Chapter 10
Recent Trends in the Surface Modification of Natural Fibers for the Preparation of Green Biocomposite

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1 Introduction

Recent economic growth and technological developments are inspiring scientific community to look for novel materials which can compete with the cutting-edge technology and at the same time should be environment friendly and sustainable too. Natural fibers reinforced in different polymer matrix offer excellent mechanical and thermal properties. That is why they are getting significant attention in this decade as a replacement of synthetic fibers as a reinforcing material in bio and green composites. Biocomposites are the composite materials in which either one or both the constituents of the composite material are biodegradable while green composites contain both the biodegradable components. Figure 1 shows various categories of biocomposites in which either the matrix is biopolymer and fiber is synthetic, fiber is natural and matrix is synthetic or both the constituents are biodegradable [42].

There are few issues with natural fibers which need to addressed, like poor adhesion and compatibility with hydrophobic polymer matrix, thermal stability, tendency to aggregates and poor resistance to moisture. Substantial amount of work on these lignocellulosic fibers and their reinforcement in different polymer matrix has been done, and a seminal number of reviews have been written. Faruk et al. reviewed all the studies done in the field of natural fiber-reinforced composites from 2000 to 2010 [18]. They discussed about various natural fibers like flax, hemp, jute, kenaf, sisal, abaca, pineapple, ramie, coir, bamboo, rice husk, oil palm, bagasse, their chemical composition, structure and properties. They also compiled various treatment methods, physical as well as chemical to improve the tensile strength, thermal properties and morphology of these fibers. They also collected the papers on different polymer matrix, thermoset as well as thermoplastic used with different natural fibers.

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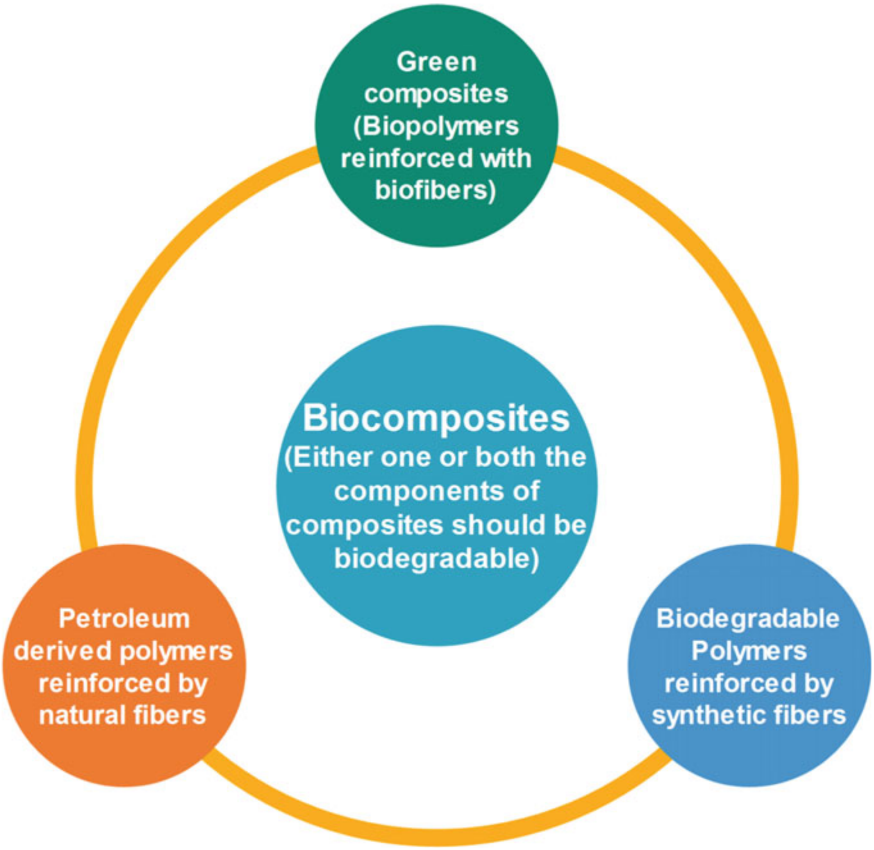

