Polymer Composites in Green Technology

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Abstract

Many sustainable polymer products with low carbon content are highly analyzed because of the rapid depletion of fossil fuel supplies, the growing demand for energy, and global warming."Green monomers" may come from bio-refineries, biological wastes, renewable oil, or plastic waste. The polymer produced from such environmentally friendly monomers is renewable and can exhibit good qualities comparable to regular polymers or occasionally even better than the current polymers. The use of green technology is part of a global push to build thriving, sustainable cities. A green economy is created by using green technology to address social, economic, and environmental values. Green technology is founded on the practise of controlling and recycling wastes in order to use them for constructive ends. This technology entails the management, incineration, and treatment of waste. Several materials made from green composites are economical in terms of using less water and power while also producing significantly less CO_2 and solid waste.

The current paper discusses practical methods, challenges, applications, and details of biopolymers, natural fibre reinforcements, as well as the characteristics of various green composites and suggestions.

Keywords: Biopolymers; Biofibers; Green composites; Fiber; Fibre dispersion; Interfacial strength.

1.1 Introduction

Green technology deals with the science and technology which is developed to save our environment. Many techniques are studied and trying to invent for better green technology by using green chemistry. The main aim of the green technology is to protect the environment from chemical hazards and breathe life back into a damaged ecosystem. This is also known as clean technology. This technology saves the earth to continue for existing of healthy life. Green technology based on the process to use waste material for beneficial purposes by managing and recycling the wastes. This technology involves waste treatment, incineration and management. By Green technology there are observed many advantages like purify water, reduce carbon emission and purify the air, good ecosystem. As, by using of green technology more trees are planted, crops are cultivated and waste is managed and recycled, which manage our daily needs.

"Green" polymers are the polymers which are prepared partly/fully from natural resources (renewable) besides petroleum. These are widely distributed materials which are obtained from bio sources (like microorganisms, plants, or trees). The global awareness due to different issues of environment has increased the production of sustainable and environment friendly green composites or materials, which can be recyclable, biodegradable and are also from renewable sources. A green composite is a material, which consists of two different phases (Fig.-1), generally a matrix or continuous phase and a disperse phase. The disperse phase contains natural fibers and the matrix phase derived from natural polymer. The third one is required for the green composite, is the interface which helps to bind disperse phase and matrix into a composite. For surface treatments, interfaces (silane, acetone and alkali treatment etc) are used to enhance the mechanical behaviors of green composites[1].

Green composites are future sustainable composites where natural fibres and natural resins play an important role for making lightweight and stronger composites those can be recyclable and biodegradable.

Different types of renewable green composites are introduced like:

i. Wood derived composites
ii. Bamboo derived composites
iii. Other plant(leaf, fruit, grass) fibre composites
iv. Bioresins and biopolymers composites originated from natural resources like animals and plants
v. Cellulose and nanocellulose composites

We can say that these materials are produced by synthetic chemical processes from bio-sources like oils of vegetable, sugars, resins as well as proteins and amino acids etc.[2]. From long years back, humans are using polymers in daily life. From long years back B.C. humans produced clothes from animal skins; 24,000 years back human used plant fibres for many product formations; 10,000 years back flax, ramie, jute fibres were used; 9000 years back wool; 5000 years back silk, and 3000 years back cotton were used by humans in their daily life.[3]. In 1220s, pigments produced from the Asian lac bug were used for paintings which are a thermoset resin[4]. During the year 1751, F. Fresneau studied the behaviours of natural rubber, derived from the Para rubber tree in South America. Many scientist were attracted towards the properties of natural rubber and in 1860, an English chemist G. Williams discovered isoprene by distilling natural rubber. After 10 years, J. W. Hyatt (1870) designed celluloid (a thermoset) which was prepared from the combination of camphor and cellulose nitrate. That time Celluloids were used specially for toiletry items as well as collar-stays, combs, cases for photography, and to prepare the 1st flexible photographic films[4]. In 1900, J. E. Brandenberger (Swiss chemist) prepared a lean transparent sheet, cellophane from restored cellulose, which was used for packaging. In the same year rayon, also prepared from restored cellulose which was generally used in markets of apparel and furnishing. In 1940s, many experiments on soybean-based composites were started by Henry Ford and few of them were used in different auto parts.

