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# Surface Treatment and Properties of Natural Fiber Reinforced Polymer Composites: A Review

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**ABSTRACT**
There has been a considerable increase in research and studies on the use of natural fibers as alternative to man-made fibers. A few of the more commonly used natural fibers for making composites using polymer matrix for different applications in both automobile and construction industries are sisal, areca, hemp, flax, kenaf, coir, bagasse, jute, cotton, bamboo, banana and pineapple. Some of the numerous advantages of natural fiber are low cost, renewability, low density, non-abrasive to the equipments, non-irritation to the skin, less health risk, recyclability,biodegradability. In this paper, a brief review of the predominant surface treatments and a comprehensive review of the properties of banana stem fiber, pineapple leaf fiber and sisal fiber based composites were presented. These agro waste composite materials are ecofriendly; however, their natural origin causes a wide range of variability in properties depending on plant age, extraction process and surface treatment of the fibers. Their properties indicated that they are suitable for various industrial applications. However, there is still need to explore other methods of producing stronger fibers for enhanced properties and performance.

**Keywords:**Natural fiber;Banana fiber, sisal fiber, pineapple fiber; Surface treatment, Properties.

## I. INTRODUCTION

Due to the hassle of global warming and environmental policies across the world in the current years, efforts are being made to carry to the barest minimum the reliance on petroleum fuels and synthetic products. This has formed the motivating factor for researchers to find an alternative. Consequently, development of bio-degradable composites has been presently certified one of the ways to surmount the hassle (Bogoeva-Gacera et al. 2013). The wide utility of natural fiber and its reinforced composite in the discipline of car industries has introduced about large decline in energy utilization in the course of motor automobile manufacturing and additionally an upward boom in their day to day fuel economic system (Rashed et al 2006). Furthermore, the elevated demand for high strength, high modulus and low density industrial primarily based materials has brought about an expanded quantity of functions for fiber laminated composite structures in many specific fields such as in aircraft structures, heat exchangers, clinical instruments, car engineering, civil engineering, enabling technologies, storage tanks and many greater (Khandan et al. 2012).Natural fibers can be considered as composites of hollow cellulose fibrils held together by lignin and hemicelluloses matrix (Jayabal et al. 2012). The more regularly used natural fibers in different applications in both automobile and construction industries encompass sisal, jute, hemp, flax, kenaf, coir, bagasse, cotton, bamboo, banana and pineapple. The merits of natural fiber over synthetic (man-made) fibers are low cost, low density, eco-friendly, easy in processing, reduced power consumption, less pollution for the duration of production, renewability, recyclability and bio-degradability(Malkapuram et al. 2009).

There has been a rising trend in research on natural fibers and its composites and the mechanical properties of the natural fibers studied have been promising. Natural fibers can be used alone or hybridized with synthetic fibers depending on the major application requirements. However, most the components obtained are used to produce non-structural components for the automotive industry such as seat backs, door panels, pack layer, coffer liners, cap rack and boot linings (Mohammed et al. 2015).Steffens et al. [8]presented a paper that discussed the role of natural fibers on aligning architectural production, both aesthetically and technologically, with the site's local culture, economy, natural diversity and geographic singularities.

Considering the high-performance trendy of composite materials commonly in terms of

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durability, maintenance/preservation and cost effectiveness, the application of natural fiber as reinforcement for polymeric matrices, introduces high quality improvement on the mechanical properties of the polymers and consequently holds large viable for industrial application.

## II. NATURAL FIBERS

Natural fibers can be considered as composites of hollow cellulose fibrils held together by lignin and hemicelluloses matrix (Jayabal et al. 2012). Structural performance of plant life has been attributed to its fibers, which additionally provide reinforcement when embedded in plastic composites. Natural fibres can be used for technologically advanced applications, such as car inner and outer parts. Natural fibers has decreased density, better thermal insulation, renewability, much less weight, low cost and decreased skin nuisance when in comparison with glass fibers. Other merits of these natural fibers in composites encompass their relative cheapness, ability to recycle, renewability and most mainly their biodegradability. John and Thomas (2008) in line with Mohanty et al. (2000) reported that the biodegradable composites from biofibers and biodegradable polymers will render a contribution in the 21st century to address the serious ecological challenge faced in recent years.