Fig. 1 Various categories of biocomposites. *Source* Author

They also discussed the factors influencing the processing of these composites, various fabrication procedures and their advantages and disadvantages. The characterization techniques like tensile testing, flexural and impact properties were also elaborated in this study. Pickering et al. discussed about recent developments and specifically mechanical performance of these green composites. They analyzed the effect of various factors like fiber and matrix selection, interface strength, geometry and orientations of fiber, fiber dispersion, porosity on the mechanical characteristics of natural fiber-reinforced polymer composites [50]. They also examined the effect of hybridization on the performance of these composites. Influence of moisture and weathering along with applications were also discussed in this review. Sanjay et al. did a comprehensive review on properties and characterization of natural fiber-reinforced polymer composites. They emphasized on tensile, flexural, impact, interlaminar, hardness and water absorption properties. Along that they also compiled the studies done on thermal and tribological properties of these novel materials.

FTIR, XRD and SEM characterizations were also discussed [55]. Ku et al. considered majorly tensile properties of these composites in their review paper [31]. They told about density, tensile strength, elongation, elastic modulus, of these natural fibers. They also collected information on density, water absorption, heat deflection temperature, coefficient of thermal expansion, tensile strength and elastic modulus of different polymer matrix like PP, LDPE, HDPE and PS. Mathematical modeling, rule of mixtures, transverse rule of mixtures, Halpin–Tsai equation, shear log theory and their application in composites were also discussed. Koronis et al. provided the application aspects of these composite materials in the field of automobile industry [30]. They discussed about green interior and green exterior composites in automobile industry. Different reinforcing elements like abaca, kenaf, hemp and flax, ramie jute, their mechanical performance and major issues and challenges regarding the application of natural fibers as reinforcement were talked in this study. The importance of matrix materials, mechanical characteristics of natural resins and concerns related to use of bio-based matrices were also analyzed. Sydow and Bienczak brought diversity of application of these natural fiber-based composites in food packaging in their review [61]. They discussed the barrier properties of these composites which is a very important aspect when we use these composite materials in food packaging. A comprehensive summary of the literature based on these diverse review papers has been presented in Table 1.

2 Issues with Natural Fibers

The main disadvantage of natural fibers is the poor compatibility and adhesion between fiber and matrix and the poor resistance to moisture absorption. Good adhesion between fiber and matrix is the key factor which ultimately decides the final properties of composites. Being lignocellulosic in nature, natural fibers are hydrophilic while the polymer matrix in which they are reinforced is basically hydrophobic in nature so compatibility between two opposite natured material is a key challenge for academicians and researchers. Lot of physical and chemical treatment methodologies have been suggested to improve the compatibility and adhesion between the fiber and matrix which is classified in Fig. 2. Mohanty et al. [43] gave an overview on different surface modification methods and their effect on the quality of biocomposites. They discussed about production, chemical composition and various properties along with advantages and disadvantages of natural fibers. Mechanism and chemistry of surface treatment methods like alkali treatment, graft copolymerization, etherification, acetylation, treatment with isocynate and maleated polypropylene were explained [43]. Li et al. [35] also compiled information on various chemical treatment methodologies of natural fibers for the application in natural fiber-reinforced composites. They reported the outcomes and findings of papers based on alkaline treatment, silane treatment, acetylation of fibers, benzoylation treatment, acrylation and acrylonitrile grafting maleated coupling, permanganate treatment, peroxide treatment, isocynate treatment and other chemical treatments [35]. John and Anandjiwala [24]

Table 1 Seminal review available on diverse aspects of natural fiber-based biocomposites

S. No.	Title	Key aspects covered	References
1	Green composites: A brief review	Summary of both academic and industrial research findings on this topical subject. Processability and rheology were also explained	[41]
2	Biocomposites reinforced with natural fibers: 2000–2010	Compilation of compositional, treatment, characterization studies	[18]
3	A review of recent developments in natural fiber composites and their mechanical performance	Mechanical performance of green composites	[50]
4	Characterization and properties of natural fiber polymer composites: A comprehensive review	Detailed review on mechanical properties and characterization studies done for these novel materials	[55]
5	A review on the tensile properties of natural fiber-reinforced polymer composites	Apart from tensile properties, modeling studies were also compiled	[31]
6	Green composites: A review of adequate materials for automotive applications. *Composites*	Technical performance of different biopolymers and their green reinforcements was compiled for automobile applications	[30]
7	The overview on the use of natural fiber-reinforced composites for food packaging	Biodegradable polymers like starch, cellulose, polyhyroxyalkanoate, chitosan, polylactic acid (PLA) and their composites reinforced by natural fibers were discussed with emphasis on food packaging applications	[61]
8	A review on synthesis and characterization of commercially available natural fibers: Part II	Less common and new natural fibers were discussed	[38]
Based on individual fibers			