As we are becoming more concern about healthy environment, good ecology, less consumption of petroleum resources, to achieve our goal the thirstiness for developing of new green composites increases day by day. The classifications, processing techniques and applications of green composites are cited in this review after studied many references for this research work.

1.1 Green Composites

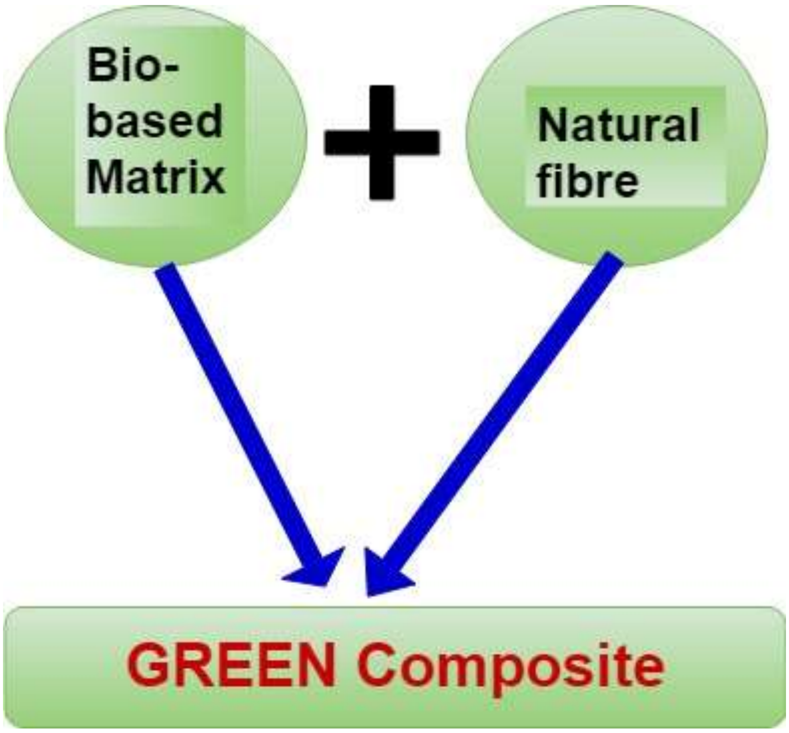

Fig. 1 Green composite from natural fibre and bio based matrix

Green composites are composed of natural fibre and bio based matrix (Fig-1). Natural fibres are classified into three parts (Table-1) i.e. Animal fibres, Nonwood fibres and Wood fibres, from where we get plenty of cellulose, proteins and lignin. Animal fibres basically comprise of proteins, and have potential reinforcements in composites. The Nonwood fibres are widely used in industries for their more attractive physical, chemical and mechanical properties. These fibres are actually lengthy fibres, with plenty of cellulose and good mechanical effects like tensile strength and degree of crystallinity. The wood fibres have more than 60% of wood particles. The wood fibres are two types, softwood fibres and hardwood fibres. The softwood fibres are lengthy and flexibility in nature, whereas hardwood fibres are not lengthy and stiff and have low degree of cellulose crystallinity. In the industry one of the most frequently applicable fibres is jute.

Table-1. Some Biofibres and their origins

Biofibres								
Animal Fibres			Nonwood plant fibres					Wood based fibres
Silk (Silkworm, spider, from the larvae of butterfly species)	Chicken fibre (Chicken feathers)	Wool (Sheep, goat, camels, rabbits, and certain other mammals.)	Straw based fibres (Rice, wheat, corn straws)	Bast (Kenaf, flax, jute, hemp)	Leaf fibres (Henequen, sisal, pineapple and banana leaf fibre)	Seeds/fruits Fibers (Cotton, coir, coconut, palm oil , and other vegetable oils)	Grass based fibres (Bamboo, bamboo fibre, switch grass,)	Soft wood (Kraft (spruce)) and hard wood(Kraft (spruce)) (Newspaper, magazine fibres)

For production of green composite materials, there are required natural fibres (hemp, flax, jute, kenaf, and sisal etc on the place of synthetic non bio fibres) (Table-1) and matrix materials derived from biopolymers/bio based resins (starch, vegetable oils, and protein). The natural fibres are used in many sectors alone or by forming composites (Table-2). Examples of bio-polymers are starch, Poly lactic acid (PLA), Poly-L-lactic acid, Starch , bio based Polyesters, Cellulose acetate, Furfural alcohol and Furan resins, Poly (butylene succinate), CNSL(Cashew nut shell liquid) etc. In Table-3 there are some bio materials, which are used for synthesis of bio based polymers.

