

# **A Review on Composite Materials from Natural Plant Resources: Recent Trends and Future Potentials**

Mr. Berhanu Tolessa<sup>1</sup>, Dr. Balkeshwar Singh<sup>2</sup>

Research Scholar, Department of Manufacturing Engineering, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia<sup>1</sup>

Professor, Department of Mechanical Design and Manufacturing Engineering, Adama Science and Technology University, Adama, Ethiopia<sup>2</sup>

**ABSTRACT:** Because of different environmental concerns natural fiber has been gaining special focus of technologists, engineers, industrial and manufacture for its extremely large potential for application in various engineering utility in the site of building construction, railway, automotive, packaging, defense etc. Further, natural fiber composite is cost effective, low density, renewable material, environment friendly and decrease CO<sub>2</sub> evolution. These natural fibers have been utilized as reinforcing agent in polymeric, cement, matrix to increase the physical, mechanical/engineering properties. Plant, animal and asbestos fiber are the main class of natural fibers which are deeply used in product development and manufacturing. From them, plant fibers percentages utilize is much higher than the animal and asbestos fibers, due to its renewability, recyclability, availability, environment friendliness. Therefore, this review mainly focused on different research works previously made on different plant fibers like jute, hemp, flax, cotton, sisal for the manufacturing of natural fiber reinforced composite products for various applications.

The main focus of the researchers in this sites were extraction and processing of different plant natural fibers, properties of plant natural fibers, natural fiber reinforced composites (NFRC) fabrication systems, properties of NFRC with various types of synthetic matrix materials like polyester, epoxy, vinyl ester, and polypropylene to achieve the best performance of NFRC for direct applications.

**KEYWORDS:** Fiber, Matrix, Composite, Plant Fiber, Natural, Synthetic.

## **I. INTRODUCTION**

Composites are combinations of two or more than two materials in which one of the materials, is reinforcing phase (fibers, sheets or particles) and the other is matrix phase (polymer, metal or ceramic). A composite material is made by combining two or more materials to give a unique combination of properties [1]. A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other [2]. Plant fibres are being increasingly developed for the reinforcement of composite materials. Among many plant fibres, flax is particularly used for this purpose [3].

Now a day reinforced polymer composite become more popular due to their various applications because of their high specific strength and light weight. Polymer (resin) is classified in two types thermoplastics (polyethylene (PE), polypropylene (PP), polyether ether ketone (PEEK), polyvinyl chloride (PVC), polystyrene (PS), polyolefin etc.) and thermosets (epoxy, polyester, and phenol-formaldehyde resin, etc.)

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

## II. CLASSIFICATION OF NATURAL FIBERS

Natural fibers are grouped into three categories. These are plant fibers, animal fibers and mineral fibers as shown in fig.1. Plant fibers are prominent types of natural fibers and these are generally comprised mainly of cellulose, hemicellulose, lignin, pectin. Important natural fibers are cotton, jute, flax, ramie, sisal and hemp. Cellulose fibers are mainly used in manufacturing of paper and cloth. This fiber is categorized into seed fibers, leaf fibers, bast fiber/ stem fiber, fruit fiber, stalk fiber.

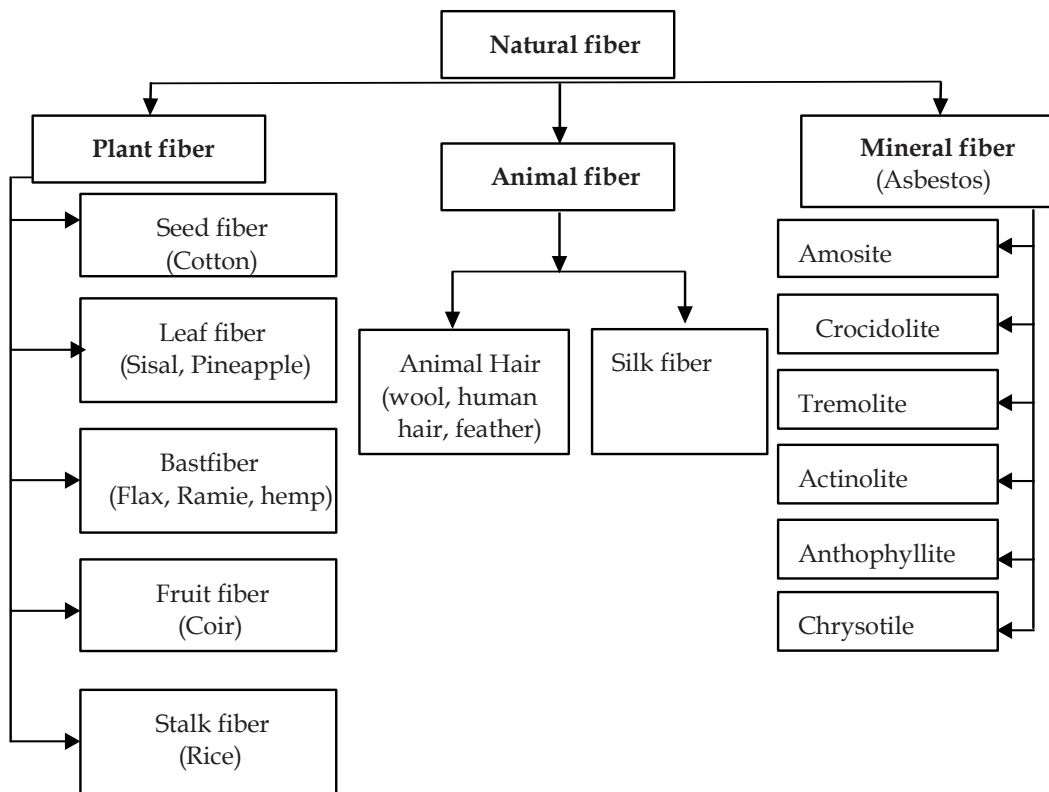


Fig.1. Classification of natural fibers

## III. EXTRACTION AND PROCESSING OF PLANT FIBERS

### 3.1 Jute Fiber

Retting is the process of extracting fiber from the long lasting life stem or bast or the bast fiber plants. The retting process of jute fiber can be categorized as: mechanical retting (hammering), chemical retting (boiling & applying chemicals), steam/vapor/dew retting and water or microbial retting. Availability of water and the cost of retting process is main parameter to select type of retting. Jute stalks after harvesting are submerged in soft running water in bundles for 20 days, and is grabbed in bundles and hit with a long wooden hammer to make the fiber loose from the jute hurd or core. Afterwards, the extracted fibbers is further washed with fresh water and allowed to dry. Finally, get dry processed fiber for different application.

