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A COMPREHENSIVE STUDY ON BIOMATERIALS AND THEIR APPLICATION IN PROSTHESIS

CHANDRASHEKHAR S. MALALLI

Research scholar, Department of Industrial Engineering and Management, BMS college of Engineering, Bengaluru, India. Email: csmalalli93@gmail.com

B.R. RAMJI

Professor, Department of Industrial Engineering and Management, BMS College of Engineering, Bangalore, India. Email: ramji.iem@bmsce.ac.in

Abstract

Natural fiber-reinforced polymer composites (NFRP) as eco-friendly and sustainable materials were receiving attention from researchers due to their manufacturing and disposal have a small load on the environment other than the synthetic polymer composites. These composites are potentially used in medical devices and various engineering applications, due to some unique characteristics, such as biocompatibility, high specific strength, low thermal conductivity, and Biodegradability. The aim of the paper is to examine the latest technology in the research and development of NFRP. This review article emphasizes research effort on fabrication of NFRP and its material properties like tensile strength, flexural strength, impact strength, biodegradability, and biocompatibility. It also reports that natural fiber PALF-Sisal reinforced polymer composites have better mechanical performance in the application of prosthesis than synthetic fiber reinforced polymers.

Index Terms: NFRP, Biocompatible, Flexural strength, Biodegradable, Impact strength, Tensile strength.

Abbreviations:

NFRP: Natural fiber-reinforced polymer composites; PALF: Pineapple leaf fiber; FTIR: Fourier transform infrared spectroscopy; DSC: Differential scanning calorimetry; TGA: Thermogravimetric analysis; SEM: Scanning electron microscope; PVA: Poly vinyl alcohol;

1. INTRODUCTION

In a modern technology, natural fibers have received more scope and can be used in many applications that replace synthetic fibers. Matched with synthetic fibers, natural fibers are little advantages, i.e., light weight, low cost, renewability, etc. [1-15]. Though natural fiber reinforced polymer composites are attractive in their mechanical characteristics so it can be used in automobiles, construction, and biomedicine due to their relatively high specific strength, biocompatibility and biodegradability [2, 3]. The large number of natural fibers available in the global agricultural market is of great significance for improving health, food sustainability with secured provision and poverty removal [4]. Hence, the UN Food and Agriculture Organization (FAO) declared 2009 as international Year of Natural Fibers.

Composites are natural materials made of two or more constituent materials with significantly varying physical and chemical properties. However, naturally occurring fibers viz. jute, hemp, sisal, bamboo, pineapple etc. were environmentally mapped with synthetic fiber, mainly because they reduce the environmental impact of natural fiber production and reduce quantities of environmentally harmful polymers [1, 20]. Mechanical properties of sisal fibers from studies made on sisal plant are found in Kenya, China and India. Tensile strength of sisal fiber ranges from 347 MPa in Kenya and China to 400-700 MPa in India. In general, the tensile strength of treated fiber composites is greater than that of untreated fibers [1, 3]. Earlier research report indicates alkali treated short fiber's tensile strength and flexural strength higher than the long fiber [26]. Though PALF as highest percentage of cellulose content and smaller microfibril angle, which is responsible factor to enhance the tensile properties [4]. The chemical composition of fiber varies with places, age, type, soil, rainfall, and farming methods. However, sisal fiber constituents include 6-7% lignin, 10% pectin, 12% hemicellulose, and 71% cellulose. The proportion of fibers varies from 10% to 40%. In general, fiber orientation includes chopped, unidirectional and random dispersion. Hence tensile strength of 30% wt. of sisal fiber-polyester composite is 25 to 59 MPa [5, 16]. Experimentations were conducted on sisal fibers-based epoxy and polyester resin [6]. Generally, natural plant fibers contain higher % of cellulose, which are mainly responsible for absorb the moisture, some spirally wound cellulose microfibers and are bound together through an amorphous lignin matrix. However, it plays a role in resisting biological attacks and provides strength [11]. The alkali treatment of mixed sisal, glass fiber, polymer composite's the impact strength, flexural strength and tensile strength were determined [7, 8]. Although sisal fiber with non-polymer composites were observed [9]. Earlier research defines the different weight percentages of PALF composite materials is reinforced with Polyvinyl alcohol completely biodegradable, also enhances better mechanical properties and so find applications in agriculture and packaging [10].

