A Review on Mechanical Behaviour of Polymers/ Sisal Fiber Reinforced Composites Material

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Abstract: **The main objective of this review paper is to study the mechanical properties of various sisal fiber reinforced composites with matrix as polypropylene (PP), epoxy, polystyrene (PS), polyethylene (PE), urea formaldehyde (UF), and polyester. In these composites sisal fibers are subjected to various fiber treatments depending upon on the matrix used. Mechanical properties of these treated composites compared to untreated sisal fiber reinforced composites are studied. An improvement in the mechanical properties such as impact strength, flexural strength, density and various other properties on these treated sisal fiber reinforced composites was observed when compared to the untreated sisal fiber reinforced composites. Finally conclusions are drawn for the present study.**

INTRODUCTION:

Composite involving no less than two materials that have assorted qualities, where one fills in as a clasp material additionally, interchange as a fiber. The properties of the composites are strong, lightweight, disintegration safe, wear safe, and engaging in appearance. Various composites have been made with various sorts of built strands in order to improve the mechanical properties. This is by virtue of the composite with built fibers, for instance, glass strands are not earth kind, provoke issues of waste glass fiber, which can't be disintegrated by nature [1]. Composites with customary fibers have various tremendous purposes of enthusiasm over composites with produced strands, for instance, negligible exertion, lighter weight, open in the kind of plants or waste, non-lethality, and does not cause skin disturbing [2]. The solace of these composites lies in how the fixings are gotten adequately from ordinary or provincial wastes and in this manner the composites can be made relative easily. Trademark fibers can be produced with the objective that its availability is sensible. Regardless, normal strands moreover have various deficiencies, for instance, sporadic estimations, solidified, weak to warm, easy to ingest water, and quickly old . Ideally composite materials used as a piece of structures where quality to weight extent into thought [3]. The following are the types of fibers:-

- Plant fibers
- Animal fibers
- Mineral fibers

Plant fibers:

Plant fibers are for a ton of designation contains cellulose: outlines cotton, flax, jute, ramie, sisal and hemp. Cellulose filaments are enacted as an assignment of the achieve of cardboard and material. The portion of these strands is as demography after: Berry filaments are the strands access from the berry case and berry e.g. kapok and cotton. Leaf filaments are the strands get from the leaves e.g. agave and sisal. Derma filaments are the strands are get from the derma including the pivot of the plant. This fiber tolerating school activity than changed filaments. In like manner, these strands are enacted as a distribution of strong yarn, texture, packaging, and paper [4].

Animal fibers:

Animal fibers for a considerable measure of designation involves proteins; outlines mohair, wool, silk, and alpaca. Creature hairs are the strands got from creatures e.g. horse hair, Sheep's downy, goat hair, alpaca hair, et cetera. Silk filaments are the strands total from seared release of horrendous crawlies for the duration of the season of address of spreads [5].

Mineral fibers:

Mineral fibers are the normally happening fiber or barely adjusted filaments access from minerals. It has adjusted arrangements they are taking after: Asbestos is the capital much of the time mischance mineral fiber. The Variations in mineral strands are the anthophyllite, amphiboles and serpentine. The Ceramic filaments are aluminum oxide, glass strands, boron carbide and silicon carbide [6].

Classification of natural fibers: - The classification are as shown in the bellow [6].
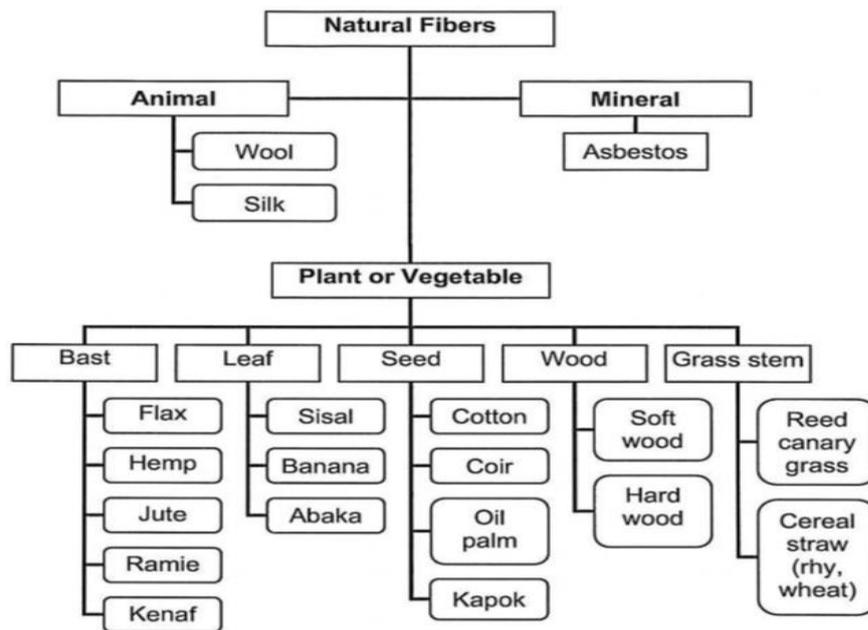
Types of composites:

Metal Matrix Composites (MMCs):

Metal matrix composites, as the name proposes, have a metal system. Instances of lattices in such composites join aluminum, magnesium and titanium. The conventional fiber joins carbon and silicon carbide. Metals are essentially braced to suit the necessities of plan. For example, the adaptable immovability and nature of metals can be extended, while broad co-compelling of warm advancement, and warm and electrical conductivities of metals can be decreased by the extension of strands, for instance, silicon carbide [7].

Ceramic Matrix Composites (CMCs):

Earthenware framework composites have clay grid, for example, alumina, calcium, aluminum silicate fortified by silicon carbide. The benefits of CMC incorporate high quality, hardness, high administration temperature limits for pottery, concoction inactivity and low thickness. Normally impervious to high temperature, earthenware materials tend to wind up plainly fragile and to break. Composites effectively made with fired networks are strengthened with silicon carbide strands. These composites offer a similar high temperature resilience of super combinations yet without such a high thickness. The fragile idea of earthenware production makes composite manufacture troublesome. Generally most CMC generation techniques include beginning materials in powder frame. There are four classes of pottery networks: glass (simple to manufacture in light of low softening temperatures, incorporate borosilicate and aluminum silicates), traditional earthenware production (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are completely crystalline), bond and cemented carbon parts [8].

Polymer Matrix Composites (PMCs):

The most widely recognized propelled composites are polymer grid composites. These composites comprise of a polymer thermoplastic or thermosetting fortified by fiber (regular carbon or boron). These materials can be formed into an assortment of shapes and sizes. They give awesome quality and solidness alongside imperviousness to consumption. The explanation behind these being most basic is their minimal effort, high quality and straightforward assembling standards. Because of the low thickness of the constituents the polymer composites regularly demonstrate phenomenal particular properties [9].

Importance of polymer matrix composites:

Polymer framework composites are included an assortment of short or nonstop filaments bound together by a natural polymer framework in which the solid fortifying scattered stage gives high quality and firmness. They were outlined with the goal that the mechanical burdens to which the structure is subjected in benefit are bolstered by the support [10]. The capacity of the framework is to bond the strands together and to exchange stacks between them. Polymer Matrix Composites are extremely famous because of their ease and basic manufacture techniques [11]. Utilization of non-fortified polymers as structure materials is constrained by low level of their mechanical properties, notwithstanding moderately low quality; polymer materials have low effect resistance. Mechanical execution is by and large streamlined by experimentation until the point when the utilitarian requests of the outline are fulfilled [12 -15]. There are two types of polymers. They are 1. Thermoplastic polymers   2. Thermosetting polymers

Natural fibers consist of low density, low cost, and biodegradability. But, the main disadvantages of natural fiber composites are the poor existing capacity between reinforcement and matrix. Therefore, chemical modifications are considered in modifying the fiber composite surface properties.

METHODOLOGY:

1. For sisal fiber reinforced polypropylene composites PP and untreated or treated sisal fibers were mixed using an internal mixer (Hakke Rheomix 3000p). The fiber contents were 10, 20, and 30 wt.%. The rotor speed was 50 rpm and a mixing temperature was 170°C. The total mixing time was 13 min. In cases of MAPP modified PP composites, MAPP was added at a content of 3 phr. Test specimens were prepared by an injection molding machine. Tensile properties of PP and PP composites were tested by following ASTM D638 using a universal testing machine (Instron, 5565). The specimen was tested at a load cell of 5 KN, a crosshead speed of 10 mm/min, and a gauge length of 50 mm. Un notch impact strength of PP and PP composites was tested by following ASTM D256 using an impact testing machine (Atlas, BPI).