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

### 3.2 Sisal Fiber

Sisal fiber can be extracted from its leaves by Retting, Boiling and Mechanical extraction ways. Water retting is a traditional biodegradation process involving microbial decomposition (breaking of the chemical bonds) of sisal leaves, which separates the fiber from the pith. The fibers are washed and processed further. This process takes 15–21 days for a single cycle of extraction and decrease the quality of fiber. Retting is a very slow, water intensive process, unhygienic, and not eco-friendly. Mechanical extraction involves inserting leaves into a machine “raspador machine” and pulling the raw material out as shown in fig.2. This process does not deteriorate fiber quality and is suitable for small-scale operations and is efficient, versatile, cost effective and eco-friendly process. Residues produced during and after extraction of fiber are about 96% which is useful for biogas generation, composting, and isolation of a steroid, ecogenin, making paper, biodegradable polymer and wax.



Fig. 2. Mechanical process of sisal fiber extraction using raspador machine[4]

### 3.3 Flax Fiber

Flax fibers were collected from different sources with the intention to provide characteristically various physical and chemical properties. The fiber bundles are located just under the skin and embedded in bast tissue. Harvested the plants are spread over the ground for retting, in which the pectin layer that binds the fibers to the bast tissue and the flax stem is broken down. In past, retting (water retting) was usually delegated by immersing bundles of flax stem into running water or in standing water in ponds. Fermentation by anaerobic bacteria degrades the pectins and other substances that bind the fibers to the stem. These fiber bundles are still relatively coarse and thick which are then processed in the hackling process for more application.

### 3.4 Cotton Fiber

Fifteen percent of world cotton production is received on roller gins and almost all the rest of cotton is seeing ginned in most countries. Cotton is a shrubby plant belongs to Mallow family. Its name refers to the cream-colored fluffy fibers surrounding small cotton seeds called a boll. The small, sticky seeds are separated from the wool in order to process the cotton for spinning and weaving. De-seeded cotton is cleaned, carded (fibers aligned), spun, and woven into a fabric that is also show to as cotton. The harvested cotton is cleaned to separate dirt, seeds, and short lint from the cotton.

## IV. PROPERTIES OF NATURAL FIBERS

### 4.1 Characteristics of Plant Fibers

Plant fibers are a composite material formed by nature. The fibers are basically not flexible, crystalline cellulose micro fibril-reinforced amorphous lignin and/or with hemi cellulosic matrix. The percentage composition of each of these components varies for different fibers. Generally, the fiber contains 60-80 % cellulose, 5-20% lignin and up to

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

20% moisture [5, 6]. During the biological synthesis of plant cell walls, polysaccharides such as cellulose and hemicellulose are produced simultaneously. Lignin fills the space between the polysaccharide fibers, cementing them together. This lignification process causes a stiffening of cell walls and the carbohydrate is covered from chemical and physical damage [5]. Hemicellulose is responsible for the biodegradation, micro absorption and thermal degradation of the fiber as it shows least resistance, whereas lignin is thermally stable but prone to UV degradation. The large differences in its chemical compositions are due to its various sources, age, extraction systems, etc.[7]. As reported by [8]sisal fiber contains 78% cellulose, 8% lignin, 10% hemicelluloses, 2% waxes, and about 1% ash by weight, whereas [9]reported that sisal contains 43–56% cellulose, 7–9% lignin, 21–24% pentosan, and 0.6–1.1% ash. The work carried out by [10]showed that the cellulose and lignin contents in sisal vary from 49.62 to 60.95% and 3.75 to 4.40%, respectively. According to [11] sisal fibers contain 66–78% cellulose, 10–14% hemicellulose, 10–1% lignin, 10% pectin, 10–22% moisture content, and 2% waxes. It is apparent from the above studies that chemical composition and other characteristics of sisal fiber depends on various agro climatic conditions under which sisal is grown, age of the sisal plant and extraction process[4].

The fibres are built up minor fibres of diameters around 15 mm and lengths between 20 and 50 mm. The fiber consists of about 10–40 elementary fibers in cross section. The elementary fibers are bound together by a pectin interphase. This interphase is much stronger than the interphase between the technical fibers (Oever, 2000). Flax fibers contain 71% Cellulose, 18.6- 20.6 % Hemicelluloses, 2.2% Lignin, 2.3% Pectin, 8-12 Moisture Content, 1.7% Waxes and 5-10° Microfibrillar Angle. Cotton fiber contains 85-90% Cellulose, 5.7% Hemicelluloses, 0-1 % Pectin, 7. 85- 8.5 moisture Content, 0.6 % Waxes. Jute fiber contain 61.1-71.5 % Cellulose, 13.6-20.4% Hemicelluloses, 12-13% Lignin, 0.2% Pectin, 12.5-13.7 Moisture Content, 0.5% Waxes and 8°Microfibrillar Angle.

Mechanical structure of plant fibers is much less when compared to those of the most largely utilize competing reinforcing glass fibers. However, because of their low density, the specific properties (property-to-density ratio), strength, and stiffness of plant fibers are comparable to the values of glass fibers [4, 5]. Table 1 indicates some of the engineering properties of natural fiber.