### 2.1 Sources and classification of Natural Fibers

Natural fibers are sometimes categorized according to their sources such as from plant, animal and mineral. Plant fibers encompass but not constrained to agro edible and decorative plant sources such as sisals, banana, jute. Generally, they are comprised broadly of cellulose and can similarly be categorized into the following depending on their source; seed fiber, leaf fiber, bast fiber, fruit fiber and stalk fiber. Animal fibers are those fibers collected from animals or hairy mammals and can in addition be labeled into the following: animal hairs, silk fiber and avian fiber. Mineral fibers are described as nonmetallic inorganic fibers that are obtained via slight modification of silica or metallic oxides such as asbestos, ceramic fibers, graphite, glass fibers amongst others.

#### 2.1.1 Chemical Composition of Natural Fibers

The three essential components of natural fibres are cellulose, hemicellulose and lignin with small percentages of smaller extractable compounds such as pectin and wax. Cellulose is a natural linear polymer polysaccharide made up of D-glucopyranose units linked together. It is the main constituent of plant cell walls that assist the plant to be stiff and robust. Li et al. (2007) and John and Thomas (2008) reported that cellulose is opposed to strong alkali (17.5wt %), however hydrolyses with ease in acid to water-soluble sugars and somewhat resistant to oxidizing agents

**Table.1 Chemical composition of natural fiber [** Malappuram et al. 2009**]**

| Fiber | Cellulose (wt%) | Lignin (wt%) | Hemicellulose (wt%) | Pectin (wt%) | Wax (wt%) |
|---|---|---|---|---|---|
| Jute | 61-71.5 | 12-13 | 13.6-20.4 | 0.4 | 0.5 |
| Hemp | 70.2-74.4 | 3.7-5.7 | 17.9-22.4 | 0.9 | 0.8 |
| Kenaf | 31-39 | 15-19 | 21.5 | - | - |
| Flax | 71 | 2.2 | 18.6-20.6 | 2.3 | 1.7 |
| Ramie | 68.6-76.2 | 0.6-0.7 | 13.1-16.7 | 0.3 | 0.4 |
| Sisal | 67-78 | 8-11 | 10-14.2 | 10 | 2.0 |
| Kapok | 64 | 13 | 23 | 23 | - |
| Cotton | 82.7 | - | 5.7 | - | 0.6 |
| Pineapple | 66.2 | 4.2 | 19.5 | - | - |
| Coir | 36-43 | 41-45 | 10-20 | 3-4 | - |
| Banana | 63-67.6 | 5 | 19 | - | - |

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Hemicelluloses are neither cellulose nor pectin rather it is a hetropolymer (matrix polysaccharide) that is very hydrophilic, soluble in alkali, easily hydrolyzed in acids and partly soluble in water of simpler structure than cellulose. John and Thomas (2008) reported that it includes many hydroxyl and acetyl groups, comprising of a combination of pentose and hexose sugars discovered in the plant cell walls. The supportive matrix for cellulose microfibrils is offered by hemicelluloses lignin in a complex hydrocarbon polymer structure which acts as a binder between the individual fibre cells. Hemicelluloses have random amorphous structure with little strength while cellulose is crystalline, strong and resistant to hydrolysis.

Lignin is a natural cross-linked phenolic polymer with high molecular weight, complex composition and structure that gives plants its strength and rigidity. It is highly unsaturated or aromatic in character. They are totally insoluble in most solvents but cannot be broken down to monomeric units nor easily removed from the fibres. Lignin is also totally amorphous and hydrophobic in nature with water holding capacity and protection against biological attacks to the plants. (Plackett 2016)

### 2.1.2 Surface treatment of natural fibers

The most disadvantage in the fabrication of natural fiber reinforced polymer composite is the chemical incompatibility between the matrix and the fiber. In order to surmount this problem, fiber surface modification needs to be made on the natural fiber using a surface modifier. Different surface treatment strategies such as mercerization (alkali treatment), isocyanate treatment, acrylation, benzoylation, latex coating, permanganate treatment, acetylation, silane treatment, thermal treatment and peroxide treatment have been used to improve fiber-matrix interfacial bonding in the course composite (Shah et al. 2012).