2. For sisal fiber reinforced epoxy composites unidirectional composites laminates with various fiber volume fractions were prepared as follows. Treated or untreated fibers were dried prior to use. A resin formulation containing desired amount of hardener was used for making prepregs. Composite laminates of $13 \times 15.5 \times 3 cm^3$ were obtained by hot pressing 10–14 pieces of prepregs (depending on the sisal contents) at 60°C for 30 min using a leaky mold, and then curing at 80°C for 6 h. The mold was kept under pressure until the resin was set into a hard mass. Composites sheets with different fiber contents were prepared under different pressures to maintain a constant sample thickness. For evaluating tensile properties of untreated and treated sisal fibers at ambient temperature, the fibers were tested by LWK-5 electronic tensile tester at a crosshead speed of 2 mm/min. Tensile and flexural properties of composite laminates were also determined by the LWK-5 tester at a crosshead speed of 10 mm/min.

3. For sisal fiber reinforced polystyrene composites unidirectionally oriented fiber composite sheets were prepared by a solution mixing technique followed by a combination of injection molding and compression molding as reported in the previous paper. Composites containing 20 percent by weight of untreated, benzoylated, triethoxyoctyl silane treated, methyl triethoxy silane treated, TDI treated and PSMA coated sisal fiber were prepared using fibers of 6 mm length. The tensile properties of the composite were measured on a Good Brand- Jeffreys Testomeric Micro 500 testing machine at a crosshead speed of 5 mm per minute and a gauge length of 50mm. A standard UTM tensile test program was used to evaluate the mechanical properties (ultimate tensile strength, Young's modulus, elongation at break and the yield point).

4. For sisal fiber reinforced high density polyethylene composites the recycled high-density polyethylene was obtained from Plaspet Polymer Recycling Industry– Maringá – PR – Brazil. The polymer was previously hand-separated from other polymers, washed with water, and cut in ~1.5 mm diameter pellets on site. Before surface modification in laboratory, the polyethylene pellets were washed again and dried at 60°C for 8 h. Surface modification conditions were previously determined [16]: the pellets were immersed in a $KMnO_4$, (Nuclear, Brazil), 0.25 mol·l–1, and solution in HCl (Nuclear, Brazil),0.50 mol·l–1 acidic medium at 25°C for 8 h. Hence, the oxidized polyethylene will be labeled PEox and the untreated polymer, PE. The composite tensile strength and modulus assays were performed according to the ASTM D-638 test method. The samples were submitted to tensile tests in an EMIC DL 2000 machine (Brazil) at a constant cross-speed of 50 mm/min. Tensile properties were determined for eight samples of each composition. The composite flexural strength and modulus were determined, in an EMIC DL 2000 machine (Brazil), using the three-point bending test method following the ASTM D-790-00 A test method. A span of 63 mm was used in a 5 KN load cell. The load was placed midway between the supports. The crosshead speed applied was 20 mm/min. The flexural properties were determined for eight samples of each composition. The notched Izod impact strength tests were conducted according to ASTM D 256-00 A at room temperature in an EMIC-Al testing machine (Brazil) using a 5.4-J hammer.

5. The LDPE-sisal composites were prepared by a solution mixing technique followed by extrusion as reported by Joseph *et al. 32*. In the solution mixing method, the fibre was added to a viscous slurry of PE in toluene which was prepared by adding toluene to a melt of the polymer. The mixing was carried out manually in a stainless steel beaker using a stainless steel stirrer for a period of 10min. The temperature of mixing was maintained at l l0°C. The mix was then transferred into a fiat tray as lumps and kept in a vacuum oven at 70°C for 2h to remove the solvent. Composites containing 10, 20 and 30wt% of fibre were prepared using fibres of length in the range 2-10mm. Tensile testing of rectangular specimens of size 120mm x 12.5mm x 3mm was carried out using an Instron Universal testing machine model 1190 at a cross-head speed of 200 mm min -1 and a gauge length of 50mm.