Table 1. Physical and Mechanical properties of different plants fiber [4,5]

Fiber	Density (g/cm <sup>3</sup> )	Tensile strength(MPa)	Elongation at break (%)	Tensile modulus(GPa)
Jute	1.3	393-773	7.0-8.0	5.5-12.6
	1.3-1.46	345-1500		2.7-3.2
Flax	1.29	663	5	160
	1.5	345-1035	2.7-3.2	27.6
	1.4-1.5	600-1100	1.5-2.4	45-100
Cotton	1.5-1.6	287-597	7.0-8.0	5.5-12.6
	1.5	200-40	6-7.0	8
Sisal	1.45	468-640	3-7.0	9.4-22
	1.35	550±100	24±0.4	4±0.6

## V. COMPOSITE FABRICATION

### 5.1 Plant Fiber Composites

There are many ways for making of natural fiber composites. Most of the techniques commonly used for making glass fiber composites are applicable for making natural fiber composites. However, the well-known method for composites making are as followings: Similar to synthetic fibre composites, the properties of NFRP composites are also affected by

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

their manufacturing processes. The selection criteria of manufacturing process of NFRP composites are dependent on their volume of production, complexity of final products, the dimensional tolerance and production time. The common manufacturing techniques for NFRP composites are given below [12,13]:

- Hand layup;
- Spray layup;
- Compression moulding;
- Filament winding;
- Injection moulding;
- Pre-impregnated NF/polymer tape.

Hand Lay-up/Spray up is one of the cheapest and most known processes for making fiber composite products. In this process, the mold is waxed and sprayed with gel coat and cured in a heated oven. In the spray up process, catalyzed resin is sprayed into the mold, with chopped fiber where secondary spray up layer imbeds the core between the laminates resulting a composite. In hand layup processing, both continuous fiber strand mat and fabrics are manually placed in the mold. Each ply is sprayed with catalyzed resin and with required pressure compact laminate is made. Resin transfer molding (RTM) provides high quality finished surface on both the sides of composites with a relatively low energy makes perfect shapes. The fabricator generally gel coats the mold halves, then lays continuous or chopped strand mat and closes the mold. Resin transfers into mold through injection pressure, vacuum pressure, or both. Cure temperature depends on the resin system. Compression molding is a molding technique for making composite materials with low unit cost with faster cycle times. Sheet molding compounds (SMC) is a sheet that sandwiches fiber between two layers of resin paste. Fiber/Fabric drop onto the paste and a second film carrier faces with another layer of resin. When the SMC is ready for molding, the mold is closed, clamped, and between 500 and 1,200 psi pressure is applied. After curing, mold is opened and the sheets were removed manually or through an injector system and ready for use. Automated injection molding of thermoset bulk molding compound (BMC) has increasingly taken over markets previously held by thermoplastics for application in electrical and automotive components, housing appliances, and motor parts. Injection molding is a fast, high volume, low pressure, and closed process. Injection speeds are typically 1–5 s and nearly 2,000 small parts can be produced per hour. Pultrusion is the continuous, automated closed-molding process that is cost effective for high volume production of constant cross sectional parts. Pultruded custom profiles include standard shapes such as channels, angles, beams, rods, bars, tubing and sheets[14].

## VI. PROPERTIES OF COMPOSITES

### 6.1 Properties of Plant Fiber Composites

Increased importance of renewable resources for raw materials and recyclability or biodegradability of the product at the end of the useful life is demanding a shift to natural fibers such as cotton, flax, kenaf, hemp, sisal etc. in applications in addition to there exist technical advantages like strength, lightweight, and noise absorption etc.

#### 6.1.1 Jute-Polyester Composite

Dynamic mechanical properties of jute composite were found to be very high.[15]processed and analyzed the mechanical properties of jute reinforced polyester composite. Tensile and flexural properties were investigated in terms of bleached and control jute composite at various fiber loading. Composites mechanical properties such as tensile, flexural strain, toughness and moduli were compared and found that 60% fiber loading showed highest tensile strength (90.52±8.83).

In between control and bleached jute polyester composite, control jute polyester composite (JPH(C)) showed highest tensile property whereas bleached jute polyester (JPH (B)) composite showed highest flexural strength as shown in table 2. Jute polyester hot curing (Bleached) composites showed 18440MPa flexural modulus and 171MPa flexural strength whereas Jute polyester hot curing (Control) composites showed 140MPa flexural strength and 13850MPa flexural modulus. Composite made from bleached fiber showed higher flexural properties due to the increase in the extent of chemisorption of bleached jute fiber surface [15].

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

Table 2. Mechanical properties of jute polyester composite[15]

Composite	Fiber Volume (%)	Tensile Strength (MPa)	Ultimate Strain (%)	Tensile modulus (MPa)
Jute Polyester Hot curing (Control)	60	132± 6.33	5.83± 0.68	2956± 774
Jute Polyester Hot curing (Bleached)	60	117± 21.32	6.687± 0.82	2106± 229
Jute Polyester Hot Curing	55	78.15± 7.45	5.04± 0.72	2535± 884
Jute Polyester Hot Curing	60	90.52± 8.83	3.82± 0.12	4189± 403
Jute Polyester Hot Curing	66	80.6± 12.5	3.27 ± .40	4072± 402
Jute Polyester Hot Curing	71	70.31± 6.89	2.85± 0.25	4328± 358

### 6.1.2. Jute Vinyl Ester Composite

[16] utilized a solution of NaOH (5%) to treat the jute fiber for 0, 2, 4, 6 and 8 hours at 30°C. For the vinyl ester resin composites reinforced by 35 wt. % jute fiber treated for 4 h, an improvement of 20% for the flexural strength, 23% for the flexural modulus and 19% for the laminar shear strength was observed. Results are summarized in Table 3.