(continued)

Table 1 (continued)

S. No.	Title	Key aspects covered	References
9	A review on natural areca fiber-reinforced polymer composite materials	Literature survey related to polymer composites reinforced with areca fibers, different characteristics of areca fibers, different surface treatment methodologies composite development with different matrices, characterization along with acoustics properties	[28]
10	Flax (*Linum usitatissimum* L.) fiber-reinforced polymer composite materials: A review on preparation, properties and prospects	Various factors like plant growth, harvesting, surface treatment methodologies along with structural property relationship of flax fibers were reviewed	[52]
11	Bagasse composites: A review of material preparation, attributes and affecting factors	Factors involved in modification and preparation of bagasse fibers and its reinforced biocomposites were analyzed	[64]
12	Mechanical properties evaluation of sisal fiber-reinforced polymer composites	Fiber percentage, fiber morphology, surface modification and hybridization aspects of sisal fiber in various polymer matrix were discussed	[57]
13	Recent developments in bamboo fiber-based composites: a review	Recent advancements in processing methodology and various applications related to bamboo fibers	[45]
14	Banana and plantain fiber-reinforced polymer composites	From fiber extraction to reinforcement and comparison with other fibers, most of the aspects	[3]
15	A review of coir fiber-reinforced polymer composites	The synthesis and development of various matrices reinforced by coir natural fiber and the mechanical and thermal characteristics have been studied	[4]

(continued)

Table 1 (continued)

S. No.	Title	Key aspects covered	References
16	Review on mechanical properties evaluation of pineapple leaf fiber (PALF)-reinforced polymer composites	Compilation of mechanical properties evaluation of PALF and several parameters affecting performance like type of fiber, its length, matrix type, fiber geometry	[63]

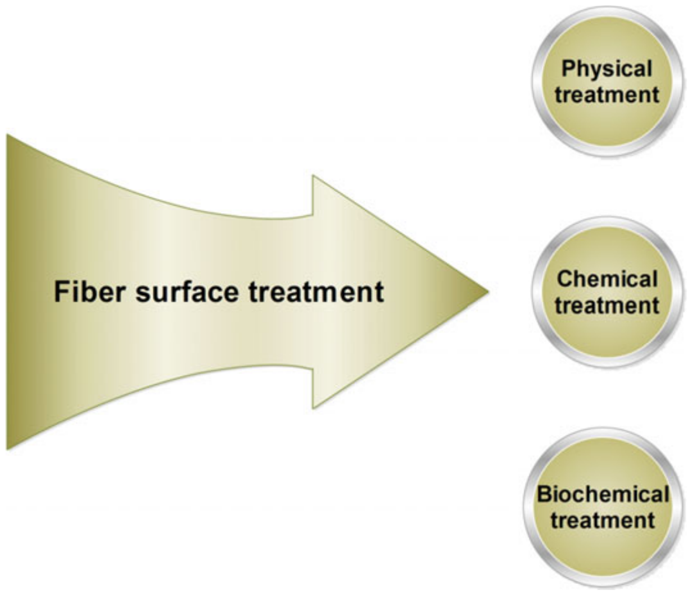

Fig. 2 Different treatment methodologies. *Source* Author

described about the latest developments of chemical modifications and characterization techniques in the field of natural fiber-based composites. They discussed the effect of chemical modification on the performance of aspen fiber composites, abaca fiber composites, bagasse fiber composites, bamboo fiber composites, banana fiber composites, coir fiber composites, date palm fiber composites, flax fiber composites, hemp fiber composites, henequen fiber composites, isora fiber composites, jute fiber composites, kapok fiber composites, kenaf fiber composites, luffa fiber composites, oil palm fiber composites, pineapple fiber composites, ramie fiber composites and sisal fiber composites [24]. Many other papers and compilation work are available in literature which is summarized in Table 2.

