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A PEER REVIEW OF THE PROCESSING TECHNOLOGIES AND APPLICATIONS OF GREEN COMPOSITES IN A BIOMEDICAL AREA

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Abstract-Use of green composites for contemporary medication, is anticipated to be a key subject of modern-day chemistry research. As such, a lot of research is being carried out on the green materials and their potential use in biomedical applications. This paper discusses about the some basic applications of green materials in the field of the biomedical area and there production. Crucial production concepts of bio-composites, like the different types of natural biocomposites, the composing material classes and the common families and their fabrication techniques are discussed. The technologies discussed include extrusion/injection, compression, and pultrusion process for fabrication of these fibers is discussed.

Keywords: Green composites, Biodegradable polymers, biomedical applications, processing techniques

1. INTRODUCTION

Excessive usage of products from petroleum, surging crude prices and exponential rise in hazards caused due to pollution have resulted in unforeseen demand of environmental friendly materials. [1], as a result, the renewable materials such as cellulose, proteins, starch, vegetable oils are being investigated for the green polymer composite [1]. Known as the green composites and bio composites, the reinforcements of these materials are extracted obtained from natural resources [2],[3]. Since time immemorial, the materials have been used to build dwellings and manufacture tools. Along with several other applications. [4]. Lately, much growth has been witnessed in the plolymer industry and the productions are eco friendly and sustainable. [5]. Several subsitutues are now being considered owing to important factors like cost-effectiveness, eco-friendliness, and biodegradability, namely -wood fiber, sisal, kenaf, flax, jute, hemp, and silk6],[7]. Not only are the materials usable in filed of mmaterials packaging, automotive, energy sector, sports, and leisure industry but also possess sustainability for biomedical applications such in implants and medical devices [8]. The major advantages of these materials are, these can be fabricated as per the requirements for various applications by adding various epoxies and, unsaturated polyester resins to these materials. Although the materials such as stainless steel and titanium are used for bone repairs due to their biocompatibility numerous times of successive surgical operations for the removal of plates and fasteners sometimes the uneven growth of bone cells nearby the plates may cause psoriasis. Table 1.1 exibits mechanical properties of some biomaterials used for biomedical applications. The table depicts materials which are flexible and can be considered for fixing the bones and making plates. Poly (lactic acid) (PLA) are primary resources available for bio medicinal applications since they are not only biodegradable but also bioresorbable which when used in implants helps as they are not required to be removed surgically. of these materials for biomedical applications is their the low strength. Owing to intrinsic properties of these fibres, the fabrication of natural composites is a daunting task in comparison to inorganic fibres. The major considerations for processing of these fibres are their hygroscopic behavior and low resistance to high temperature due to which only limited resins could be used as matrix. The techniques and equipment used for fabrication of these fibers are similar to that of conventional inorganic fiber composites. The common techniques used for fabrication of these materials include extrusion/injection, filament winding, compression, and pultrusion process.

Table-1.1 Mechanical Properties of Some Biomaterials [9]

	Elastic modulus(GPa)	Yield strength(Mpa)	Tensile Strength(Mpa)	Elongation to faliure%
Al2o3	350	_	1000-10,000	0
CoCr Alloy	225	525	735	10

Stainless steel	210	240	600	55
Ti-6AI-4V	15-30	30-70	70-150	0-8
Bone(cortical)	3	_	35-50	0.5
PMMA	0.6-1.8	_	23-40	20-400
HDPE	Strong			
Cartilage	Viscoelastic	_	7-1	20

Table-1.22 Mechanical Properties of Some Natural Fibers[9]

	Tensile strength(MPa)	Elongation at break(%)	Young modulus(GPa)
Natural fibers			
Flax	300-1500	1.3-10	24-80
Sisel	80-840	2-25	9-38
Jute	200-800	1.16-8	10-55
Kenaf	295-1191	3.5	2.86
Wool	120-972	25-35	2.3-3.4
Spider silk	875-972	17-18	11-13

2. NATURAL FIBERS

From last few years, it has been observed that there has been a dramatic shift for using natural fibers such as flax, jute, hemp, pineapple and sisal etc. for making composites as the decompositions of these materials do not have a severe effect on the environment for universal sustainability. Table 2 shows the mechanical properties of potential natural fibers which can be used for composite applications. In green composites, the traditional composite with non-biocompatible matrix is substituted by bio-engineered composites. The main aspect of the selection of materials for biocompatibility is these materials should not have an unfavorable effect on the host tissues. The use of materials like PLA and poly (glycosides) (PGA) can be used to make green composites. However, apart from recyclability, these composites must have good strength and or thermal stability. The major problem associated with these composites is their low strength and low service temperature. The physico-mechanical properties of these composites must be understood before using them in biomedical applications.