Table 3. Flexural properties of jute vinyl ester composite

Fiber volume(%)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Breaking Energy (J)
0	2.120	2.951	0.8227
8	106.30	4.220	0.2948
15	128.60	5.544	0.3399
23	145.70	7.355	0.3531
30	180.60	10.030	0.4799
35	199.10	11.890	0.5543

### 6.1.3 Jute Epoxy Composite

After Jute polyester analysis, [17] examined the effect of 50 % fiber loading of (control and Bleached) jute fiber reinforced epoxy composite on mechanical performance and found that bleached composite showed better flexural and

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

impact strength whereas controlled jute epoxy composite showed higher tensile strength at 50 % fiber loading which are summarized in Table 4. In bleaching, fiber delignified and dewaxed and cell sort out with each other and surface becomes clean with increased micro roughness which enhances the fiber matrix mechanical interlocking.[18] also in to find out the effect of coupling agent between fiber and matrix and observed enhancement in mechanical performance. Impact strength of bleached jute epoxy composite (107.94 J/K) is higher than the control jute epoxy composite (94.46 J/K). [17] Also studied the effect of chemical modification on the impact energy of jute/Flax/hemp epoxy composite and concluded that the modified surfaces can further bond with epoxy resin and enhanced better bonding which resulted in increased impact strength.

Also observed 60 % enhancement in strength on adding fiber volume  $V_f$  from 0.15 to 0.22 in hemp/ interfacial adhesion, through chemical bonds between the fiber and coupling agent/film former and the coupling agent/ film former and matrix. 1 wt. % NaOH for 4 hours was found to be the optimal condition for the fiber surface treatment. The fiber surface treatments reduce the water uptake and the diffusivity of the composites compared to the untreated state.[19]studied the tensile, flexural and impact properties of control and bleached jute reinforced epoxy composite (JEH 50 (C) and JEH 50 (B) respectively), in which JEH 50 (B) possess a higher (107.94 j/m) Izod impact strength than that of JEH 50 (C) (94.46 j/m); that means JEH 50 (B) composite has more toughness, and hence, can resist the fracture under stress applied at high speed. JEH 50 (B) showed higher impact strength (14,701.38  $\text{j.m}^2$ ) than the JEH 50 (C) (11482.14  $\text{j.m}^2$ ). Here resin replaces the role of the lignin in jute fiber epoxy composite, but jute epoxy composite showed the contrary as the impact strength decrease on further increase in volume fraction.

Table 4.Mechanical properties of Jute Epoxy composite

Composite	Fiber Volume (%)	Ultimate Strength (MPa)	Ultimate strain (%)	Tensile modulus (MPa)	Flexural strength (MPa)	Flexural Modulus (MPa)	Izod Impact strength (J/K)	Charpy Impact strength (J/K)
Jute Epoxy (control)	50	148.3±6.94	6.29±0.93	3184± 620	155.82±13.59	14232± 2216	94.46	11482.14
Jute Epoxy (Bleached)	50	131.09±23.563	7.41±0.90	2348±261	196.12±18.99	20445± 2240	107.94	14701.38
Jute epoxy	40	139.8± 4.59	7.32±0.69	2826±146	-	-	-	-
Jute Epoxy	50	148.3± 6.94	6.29±0.93	3184±185	-	-	-	-
Jute Epoxy	57	143.36± 4.06	5.98±0.92	3060±185	-	-	-	-

### 6.1.4. Jute Polypropylene/ Polystyrene Thermoplastic Composite

Earlier work on jute polypropylene composite developed utilizing different coupling agent like Maleic anhydride grafted polypropylene (2% wt. MAHgP) indicated enhanced tensile strength. The interfacial shear strength increases 91% for PP1-jute composite and 68% for PP2 jute composite (jute polypropylene). Concluded that the intrinsic tensile properties of jute fiber are propositional to fiber cross sectional area associated with its perfect circle shape, the measured fiber tensile strength actually increase with jute cross sectional area at a constant gauge length. An increase of the tensile strength occurs for jute/pp composites in humidity aging conditions which are attributed to the improvement in both polymer and interfacial adhesion strength. Coupling agent MAHgPP (2%) in jute PP composite increases the

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

storage modulus at 19.8% fiber content, which show the enhanced adhesion between fiber and matrix due to the coupling agent, leading to the better transfer of stress from matrix to the fiber[20].

Interfacial Shear Stress (IFSS) between fiber and matrix is much lower (3.49MPa) than the synthetic fiber and thermo sets. The IFSS with 2 wt.%NaOH and 2 wt. % KH 550 treated jute PP composite increases approximately 51%,39% and 22% than untreated Jute PP composite[21]. In another study, effect of coupling agents on both interfacial and bulk mechanical properties of jute fiber/polypropylene composites were find out with three kinds of maleic anhydride grafted polypropylene (MAHgPP), namely Exxelor PO 1020 (Ex), Polybond 3200 (PO) and TPPP 8012 (TP) were used as matrix modifier. Ex was found to achieve the best mechanical properties at a content of 2 wt. % as shown in table 5.

Utilizing jute fiber as the reinforcement increased the storage modulus with increasing fiber content. However, the moisture uptake caused a reduce in the storage modulus for most temperatures and also in glass-transition temperature at the same fiber content.

Table 5. Mechanical properties of jute –Polypropylene/Polystyrene composite

Type of Composite	Fiber Volume (%)	Tensile Strength (MPa)	Young's Modulus (Gpa)	Impact strength	Flexural Strength (MPa)
Jute fiber Mat polypropylene Composite		28.4±0.90	-	65±3.2 j/m	35.1±1.2
Pure Polypropylene + pure Polystyrene (50/50)	0	24.73±0.99	1.1745	3.89 KJ/M <sup>2</sup>	-
Pure Polypropylene + pure Polystyrene (50/50) + 10% fiber	10	30.99±0.85	1.2163	3.11 KJ/M <sup>2</sup>	-

## 6.1.2 Sisal Composite

### 6.1.2.1 Sisal Polyester Composite

Most of the physico-mechanical properties of composites made from fibers are shown in Table 6.4. The density of these composites is 0.99 to 1.12 g/cm<sup>3</sup>. The surface modification of sisal fibers caused a modest improvement of 15 to 33% in tensile strength, 45 to 79% in tensile modulus and 21 to 29% in both flexural strength and flexural modulus (silane-treated samples showed an improvement of 62% in flexural properties). This prominent shows improved fiber-matrix adhesion. The interface formed is much less stiff than the resin matrix and provides a changing mechanism to decrease interfacial stress concentration. Further, it may also protect fiber to fiber contacts, which are sources of high stress concentrations in the final composites[22].