Plant oil resin reinforced with ramie stockinette composite fiber socket it resists higher load (6180 N) than that of nylon glass socket (2223 N) [13]. Methyl methacrylate resin reinforced with water hyacinth fiber (fiber with an angle of 45º) has a higher tensile strength (48 N) than nylon glass fiber (43 N) [14]. However, the use of agricultural biomass pineapple leaf fiber-reinforced lower limb prosthetic socket polymers instead of non-recyclable synthetic fiber-reinforced prosthetic sockets [3, 4]. Table 1 indicates the natural fibers physical properties. Fig 1. Defines the structure of natural fiber. The physical and mechanical structure (morphology and molecular structure) were analyzed by FTIR, DSC, SEM, TGA and Leica biological microscope [12]. The surface of the fiber becomes rougher and mechanical properties parallel to the synthetic fiber can be obtained [11-26]. Table 2. Lists the latest composite materials manufactured by different processing approach.

This is understandable that Natural Fiber Reinforced Polymer has encountered momentous changes in the past few decades, eventually become an ideal material for

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many applications. Due to extensive research on NFRP, which defines to the development of NFRP. The article reviews the performance of natural fiber composites in terms of mechanical properties, chemical and water resistance, biodegradability and characteristics. The survey also notified the effects of various hybridizations on the work of NFRP.

2. PINEAPPLE

Pineapple belongs to a subclass of monocotyledonous plants, belonging to the genus Bromeliad, and false pineapple, it is called "Queen of Fruit Crops" and be a part of the bromeliaceae. It is classified as one among the world's tropical fruits, as well as a rare monocot fruit like bananas. Pineapple is a fruit that originated in Brazil and has since spread to other parts of the world, particularly tropical regions. Asia (India, Philippines, China, Indonesia, and Thailand), Central and South America (Brazil and Costa Rica) and Africa (South Africa and Nigeria) are the dominant countries of growing this vegetation. In 2012, pineapple was largely produced by the Thailand, next to that was produced by Philippines, Brazil and Costa Rica [12]. According to the classification method of Hume and Muller (1904), the three categories of pineapple are available. These are Spanish pineapple, Cayenne pineapple and Queen Ananus. Since 1990, the World has produced 23.33 million metric tons of pineapple, and the planting region has also enhanced. The world's largest producing continent is Asia which produces up to 10.88 million metric tons (46.62%), followed by the United States 8.68 million metric tons (37.18%) and 3.65 million tons in Africa (15.65%).

Table 1: The physical properties of natural fiber [71]

Fiber	Fiber diameter (μm)	Fiber density (g/m^3)	Tensile strength (MPa)	Tensile modulus (GPa)	% of Elongation
Abaca	10-30	1.5	430-813	31.1-33.6	2.9-10
Bamboo	88-125	0.91-1.26	503	35.91	1.4
Bagasse	-	1.2	20-290	19-27	1.1
Banana	100-250	1.35	529-914	27-32	2.6-5.9
Coir	150-250	1.15-1.25	131-220	4-6	15-40
Cotton	-	1.51	400	12	0.3-10
Flax	25	1.4	800-1500	60-80	1.2-1.6
Hemp	25-600	1.48	550-900	70	1.6-4.0
Henequen	-	1.2-1.4	430-570	10-16.3	3.7-5.9
Jute	25-250	1.3-1.48	393-800	0.13-26.5	1.16-1.80
Kenaf	-	1.25-1.4	284-930	21-60	1.6
Pine apple	50	1.44	413-1627	60-82	14.5
Ramie	20-280	1.3-1.5	400-938	61.4-128	3.6-3.8
Rice husk	-	0.5-0.7	-	-	-
Sisal	50-200	1.3-1.4	390-450	12-41	2.3-2.5

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Fig. 1: Structure of natural fiber composites [71]