Silane chemical treatment has also helped to increase the resin wetting of fibers by bringing down the amount of cellulose contained in the fiber, thereby chemically causing interconnection between the interface of the fiber and matrix (Kanishkar et al. 2019).

Treatment through peroxide is a method the same as the instigation step of the free-radical chemical process, which causes adhesion in polysaccharide fiber-reinforced thermoset composites.Peroxide treatments can considerablyscale back the water absorption of natural fibers or fillers, which in flipwill improve the surfaceadhesion between fibers or fillers and hydrophobic compound matrices (Li et al. 2016).Ahmad et al. (2019) reported thatthe mechanical properties (tensile) of peroxide-treated natural fiber-reinforced composites exhibited apparent enhancement.

On acrylation treatment, an acetyl group reacts with deliquescentgroupteams of the fiber to come up with esterification that brings down its deliquescent nature by grippingwetness from the fiber (Teli et al. 2013).

Another method of treatment is the physiochemical treatment which involves the amalgamation of both physical and chemical treatments to aid the chemical reactions and improve disconnection of fiber bundles (Senthamaraikannan et al. 2019).

Alkali treatments greatly improve the resin pick-up or wettability of natural fibers during composite fabrication only when the fibers are post treated with other chemical such as silane solution. This synergetic effect has a long-lasting effect on the mechanical behaviour of the fiber. Among the various treatment techniques known, surface modification by chemical treatment such as mercerization (alkali treatment) is the most commonly used chemical process which gets rid of non-cellulose components and a part of amorphous cellulose (Sreekumar et al. 2009).

## 2.2 Natural Fiber Reinforced Composites

The interest in the use of natural fiber reinforced polymer composite materials is on the rise, both in terms of their engineering applications and elemental research. Fiber reinforced polymer composites have for long performed fundamental role in a range of purposes due to their high specific strength and modulus. Natural fiber reinforced polymer composites are composite materials consisting of a polymer matrix embedded with high-strength natural fibers like jute, banana, coir sisal, pineapple, kenaf, and flax (Ku et al. 2011). Much investigation had been carried out on various natural fibers to study their suitability and capability when embedded in polymeric matrices. Arib et al. (2006) studied the impact of pineapple leaf fiber as a function of its volume fraction on the mechanical behaviour of the composite and found it to have a significant effect on the mechanical properties of the composite. Venkateshwaran et al. (2013) investigated on Fiber surface treatment and its impacts on the mechanical and visco-elastic behavior of banana epoxy composites and confirmed an enhanced tensile, flexural and impact strength by 17%, 4.3% and 35.5% respectively. On

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reinforcing epoxy with sisal, Gupta et al. (2016) reported a rise in the flexural and tensile strength with rising fiber contents.

### 2.2.1 Polymer resin

There are two major types of polymer matrix/resin; the thermoplastic and the thermoset polymer resin. The resin, its chemical composition and physical properties are essentially acknowledged to have an effect on the processing, fabrication and ultimate properties of a composite material. They are put into any shape without difficulty, are well-suited with most other substances and cure readily (by heat or catalyst) into an insoluble solid. Thermoset polymers are extremely cross-linked polymers which cure by the appication of both solely heat, jointly application of heat and pressure and or light irradiation. This cross-linked structure offers thermoset polymer good properties such as high flexibility which offers the ease of fashioning desired ultimate properties, great strength and modulus as reported by (Ticoalu et al. 2010 and Faruk et al. 2012). Although there are many different types of resin utilized in the composite industry, polyester, phenolics and epoxy resins are the most commonly used thermoset.