Elongation at break of silane-treated composites is lower than that of the others. The high energy to break off surface-treated composites indicates that the matrix is controlling the growth of cracks as fracture proceeds. Work carried out by[23]showed that sisal polyester composites resulted a tensile strength, tensile modulus, impact strength of 7 MPa, 1.7GPa and 328±65 respectively. However, the elongation at break (1.7%) found to be higher than that of the similar polyester sisal composites as reported by [23].A 69% reduce on tensile strength and a 46% decrease on elongation at break was observed with sisal addition for the polyester– sisal composites. A weak fiber–matrix interface was predicted for this composite, since no fiber treatment or matrix modification was delegated. The weak interface and the low fiber volume fraction employed are held responsible for the low mechanical properties and premature failure of that composite.

### 6.1.2.2 Sisal Epoxy Composite

Incorporation of the sisal fiber significantly increase the tensile strength and Young's modulus of the epoxy resin composite (46% (v/v) and is summarized in Table 6. As reported by sisal epoxy composite showed a Young's modulus



## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

of about 20GPa and tensile strength of 210 MPa. Flexural modulus of unidirectional sisal– epoxy composites indicated 16GPa (40% v/v) (Bisanda& Ansell, 1991) and flexural strength was 266 MPa. For nonwoven sisal mats,[24] reported that sisal–polyester composites (50% v/v) had a tensile strength of 30 MPa and a tensile modulus of 1.15 GPa for which composites were manufactured by impregnation of the nonwoven sisal mats and then compression molded during 2 h. The tensile behavior of the sisal reinforced composites is illustrated by [23]. Another important mechanical property i.e. impact strength of sisal epoxy composite were analyzed by [25] and it was found in the range of 65 – 80 KJ/m<sup>2</sup>. Silane treated matrix (SM) composites resulted caused a marked increase on its tensile modulus. This behavior is thought to be due to an enhancement on fiber/matrix adhesion, caused by the incorporation of the silane coupling agent.

Table 6. Mechanical Properties of Sisal Epoxy Composite

Composite	Fiber Volume (%)	Tensile Strength (MPa)	Elongation at break (%)	Tensile Modulus (GPa)
Epoxy	0	76	7.3	3.1 - 3.2
Sisal Epoxy composite	28	169±23	2.3	14.2±1.6
Sisal Epoxy composite	35	183±16	2.2	14.5±1.6
Sisal Epoxy composite	46	211±12	1.9	19.7±1.5

### 6.1.2.3 Sisal Urea Formaldehyde Composite

Mechanical properties of Sisal fiber reinforced urea-formaldehyde resin composites as shown in table 7. The composite with 50% (w/w) sisal fiber showed optimal charpy impact strength (9.42kJ/m<sup>2</sup>). Whereas the flexural strength, wear resistance and water absorption properties are proved to be excellent in the composite with 30% (w/w) sisal fiber under the present experimental conditions adopted. The fibers themselves possess a higher wear resistance than the matrix and should protrude from the SEM surface that these composites in fiber board can be expanded [26].

Table 7. Mechanical Properties of Sisal – Urea formaldehyde composite

Composite	Fiber volume (%)	Charpy Impact strength (KJ/m <sup>2</sup> )	Flexural Strength (MPa)	Flexural Modulus (GPa)	Density (g/cm <sup>3</sup> )
Sisal – Urea formaldehyde composite	30	5.75	58.58	7.63	1.53
	40	6.5	55.80	5.27	1.52
	50	9.5	53.07	4.93	1.48
	60	7	37.73	4.09	1.44
	70	6.8	15.28	1.59	1.22

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

### 6.1.2.4 Sisal Polystyrene / Polypropylene Composite

Polystyrene with maleic anhydride (PSMA), toluene diisocyanate (T'DI), methyl triethoxysilane and triethoxyoctylsilane) on sisal fiber were tried to improve its efficiency as reinforcement in polystyrene-sisal fiber composites. All fiber modifications improve the tensile properties of the composite. The decreased in hydrophilicity of the treated fiber and increased thermodynamic compatibility of the treated fiber with the polymer matrix are responsible for the improvement in the mechanical properties. The maximum change in tensile properties was observed with PSMA coating as shown in Table 8. In all cases except PSMA coating, fiber modification decreases the impact strength of the composites and PSMA coating showed an improvement in the impact strength. Flexural strength of treated composites exhibits an improvement in all cases except benzylation. Flexural modulus showed a decrease in both benzyolated and toluene diisocyanate treated fiber composites and change in the case of silane treated fiber composite. PSMA treated fiber composite, however, shows no considerable variation in flexural modulus. Flexural strain also showed no considerable variation with fiber modification [27].

The mechanical and dynamic mechanical properties of PP-sisal fiber composites have been investigated and summarized in Table 8. Based on these studies, it can be concluded that sisal fibers could reinforce the PP matrix when used in optimal concentration of fibers and coupling agents[28].