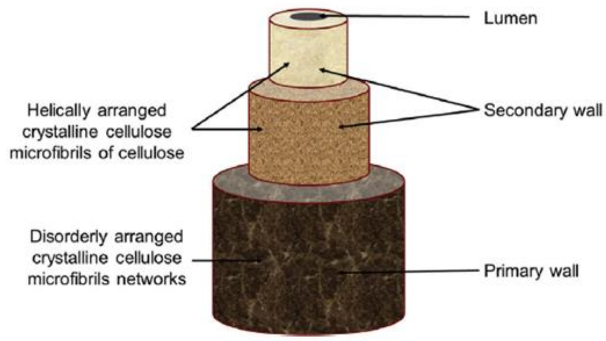

Table 2: Fabricated techniques of composites by different processing methods

Matrix	Types of Fiber	Method of Fabrication	References
Vinyl-ester matrix	PALF	Hand-layup method	[15]
Polyester matrix	Sisal fiber	Resin transfer molding technique	[16]
Polyester matrix	Jute fiber Palmyra and leaf stalk fiber	Compression molding	[17]
Epoxy matrix	Flax–Carbon fiber	Platen press process	[18]
Epoxy matrix	Flax hemp/ Jute/ fiber	Hand-layup method	[19]
Epoxy matrix	Sisal fiber and Aloevera	Hand layup method	[20]
Epoxy matrix	Pineapple, Glass and Jute fiber,	Hand layup method	[21]
Epoxy matrix	Glass /Carbon	Vacuum bagging technique	[22]
Epoxy matrix	Ramie fiber	Vacuum infusion process	[23]
Epoxy matrix	Kenaf fiber	Hand lay-up technique	[24]
Epoxy matrix	Flax/Linen/Bamboo	Vacuum bagging process	[25]
Plant oil resin	Ramie/Stockinet	Standard layup method	[13]
Epoxy resin	Coir-glass	Hand lay-up method	[26]
Poly-lactic acid	PALF/chopstick	Counter-rotating internal mixer	[27]
Polypropylene matrix	Kenaf/Jute	Hot pressing method	[28]
Methyl methacrylate	Water hyacinth	Compression molding	[14]
Polypropylene matrix	Hemp fiber	Twin-screw extruder	[29]
Polypropylene matrix	Glass fiber / Short hemp fiber	Injection molding technique	[30]
Polypropylene matrix	carbon /Sisal, Glass /Sisal	Method of single-screw Co-rotating extrude	[31]
Polypropylene matrix	Coir fiber	Method of twin-screw extruder	[32]

3. PINEAPPLE LEAF

The stem of the pineapple plant is short. It will produce leaf rosettes near the maturity period, which are elongated and spit out spirally configured fibrous leaves. The adult plant has around 80 leaves of various shapes, lengths. When mature, they have leaves which are 2–3 inches wide, 3 feet long, sword-shaped and dark green, with spines on their edges. The leaves are pointed, thin, long and waxy with inherent hardness [13].

3.1 Composition of PALF

The molecular chain arrangement of cellulose content of PALF is equivalent to that of cellulosic fibers present in the cotton. Comparatively, type I cellulose content maximum in PALF and low microfibrillar angle which provides the enormous mechanical strength.

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However, raw fiber can withstand high stress-strain. Many researchers have studied the physical properties, mechanical and chemical contents of the PALF (see Table 3.). It has been estimated that, the quality properties of the PALF are maximum. PALF has co-related specific strength, mechanical specific modulus properties concerning the glass fiber. While estimating through the Optical microscope, it has been come to conclusion that the PALF is also a vegetable fiber having multiple cells with a diameter approximately of 10μm and the average 4.5μm length, and diameter of an elementary fiber is up to 25–34μm. The aspect ratio (AR) is of about 450, In comparison with the jute fiber it will boost by four time and equals to the sisal in the capacity of fiber bundle [2]

Table 3: Individual physical and mechanical properties of pineapple leaf fibre (PALF) [2]

Diameter of Fiber (micrometer)	Tensile strength of fiber (MPa)	Young's Modulus of fiber (GPa)	Fiber Elongation at break (%)	Density of fiber (g/cm^3)
5.0-30.0	170	6.26	0.8-1.6	1.44
105-300	293	18.934	1.41	-
50-91	210-695	15-53	-	-
60	413-420	6.2	1.6	1.52
30-60	413	6.5	1.6	1.52
20-80	413-1627	34.5-82.5	1.6	1.526