6. For sisal fiber reinforced urea formaldehyde composites a mixture of SF, UFR, and inorganic filler $CaCO_3$, curing agent (NH_4Cl, 3 wt% of resin) and mold release agent (zinc stearate, 1 wt% of the total mixture mass) was prepared, and then put it in an oven for 2 h at 90°C.The blends were taken for composite fabrication available as such. The specimens were produced through compression molding under a pressure of 8 MPa at 140–145°C for 4 min. After that, the composites were post-cured at 120°C for 2 h. The composites containing 30, 40, 50, 60 and70 wt% SF, contained UFR 50, 40, 30, 20 and 10 wt%, respectively.

7. For sisal fiber reinforced polyester composites nonwoven sisal mats 30 X 30 cm2 from untreated and surface-treated sisal fibers were prepared in the laboratory using poly(vinyl acetate) emulsion as a binding agent. They were impregnated with unsaturated polyester resin containing 1.5 wt% methyl ethyl ketone peroxide and 1.5 wt% cobalt naphthenate. The four impregnated plies were stacked, pressed between two resin-coated brass plates (sisal content - 50 ~01%). and compressed on a hydraulic press for 2 h at a pressure of -1.5 MPa. Poly(vinyl alcohol) was used as the mold release agent. The laminates were cured at room temperature for 24 h and then post-cured at 80°C for 4 h at a pressure of -1 MPa.

RESULTS AND DISCUSSIONS:

1. Mechanical properties of sisal fiber reinforced thermoplastic composites:

a) **Sisal fiber reinforced polypropylene composites:**

In this composite sisal fiber is reinforcement and polypropylene is polymer matrix. Sisal fiber (SF)/polypropylene (PP) composites were prepared at fiber content of 10, 20, and 30 wt.% and their mechanical properties were characterized. Tensile properties and impact strength of untreated and interfacial modified composites are as follows:

S.No	Type of composite	Fiber content (Wt%)	Young's Modulus (GPa)	Elongation at break (%)	Tensile Strength (MPa)	Impact Strength (KJ/m²)
1.	PP+UTSF	10 20 30	0.7 0.88 0.92	12.5 10.5 7.0	23 24 25	17 15 14
2.	PP+ATSF	10 20 30	0.68 0.86 0.98	14.5 12.5 9.5	24 25 26	19 16 15
3.	PP+HTSF	10 20 30	0.74 0.94 1.06	16 12 8.5	25 26 27	21 19 17
4.	PP+UTSF+ MAPP	10 20 30	0.74 0.92 1.1	16.5 12.5 10	27 28 29	22 19 17

UTSF: Untreated Sisal fiber

ATSF: Alkali treated Sisal fiber

HTSF: Heat treated Sisal fiber

MAPP: Maleic anhydride grafted polypropylene

Alkalization and heat treatment enhanced tensile strength, Young's modulus, elongation at break, and impact strength of the PP composites [16]. From the results, at same fiber content, the improvement in mechanical properties of alkali treated and heat treated sisal fiber/PP composite was caused by not only enhanced interfacial adhesion between the fiber and the PP matrix as but also properties of the fibers, themselves.

Incorporating MAPP into sisal fiber/PP composites resulted in a superior increase in the mechanical properties comparing to the fiber treatment. MAPP enhanced the interfacial adhesion between non-polar PP and polar sisal fibers through the interaction between the hydroxyl groups of fibers and the carboxyl groups of MAPP. PP chains of MAPP also diffused into PP matrix leading to the physical entanglement of PP molecules. With increasing fiber content, tensile strength and Young's modulus of the PP composites with and without interfacial modification were increased. This was due to the reinforcing effect of the fibers. But, elongation at break and impact strength of the PP composites decreased.

b) **Sisal fiber reinforced epoxy composites:**

In this composite sisal fiber is reinforcement and epoxy is polymer matrix. The effect of fiber treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composites were characterized. Treatments including alkalization, acetylation, cyanoethylation, the use of silane coupling agent, and heating were carried out to modify the fiber surface and its internal structure.