Table 8. Mechanical properties of sisal Polypropylene (PP)/Polystyrene (PS) Composite

Composite	Fiber volume (%)	Tensile Strength (MPa)	Flexural Strength (MPa)	Impact Strength (J/m)
Polystyrene	0	35	48	-
Untreated sisal PS composite	0	43	72	-
Sisal-PP	0	17.80	19.60	23.25
Sisal-PP	6.8	24.17	34.83	40.50
Sisal-PP	10.3	26.11	46.35	46.10
Sisal-PP	21.0	29.25	48.96	51.79
Sisal-PP	31.0	23.21	43.41	39.83

### 6.1.3 Flax Composite

#### 6.1.3.1 Flax Polyester Composite

The mechanical properties of short fiber reinforced composites are predicted to ley on the intrinsic properties of both matrix and fiber, on aspect ratio, content, length and fiber matrix adhesion that is responsible for the efficiency of load transfer in the composite. In flax polyester composite, tensile modulus E increase with fiber content as shown in Table 9. Tensile strength of polyester composite tends to 20 MPa to 21 MPa at 12.5 % flax loading, 19.4 MPa at 25% flax loading and decreases at 37.5% loading (16.2%). Critical fiber length also affect the stress transfer from fiber to matrix, means critical fiber length is inversely proportional to the interfacial strength[29]. [30]studied the effect of acetylation on mechanical properties and found tensile and flexural strength of composite increase with increasing the degree of acetylation and contrary to it, Charpy impact strength of composite were found to reduce with increasing degree of

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

acetylation.[31] worked out the cold plasma treatments on mechanical properties of unsaturated polyester composite. The mean value of tensile modulus, tensile specific modulus, breaking strength, breaking strain of untreated pure resin and composite were determined. The value of the tensile specific modulus and breaking strength of the reinforced composite higher than for the polyester, matrix.

Table 9. Mechanical properties of flax Polyester composite

Composite	Fiber volume (%)	Breaking strength (MPa)	Breaking strain (%)	Young's Modulus (MPa)
Polyester	0	20.0	19.6	435
Flax polyester	12.5	21.7	14.1	760
Flax polyester	25	19.4	6.1	1112
UPR	-	70	2.2	3.7
Flax composite	-	1150	3	70

### 6.1.3.2 Flax Epoxy Composite

Modulus of epoxy resin is 2909MPa whereas the flax fiber has low modulus. The mechanical properties depend on defects and dispersion in geometry of fibbers. The fiber has a polygonal cross section that contains many defects along their length.[32] determine the modulus  $E_1$  of unidirectional flax epoxy composite using equation below for a fiber volume fraction 40% and compared with experimental results as shown in Table 10. Longitudinally flexural modulus  $E_1$  is 12000 MPa, for unidirectional composite and measured modulus of the woven flax reinforced composite is 3500 MPa.

Table 10. Flexural strength of flax epoxy composite

Composite	Fiber (%)	Thickness (mm)	Flexural stiffness (J)	Flexural Modulus
Flax Epoxy	34	2.28±0.01	82900±1800	3500±150
Glass Epoxy	50	1.03±0.01	41800±900	19000±1000

### 6.1.3.3 Flax Polystyrene Composite

Tensile strength of a material is the maximum amount of tensile stress that can be subjected to before it breaks. Polystyrene blend indicates tensile strength (125N/mm<sup>2</sup>) enhancement of raw flax fiber loading to 175 N/mm<sup>2</sup> and extension increases up to 4.3 mm shown in Table 11. Grafting with MMA on flax increases the water resistance due to MMA has less water affinity[33].

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

Table 11. Mechanical properties of Flax Polystyrene (PS) composite

Composite	Compressive strength (N/mm <sup>2</sup> )	Compression	Tensile strength (N/mm <sup>2</sup> )	Extension
PS	100±5.5	00.27±0.02	125±3.6	0.42±0.05
Flax PS composite	400±3.6	0.9±0.04	175±4.6	4.3±0.01

### 6.1.3.4 Flax Polypropylene Composite

MAPP (Maleic Anhydride polypropylene) treatment were performed and it was found that flexural strength of flax pulp and fiber PP composite is higher than that for neat polypropylene blend because the fibres have higher stiffness than polymer. Composites made with a 10 wt. % MAPP treated fiber have the highest flexural and tensile strength as shown in Table 12 [34].

Table 12. Mechanical properties of Flax Polypropylene (PP) composite

Composite	Tensile Strength (MPa)	Tensile Modulus (MPa)	Charpy Strength (MJ/mm <sup>2</sup> )	Impact Flexural Strength (MPa)	Flexural Modulus (MPa)
PP	27	700	-	35	1400
Flax PP	19	17500	-	48	3400
Flax PP	39	4200	19	56	3800

### 6.1.4 Cotton Composite

The work done by [35] discussed the variation in composite strength as a function of fiber volume ( $v/v$ ) for longitudinally placed cotton fiber with polyester resin. The composite strength with polyester resin is summarized in Table 13. It is observed that composite strength in the range of 27.94 MPa to 71.16 MPa for longitudinally placed cotton fiber with 10.41% to 35.27%. The variation in composite elastic modulus as a function of  $f v$  for longitudinally placed cotton fiber with polyester resin is observed in the range of 2.70GPa to 4.04GPa for longitudinally placed cotton fiber adjacent to the  $f v$  range of 10.41% to 35.27%. This is in line with the rule of mixture which predicts the linear increase in composite strength with increase in volume fraction of fibers holds true for longitudinally placed fiber composite for all the fiber matrix combination.

Table 13. Tensile properties of Cotton polyester composite

Composite	% Fiber Volume	Tensile Strength (MPa)	Elastic Modulus (GPa)
Cotton- Polyester	10	28	2.8
	20	45	3
	25	53	3.4
	28	62	3.6
	35	72	4

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

## VII. OPPORTUNITIES AND CHALLENGES NFRC

Natural fibers have received much interest among technologists and scientist for applications in civil, military, industrial, space craft and biomedical sectors. In the past three decades, developing interest for natural fibers composites has resulted in extensive research. The driving forces are (i) cost reduction, (ii) weight reduction and (iii) marketing (application of renewable materials). Recent research however showed that significant changes of these properties are possible.