4. PALF EXPLORATION

For the extraction of the PALF, the water retting is preliminarily used and next to carried out by the manual method which involves the tool of hand scrapping called 'ketam'. The extraction by a decorticator which involves the mechanism of leaves' crushing. After receiving the fibre bundles, they are presented to the scutching mechanism, which requires physical separation from one another. Scutching includes two steps i.e., swingling and breaking [2]. In generally PALF was extracted by holding the leaves firmly against a hard, smooth base, and rubbing their surfaces with pumice. The fibers obtained were removed and washed with methanol for 2h. They were then dried and weighed [72].

5. SISAL

Sisal (Spanish: sisal), also known as Agave sisalana, is a plant native to southern Mexico that has been widely cultivated and naturalised in a number of nations. It creates fibres that are good and are utilised in a variety of products. Because hemp has been the primary source of fibre for centuries and other fibre sources are named after it, it is frequently referred to as "sisal." Sisal fibre is generally used for ropes and strands,

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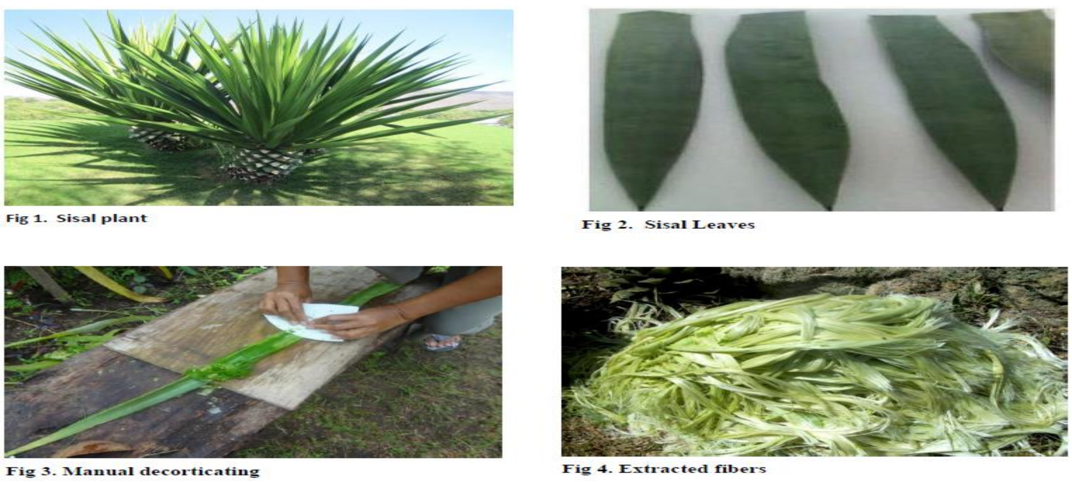
but it may also be found in paper, fabric, footwear, headgear, purses, carpets, geotextiles, and darts, among other things. They are also utilised in composite glass fibres, rubber, and cement products as reinforced composites materials [1].

5.1 Exploration of sisal fibres and alkaline treatment

The methods for extracting fiber are mechanical degumming and manual. Degumming is a method of extracting fiber via microbial processes. It is a biological phenomenon; it needs warm temperature and moisture for microbial action. Then, manual peeling is a task of scraping and breaking sisal leaves with a blunt metal or wooden pole. When the scrapping of the leaves are done. The fiber is extracted by manually removing the pulp from the sisal leaf. The fiber was immersed in water for 2 hours, then washed and combed to remove any remaining pulp. The fibers were then air-dried for 3 days at room temperature [1]. Figure 3 shows the extraction process of sisal fiber.

Fig. 2:1) Sisal plant, 2) Leaves, 3) Manual decorticating and 4) Extracted fibers [1].



As shown in Figure 3, the fiber is treated with an alkaline solution of sodium hydroxide (NaOH) to clean the surface of the fiber and improve the adhesion to the matrix. The alkaline solution is a mixture of distilled water and 4% (weight) NaOH particles. The weight ratio of fiber to solution is maintained at 1:11. Soak the sisal fiber in the solution for 2 h. After soaking, the fibers were washed with running water to rinse off all the NaOH, and dried at room temperature for up to 3 days [1]. For comparison, untreated fibers were also used as test samples.