Table-2
Different natural fibres with their uses:

Natural fibres	Uses
Jute fibre	Pilot's cabin door and door shutters
Bast fibres and jute fibres	Interior door panels, door trims
Banana fibre composites/coir/sisal fibres	Automotive seat shells
Sisal fibres	Heater housings
Flax/kenaf/hemp/jute fibres	Package trays, truck liners, door trims and under body coverings
Flax/jute/sisal/banana/ramie fibres	Interior aircraft applications, flooring.

Table-3. Some biopolymers and their starting material-

Bio based polymers	Starting material
Polyester or poly-3-hydroxybutyrate (PHB)[5]	Glucose and Glycerol
Polyamide 11[6]	Castor oil
Polyurethanes[7]	Vegetable oils
Polyether polyols[8]	Castor oil
Poly Styrene [9]	Glucose
Poly Lactic acid[9]	Glucose, Glycerol
Natural rubber[9]	Mevalonate
Poly Propylene glycol[10]	Glycerol
Epoxy polymers[11]	Cardanol

1.2 Factors affecting mechanical performance of green composites

1.2.1 Selection of Fibres

Generally Fibres are categorised on the basis of its origin i.e. plants or animals or minerals. Cellulose is the main part of all plant fibres structural components, but animal fibres contain protein.Due to presence of more cellulose and cellulose micro fibrils, the alignment of bast fibres like flax, hemp, kenaf, jute and ramie become more in the perfect direction, so bast fibres are used in most of the composites in different sectors. The different effects of natural fibres depend on chemical arrangement and their structures, by which the types of fibre, conditions for growing, time required for harvesting, methods of extraction, treatment process and storage ideas are determined. Over 5 days after optimum harvest time the reduction by 15% of strength has been seen[12] . Extraction of flax fibres manually has 20% higher strength than mechanically extracted fibres[13]. But glass fibre has high Strength and stiffness than natural fibres.

Fibre length is the ratio of a fibre length and fibre diameter that influences the mechanical properties of green composites. In green composites having non lengthy fibres, the load (tensile) is transferred from the matrix to fibre through the interface. At end point of fibre, there is null value for tensile_stress and that increases with the extension of the fibre. So, a length higher than the critical length (La) is required for fibre, which can break during tensile loading of composites[14]. Actually fibre length must be higher than the La of a fibre for reinforcing effectively in a composite. The critical fibre length can determine the surface of fracture since the average pull out length of a fibre cannot be longer than half of the critical fibre length. Mathematical expression for La is

$$\frac{La}{d} = \frac{\sigma_f}{2\tau_i}$$

Where'd' is the diameter, σ_f is tensile_strength and τ_i is interfacial_strength of the fibre.

It is found that La changes with the nature of matrix, process for treatment and weight of fibre. Lodha and Netravali in 2002 calculated the stress of fracture in green composites (ramie fibre and soy protein isolate), it was shown that the fracture stress increased with the increment of length of fibre and weight of fibre. The averaged IFSS (fibre-matrix interfacial shear strength) was 29.8 MPa and the critical fibre length was 2.54 mm, evaluated by using Microbond technique. But that biocomposite containing 10 wt % fibre and 5 mm fibres were not significantly reinforced with higher critical length.[15]

1.2.2 Matrix selection

One of the important parts of green composites is bio derived matrices. The matrix keeps safe the fibres from environmental factors, erosion and also gives load to fibres. Now a day's biopolymers are used due to their light weight and capability of processing at very low temperature, give environmental safety and biodegradability[16].

As most of the natural fibres used for reinforcement in NFCs are not thermally stable in more than 200°C or they can be processed at higher temperature for a short time period so there are very limited Matrices at the degradation point of natural fibres[17]. It has been shown from different studies that PP has lower strength and stiffness with natural fibres than PLA[18].