The utilize of plant fibbers as reinforcement in composite materials is finding increasing interest in the automotive and building industry, and the properties of plant fiber composites have been addressed in numerous research studies. This substitution offers many benefits:

- Economic: lower costs on account of significantly decrease cycle times, energy savings.
- Technical: mechanical properties identical to those of traditional reinforcements, reduced tool wear and tear, high geometric stability of the manufactured parts, good insulation characteristics;
- Environmental: renewable resource, easy to recycle, no material toxicity, reduced fossil fuels content, CO<sub>2</sub>-neutral materials.

Natural fiber composite materials are being utilized for manufacturing many components in the automotive sector [36, 37]. Like glass, the natural fibers combine readily with a thermoplastic or thermosetting matrix to produce commodity goods. Typical market specification natural fibre composites includes ultimate breaking force and elongation, impact strength, flexural properties, acoustic absorption, fogging characteristics, flammability, and suitability for processing: temperature and dwell time, odor, water absorption, dimensional stability, and crash behavior. Brazilian trucks trim parts were made of a mixture of jute, coffee bag wastes, and polypropylene bags show that recycling sometimes can lead to advanced applications. The utilize of plant fiber based automobile parts such as trim parts, various panels, shelves, and brake shoes are attracting automobile industries worldwide because of its reduction in weight of about 10%, energy production of 80%, and cost reduction of 5%. Conservative estimates indicate that about 6,000 TPA plant fiber-based composite parts can find their way into passenger cars and multi-utility vehicles.

Composite materials offer some significant benefits to metals in many structural applications in railways to the effect that they are lightweight, cost-effective, corrosion resistant, energy saving. Growth of biodegradable materials as an alternative to synthetic materials such as glass fiber-reinforced plastics and other synthetic plastics is the challenge for the present and future generations in the context of global climate change. Worldwide, considerable work is being done by several researchers for the development of biodegradable polymers leading to manufacturing of biodegradable polymer composites for various engineering applications[38,39].

## VIII. CONCLUSIONS

Because of various environmental concerns natural fiber has been gaining special attention of technologist, engineers, industrial and manufacture for its enormous potential for application in various engineering utility in the site of building construction, railway, automotive, packaging, defense etc. Further, natural fiber composite is cost effective, low density, renewable material, environment friendly and reduces CO<sub>2</sub> evolution. These natural fibres have been in use as reinforcing agent in polymeric, cement, matrix to increase the physical, mechanical/engineering properties. Few research papers are available on thermo plasts-based hybrid fiber-reinforced composite compared to thermosets-based hybrid fiber-reinforced composite. There are a very less research papers on hybrid sisal and jute FRP composite. Characterization of this hybrid composite may be a good topic for researchers. The main focus of the researchers in this sites were extraction and processing of many plat natural fibers, properties of plant natural fibers, natural fiber reinforced composites (NFRC) fabrication methods, properties of NFRC with many types of synthetic matrix materials like polyester, epoxy, vinyl ester, and polypropylene to get the best performance of NFRC for direct applications. Natural fibres can be obtained in the nature, making them to be new materials for reinforced polymer composites for various engineering applications[40]. From the highlighted different fabrication methods of jute fiber reinforced polymer composites and mechanical characterization, improvement plan can further researched to find new ways to increase the mechanical properties.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