6. TENSILE STRENGTH

According to the ASTM D3039 standard tensile test specimens were prepared and using a universal testing machine to test a specimen. Young's modulus, Tensile strength, and percentage of elongation are directly related to the denture socket reported that the pineapple fiber epoxy composite material and the pineapple fiber polyester composite material, the optimal fiber loading that produces the highest tensile strength is 50 wt. % Fiber loading, and it is also observed that the fiber loading is between 40 and 50 wt. % there is a slight increase in tensile properties [3]. The renewable natural fibers have the potential to reduce the hazards associated with manufacturing prosthetic socket without reducing and damaging the strength of the socket. In other study, Water hyacinth fibers with 45^0 woven patterns reinforced with the methyl methacrylate resin, and obtaining a maximum tensile strength is 47.19MPa and this composites specimen withstanding maximum load of 177 kg/mm^2. However, they replace the conventional acrylic and glass fiber composite (43 MPa) used in prosthetic limb socket [14].

Alkaline treatment of fibers which are enhance tensile, compressive and impact strength. Content of fibers in the composite varies by volume it increases impact strength fiber composites. However, compressive and the tensile strength are reduced. Where the fiber content increases with increasing the rate of water absorption rate [1]. [2] In generally mechanical properties and its few factors that affect the performance, such as variety type, porosity, orientation of fiber, length of fiber, type of matrix. The treatment of surface, coupling agent to increase the mechanical strength, technical solutions to the conventional problems in the processing of the improvement of tensile properties, the improvement of durability, interface incompatibility, and thermal stability [4]. However the typical functions of fiber reinforced composites including thermal energy, biodegradability, vibration damping and thermal insulation performance. Therefore, the composite materials were made of full usage of their functions rather than the mechanical properties are very significant in natural fiber reinforced composite materials for future development [5].

The hybrid composite specimen prepared by glass-sisal fiber reinforced with epoxy with various length. Compared with the lengths of fiber 1cm and 3 cm, in which fiber length has been 2cm the mechanical properties are optimally enhanced. The chemical resistance of other chemicals is significantly improved, except for toluene and sodium carbonate [7]. [8] sisal-glass hybrid composites developed by varying sisal fiber content of 0, 10, 20, 30, and 40 wt. %. It is observed that tensile strength in longitudinal fiber is higher than the fibers are in transverse direction. Generally maximum tensile strength resulted in pure glass fiber composites and it’s also showing maximum flexural strength. Scanning electron microscope (SEM) were used to analyze the internal structure of the surface fracture, fiber delamination and failure morphology.

In generally the mechanical properties and water absorption properties of the sisal fiber after alkaline treatment kept under different temperature and time conditions, and described the water absorption and its mechanical properties. However tensile properties (modulus and tensile strength) of the short sisal fiber reinforced cellulose derivative with various fiber loads were corelated with the calculated values were getting from the theory of reinforcement [9]. Mortar reinforced with long unidirectional plant fibers mechanical properties (such as palm fiber and sisal fiber). The laminated mortar samples were produced with volume fraction fibers ranging from 0 to 1.95 percent [10]. The fiber-reinforced polymer composite material proposed has many usages i.e., easy processing, low density and high strength. A single polymer matrix due to the addition of more than one fiber has led to the development of hybrid composite materials. The mechanical properties of single fiber reinforced polymer composites can be enhanced by Hybridization. So, it will be the positive signs of advancements in the mechanical properties by the introduction of relatively high elongation fibers [11]. However, the yield of pineapple leaf fiber is between 2.5-3%. The physical and mechanical structure (morphology and molecular structure) of the fiber was analyzed by different instruments (such as FTIR, DSC, TGA and its structure under the microscope) [12]. In general prosthetic limb made of a plant-based composite material, so hemp fiber mesh reinforced with the vegetable oleoresin, which bears a higher load of 6180N than the 4255N nylon glass tube [13]. Therefore, the plant resin and hemp fiber composite socket have an alternative standard layout. The tensile strength of several natural fiber-reinforced matrix composites is shown in Table 4.