Table 2 Compilation of available work on surface treatment methodologies of natural fibers

S. No.	Title	Key aspects covered/discussed	References
1	Surface modifications of natural fibers and performance of the resulting biocomposites: An overview	Various treatment methodologies for natural fiber reinforcement in synthetic as well as biodegradable polymers were discussed	[43]
2	The surface modification of cellulose fibers for use as reinforcing elements in composite materials	Different physical treatment methodologies like plasma, laser, corona, radiation for natural fibers along with chemical methods such as grafting and alkali treatment were discussed extensively	[9]
3	Chemical treatments of natural fiber for use in natural fiber-reinforced composites: A review	Chemical treatments including silane alkali, benzoylation, acetylation, maleated coupling, acrylation, treatment with isocyanates, permanganate and others were discussed	[35]
4	Recent developments in chemical modification and characterization of natural fiber-reinforced composites	Various treatment methodologies to make natural fiber more compatible and less hydrophilic	[24]
5	Pretreatments of natural fibers and their application as reinforcing material in polymer composites—a review	Plasma treatment and graft copolymerization were emphasized along with discussion of other treatment methodologies of natural fibers	[26]
6	Physical modification of natural fibers and thermoplastic films for composites—A review	Steam explosion, thermomechanical methods, plasma, corona treatment were analyzed in detail along with other physical methods	[46]
7	Chemical treatments on plant-based natural fiber-reinforced polymer composites: An overview	Along with traditional treatment methodologies, information on some new chemical treatments like stearic acid, triazine sodium chlorite was presented	[25]
8	Surface modification of plant fibers using environment-friendly methods for their application in polymer composites, textile industry and antimicrobial activities	Recommended environment-friendly methods such as enzyme treatment, plasma treatment, fungi and bacteria	[27]
9	Surface treatments of natural fibers—a review: Part 1	Special discussion on electric discharge, mercerization and graft copolymerization	[2]

(continued)

Table 2 (continued)

S. No.	Title	Key aspects covered/discussed	References
10	Interface and bonding mechanisms of plant fiber composites: an overview	In-depth analysis of structure property relationship of fiber and matrix and according to that selection of suitable treatment methodology	[65]
11	Hydrophobic treatment of natural fibers and their composites—A review	Different treatment methods were suggested to decrease the moisture absorption and degradation of fiber	[5]
12	Radiation-induced modifications in natural fibers and their biocomposites: opportunities for controlled physicochemical modification pathways	Effect of electron beam and gamma (γ) radiation on natural fibers were compiled	[32]
13	Effects of fiber treatment on mechanical properties of kenaf fiber-reinforced composites: a review	Effect of treatment methodologies on a specific fiber kenaf and its reinforced polymer composites	[21]

3 Different Surface Treatment Methodologies for Natural Fiber

From Table 2, it is clear that lot of experimentation and research work had been done to improve the performance and compatibility of natural fibers with polymer matrix but with the advent of newer characterization techniques like high precision microscopy, surface characterization and innovation in knowledge like nanotechnology and biotechnology there is always a scope of improvement in the existing performance of natural fiber-based polymer composites. All the treatment methodologies and their recent developments have been discussed below in a systematic manner.

3.1 Physical Treatment

Physical treatment is applied on natural fibers to basically serve two purposes (a) to separate the bundles of fibers into filaments (b) modification of fiber surface to make it more compatible with polymer matrix [9, 46]. Following are the different treatment schemes used for this purpose (Fig. 3).