## REFERENCES

- [1] Sanjay MR, Arpitha GR, Yogesha B. (2015). Study on Mechanical properties of Natural Glass Fibre Reinforced Polymer Hybrid Composites (2), pp.2959-67.
- [2] Autar K. Kaw, (2006), Mechanics of composite material second edition.
- [3] Baley C., A. Bourmaud, (2014), Average tensile properties of French elementary flax fibers, Mater. Lett. 122, 159–161, <https://doi.org/10.1016/j.matlet.2014.02.030>.
- [4] Saxena, M., Pappu, A., Haque, R., & Sharma, A. (2011). Sisal Fiber Based Polymer Composites and Their Applications Cellulose Fibers: Bio- and Nano-Polymer Composites. Springer Book ISBN 13 783642173691.
- [5] Taj S., Munawar, M.A., & Khan, S.U. (2007). Review: Natural fiber-reinforced polymer composites. Proc Pakistan AcadSci, Vol 44, No.2, pp.129–144.
- [6] Wang, W., Cai, Z., & Yu, J. (2008). Study on the chemical modification process of jute fiber. Journal of Engineered Fibers and Fabrics, Vol. 3, No. 2 pp. 1-11.
- [7] Chand, N., Tiwary, R.K., & Rohatgi, P.K. (1988). Bibliography resource structure properties of natural cellulosic fibers – an annotated bibliography. J Mater Sci., Vol.23, No. 2, pp. 381–387.
- [8] Wilson, P.I. (1971). Sisal, vol 2. In: Hard fibers research series. Vol. 8, FAO, Rome
- [9] Rowell R.M., Schultz T.P., & Narayan R. (2000). Emerging technologies for materials and chemicals for biomass. Series of ACS Symp. ISBN 13 : 9780841221710,
- [10] Chand N., & Hashmi S. (1993). Effect of plant age on structure and strength of sisal fiber. Met Mater Process, Vol. 5, pp. (51–57)
- [11] Mohanty, A.K., Misra, M., & Drzal, L.T. (2005). Natural fibers biopolymers and biocomposites (1 edition), CRC press, ISBN 084931741X
- [12] Naidu AL, Jagadeesh V, Raju Bahubalendruni MVA. (8:56-68; 2017). A Review on Chemical and Physical properties of natural fibre reinforced composites.
- [13] McGregor OPL, Duhovic M, Somashekar AA, hattacharyya. (101:59-71; 2017). Pre-impregnated natural fibre-thermoplastics composite tape manufacturing using a novel process.
- [14] Saxena, M., Asokan, P., & Bakshi, P. (2008). Sisal potential for engineering application – an overview. In: Sisal fiber technologies for sustainable rural employment generation. Allied Publications, New Delhi, pp. (112–154)
- [15] Dash, B.N., Rana, A.K., Mishra, H.K., Nayak, S.K., Mishra, S.C., & Tripathy, S.S. (1999). Novel, low-cost jute-polyester composites. Part 1: processing, mechanical properties, and SEM analysis. Polymer Composites, Vol. 20, No. 7, pp. (62-71)
- [16] Ray, D., Sarkar, B. K., Rana, A. K. & Bose, N. R. (2001). Effect of alkali treated jute fibres on composite properties. Bulletin of Materials Science. Vol. 24, No. 2, pp. (129-135)
- [17] Mishra, H.K., Dash, B.N., Tripathy, S.S., & Padhi, B.N. (2000). A Study on mechanical performance of jute – epoxy composites. Poly.-Plast. Technol. Eng., Vol. 39, No. 1, pp. (187–198)
- [18] Gassan, J., & Bledzki, A.K. (1997). Effect of Moisture Content on the Properties of Silanized Jute-Epoxy Composites. Polym Compos., Vol.18, No. 2, pp. (179-184)
- [19] Maschinenwesen, D.F. (2006). Investigation on jute fibres and their composites based on polypropylene and epoxy matrices. PhD Dissertation, University of Dresden Vietnam
- [20] Doan, T.L., Gao, S., & Mader, E. (2006). Jute/polypropylene composites. Effect of matrix modification. Composites Science and Technology. Vol. 66, pp. (952-963)
- [21] Liu, X.Y., & Dai, G.C. (2007). Jute fibre/polypropylene composites II. Thermal, hydrothermal. Express. Polym. Lett., Vol. 1, pp. (299)
- [22] Kardos, J.L. (1985). Molecular Characterisation of Composite Interfaces (Plenum Press), H. Ishida and G. Kumar, eds., New York
- [23] Fonseca, V.M., Fernandes, V.J., Carvalho, L.H., & Almeida, J.R.M. (2004). Evaluation of the mechanical properties of sisal–polyester composites as a function of the polyester matrix formulation. Journal of Applied Polymer Science, Vol. 94, pp. (1209–1217)
- [24] Oksman, K., Wallstro, L., Berglund, L.A., & Filho, R.D.T. (2002). Morphology and mechanical properties of unidirectional sisal–epoxy composites. Journal of Applied Polymer Science, Vol. 84, pp. (2358–2365)
- [25] Rong, M.Z., Zhang, M.Q., Liu, Y., Yan, H.M., Yang, G.C., & Zeng, H.M. (2002). Interfacial interaction in sisal epoxy composites and its influence on impact performance. Polymer Composites, Vol. 23, No. 2, pp. (182-192)
- [26] Zhong, J. B., & Wei, J.L.C. (2007). Mechanical properties of sisal fibre reinforced urea formaldehyde resin composites. Express Polymer Letters, Vol. 1, No.10, pp. (681–687)
- [27] Nair, K.C.M., & Thomas, S. (2003). Effect of Interface modification on the mechanical properties.

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 1, January 2020

- [28] Mohanty, S., Verma, S.K., Nayak, S.K., &Tripathy, S.S. (2004). Influence of fiber treatment on the performance of sisal-polypropylene composites. Journal of Applied Polymer Science. Vol. 94, pp. (1336-1345)
- [29] Baiardo M., Zini E., &Scandola, M. (2004). Flax fiber-polyester composites. Composites: Part A, Vol. 35, pp. (703-710)
- [30] Bledzki, A.K., Mamun, A.A., Lucka-Gabor, M., &Gutowski, V.S. (2008). The effects of acetylation on properties of flax fibre and its polypropylene composites. Express Polymer Letters, Vol.2, No.6, pp. (413-422)
- [31] Marais, S., Gouanve, F., Bonnesoeur, A., Grenet, J., Poncin-Epaillard, F., Morvan, C., &Metayer, M. (2005). Unsaturated polyester composites reinforced with flax fibers: effect of cold plasma and autoclave treatments on mechanical and permeation properties. Composites: Part A. Vol. 36, No. 7 pp. (975-986)
- [32] Lamy, B., &Pomel, C. (2002). Influence of fiber defects on the stiffness properties of flax fibers-epoxy composite materials. Journal of materials science letters. Vol. 21, pp. (1211-1213)
- [33] Kaith, B.S., Singha, A.S., Kumar, S., &Kalia, S. (2008). Mercerization of flax fiber improves the mechanical properties of fiber-reinforced composites. International Journal of Polymeric Materials. Vol. 57, pp. (54-72)
- [34] Cantero, G., Arbelaz, A., Llano-Ponte, R., & Mondragon, I. (2003). Effects of fibre treatment on wettability and mechanical behavior of flax/polypropylene composites. Composites Science and Technology, Vol. 63, pp. (1247-1254).
- [35] Gohil, P.P., &Shaikh, A.A. (2010). Experimental investigation and micro mechanics assessment for longitudinal elastic modulus in unidirectional cotton-polyester composites. International Journal of Engineering and Technology, Vol. 2, No.2, pp. (111-118)
- [36] Karus, M., &Gahle, G.C. (2006). Use of natural fibers in composites for the German automotive production from 1999 till 2005. Slowed growth in the past two year's new production techniques arising. Nova-Institut, Hurth
- [37] Xin, X., Xu, C. G., & Qing, L. F. (2007). Friction properties of sisal fiber reinforced resin brake composites. Wear, Vol. 262, pp. (736-741)
- [38] Lu, X., (2004). Environmental degradability of self-reinforced composites made from sisal. Compos Sci Techno, Vol. 164, pp. (1301-1310)
- [39] Oudshoorn, K. (1995). Biogas from sisal waste – a new opportunity for the sisal industry in Tanzania. Energy Sustain Dev, Vol. 2, No.4, pp. (46-49)
- [40] Pickering KL, Enfendy MGA, Le TM.(2016;83:98-112). A Review of Recent Developments in Natural Fibre Composites and their Mechanical Performance.