Different types of plants and most of the bacteria are naturally produced variety of compounds which have capabillity to produce polymers. They have the metabolic machinery that helps to synthesis to provide organic chemicals[19]. Many precursors (lignocelluloses, cellulose, hemi_cellulose, lignin, ash, starch, chitosan, chitin, alginates, or polysaccharides) used as the substrate to form applicable monomers for biopolymers. By polymerization the bio derived monomers are converted to biopolymers with suitable techniques. By Myriant Company succinic acid, was successfully synthesized from corn glucose and lingocelluloses.

Reverdia(2012) studied that by Roquette and DSMItaly were produced about 10,000 tonnes/year of succinic acid from glucose in Cassano Spinola(Italy), by using a recombinant E. coli. From Succinic acid, there were produced many chemicals (1,4-butanediol, succino-nitrile, dimethyl succinate, 2-pyrrolidone, tetrahydrofuran, γ-butyrolactone, 4,4-bionolle,N-methyl-2-pyrrolidone, 1,4-di-aminobutane, succinimide) [20].

1.2.3 Interfacial strength

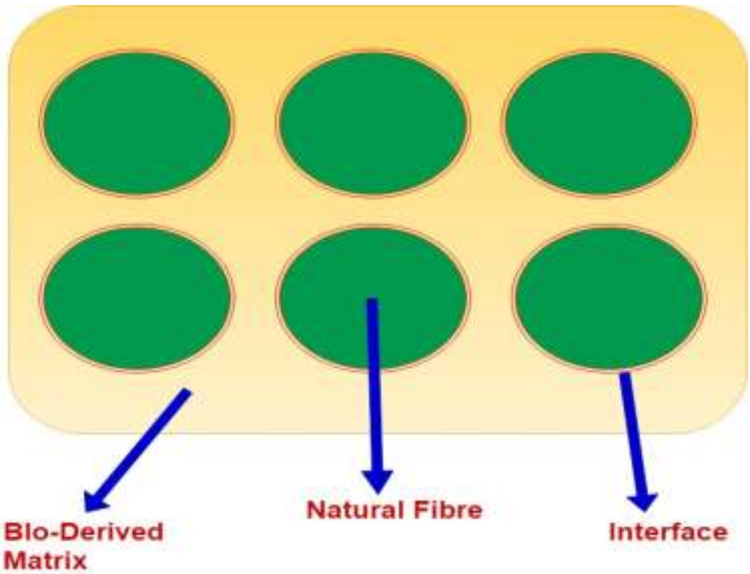

Fig -2. Interfacial bonding in between fibre and matrix,

The mechanical properties of composites also depend on the interfacial bonding in between fibre and matrix, as by the interface, stress shifts in between matrix and fibres (Fig-2). For favourable reinforcement better interfacial bonding is required. Mostly, due to hydrophobic nature of matrices and hydrophilic nature of plant based fibres, there is a limited interaction between them and forms poor interfacial bonding, which decreases the mechanical behaviour and low moisture resistance. Wettability of Fibre also affects the mechanical behaviours like toughness, tensile and flexural strength of composites[21]. By applying appropriate Physical and chemical actions the wettability of the fibre can increase which enhance the interfacial strength[22-24]. Occurrence of interfacial bonding depends upon the activities and behaviours of mechanical interlocking, electrostatic and chemical bonding and bonding nature in inter_diffusion[25]. The interfacial strength is determined from the type and density of Chemical bonding. Chemical bonding takes place when a bond forms between the chemical groups present in the matrix and on the fibre surface. Chemical bonding is formed by the use of a coupling agent, which plays a vital role in chemical bonding between fibre and matrix, as it behaves as a bridge in between them. At the same interface simultaneously, there can be possible more than one types of bonding[26]. Carboxyl and hydroxyl groups are mostly used as coupling agents and due to increase of these types of groups, enhance the interfacial bonding and surface polarity. Hence the chemical and physical activities help to increase surface polarity, fibre roughness. Many physical and chemical properties are studied by researchers to increase the mechanical properties of NFCs.

By treatment of Alkali, some extra fibers (Hemicellulose, lignin, pectin and fat) are removed from cellulose which improves roughness and area of surface, interfacial bonding, modifies structure of cellulose and increase crystallinity[27 28].