S.NO	Type of composite	Fiber Volume Fraction V_f (%)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Tensile Strength (MPa)	Young's Modulus (GPa)
1.	UTSF/Epoxy	50	200	300	275	460
2.	HTSF/Epoxy	50	250	400	300	460
3.	ATSF/Epoxy	50	225	360	340	275
4.	ACSF/Epoxy	50	325	375	260	200
5.	ANSF/Epoxy	50	220	400	250	225

UTSF: Untreated Sisal fiber

ACSF: Acetylated Sisal fiber

ANSF: Cyanoethylated Sisal fiber

SCSF: Organosilane coupling agent treated Sisal fiber

HTSF: Heat treated Sisal fiber

Mixed treatments (AT+SC)SF, (AT+HT)SF

From the above table HTSF shows a much more significant increase in tensile strength due to the improved crystallinity of cellulose. Similarly, ACSF exhibits an improved tensile strength while ANSF and SCSF are provided with lower tensile strength, which is consistent with the changes in cellulose crystallinity.

It is noted that all chemical treatments result in greater extensibility and lower modulus. Tensile strength of ACSF/epoxy composites is even slightly lower than that of untreated sisal/epoxy. A relatively high flexural performance of ACSF composite compared to ATSF and UTSF composites was observed. Among the composites reinforced by chemically treated fibers studied in the current paper, ANSF laminates have the lowest tensile and flexural strengths. Heat treated sisal has shown superior tensile properties due to the increased crystallinity. When the fiber is added to epoxy, tensile and flexural strengths of the composites are higher than those of untreated sisal composites. It should be noted that flexural strength of HTSF composites is lower than ACSF/epoxy [17].

c)   Sisal fiber reinforced polystyrene composites:

In this composite sisal fiber is reinforcement and polystyrene is polymer matrix. The effect of interface modification on the mechanical (tensile, impact and flexural) properties of polystyrene- sisal fiber composites was investigated. The interface modification was performed by treatment of sisal fibers with benzoyl chloride, polystyrene maleic anhydride (PSMA), toluene diisocyanate (TDI), m ethyl triethoxy silane and triethoxy octyl silane. These interface modifications improve the compatibility of hydrophilic sisal fiber with a hydrophobic polystyrene matrix and change the tensile, impact and flexural properties of the composite, but to varying degrees depending on the fiber modification.

S.NO	Type of composite	Fiber content (Wt%)	Tensile Strength (MPa)	Young's Modulus (MPa)	Elongation at break (%)
1.	USF/PS	20	43	1000	8
2.	SeSF/PS	20	44.5	1400	6
3.	BSF/PS	20	45	1010	7
4.	TSF/PS	20	46	1010	6
5.	SmSF/PS	20	47	1010	7
6.	MSF/PS	20	48	1300	7

USF: Untreated Sisal fiber

SeSF: Triethoxyoctyl silane treated Sisal fiber

BSF: Benzoylated Sisal fiber

TSF: Toluene diisocynate treated Sisal fiber

SmSF: Methyl Triethoxy silane treated Sisal fiber

MSF: Polystyrene Maleic anhydride treated Sisal fiber

Composites containing 20 percent by weight of untreated, benzoylated, triethoxyoctyl silane treated, methyl triethoxy silane treated, TDI treated and PSMA coated sisal fiber were prepared using fibers of 6 mm length. The symbols U206, B206, Se206, Sm206, T206 and M206 denoted these composites respectively. In these notations the first letter denotes the nature of the fiber viz. U-untreated, B-benzoylated, Se-triethoxy octyl silane treated, Sm-methyl triethoxy silane treated, T-toluene diisocyanate treated and M-polystyrene maleic anhydride treated fiber. The first and second digits together denote the weight percentage of the fiber and the third digit denotes the length of the fiber.