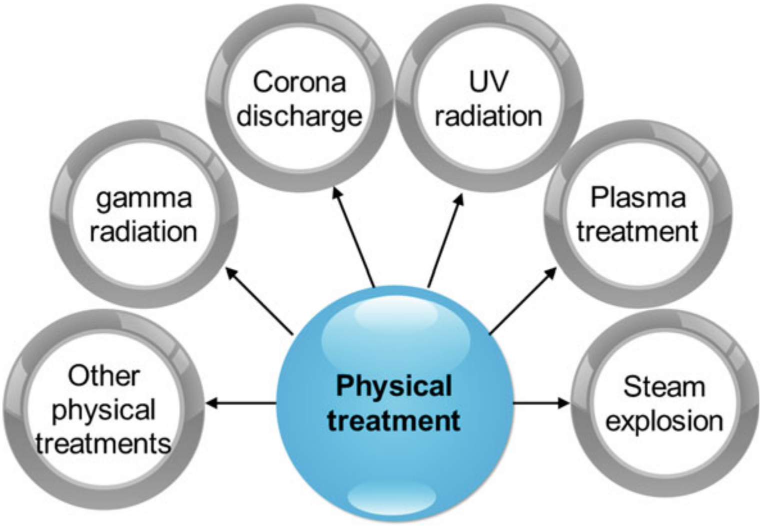

Fig. 3 Different physical treatment for natural fibers. *Source* Author

3.1.1 Steam Explosion

Steam explosion method was developed by Mason as a biomass pre-treatment technique. By using saturated water steam, raw materials are heated 160–260 °C for seconds to minutes time duration at some specific pressure and then suddenly, pressure reduced to atmospheric pressure. At high-pressure and high-temperature condition, raw material expanded because of overheated liquid and gap which would be filled by steam, when pressure is reduced then vaporization of overheated intracellular leads to cellulose explosion due to quick expanding volume, several holes formed so that molecular substances can release from cell. This method got popularity among researchers because of its tremendous advantages, such as no pollution, economical and energy efficient. Steam explosion technique is a fast pre-treatment for affecting plant cell with a sharp change in pressure at high temperature. By this treatment, lignocellulosic materials spilt into its main constitutes such as cellulose, hemicellulose and amorphous lignin. Cellulose percentage increased during steam explosion and increment in crystallinity of stem exploded banana fiber (54.1), pineapple leaf (63.7) and jute fiber (52.9) was obtained [1]. Steam explosion on commercial cellulose was used at temperature (150–200 °C) and reaction time 5–30 min, in initial characterization 91.9% cellulose content was obtained, no degradation was seen in thermal property, and steam explosion method is recommended better substitute over other mechanical treatments [36]. Review of properties of PALF fiber using different methods also suggested steam explosion method for removal of non-cellulosic content from fiber by exposing fiber in steam with its additive at high temperature and high pressure [63]. Lei and fang also improved the performance of sisal fibers by continuous steam explosion [33].

3.1.2 Plasma Treatment

Sir William Crookes described plasma as the fourth state of mater in 1879 and in 1929, first time "plasma" term was used by Langmuir. Plasma consists of electron, neutral atoms, positively and negatively charged molecules. Plasma contain characteristics of visible glow discharge which has colors, and range of blue white to dark purple depends on gas type. Plasma treatment is considered as an eco-friendly treatment for modification of fiber's surface. This treatment has advantages such as that it requires very less chemical because of less consumption during treatment [60]. After this process, no more drying is needed as it is a dry process, does not destroy bulk properties, by this method material can easily be modified which are hard to modify, it does not produce any waste, and this process takes very less time. Surface modifications of cellulose and poly vinyl alcohol were done by using non-thermal argon plasma, and this treatment did not hamper the arrangement of various polymer chains in the composites [13].

3.1.3 Treatment by UV Radiation

The effect of UV radiation on the performance of natural fiber-based composites depends on several parameters like intensity of radiation, exposure duration and wavelength of exposure. Under optimized conditions, it improves the performance of natural fiber-based composites. Mahajan et al. compiled the research work related to UV radiation effect on natural and synthetic fiber-based composites [39].

3.1.4 Corona Discharge Treatment

This technique uses low-temperature corona discharge to induce changes in the fiber surfaces to make it more compatible with polymer matrix. Corona discharges are comparatively lower power electrical discharges that occur in the range of 1 atmospheric pressure range. The corona is produced by heavy electric fields linked with small cross-sectional wires, needles on an electrode [10] used corona treatment on flax natural fiber along with other treatments. They applied 1 kW of discharge power at the rate of 4 m min^{-1}, 5 times of each side and found that contaminants were removed and surface roughness had increased [10].

3.1.5 Treatment by γ Radiation

Gama radiations consisting very high energy are capable of modifying the properties of polymer surfaces. The optimum exposure of gamma radiation improves the tensile properties of composite materials in some extent for the use of materials in different practical purposes. The cause of this enhancement in tensile properties was the high-energy gamma radiation, capable of making cross-link among the molecules. A significant amount of improvement due to gamma radiations in various composites like jute polyester and jute pp was experimented by Kabir et al. [59].