### 2.2.2 Mechanical properties of Composite

In order to study the mechanical properties of natural fiber composite, the reinforcement impacts of the surface-treated fibers with polymers and the composite processing technique should be given an extremely good attention. This is because, the properties exhibited by composite materials are reliant on the interfacial characteristics between the hydrophilic fiber and the hydrophobic matrix. Also, the stress transfer between the fiber and the matrix is controlled by the fiber-matrix phenomena. Most of the researches on natural fiber composite involve study of mechanical properties as a function of fiber length, fiber loading, processing temperature, arrangement of fibers, impact of various chemical treatments of fibers and use of coupling (Abdul et al. 2012). Jayabal (2012) studied the impact of surface modification as a function of different levels of soaking time and concentration of NaOH solution on the mechanical properties of coir-polyester composite. After testing the mechanical properties of the treated coir-polyester composites based on flexural, impact and tensile strength, the result showed the properties all increased. Also, Sethy (2011) modified the short bamboo fiber using silane and NaOH. The result showed that both treatment methods enhanced the properties of its composite laminates with the treated bamboo fiber reinforced composites showing superior tensile modulus and flexural properties than the untreated bamboo fiber composites.

## III. FIBER TYPES

1. Fibers are classified based on their morphological structure namely: Bast fibers, leaf fibers and seed fibers.

### 3.1 Banana stem fiber and its composite

Banana fiber is a bast fiber, a waste product of banana cultivation and also a lingo-cellulosic fiber extracted from the pseudo-stem of banana plant (Bharath 2015). The pseudo-stem is cylindrical in nature with a clustered aggregation of leaf stalk bases. The fibres can be found at the outer sheath of the stalk.

a b

**Figure1**: *(a) banana pseudo stem (b) extracted banana fiber[Ezema et al. 2012)*

### 3.1.1 Properties of banana fibre composite

Table 2 presented a summary of the effects of effect of fiber loading, soaking parameters on the mechanical properties of treated Banana fiber reinforced polymer composites.

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Joseph et al. (2002) studied the impact of banana fiber length (0,10,20,30,40)mm and fiber loading (0,16,27,32,45)% on the tensile, flexural and the impact strength of its phenolformaldehyde reinforced composite laminates. They reported that the tensile and flexural strength all increased with increasing fiber length and fiber loading. The impact strength increased with increasing fiber loading but started decreasing after reaching a maximum strength at 30mm fiber length.
Marwan and Nasim (2015) reported that Material properties of banana reinforced Green-Compressed Earth Block (GCEB)are largely influenced by fiber type, fiber volume, fiber geometry and length (aspect ratio), fiber surface conditions, method of production, and composition of matrices.

Jannah et al. (2009) investigated the impacts of alkali and acrylic acid treatment of woven banana fiber on the flexural, impact and water absorption properties of its reinforced unsaturated polyester composites. The result showed an imporoved mechanical and water absorption properties of the composites with acrylic acid treatment compared to the alkali treatment and untreated fiber composites. The treatment impacts on the banana fibers were also characterized by means of scanning electron microscopy (SEM).

Arya et al. (2016) studied the thermal and mechanical properties of polypropylene/banana fiber composite and reported a better thermal stability for the treated composites and rise in the hardness and tensile properties of the treated samples compared to the untreated, while a decrease was observed for the impact properties of the treated samples.

Ezema et al. (2014) investigatedintothetensileandmorphologicalpropertiesofbananastemfiberreinforcednaturalrubber composite and reported that thestrengthandmodulus of the polyester matrix rose considerably as a result of reinforcementwithbananafibers. He also noted that further improvement in the mechanical properties were observed with chemicalmodification of the bananafibers with NaOH and Na2SO3 which indicated goodbonding fromtheir SEM results.