From the table it is clear that the fiber modification improves the tensile strength of the composites and the improvement follows the order M206 > Sm206 > B206=T206 > Se206 > U206. The Young's modulus of the treated composites shows improvement and follows the order Se206 > M206 > B206 = T206 =Sm206 > U206 > PS. The improvement in the Young's Modulus may also be attributed to the improvement in the adhesion between the fiber and matrix. The effect of fiber treatment on percentage of elongation at break of the PS-sisal composite is given and follows the order PS > U206 > B206 = M206 =Sm206 > T206 = Se206. When the fiber matrix adhesion is higher, the composite will break at a lower elongation, confirming the better adhesion between the fiber and matrix in the case of treated composites. Fiber modification reduces hydrophilicity of the fiber and improves the physical/chemical interactions between the fiber and polystyrene matrix. The improvement in tensile properties of benzoylated and TDI treated fiber composite is attributed to the presence of phenyl structure in treated fiber similar to that of polystyrene, which improves the thermodynamic compatibility between the fiber and polystyrene [18].

2. Mechanical properties of sisal fiber reinforced thermosetting composites:

a) Sisal fiber reinforced Polyethylene composites:

1) Sisal fiber reinforced high density polyethylene (HDPE) composites:

In this composite sisal fiber is reinforcement and high density polyethylene is polymer matrix. Natural fibers are widely used as plastic composite material reinforcements. In this work, composites of postconsumer high-density polyethylene (HDPE) reinforced with sisal fibers were prepared. PE and sisal fibers were chemically modified to improve their compatibilities, try to increase the hydrophobic character of the sisal fiber and hydrophilic character HDPE. Sisal was mercerized with a NaOH solution and acetylated and the PE was oxidized with $KMnO_4$ solution. The chemically modified fibers were characterized by Fourier Transformed Infrared Spectroscopy (FTIR) and 13C Nuclear Magnetic Resonance Spectroscopy (13C NMR). The composites were prepared by extrusion of modified and unmodified materials containing either 5 or 10 wt% fibers.

S.NO	Type of composite	Fiber content (Wt%)	Tensile Strength (MPa)	Tensile Modulus (MPa)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Impact Strength (MPa)
1.	PE/S PE/S	5 10	20 21	17.5 18	23 25	17 20	57 63
2.	PEOX/S PEOX/S	5 10	18.5 18	16.5 18	22 23	18 21	55 45
3.	PE/Sac PE/Sac	5 10	19 .5 19.5	17.5 18	20 23	17 20	60 65
4.	PEOX/Sac PEOX/Sac	5 10	18.5 19	16.5 17.5	20 24	16 20	44 55

PE: Polyethylene

S: Sisal

PEOX: Oxidized Polyethylene

Sac: Acetylated sisal fibers

The tensile properties of PE, PEox and composites with 5 and 10 wt% of either S or Sac are observed. A gradual decrease in the tensile strength was observed to PE/sisal composites comparatively to that of the pure polymer matrix. The composites with modified PEox and S or Sac presented the lowest tensile strength values. PE/S10 presented values near to the tensile strength value of pure PE. Moreover, the addition of sisal to the polymer matrix increases the tensile modulus significantly

from almost 450GPa for PE to approximately 520GPa for PE/S10, PE/Sac10, PEox/S and PEox/S10, an increase of 16%. Among composites, those with 5% of reinforcement presented the lowest tensile modulus values.

The flexural properties of PE and four different composites reinforced with either 5 or 10 wt% sisal fiber were. The flexural strength of PE/S5 and PE/S10 was improved by approximately 10 and 15%, respectively. As already observed in the tensile measurements, the flexural strength values of composites containing PEox decreased when compared with those of composites with the same quantity of reinforcement, for instance, the composite PE/S10 presented values near to 25 MPa, but the composite with the same quantity of fibers and matrix oxidized (PEox/S10) presents values around 22 MPa. This result could be explained by the absence of phase compatibility between sisal fibers and polymer surface after chemical modification. The flexural modulus increased significantly (c.a. 55%) in all composites with 10% of reinforcement.

The Izod impact tests were conducted on notched specimens at room temperature. Relative to the pure PE Izod impact strength, the value of acetylated sisal composite (PE/Sac10) is 40% higher, and the composites with modified matrix (PEox/S and PEox/Sac) presented the lower values [19].

2) Sisal fiber reinforced low density polyethylene (LDPE) composites:

In this composite sisal fiber is reinforcement and low density polyethylene is polymer matrix. The effect of chemical treatment on the tensile properties of sisal fibre-reinforced LDPE (low density polyethylene) composites was investigated. Treatments using chemicals such as sodium hydroxide, isocyanate, permanganate and peroxide were carried out to improve the bonding at the fibre-polymer interface. The treatments enhanced the tensile properties of the composites considerably, but to varying degrees.