Esterification takes place by acetylation process where acetyl groups react with hydroxyl groups present on the surface of fibres which increases interfacial_bonding, tensile_strength, and hydrophobicity[29], as well as structural and thermal stability and resistivity (fungal attack) in NFCs [30-32]. But more treatment causing harm to mechanical properties due to degradation of cellulose and cracking of fibers[30].

Silanes treatment also provides a bridge between hydrophilic groups of the fibre and hydrophobic groups in the matrix. At first silane treated with bio fibres where hydrolysis of silane (alkoxy groups) in presence of water takes place to obtain Si–OH groups further which interacts with -OH groups present on the surface of fibre[33 34]. In this process hydrogen bonding /covalent bonding generally occurs.

1.2.4 Fibre dispersion

Fibre dispersion is a method which influences the properties and behaviours of short fibre composites and other NFCs, generally having hydrophilic and hydrophobic fibres and matrices respectively[35]. Use of lengthy (longer) fibres can again enhance their capacity to form composite. Better fibre dispersion boosts the bonding in interface; reduce voids by completely surrounding of fibres along the matrix[36]. Parameters like temperature and pressure also affects Dispersion.

1.2.5 Fibre orientation

Orientation of fibre affects more the mechanical behaviours of composites. If there is a parallel alignment of the fibre takes place in the direction of the applied load can give better mechanical effects[37-39]. In case of continuous synthetic fibres, it is easier to align properly than natural fibres. Some alignment can be possible in throughout injection moulding, which depends both on viscosity of matrix and moulding design[40] .

For best degrees of alignment in fibres, the longer natural fibre are indentified and kept by hand in sheets sealing with matrix to reduce porosity. By spinning process which is a traditional process for fibres are also be employed to produce a long yarn.

Recently, DSF (Dynamic sheet forming) process is used for fibre alignment in composites, which provides high level mechanical performance as compared with other techniques used for short fibre processing. This method is used to align fibre traditionally to produce paper. At University of Waikato recently published about strengths (above 100 MPa) for discontinues (short) hemp as well as harakeke fibre alignment in PLA by using DSF.

1.2.6 Composite manufacturing

When a natural fibre is reinforced with a matrix (resin) a biocomposite is formed which has the properties of the matrix and fibres that were used and biocompatibility in nature. The matrices are used generally polymers obtained from renewable resources. It protects the fibres from environmental factors to reduce degradation and damage by holding the fibres together and helps to shifts the tensile loads on it. As biocomposites have many applications in our day to day life as used for production of different types of papers, clothes, rayon, silks cotton and applied in industries like automobile sector, coaches for railway, in aerospace, for constructions, and packing materials, the interest in production of biocomposites are growing rapidly as these are renewable, cheap, recyclable, and biodegradable [41- 44].

The processes involves for production of biocomposites are: pressing by machine, winding of filaments, pultrusion, extrusion, injection molding, molding by compression, molding by resin transfer and sheet molding process.

The in-situ polymerization process is used for nanofillers dispersion in monomers, which is escorted by solution polymerization or bulk polymerization. To find a better dispersion in polymer matrix the nanofillers are regularly changed by functional group which develops a good interaction between the nanofillers and polymers and give higher performances of final products [45 46]. Increasing melt and impact strength, thermal stability, permeability of biopolymers as well as reinforcing nanoparticles can make biocomposites retaining original characteristics with benign properties[47].

1.7 Porosity

If any void is formed during processing due to insertion of air then porosity forms. The porosity forms due to low wettability and low compactability of fibres, hollow features like lumens within fibres or fibre bundles due to high pressure and temperature[48]. Porosity in NFCs is generally due to presence of more fibre content or more rapidly compaction and also relies on fibre types and orientations.

2. Mechanical performance of natural fibres and composites

Physical properties of each natural fibre play an important role to measure different properties and in applications of NFCs. The physical properties like dimensions of fibres, fibre defects, strength, crystallinity, inner structure, discrepancy are very important to calculate mechanical performances in NFCs. With the stronger interface there is an increase in efficiency of stress transfer to the fibre from the matrix. The change in natural fibres takes place by physical processes like stretching, thermal treatment and formation of hybrid long yarns. The physical processes help to modify structural properties and properties of the fibre's surface and the mechanical bonding of polymers, but don't change the fibre's chemical structure.