Khan et al. (2013) chemically treated banana stem fibre by bleaching, alkalization and acetylation and thereafter reinforced maleic anhydride grafted polypropylene/low density polyethylene with it at varied fibre contents (0,10,20,30,40)% and reported an improvement on the tensile, flexural and impact properties than the untreated ones. The best ultimate tensile strength was achieved at fibre loading of 20%, while that of maximum impact and flexural strength values were obtained with 10% fibre loading.
Jordan et al. (2017) studied the peroxide and permanganate treatment of banana pseudo-stem fibers and its effects on its single fiber and the reinforced LPDE polymer composites. The result of the investigation proved significant improvements in the properties both the chimically treated single fiber and the reinforced composites.

**Table 2 Effects of fiber loading, soaking parameters on the mechanical properties of treated Banana fiber reinforced polymer composites**

| Treatment | Soaking time (hrs) | Soaking temp (oC) | Fiber loading (%) | Ply angle (degree) | Resin | Tensile strength (Mpa) | Flexural strength (Mpa) | Impact strength (Kj/m2) | Ref |
|---|---|---|---|---|---|---|---|---|---|
| NaOH | 0.33 | 25 | 5 | - | Polyester | - | 58.0 | 33.2 | Jannah et al. (2009) |
| | | | | - | | | | | |
| | | | 10 | - | | - | 61.0 | 42.4 | |
| | | | 15 | - | | - | 58.0 | 56.5 | |
| | | | 20 | - | | - | 57.0 | 48.7 | |
| Untreated | | | 5 | - | | - | 57.0 | 27.3 | |
| | | | 10 | - | | - | 58.0 | 37.0 | |
| | | | 15 | - | | - | 57.0 | 54.2 | |
| | | | 20 | - | | - | 55.0 | 43.4 | |
| NaOH+Na2SO3 | 24 | 25 | - | 0 | Natural rubber | 4.0 | - | - | Jannah et al. (2009) |
| | | | | 45 | | 1.2 | - | - | |
| | | | | 90 | | 0.1 | - | - | |
| Untreated | - | - | | 0 | | 3.7 | - | - | |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 45 | | 0.5 | - | - | |
| | | | | 90 | | 1.0 | - | - | |

Vardhini et al. (2018) modified banana fibre with alkali, laccase and xylanase enzymes at various concentrations (10,15,20)% separately. Polypropylene was reinforced with both the treated and untreated banana fibres, using compression moulding technique. They reported that the various treatments increased the tensile and impact strength by 24 - 69% and 120% respectively with 20% xylanase enzyme treatment

### 3.2 Sisal fibre and its composite

Sisal fiber is a leaf fiber extracted from the sisal plant which is generally used for making ropes, mats, carpets etc. Sisal belongs to the family Agaveceae (Agave Sisalana). These plants are generally grown in tropical and sub-tropical region, owing to their better growth at temperature above 25$^{o}$C. Sisal plants leaves are of sword-shaped that are about 1.5cm long. Generally, a sisal plant has the ability to produce around 150 leaves within its lifespan of around 6years ( Arthanarrieswaran et al. 2014).

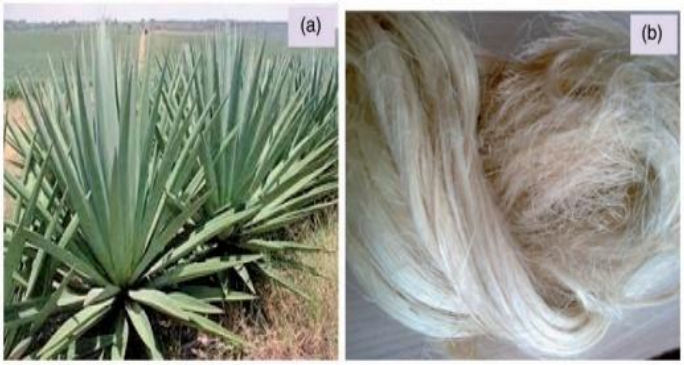


**Figure 2***: (a) Sisal plant, (b) Extracted sisal fiber ( Sahu and Gupta 2017)*

#### 3.2.1 Properties of sisal fibre composite

Table 3 presented the effect of fiber loading, soaking parameters on the mechanical properties of alkali treated sisal fiber reinforced polymer composites. Sreekumar [17] modified sisal fiber using NaOH, heat treatment, benzoylation and silanization to improve interfacial bonding with polyester resin. After the results of the tensile, flexural and impact porperties of all polyester composites reinforced with various treated fibers were analyzed and compared with those of untreated fiber composites, he found that all the treatment methods increased the flexural, tensile and impact properties of the treated fiber reinforced polyester composite when compared with the untreated. The scanning electron microscopy was also applied in studying the morphology of the treated sisal fiber.