Table 4: Tensile strength of various natural composites.

Natural Fibers	Matrix	Wt.%	Tensile Strength (MPa)	Reference
PALF	Polyester	50	69.12	[3]
PALF	Epoxy	50	80.12	[3]
PALF	Poly vinyl alcohol	40	33	[2]
Sisal	Polypropylene	30	35	[33]
Bamboo	Polypropylene	50	28.95	[34]
Water hyacinth	Methyl methacrylate	70	47.19	[14]
Ramie-stockinett	Plant oil resin	10	80.8	[13]
Coir	Polypropylene	30	26.616	[35]
Flax	Polypropylene	30	25	[36]
Hemp	Polypropylene	30	18	[37]
Kenaf	Polypropylene	30	46	[38]
Jute	Polypropylene	20	24	[39]
Banana	Polypropylene	30	45.25	[40]
Cotton	Polypropylene	30	35.3	[41]

7. FLEXURAL STRENGTH

The composite material’s flexural strength is different from the tensile strength, by means it will not match the same features as the tensile strength. This is because of the greater impact Parameters which increases its performance. If stronger is the fiber reinforcement, higher is the tensile strength, if it is breaking easily then the strength of the flexural is higher. This process depends upon the homogeneity and heterogeneity of the fiber composite materials. The bending strength is much needed in the design of

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beams, shafts and other structures [42]. The most influential parameter is higher the availability of fibers when determining the bending strength of composites. Bending characteristics are very important in denture sockets, because the materials used must be strong, flexible to support the weight of the human body, and able to withstand the dynamic loads that may occur in the gait system [3]. The fiber impregnation, the flexural strength and flexural modulus increases as the fiber-fiber contact increases. Compared with glass fiber and pineapple polyester composite material, epoxy composite material has higher strength, which can be explained that the epoxy composite material reinforced by pineapple leaf fiber is higher than tensile stress due to its higher bending strength and modulus strength. More able to withstand bending force [43]. At higher the fiber volume ratios, the flexural modulus reduced by the contact of fibers. The void formation and fiber orientation are some of the main reasons [44].

The mechanical properties of composites of PALF and banana fiber reinforced polymer are compared with glass fiber reinforced composites [3, 45]. A phenol-formaldehyde matrix is used to make composite materials with different fiber lengths. When the fiber content increased from 10% to 40%, the bending performance of the composite material increased by 24%. Compared with glass fiber composites, the change in bending strength of 40% banana fiber composites is only 5 MPa. Compared with the non-interacted composite material strength with the value of 141.30 MPa, the flexural strength of the alkali-treated bamboo epoxy composite material is increased by 182.29 MPa [46]. Flexural strength of pure, treated, untreated, and epoxy kenaf fiber composites were studied. Compare with the pure epoxy composites, bending strength of treated, untreated fiber composites increased by 74% and 67%, respectively. This is because the matrix penetrates into the fiber structure, making the combination of matrix, fiber sparser, which results in withstanding bulk load-bearing capacity and it resists the fiber peeling, pulling outwards. In comparison to the fiber length, 6% alkali treated short fiber (10 mm) has higher flexural strength than 5% alkali treated fiber (15 mm). The bending characteristics can be determined sophistically by the chemical treatment identified in [26, 47].

Studies have shown that shorter-length fibers treated with high-concentration alkali can improve bending properties. Fiber reinforcement content has an impact on the strength of flexural and flexural modulus. By the results it is concluded that the flexural modulus of the composite increased, but the flexural strength of the composite specimen reduced. This is because of the kinking of the fiber reinforced material. The fiber’s kinks are the root cause of debonding of the fiber under low bending load [48]. After 25% by weight Kenaf fiber is treated with 5% NaOH solution and 5% silane, it shows the greatest bending strength. The author suggests that the combination of alkali and silane treatment can improve the flexural strength [49]. [50] Discussed the mechanical properties of kenaf and hemp fiber reinforced epoxy composites and its effect by the application of chemical treatment. The outcomes showed that the flexural strength

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characteristics of the chemically treated composite material did not change significantly. [51] To characterize, uraua fiber reinforcing with polyethylene during fabrication process added hydroxyl polybutadiene act as an impact modifier, and it's developing good adhesion to fiber and matrix. Although, the reduced flexural strength due to rubber behavior of polyethylene. Following Table 5. Indicates the flexural strength of various natural fiber-composites.