3.1.6 Ultrasonic Treatment

Ultrasonic techniques are not so popular or used in comparisons with other methods. But this is also an effective method for removal of various substances and pollutant, without using surfactants from fiber surface. It is an electromagnetic radiation which has range from 10 to 400 nm. From past some years, ultrasonic method has been used in several industries [12]. Renouard et al. showed that ultrasonication can be a useful method to modify lignocellulosic material composition. They used coir, hemp and short flax fibers for their work. After 24 h, they observed the optimal degradation and found that ultrasonic application on these fibers only degraded hemicelluloses present in the fibers [54].

3.1.7 Other Physical Treatments

Apart from abovementioned treatments, there are few other physical treatments like simple mechanical treatments which involve stretching, rolling, etc., which can improve the tensile strength of the fiber but at the same time can increase elongation [66]. Solvent extraction is also used some times to get high content of cellulose in plant fibers however a precaution is required that this can not degrade the fiber surface [51]. Thermal treatment, fiber beating and laser treatment are few other physical treatment methods that can be used depending on situation and properties of fibers [40].

3.2 Chemical Treatment Methodologies

These lignocellulosic fibers contain basically cellulose, hemicelluloses and lignin. Cellulose is the main component which is responsible for providing strength to the fiber. Different chemicals are applied for treatment of natural fibers. The main purpose is to increase the cellulose content of the fiber and to remove the unwanted impurities like wax and oil. Chemical treatment also improves the adhesion between fiber and matrix by creating some new bonds and disturbing old structure. Different chemical treatment methodologies are shown in Fig. 4. The detailed description of various chemical treatment methods used is given below, and recent developments and findings have been covered in Table 3.

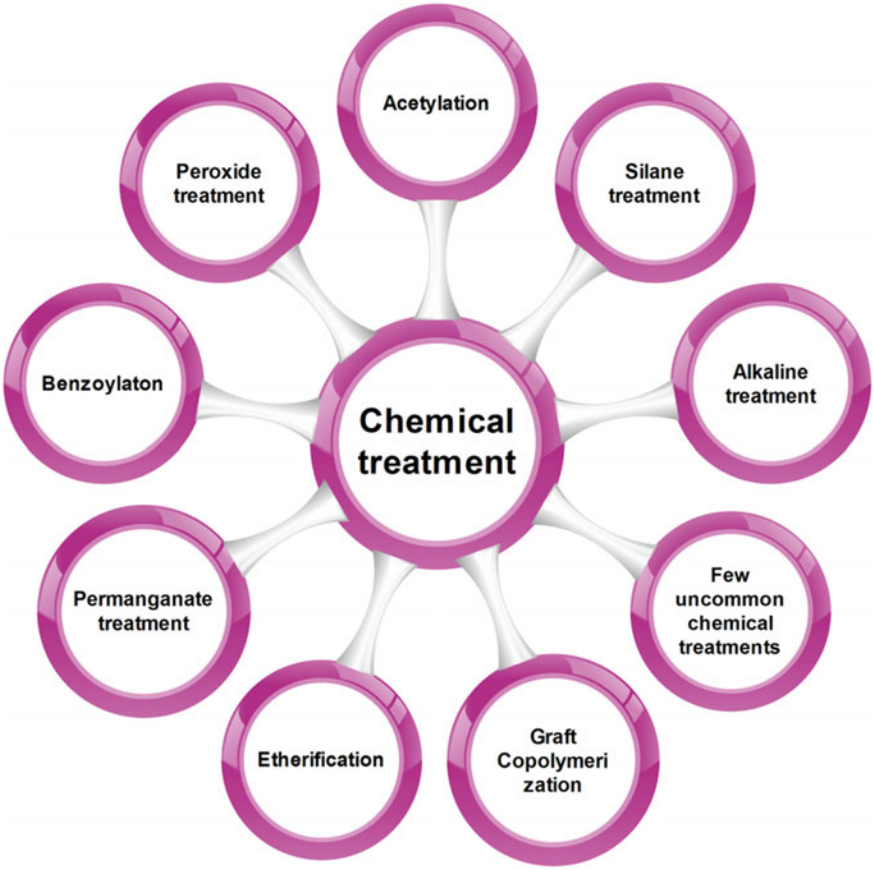

Fig. 4 Different chemical treatment for natural fibers. *Source* Author

3.2.1 Alkaline Treatment

Treatment of natural fibers with optimum concentration of alkali is very economical and promising treatment methodology. The chemical changes occur according to the reaction.

$$\text{Fiber} - \text{OH} + \text{NaOH} = \text{Fiber} - \text{O} - \text{Na} + \text{H}_2\text{O} + \text{surface impurities}$$