Table-4. Physical Properties of some natural fibres and glass fibre

Fibres	**Tensile_Strength (MPa)**	**Young's_modulus (GPa)**	**Elongation at brake (%)**	**Density (g/cm^3)**
Cotton[49]	287-587	5-13	7-8	1.5–1.6
Jute[50,51]	187-773	13-26.5	1.5-3.1	1.23
Flax[52]	345-1500	27-39	2.7-3.2	1.5
Hemp[50 51]	580-1110	70	1.6-4.5	1.35
Ramie[50 51]	400-938	61.4-128	2.0-4.0	1.44
Sisal[50 51]	507-885	9.4-22	1.9-3.0	1.2
Coir[49]	175	4.0-6.0	30.0	1.2
Henequen[53]	430-570	10.1-16.3	3.7-5.9	1.2
Banana[50 51]	529-914	8-32	3-10	1.35
Bamboo[54]	391-1000	11-30	2	0.8–1.4
Oil palm [49]	248	3.2	14	0.7–1.55
Kenaf[50 51]	295 -930	53	2.7 -6.9	1.2
Curaua[52]	500–1100	11.8–30	3.7–4.3	1.4
Glass	2000–3500	70–73	2.5-3.7	2.55

fibre[52]				

Table-5. Study of Some composites mechanical behaviour:

Composites	Elongation to break (%)	Tensile strength(MPa)	Young modulus(GPa)	Processing
Starch + jute(30%)[55]	2 ± 0.2	26.3 ± 0.55	2.5 ± 0.23	Injection molding
PLA + jute(30%) [56]	1.8	81.9±2.9	9.6 ± 0.36	Injection molding
PHBV + jute(30%)[57]	0.8	35.2 ± 1.3	7 ± 0.26	Injection molding
PLLA + flax(30%)[58]	2.3 ± 0.2	98 ± 12	9.5 ± 0.5	Compression molding(Film stacking)
PHB + flax(30%) [58]	7 ± 1.5	40 ± 2.5	4.7 ± 0.3	Compression molding (Film stacking)
PLA + flax(30%)[59]	1 ± 0.2	53 ± 3.1	8.3 ± 0.6	Twin screw extruder and compression molding
PP + fiberglass(30%) [52]	3.01 ± 0.22	82.8 ± 4.0	4.62 ± 0.11	Compression molding

2.1 Advantages of natural fibre based Green composite

Table-4 is the study of mechanical values for natural fibres and glass fibres. In table-4 we can see most of the natural fibres are very closest to the middle of each certain range. From this table we can differentiate mechanical strength values between the glass and natural fibres collected from different research paper's stiffness values & density values. From the table-4 we can assume that most of the natural fibres can compete with the glass fibres, generally jute, flax, hemp, sisal, chicken feather fibre, kenaf, bamboo etc. The most advantage of natural fibres are low cost, light weight, easily renewable, lower energy consumption, less investment, easier to handle and process, better specific mechanical behaviours, recyclable, and good thermal insulation as compared to glass fibres[60]. Kimet al.[61]

observed that at large strain rates, NFCs had very good energy absorption capacity as compared to glass fibre based composites. For structural based applications bast fibres show best properties; as flax has the capacity of perfect potential combination, high strength at very less cost as well as lightweight with high stiffness, Jute is also very common fibre, but lesser strong and stiff as compared to flax[62]. Natural fibres are cheaper with low densities than glass fibres, but the strength of natural fibre is remarkably low. But due to better specific modulus values, natural fibres prefer for implementation in different sectors, in which place the stiffness and weight of a fibre are important concerns[62]. The renewed interest in natural fibre composites are emerging as a viable alternative to glass-fibre reinforced polymer (GFRP) composites for many reasons. As NFCs are 25% to 35% stronger than glass fibre with the same weight and also same execution capacity for lesser weight. In automotive materials, NFCs minimize the component mass and reduce the energy consumption by 70-80% during the production of composites and reduces the machinery maintenance, production costs by up to 25-30%. NFCs have no more brittle nature as compared to glass fibre composites, which is a very specific requirement in the compartment of passenger transport. Cultivation of natural fibre actually requires solar energy, but glass and glass fibre production require fossil fuels/ electrical fuels. So, emissions of pollutant from glass fibre production are usually more than natural fibre production.

