide) concentrations throughout time intervals (24, 48, 72, 96, and 110 hours). Thickness swelling is a significant factor in determining the dimensional stability of materials, especially in applications where changes in volume owing to water absorption can affect performance.

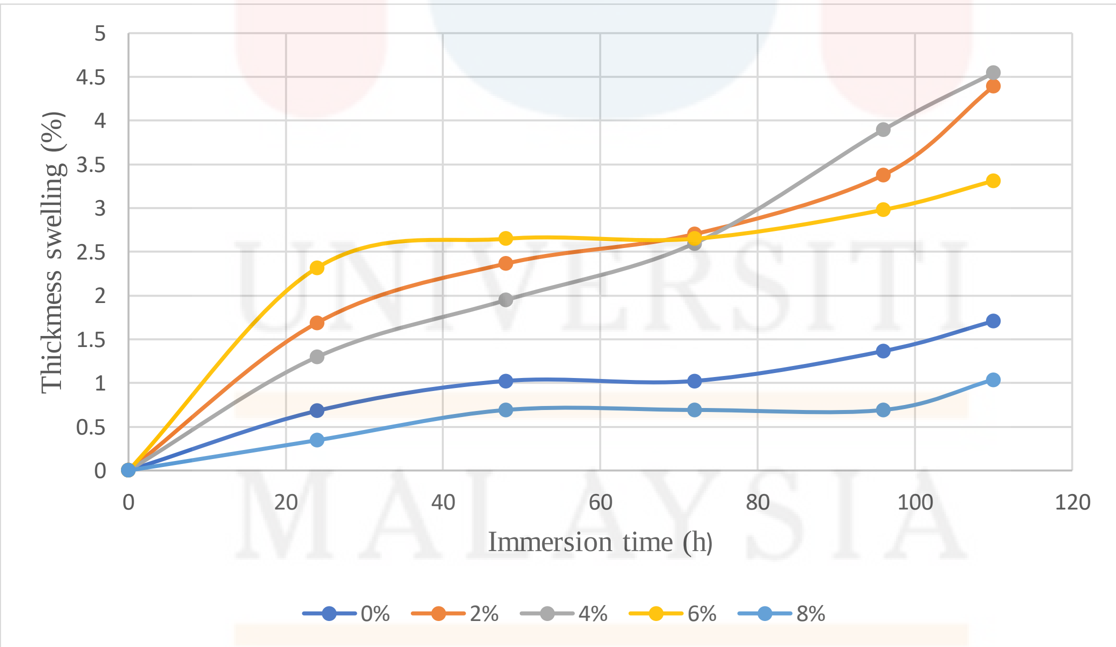

Figure 4.6: Thickness swelling for untreated and treated pineapple leaf fibre-UPE bio-composites.

In the untreated samples, thickness swelling is constant at 0% over all time intervals, demonstrating the resilience of untreated pineapple leaf fibres. In contrast, the treated samples show concentration-dependent changes in thickness swelling. At 24 hours, the samples treated with 2% NaOH showed a modest rise in thickness swelling (1.69 %), indicating a little impact of the treatment on dimensional stability. However, at 4% NaOH concentration, a significant decrease in thickness swelling of 1.30 % is detected, showing a good influence on swelling reduction.

The concentration-dependent trend persists at 48 hours, with the 4% NaOH-treated samples exhibiting the least thickness swelling (1.95 %). As the concentration of NaOH increases, so does the thickness swelling, reaching 2.65 % at 6% and 0.69 % at 8%. This shows a complex interaction between the chemical treatment and the material's ability to swell. The 8% NaOH concentration has the lowest thickness swelling, which corresponds to the data in water absorption and demonstrates its efficacy in decreasing dimensional alterations.

Analysing the following time intervals reveals dynamic behaviours. At 72 hours, the 4% NaOH-treated samples exhibit the lowest thickness swelling (2.60 %), highlighting the concentration's long-term favourable impact on dimensional stability. The untreated and 2% NaOH-treated samples show greater swelling, highlighting the importance of NaOH treatment in reducing thickness swelling.

The pattern persists in the 96-hour period, with the 4% NaOH-treated samples showing the least thickness swelling (3.90 %). This concentration-dependent behaviour points to a complex link between NaOH treatment and the material's ability to withstand dimensional alterations. The 8% NaOH concentration again shows lesser thickness swelling (0.69 %), demonstrating its efficiency in improving dimensional stability. The chemical characteristics of the solution may have limited or restricted the material's ability to absorb water. It is interesting to note that the thickness and swelling values alter over time, emphasising the process's dynamic nature. Research by Aravindh et al. (2022) also find that, the presence of high moisture content in fibre induces swelling of the fibre and matrix inside composites, creating dimensional stability.

At 110 hours, the overall patterns continue, with 4% NaOH-treated samples continuously outperforming others in terms of reduced thickness swelling (4.55 %). The untreated and lower concentration-treated samples show greater thickness swelling, highlighting the concentration-dependent effect of NaOH treatment. Research by Aravindh et al. (2022) also find that, the water absorption nature was increased, resulting in poor wettability.

In conclusion, the presented data on thickness swelling demonstrate that NaOH concentration has a substantial influence on the dimensional stability of pineapple leaf fibre bio-composites. The concentration-dependent trends indicate that the chemical treatment alters the fibre structure, affecting its propensity to swell in the presence of water (Aravindh et al. 2022). The 4% NaOH concentration is particularly successful in minimising thickness swelling throughout a variety of time intervals, indicating a possible path for improving the dimensional stability of bio composites. The findings highlight the necessity of customising NaOH treatment parameters to achieve desirable performance characteristics in applications where dimensional stability is crucial, such as the production of composite materials for construction or outdoor use.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS.

5.1 Conclusion.

In conclusion, the mechanical and physical evaluation of chemically treated pineapple leaf fibre/polyester bio composites sheds light on the potential applications of these sustainable materials in a wide range of engineering and industrial areas. The study thoroughly evaluated the effects of chemical treatment on pineapple leaf fibres, highlighting its importance in increasing the fibres' compatibility with the polyester matrix. The observed increases in mechanical parameters, such as tensile strength, tensile modulus, elongation break, and FTIR analysis, highlight the importance of surface modification in optimising bio composites' overall performance.

The results of the study indicate the huge potential of chemically treated pineapple leaf fibres as reinforcement in bio composites, giving an ecologically friendly alternative to traditional materials. This innovation has far-reaching ramifications, providing a sustainable solution for applications in automobile, construction, and packaging. This study's findings serve as a stepping stone in the evolution of composite materials, propelling the creation of high-performance, ecologically responsible alternatives. Continued study along this path has the potential to refine the application of natural fibres in composite materials to create a more sustainable and environmentally responsible future for material science and engineering.

5.2 Recommendations

Several recommendations can be made to develop this subject based on the Mechanical and Physical Characterization of Chemically Treated Pineapple Leaf Fiber/Polyester Bio composites. To begin, more research into the optimisation of chemical treatment procedures for pineapple leaf fibres is required, with the goal of achieving an ideal balance between effective impurity removal and minimal fibre destruction. Furthermore, to establish their viability for real-world applications, these bio composites must undergo a rigorous examination of their long-term durability and environmental impact. Material scientists, engineers, and environmental specialists are urged to work together to solve problems and improve production processes. Furthermore, broadening the study to encompass a broader range of fibre loading ratios and investigating potential synergies with other natural fibres should provide useful insights. Finally, efforts should be put towards scaling up production techniques to commercialise these bio composites fostering sustainable and environmentally friendly alternatives in a range of businesses.

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