Table 5: Flexural-strength of various natural composites

Natural Fiber	Matrix	Weight%	Flexural Strength (MPa)	References
PALF	Polyester	50	53.02 ± 1.20	[3]
PALF	Epoxy	50	81.27 ± 1.27	[3]
Sisal	Polypropylene	30	20	[2]
Bamboo	Polypropylene	50	49.56	[33]
Coir	Polypropylene	30	50.532	[34]
Flax	Polypropylene	30	43	[35]
Hemp	Polypropylene	30	33	[36]
Kenaf	Polypropylene	30	58	[37]
Jute	Polypropylene	20	45	[38]
Banana	Polypropylene	30	48	[39]
Cotton	Polypropylene	30	145	[40]

8. NATURAL FIBER COMPOSITE'S IMPACT STRENGTH

Generally, the impact strength of pure polymer specimen was very poor, Because of their brittleness the energy would be absorbed by the material under a gradual load per unit area it will defined as impact strength. The introduction of fibers into the polymer can improve the toughness of the composite material, which is conducive to improving the impact strength [52]. [53] The impact strength of composite fiber factor that affects the bonding between fibers and matrix. The impact strength increases as the fiber load increases because of the good adhesion between fiber-polymer composites. [54] In various research study defines that the impact strength energy absorption of the composites are largely depends upon on the bonding between the hydrogen fibers and the fiber type are critical to enhancing the impact strength. [55] Reported that when the weight percentage of fiber-reinforced materials was increased, the impact strength of composite materials increased linearly.

Prepared permeable bamboo and epoxy composite materials and discussed the various properties (mechanical) of the composite materials. In which it effects of the infiltrated bamboo fiber reinforced material, compared with the bamboo fiber composite material (49.33 kj/m^2), the composite material's impact strength is increased to be 67.14 kj/m^2 [56]. The thickness of the coconut shell fiber-polyester composite material was changed from 2-6mm, and the strength of impact of the composite material was studied. The

6mm composite material absorbs more impact energy than other composite materials [57]. [58] Studied the enhanced mechanical properties of jute-epoxy resin and jute-polyester matrix. Compared with jute epoxy resin, jute polyester composite exhibits the greatest impact strength. Natural fibre reinforced polymer composites' impact strength is shown in Table 6.

Table 6: Impact strength of various natural composite

Fiber	Matrix	Weight %	Impact strength (J/m)	References
PALF	Polyester	50	65	[3]
PALF	Epoxy	50	48	[3]
Sisal	Polypropylene	30	58	[33]
Banana	Polypropylene	30	46.03	[40]
Bamboo	Polypropylene	50	27.32	[34]
Coir	Polypropylene	30	24.32	[35]
Jute	Polypropylene	20	39.62	[39]
Hemp	Polypropylene	30	40.13	[37]

9. BIO-DEGRADABILITY CHARACTERISTICS OF NATURAL FIBER COMPOSITE

PVA, cassava-based bioplastic resin, thermoplastic starch (TPS), poly-hydroxy-butyrate-hydroxy-valerate (PHBV), and soy-based resin are types of biodegradable polymers [2]. Composites are today's miracle materials, fiber composites have become indispensable in a wide range of applications due to their high strength, flexibility and standardization. Few researchers have described the deterioration mechanism of fiber composite materials by experimental studies on photodegradation, exposure to various environmental conditions, and attack by micro bacteria. Some researcher analyses first resin at surface of specimen decomposes, then embedded abaca fiber-resin are exposed, it formed the interfacial gap. Finally, degradation in abaca bundles and resin composites [4]. To secure the longer durability of these composite materials while study their biodegradability test. The weight loss of the composite material after degradation understands the degradation mechanism. It has been found that the influence of the environment in which NFRP is used is a crucial factor, because natural fibers are easily degraded in biological, chemical, photochemical and aqueous environments. Generally, in biological environments bacteria and fungi are used to test the biodegradability of composite specimen [59]. Ideally, these tests are performed only on bio-degradable thermoplastic composite specimen. The disposal of the non-biodegradable composite specimen has become an important reason for the current evolution of bio-degradable composite materials. nowadays, researchers are committed to improving the bio-degradability of composite materials by modifying the matrix and reinforcing materials. [60] The biodegradability of wood polymer composites during the fungal decay test. Their results indicates that the esterification of the fiber, the fungi attacked on the fiber