The alkali treatment removes a certain amount of lignin, hemicellulose, oils and waxes. The removal of these cementing materials causes the crystallinity index and cellulose content of the fibers to increase. The tensile strength also increases due to increased cellulose content. The improvement in performance of composites because of alkali treatment of natural fibers which have been studied by several researchers. The increasing roughness and fibrillation are assumed to be responsible for better

Table 3 Compilation of some recent chemical treatment of natural fibers

S. No.	Fiber	Matrix	Treatment method	Observation/key findings	References
1	Milki weed	PVA	5% NaOH at 50–60 °C for different time	PVA composites were prepared by hand layup method. Tensile properties of alkali treated composites were significantly high as compared to untreated samples	[56]
2	Kans grass filler	HDPE and LDPE	Maleic anhydride grafted compatibilizer	Performance of kans grass filler-based polyethylene and polypropylene composites has been improved at 10% filler loading	[7, 8]
3	Hemp fiber	PLA and epoxy	Silane and acetic anhydride	PLA composites based on hemp fibers were developed, and 10–13% more activation energy was observed in case of acetic anhydride treated composites while epoxy composites observed improved performance in case of silane treated composites	[49, 58]
4	Kenaf	PLA	Hydrogen peroxide in alkaline medium	Treatment improved the adhesion between Kenaf fiber and PLA matrix	[53]
5	Polyethylene fibers	Natural rubber	Potassium permanganate	Several microfibrillation between the microfiber and the natural rubber matrix was observed	[34]

(continued)

Table 3 (continued)

S. No.	Fiber	Matrix	Treatment method	Observation/key findings	References
6	Alpha fiber	Polypropylene	Etherification	Significant improvement in the properties of composites as compared to untreated one	[6]
7	Bagasse	Polypropylene	Ionic liquid	Ionic liquid treated composites upgraded the properties of composites	[47]
8	Agave Americana	–	Stearic acid	Treatment improved the properties of fiber	[37]

adhesion between natural fiber and polymer matrix. Devnani and Sinha [16] applied different concentrations of alkali that is 5 and 10% on African Teff straw fiber and found that there is significant improvement in the properties of fiber in terms of strength, morphology and crystallinity [16]. They also worked on kans grass fiber and got excellent results with 5% treatment of NaOH [17].

3.2.2 Graft Copolymerization

Modification of natural fibers through graft copolymerization is another very popular method to improve the physical and chemical properties of natural fiber-based composites. Through grafting, a suitable polymer is attached to the fiber surface whose solubility parameter is same with the polymer matrix. Grafting does not affect the biodegradability of cellulosic fiber. Grafting of methyl methacrylate and acrylonitrile is the well-established practices for natural fibers [20]. Maleic anhydride grafted polyethylene and polypropylene were used as a compatibilizer to improve the adhesion between kans grass filler and HDPE as well as PP composites [7, 8].

3.2.3 Silane Treatment

The chemical formula of silane is SiH_4, and these coupling agents can reduce the hydrophilic tendency of natural fibers by removing the hydroxyl groups. The hydrolyzable alkoxy groups form silanol in the presence of moisture. The hydroxyl group present in fiber then reacts with forming stable covalent bonds.

$$CH_2CHSi(OC_2H_5)_3 + H_2O = CH_2CHSi(OH)_3 + 3C_2H_5OH$$

$$CH_2CHSi(OH)_3 + Fiber - OH = CH_2CHSi(OH)_2O - Fiber + H_2O$$

Silane treatment in the case of hemp fibers was reported more effective as compare to alkali treatment [58].

3.2.4 Acetylation

Acetylation is another important surface treatment method for natural fibers to make it more hydrophobic. It also reduces the swelling tendency of natural fibers in the presence of water. The acetyl group reacts with hydroxyl group of water and reduces the hydrophilic behavior of natural fibers. This method also improves the dimensional stability.

$$Fiber - OH + CH_3 - C(=O) - O - C(=O) - CH_3 = Fiber - OCOCH_3 + CH_3COOH$$

Flax fibers were acetylated by putting in solution consisting of 250 ml toluene, 125 ml acetic anhydride and a small amount of catalyst perchloric acid (60%). The temperature was kept at 60 °C. More than 25% enhancement in strength was experienced in case of flax-based polypropylene composites [11].