S.NO	Type of composite	Fiber content (Wt%)	Tensile Strength (MPa)	Modulus (MPa)	Elongation at break (%)
1.	Untreated sisal/PE	30	31.12	3086	2
2.	Alkali treated sisal/PE	30	34.27	3328	1
3.	Isocynate treated sisal/PE	30	41.5	4066	4
4.	Benzoyl peroxide treated sisal/PE	30	40.90	4018	3
5.	Dicumyl peroxide treated sisal/PE	30	41.80	4156	4
6.	$KMnO_4$ treated sisal/PE	30	38.80	3816	3

PE: Polyethylene

From the table it is clear that tensile strength and modulus increase with fibre loading. However, it is seen that the alkali treated composites showed superior tensile properties than untreated composites. This is due to the fact that alkali treatment improves the fibre surface adhesive characteristics by removing natural and artificial impurities, thereby producing a rough surface topography. The tensile properties of CTDIC treated, alkali treated and untreated sisal-PE composites having 30% fibre loading. CTDIC treated fibre composites show superior tensile strength and modulus than alkali treated and untreated composites. The effect of Dicumyl peroxide (DCP) and Benzoyl peroxide (BP) concentration on the tensile strength of sisal-LDPE composite at 30% fibre loading were observed. It is clear that DCP is more effective than BP at all levels of peroxide addition.

It is interesting to note that peroxide treatment improves the tensile properties significantly. BP treated composites also show a similar increase in tensile properties. The modulus values of the treated composites also show a similar trend. It is interesting to note that the tensile properties of permanganate treated composites showed a significant improvement as compared to untreated composites [20].

b) Sisal fiber reinforced urea formaldehyde composites:

In this composite sisal fiber is reinforcement and urea formaldehyde is polymer matrix. Alkali-treated sisal fibers were used as novel reinforcement to obtain composites with self-synthesized urea formaldehyde resin as matrix phase. The

composites were prepared by means of compression molding, and then the effects of sisal loading on mechanical properties such as impact strength, flexural strength were investigated.

S.NO	Type of composite	Fiber content (Wt%)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Density (g/cm³)	Specific Strength (MPacm³/g)	Specific modulus (GPacm³/g)
1.	SF/UF	30	58.58	7.63	1.53	38.29	4.99
2.	SF/UF	40	55.80	5.27	1.52	36.71	3.47
3.	SF/UF	50	53.07	4.93	1.48	35.86	3.33
4.	SF/UF	60	37.73	4.09	1.44	26.20	2.84
5.	SF/UF	70	15.28	1.59	1.22	12.52	1.31

SF: Sisal fiber

UF: urea formaldehyde

The composite with 30 wt% sisal fibers gives excellent flexural strength which shows that it has the most superior bonding and adhesion of all the composites. It is observed that with decrease of SF content from 70 to 30 wt%, the flexural strength increases sharply i.e. from 15.28 to 58.58 MPa, increasing by about 283.4%. Meanwhile, the flexural modulus increases from 1.59 to 7.63 GPa. As the improved mixing will provide better distribution of sisal, the bridging gaps between the fibers can conduct more effectively [21].

c) Sisal fiber reinforced polyester composites:

In this composite sisal fiber is reinforcement and polyester is polymer matrix. The effect of several chemical treatments, viz. organotitanate, zirconate, silane, and N-substituted methacrylamide, on the properties of sisal fibers used as reinforcement were investigated.

S.NO	Type of composite	Fiber content (Wt %)	Tensile Strength (MPa)	Elongation (%)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Flexural Modulus (GPa)
1.	Untreated SF/Polyester	50	29.66	9.52	1.15	59.57	11.94
2.	N-Substituted methacrylamide treated SF/ Polyester	50	39.48	9.75	2.06	76.75	15.35
3.	Silane treated SF/Polyester	50	34.14	5.71	1.75	96.88	19.42
4.	Titanate Treated SF/Polyester	50	36.26	8.00	1.67	75.59	15.13
5.	Zirconate Treated SF/Polyester	50	34.69	9.51	1.39	72.15	14.46

SF: Sisal fiber

An improvement in the properties was observed when sisal fibers were modified with surface treatments. The strength retention of surface-treated composites (except silane) is high compared with untreated composites. It is observed that N-substituted methacrylamide-treated sisal composites exhibited better properties.