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was resisted. The study concluded that resistance to biological attack of any natural fiber composite material can be improved by esterification on the fiber.

The biological composition of jute fiber composites material under laboratory conditions. Composite sample is exposed to maintained moisture, observes the composite materials that have been treated with fibers exhibit resistance to bio-availability. High concentration alkali treatment shows higher resistance than low concentration alkali treatment [61]. [62] However, the biodegradability of composite materials are an anaerobic digestion, composting, and long-term soil culture environments. Surface damage was recorded in the SEM image of the polyester composite, but no surface damages in poly-propylene and poly-ethylene. [63] The polyurethane (PU) foam prepared with crude-glycerin and petroleum-based polyols was used to study their biodegradability. These foams were studied under an anaerobic digestion and soil cultivation conditions. It was found that when crude glyceryl polyols were used, microbes attacked the foam’s ester segment more. [64] The ester bonds of PU foam were attacked by micro-bacterial. In the polyester-matrix, the attack of microorganisms is also mainly caused by the hydrolysis of the ester bond [65]. The further increased biodegradation of sisal fiber causes the loss of mechanical strength of the composite specimen. [66] Reported that the manufacturing method of composite materials has a significant impact on biodegradation. Similarly, it was found that the biodegradability of the composite material was higher, because the increase in sample time was a burst of ultraviolet radiation. It is worth noting that the lignin component can be degraded by ultraviolet radiation, and moisture will weaken the cellulose structure of the fiber [67].

Studied Poly Propylene composites with wood chip reinforcement. The composite material is exposed to the various degradation conditions, including micro-bacterial attack and weather conditions. The inclusion of wood chips increases the bio-degradability of the composite due to the hydrophilic nature of wood chips. Significant degradation due to the micro-bacterial attack and hydrolysis [68]. The degradation of the interface area of bamboo fiber composites [69]. However, in the soil burial test, the biodegradability of poly-lactic acid and flax fiber composites was studied [70]. It was found that the strength of the composite material was reduced due to the degradation. To the research bio-degradation of composite materials increases due to the increase in fiber content of composite specimen.

10. CONCLUSION AND FUTURE SCOPE

It is found from the research that there are many studies in the field of natural fibers and natural hybrid composite materials, and have a broad range of applications in various manufacturing field. While in depth analysis of natural polymer composites and its performance, including mechanical properties, processing characteristics, and biodegradability characterization to analyze the effects of various types of alkaline treatments and hybridization. However, hybrid composite materials have been developed due to their excellent properties and provide solutions to the limitations of natural fiber composite materials in various medical and industrial application. This opens up the manufacture of new composite materials that combine natural fibers and man-made fiber materials, which will be a better scope for solving economic and ecological problems are in current and future issue. What's more, the quality of natural fibers can be improved through chemical treatment, which will lead to a revolution in commercialization. Although NFRP showed excellent performance, Due to fiber modifications and poor processing processes, the composite material was found to be uneven. The goal of future study is to gain a better knowledge of how natural fibers interact with polymer matrix.

The increased usage of NFRP in the automotive, medical, and other production industries due to technology advancements contributes to a more sustainable and environmentally friendly. Because composite materials, such as low-weight, cheap material, biodegradation, can be used as prosthesis in bio-medical application to solve unsolved dilemmas. Extending the implementation of NFC to construction and building materials can help to reduce the use of forest land for the manufacture of wood items. The use of several natural fibers in composite manufacture was investigated. However, PALF and Sisal fibers must be tested in composite material fabrication and performance analysis, which will lead to the development of novel composite materials with superior performance.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationship that could have appeared to influence the work reported in this paper.

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