From table-5, we can compare the mechanical properties of green composites with glass fibre based composite and observe the better mechanical values in green composites. From the studies of Oksman et. al.[63] they produced PLA/flax green composites and emphasized the properties of PLA/flax composites than mostly used PP/flax composites. From the study they observed that the mechanical properties of PLA/flax green composites had 50% more efficiency than PP/flax composites.

Bio derived matrices and natural fibre composites were prepared and examined and it was observed that these had very positive impact regarding environmental benefits, better mechanical effects and very low weight[64-70].

Vilaseca et al.[71] have fabricated starch with jute strands by the method of injection moulding to form green composites. They compared the mechanical properties of various percentage composition of alkali treated and untreated jute strands. The tensile strength of alkali untreated jute in above green composites, it was observed the increment of tensile strength with the fibre quantity (10, 20, and 30%(w/w)) and also for alkali treated jute strands in the above green composite, it was observed the increase in stiffness and strength with increase in fibre contents. There also observed that the humidity absorbance capacity of the green composite is very low (tested for 72 days in open air).

Averous et. al.[72], they prepared TPS composites from leaf and wood cellulose fibres and bio matrix (derived from wheat starch by applying water/glycerol for plasticization). It was observed that at 30^{o}c of transition temp., there was an increase of mechanical behaviours. There are certain observations and experiments were done about the applications of cellulose esters as matrix in different biocomposites[73-77]. Many of the natural fibre and cellulose ester based composites were prepared by different methods (injection moulding, extrusion, blow and rotation moulding) and the temperature 180 ^{o}c to 240 ^{o}c required for preparation of cellulose esters and Tg values are 140 ^{o}c to 190 ^{o}c for the cellulose esters many plastic applications[78].

3. APPLICATIONS

Green composites have very favourable advantages for different companies, due to gradually diminishing in petroleum reservoirs. So the green composites are used widely in many sectors like automotive parts, constructions, wind turbine blades, biomedical applications, food packaging and others etc (Fig-3).

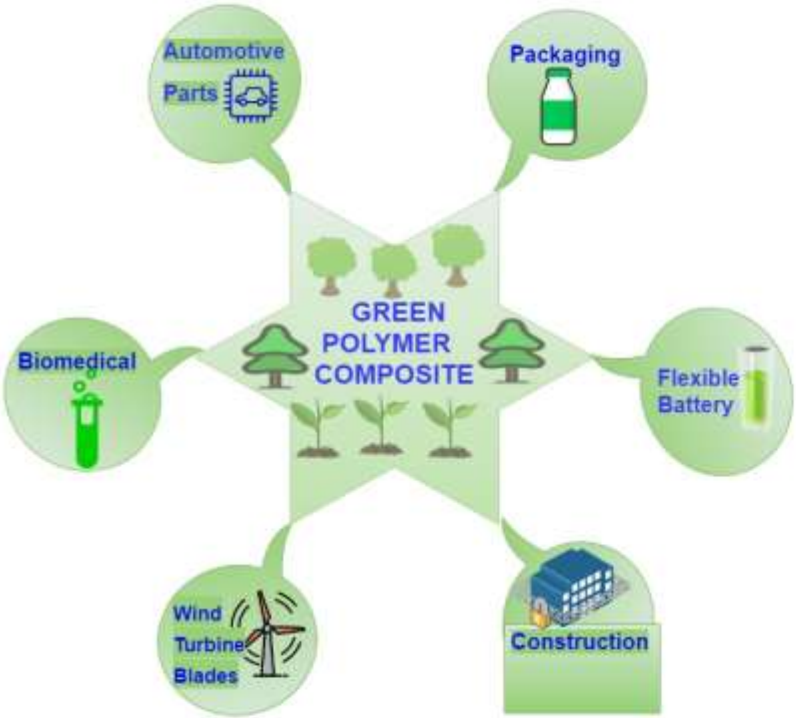

Fig-3. Different applications of Green polymer composites

- Shih et al.[79], in this research they reused the fibre based replaceable, with PLA and prepared green composites to manage wastes in many countries.
- Green composites are also used in wristwatch (Patch) made from biodegradable paper[80], other green composites are also prepared from disposable_chopsticks[79], and lignin based carbon fibre[81].
- Green composites play an important role in tissue engineering, as drugs carrier and bone scaffolds in the biomedical applications[82-85].