**Table 3 Effects of fiber loading, soaking parameters on the mechanical properties of alkali treated sisal fiber reinforced polymer composites.**

| Concentration (%) | Soaking time (Hrs) | Soaking temperature (oC) | Fiber loading (%) | Resin | Tensile strength (Mpa) | Flexural strength (Mpa) | Impact strength (Kj/m2) | Ref |
|---|---|---|---|---|---|---|---|---|
| 2 | 24 | 27 | 20 | Epoxy | 15.64 | 60.89 | 6.93 | Owen and Ogunleye (2015) |
| 5 | | | | | 12.17 | 58.8 | 8.5 | |
| 10 | | | | | 11.28 | 56.5 | 8.3 | |
| 20 | | | | | 9.46 | 38.8 | 5.87 | |
| Untreated | | | | | 8.37 | 40.48 | 5.8 | |
| 0 | | | 20 | Epoxy | 49.1 | 82.7 | 490.0 | Senthilkumar (2017) |
| 3 | 1.25 | 25 | | | 55.0 | 83.6 | 276.7 | |
| 6 | | | | | 41.1 | 122.3 | 183.3 | |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 9 | | | | | 34.0 | 77.2 | 183.3 | |
| 2 | 4 | 60 | 50 | Epoxy | 330.0 | 230.0 | - | Rong et al. (2001) |
| | | | 58 | | 380.0 | 280 | - | |
| Untreated | | | 50 | | 280.0 | 210.0 | - | |
| | | | 58 | | 330.0 | 240.0 | - | |
| 5 | 6 | 70 | 5 | Polylacticacid | 58.0 | 99.0 | 3.3 | Rajesh et al.. (2015) |
| | | | 10 | | 63.0 | 101.0 | 3.2 | |
| | | | 15 | | 67.0 | 105.0 | 3.1 | |
| | | | 20 | | 68.0 | 112.0 | 3.0 | |
| | | | 25 | | 60.7 | 87.0 | 2.9 | |
| Untreated | | | 5 | | 55.3 | 92.0 | 3.1 | |
| | | | 10 | | 60.5 | 96.0 | 3.3 | |
| | | | 15 | | 60.7 | 98.0 | 4.0 | |
| | | | 20 | | 62.0 | 110.5 | 5.5 | |
| | | | 25 | | 60.0 | 93.0 | 5.9 | |
| 10 | 24 | 30 | 30 | Epoxy | 53.7 | 44.6 | 22.3 | Premnath (2018) |
| Untreated | | | | | 42.5 | 39.8 | 19.5 | |
| 4 | 1 | 25 | 40 | Epoxy | 28.0 | 23.0 | 21.0 | Koyuncu (2017) |
| Untreated | | | | | 25.0 | 20.5 | 16.3 | |

Senthilkumar (2017) studied the effect of alkali treatment as a function of concentrations (0,3,6,9)% NaOH solution on the mechanical properties of sisal fibre reinforced epoxy composites. From the result of the test conducted, the tensile and flexural strength of alkali treated composites were improved compared to the untreated fibre composites. On the other hand, the impact strength of the treated fibre composites were decreased compared to the untreated ones.

Srivatava et al. (2014), investigated the tensile and flexural properties of sisal fiber reinforced epoxy composites. The composites was fabricated at various fiber volume content (15,20,25,30)% of sisal fibers. The arrangement of the fibers in the composite were in unidirectional and mat form. The result of the experiment showed that the tensile and flexural strength (132.73 and 288.6)Mpa of the sisal fiber epoxy composites, both in unidirectional and in mat form were found to be maximum at 30wt% of sisal fiber content. Composite in unidirectional orientation of fibers was found to give better tensile and flexural properties in comparison to the mat form.