3.2.5 Peroxide Treatment

Being a convenient method, peroxide treatment is also attracting researchers to improve the mechanical properties of natural fibers. **Benzoyl peroxide** and **dicumyl peroxide** are the common organic peroxides which have been used extensively for the natural fibers to improve their performance. During the process, decomposition of organic peroxide takes place in free radicals and this free radical reacts with cellulose of the fiber. Treatment of kenaf fiber was done in alkaline medium containing hydrogen peroxide. Substantial improvement in the morphology and strength was observed in its PLA-based composites [53].

3.2.6 Benzoylation

Importance of benzoylation is to decrease hydrophilic nature of natural fiber and to increase adhesion between fiber and matrix. Benzoyl chloride is the common reagent used for this purpose, and it reacts with hydroxyl group of the cellulose and improves the performance of the natural fiber. Remarkable improvement in mechanical properties of sugar palm fiber was observed in case of alkali pretreated and benzoylated fibers [44].

3.2.7 Permanganate Treatment

Potassium permanganate is the chemical which is used for this method. The Mno_4^- group of the potassium permanganate reacts with cellulosic group of the natural fiber and forms a complex ion. Highly reactive Mn ion induces the graft polymerization. $KMnO_4$ treatment enhanced the roughness and fibrillation in polythene fibers which significantly improved the properties of its rubber composites [34].

3.2.8 Etherification

Etherification is a chemical treatment which facilitates fiber to react easily with polymer chain of matrix by grafting bifunctional monomers [48]. A significant improvement was noted in thermal stability of alfa fiber-reinforced polypropylene composites in case of etherified fibers [6].

3.2.9 Few Uncommon Chemical Treatments

Apart from these treatments, there are few other uncommon treatments which researchers have experimented and got encouraging results. **Ionic liquid treatment** by ChOAc (choline acetate) in case of bagasse powder improved the performance of its polypropylene composites [47]. Similarly, 1% **stearic acid** solution in ethanol significantly removes the amorphous portion of the Agave Americana fiber [37]. An eco-friendly **sodium bicarbonate** treatment was also applied on sisal fibers, and improvement of performance was observed in its epoxy composites as compare to untreated one [19].

3.3 Biochemical Treatment (Enzymatic and Fungi)

The abovementioned chemical treatment used for surface modification has many advantages but in spite of that they are toxic in nature which can create problems for the environment. A new biochemical treatment method is **enzyme treatment** which is getting importance day by day because of its environment-friendly nature. Enzymes attack basically on non-cellulosic components of fiber moreover enzymes can be recycled and cost effective too. Ramie fiber was treated by bacterial cellulase. Fibers modified enzymatically were incorporated as reinforcing material for the fabrication of poly(butylene succinate) biocomposites. Due to enzymatic treatment, polysaccharide layers and gum from the surface of ramie fibers were removed and hence contributed toward the enhanced compatibility between fibers and poly butylene succinate [62]. Use of enzymes as alternate of dew retting was also analyzed. Enzyme retting with polygalacturonas enzyme was experimented for flax fibers and improvements were observed in its biocomposites [14, 15]. Pectane lyase enzyme pre-treatment was used for the development of bagasse/PLA composites, and effect was observed [22]. Another eco-friendly biochemical method is fungi treatment. White rot fungi treatment caused the pits on hemp fiber surface which not only provided the roughness on fiber surface but also increased the adhesion between fiber and matrix [23, 29].

4 Conclusion

Bio-based green composites are the promising option as a replacement of synthetic fiber and matrix-based composites whose sustainability is dwindling because of dependence on non-renewable petroleum feed stock. Natural fiber-based green composites are not only environment friendly but also offering versatile properties, at the same time they are creating potential of employment opportunities in the rural sector where these fibers originate. To overcome the existing issues like poor adhesion, compatibility and thermal degradation, various treatment methodologies have been suggested by researchers including physical, chemical and biochemical route. Compilation of existing literature including alkali treatment, graft copolymerization along with few uncommon treatment methodologies like ionic liquid treatment have been discussed. Suitable treatment methodology along with optimum concentration and exposure can definitely improve the properties of natural fiber-based green composites and overcome the existing shortcomings with these novel materials. With suitable treatment method, natural fiber-based green composites have huge potential to replace the existing synthetic composites.

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