- Biodegradable materials such as PLLA, cellulose, PDLLA are used with biopolymers like PLGA, PLA, PEG, and chitosan for formation of different useful green composites[86].
- As chitin derived chitosan is free from toxicity, and less processing impact on environment, so it is used more in different sectors[87 88].
- Biodegradability food packaging system is a demanding issue in the European countries[89]. So there are many biopolymers and biopolymer based nano composite materials are used for food packaging[90]. Mainly materials used for food packaging are derived from the composites like polysaccharide and starch based; polysaccharide and cellulose based; protein based; PHA based; and PLA based.
- Toyota has prepared 1st fully (100%) bio derived automotive parts(like Raum spare wheel cover) in the world from kenaf/PLA non-woven sheets by press-mould process.
- By John Deere, Soybean and natural fibre based composites (by using RIM process) are used to prepare body panels and cab roofs for hay balers which are 25% light weight. More recently, EcoTechnilin prepared a sandwich panel composite from nonwoven flax and bioresins with honeycomb core of paper in the Jaguar F-type (for load floor)[91].
- The Ford Motor Company used bio composites made from natural fiber and wheat straw in 2010 and by using this they can reduce 9 metric tons petroleum usage and 13.5 Mt/year emission of CO.
- For injected instrument and door panels, consoles are prepared form biomat (hemp/ PBS) by Faurecia .
- Coconut fibres and rubber latex composites are used in the A-class model of Mercedes Benz for seats[92]. A recent concept for car is aroused by Forest and

Biomaterials supplier , Finland and Applied Sciences, HM University, Helsinki who are developed the major replacement of plastic parts with high durable and safe qualitative biomaterials, in the place of UPS Formi and UPM Grada, were used to manufacture the passenger compartment floor, centre console, display panel cover, door panels, front mask, dashboard, and interior panels. It was observed that the car made from these materials is closely 150 kg low weight and lower fuel consumption capacity than its counterparts.[93].

- In 2013, the 100% biocomposite based building Facade clad from hemp fibre and a bio based resin, was established (gas receiving station Netherlands)[94 95].
- Only natural fibres can also be used in insulation, roofing, and geo_textiles. Hemp slivers can deliver structure and very good insulation behaviours, which is made from wastes of hemp fibre are used as hemp lime (blocks or sheets) onto walls. In the Adnams Brewery warehouse construction, hemp lime was used in Suffolk, United Kingdom. By using the hemp lime, it saves almost £40,000/year by keeping constant temperature of 16°C except heater and air coolers [94]. Due to high carbon capture capability hemp fibre fleece are used as insulating materials in Germany [94]. 35,000 protective blocks made from GreenGran granules (natural fibre-reinforced biopolymers PLA and PHB) were placed on riverbanks and dams to prevent riverbank erosion [96].
- Since the year of 2016, China used hundred sets of 800KW bamboo wind turbine blades as these have large wind strength and good stiffness and toughness and reduced cost of 15% compared to glass fibre based wind turbine blade [97].

4. Conclusion

Research and development for biomaterials are being accelerated in order to replace petroleum-based materials and protect the environment. Biocomposite can be used in many different industries around the world because of its low cost and excellent durability. The product purity, renewability, and affordability of biocomposites are their greatest advantages. Due to their high strength-to-weight ratio and ability to address the issue of other materials' inability to be recycled or biodegraded after their useful lives, Natural Fibre Reinforced Biocomposites have become increasingly important in a variety of fields. As a result, dumping is a major issue in modern society. Due to their biodegradability, affordability, and superior mechanical qualities, natural fibres and biocomposite materials have a significant positive impact on the environment. To prevent the globe from becoming a garbage dump, further research is needed to improve moisture resistance, mechanical strength, and fire retardant capacity.

GO GREEN AND MAKE GREEN

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