Salisu et al. (2015) investigated the effects of alkali, benzoyl chloride and silane treatments on mechanical properties of sisal fiber unsaturated polyester reinforced composites and reported that the fibre chemical modification improves its adhesion to the matrix as well as the mechanical properties of the composites.

Oladele et al. (2014), studied the effects of extraction of fibre by soil retting and chemical treatment on the mechanical properties of sisal fibre reinforced polyester composites. The treatments were conducted at an elevevated temperature of 70$^{o}$C for 2hrs using 2% solution each of NaOH, KOH, $H_2O_2$ and Ethanol. Sisal reinforced polyester composites were developed using both treated and untreated fibres for test of mechanical properties. The results showed that KOH treated fibre reinforced polyester composite, followed by that of ethanol treated, gave the best enhancement of the tensile and hardness properties of the sisal reinforced polyester composites than other treatments.

Boopathi et al. (2014) studied the impact of curing temperature (40,60,80,100)$^{o}$C and fibre volume fraction (15,30,45)% on the mechanical properties of sisal fibre reinforced polyester composites. The result of the test carried out for the tensile and impact strength of the fabricated composite laminates showed that the tensile strength of the composite rose with rising curing temperature to the maximum of 27.5Mpa at 60$^{o}$C. Also, the impact strength (36kj/m$^2$) of the sisal fibre reinforced polyester composite was found to be maximum at 30% fibre volume fraction and 80$^{o}$C curing temperature.

Salisu et al. (2015) investigated the effect of benzoyl and silane treatment on the mechanical properties of sisal fiber reinforced polyester composites. In the treatment of sisal using benzoyk

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chloride, 10% concentration and 15minutes soaking time were used at room temperature. By silane treatment, 1% concentration of phenyltriothysilane in acetone and 15minutes soaking time were used at room temperature. The result of the investigation on the mechanical properties showed that both treatment techniques showed a higher tensile and flexural strength than the untreated composites.

### 3.3 Pineapple leaf fibre (PALF) and its composite

Pineapple leaf fiber is a multicellular and lignocellulosic extracted from the leaves of the plant Anamus-cosomus belonging to the Bromeliaceae family by retting (Arib et al. 2006). PALF is cultivated chiefly in coastal and tropical regions, primarily for its fruits purpose.

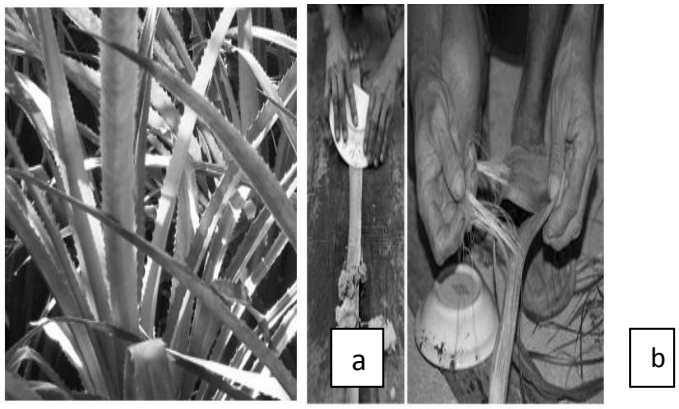


*Figure 3 :(a) Pineapple mature plant, (b) manual extraction of pineapple leaf fiber* (Leao et al. 2014)

#### 3.3.1 Properties pineapple leaf fibre composite

Mathivanan et al. (2017) modified pineapple leaf fiber with various concentration of alkali (0,3,5,7)% before using them to reinforce tapioca based Bioplastic resin. When the composite laminated specimen was tested for their mechanical properties, it was found that alkali concentration affects the strength of the composite, with the 5% concentration of the alkali solution showing the optimum concentration for NaOH treatment. Zin et al. (2018) studied the effect of alkali treatment as a function of concentration (4,6,8) % and soaking time (1,3) hrs on the tensile and interfacial shear strength of pineapple leaf fiber – epoxy composite. The result of the analysis showed that 6% NaOH treatment with 3hours soaking time gave the highest tensile strength and also found that 6% NaOH treatment with 1hour soaking time gave the highest interfacial shear strength. Scanning electron microscopy was used to study the morphology of the treated composite.