Most of the physico-mechanical properties of composites made from surface-treated fibers show improvements over the properties of untreated composites. 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). Elongation at break of silane-treated composites is lower than that of the others [22].

CONCLUSIONS:

- In the case of sisal fiber reinforced polypropylene composites the interfacial modifications led to improved mechanical properties of the PP composites. Mechanical properties of the PP composites treated with alkalization and heat treatment were similar. This suggested that these techniques for fiber treatment were comparable. Adding MAPP provided the most effective enhancement in mechanical properties of the PP composites. With increasing fiber content, tensile strength and Young's modulus of the PP composites increased while elongation at break and impact strength decreased.

- In the case of sisal fiber reinforced epoxy composites the effect of fiber treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composites were studied. Treatments including alkalization, acetylation, cyanoethylation, the use of silane coupling agent, and heating were carried out to modify the fiber surface and its internal structure. Sisal fibers can be effectively modified by chemical and physical treatments. Composites reinforced by treated sisal is a way of heading for potential structural materials. Treatment of sisal fibers which increases (i) fiber strength and (ii) the adhesion between the fiber bundles and the matrix, while it does not introduce any new bonding to the intercelullar region to hinder cell pull-out would favor an overall improvement of mechanical properties (especially tensile properties) of sisal laminates.

- In the case of sisal fiber reinforced polystyrene composites various chemical treatments (benzoyl chloride, toluene diisocyanate (TDI), methyl triethoxy silane and triethoxy octyl silane) 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, but to different extents. Flexural strength of treated composites exhibits an improvement in all cases except benzoylation. Flexural modulus shows a decrease in both benzoylated and toluene diisocyanate treated fiber composites and an improvement in the case of silane treated fiber composite.

- In the case of sisal fiber reinforced high density polyethylene composites unmodified and oxidized recycled HDPE composites reinforced with unmodified and acetylated sisal fiber were fabricated by extrusion and injection molding. The incorporation of sisal fibers into the PE matrix increased appreciably the tensile and flexural modulus of the composite prepared with 10 wt% of acetylated sisal fiber and unmodified polyethylene matrix. This composite presented an increase of 40% in impact strength comparatively to values obtained to pure HDPE.

- In the case of sisal fiber reinforced low density polyethylene composites the effects of different fibre treatments such as alkali, isocyanate, permanganate and peroxide on the tensile properties of sisal-LDPE composites were investigated as a function of fibre loading, fibre length and orientation. Alkali treated fibre composites showed better tensile properties than untreated composites due to their rough surface topography and increased aspect ratio. It has been seen that CTDIC treated composites exhibit superior mechanical properties. This may be due to the fact that the long chain structure of CTDIC linked to the cellulosic fibers makes the fibre hydrophobic, compatible and highly dispersible in the PE matrix. Peroxide treated composites showed an enhancement in tensile properties due to the peroxide induced grafting. Permanganate treated composites also showed a similar trend due to the permanganate induced grafting. Among the various types of treatments, CTDIC and DCP treatments showed the maximum properties.

- In the case of sisal fiber reinforced urea formaldehyde composites the composite with 30 wt% sisal fibers gives excellent flexural strength which shows that it has the most superior bonding and adhesion of all the composites. It is observed that with decrease of SF content the flexural strength increases sharply and the also flexural modulus increases.

- In the case of sisal fiber reinforced polyester composites the effect of several chemical treatments, viz. organotitanate, zirconate, silane, and N-substituted methacrylamide, on the properties of sisal fibers used as reinforcement were studied. An improvement in the properties was observed when sisal fibers were modified with surface treatments. The strength retention of surface-treated composites (except silane) is high compared with untreated composites. It is observed that N-substituted methacrylamide-treated sisal composites exhibited better properties. Most of the physico-mechanical properties of composites made from surface-treated fibers show improvements over the properties of untreated composites.

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