Panyasart et al. (2014) investigated the effect of alkali and silane treatment of pineapple leaf fiber as a function of fiber content (0,20,30,40)% on the tensile properties of its reinforced polyamide-6 composites. From the result, it was found that the proper fiber treatment and fiber loading in the study was alkali treatment and 30%wt respectively for the most enhancements in tensile properties. Fractured surface of the composites were also observed under a scanning electron microscope (SEM).

Pratumshat et al. (2015) studied the effect of silane treatment of PALF on mechanical and thermal properties of its reinforced polylactic acid composites. The result of the experiment showed improvements in the tensile and impact strength of the treated composites when compared to the untreated composites.

**Table 4 Effects of fiber loading, soaking parameters on the mechanical properties of alkali treated pineapple leaf fiber reinforced polymer composites.**

| Conc (%) | Soaking time (Hrs) | Soaking temperature (oC) | Fiber loading (%) | Resin | Tensile strength (Mpa) | Impact strength (Kj/m2) | Hardness (shore-D) | Ref |
|---|---|---|---|---|---|---|---|---|
| 5 | 5 | 25 | 0 | Polyamide-6 | 62.3 | - | - | Panyasart et al. (2014) |
| | | | 20 | | 73.7 | - | - | |
| | | | 30 | | 78.2 | - | - | |
| | | | 40 | | 73.5 | - | - | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | 5 | 30 | - | Polycarbonate | - | - | - | [Threepopnakkul et al. (2009) |
| 5 | | | - | | 67.0 | 6.4 | - | |
| 10 | | | - | | 65.0 | 4.0 | - | |
| 20 | | | - | | 72.0 | 4.0 | - | |
| 5 | 1 | 25 | 0 | Polypropylene | 14.8 | - | 75.0 | Kasima et al. (2015) |
| | | | 30 | | 16.7 | - | 64.0 | |
| | | | 40 | | 11.1 | - | 64.0 | |
| | | | 50 | | 10.3 | - | 66.0 | |
| | | | 60 | | 12.7 | - | 56.0 | |
| | | | 70 | | 3.5 | - | 55.0 | |
| 0 | 18 | 28 | 20 | Natural rubber (NR) | 7.2 | - | - | Lopattananon et al. (2006) |
| 1 | | | | | 5.9 | - | - | |
| 3 | | | | | 6.0 | - | - | |
| 5 | | | | | 10.0 | - | - | |
| 7 | | | | | 7.8 | - | - | |

## IV. CONCLUSION

A review of the various surface treatments and properties of banana, sisal and pineapple fibers – all agro waste materials and their composites has been presented. These fibers though with mechanical properties less than synthetic fibers such as glass and carbon have also exhibited good mechanical properties and are fast replacing the synthetic fibers in some applications due to their low cost, easy of processing, and biodegradability. From this review, these natural fibers indicated a low density characteristic which is very important in energy consumption considerations in automobile and transport applications. The major drawback to the extensive use of these natural fibers is their high affinity for water/moisture which various surface treatments are addressing and the variability in their mechanical properties due to the crop age, extraction method, surface treatment and other processing conditions. The mechanical properties of these natural fibers composites as reviewed is good enough for both automotive, and construction industries applications. However, further improvement to these properties can be achieved by adopting faster methods of these fiber extractions as to avoid rotting and weakling of the fibers as experienced with water retting methods. This trend can be achieved using enzymes retting methods – which takes about 3days to produces stronger fibers against dew or water retting that takes weeks. Again other cleaner technology of fiber extraction should be explored and also more surface treatment chemicals with varying concentrations should be explored to bring about an ideal route in natural fiber processing and utilization for polymer matrix composite applications.

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