3. PLANT FIBERS

The plant-based fiber-reinforced polymer composites have attracted a lot of the interest from researchers to use this alternative for synthetic fiber composites, like glass and carbon. So many attempts have been done for reinforcing natural fibers such as jute, bamboo, sisal, coir, hemp, and flax etc. with thermoplastic and thermo set polymers for the formation of natural composites..Wambua et al. [10] experimentally investigated the strength enhancement of various plant-based fiber polymeric composites. The results revealed that hemp fiber with 35% fiber volume fraction showed good better tensile strength in comparison to that of sisal and jute fibers while the coir fiber showed least tensile strength. Table 3.1 shows the comparison between the mechanical properties of E-Glass with natural fibers. Motaleb et al.[11] fabricated the pineapple leaf fibre (PALF) reinforced polypropylene (PP) using a compression moulding process. The treatment of fibers was carried using NaOH.The results revealed that there was a significant improvement in the mechanical properties of fibers. Silva et al. [12] investigated the tensile behavior of sisal fibers and found that hollow structure inside the sisal fiber can reduce the strength of the composite. Their fore selection of higher density of the fiber is required for using it in load-bearing applications. Although wood fiber has some good mechanical properties due to its high specific strength and Young modulus to use it as biodegradable materials due to its hydrophilic nature as compared with carbon and glass fibers its applications are limited [13]. Wan et al. [14] observed the properties of bamboo fiber by reinforcing it with Polyvinylchloride (PVC) and observed that due to moisture content and granule size mesh the mechanical properties were not consistent.

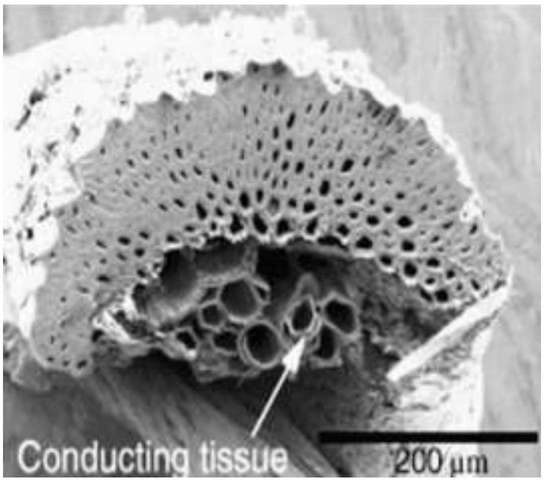

Fig.1. Sisal Fiber [11]

Fig.2 Cocoon Silks [16]

Table-3.1 Comparison Between Mechanical Properties of E-Glass With Natural Fibers [9]

Properties/fibers	**E-glass**	**Hemp**	**Jute**	**Ramie**	**Coir**	**Sisel**	**Flax**
Density	2.55	1.48	1.46	1.5	1.25	1.33	1.4
Tensile Strength(MPa)	2400	550-900	400-800	500	220	600-700	600-700
Tensile modulus(GPa)	73	70	10-30	44	6	38	60-80
Elongation Break(%)	3	1.6	1.8	2	15-25	2-3	1.2-1.6
Moisture absorption(%)	_	8	12	12-17	10	11	7

4. ANIMAL-BASED USED FOR THE PRODUCTION OF GREEN COMPOSITES

Animal-based fibers are playing important role in other alternatives for production of biodegradable and biomedical applications. These are made from wool, spider and silkworm silk. Moreover due to the steadiness of these fibers as compared to spherical proteins due to presence hydrogen bonding and hydrophobic nature like the protein. Silk fibers are obtained from silkworms[15]. Wray et al.[16] used Silk fibroin for biomedical application in tissue regeneration. In which amino acid composition analysis was used for detection of serein residuals in silk solutions. The results showed that the degumming conditions considerably affect cell viability on the silk fibroin material and its capacity to form three-dimensional porous scaffolds from the silk fibroin. Zhao et al.[17] experimentally investigated the mechanical properties of cocoons and found that mechanical properties of B. more cocoons are good while thermo-mechanical parameters vary along the thickness direction of a cocoon in a suitable way moreover there were the discrete difference in the longitudinal and transverse directions.[17].

4.1 Chicken Feather Fiber (CFF)

Chicken feathers hold the unique advantage of low relative density and good thermal and sound insulating properties. There they can be used in a number of applications, for feather disposal as billions of chicken are culled per year moreover technologies for the production of chicken feathers into fibrous (feather fiber) and particulate (quill) fractions are developed and patented for biomedical applications. Reddy et al.[18] developed bio-thermoplastics with chicken features for using in tissue engineering with compression moulding process. As the major protein in fibers is biocompatible and have cross-linking properties. The thermoplastic films from features were prepared and investigated the results revealed that feather films were water secure and had good strength. This can be used for fabrication of biomaterials for various biomedical applications. Martelli et al [19] investigated the influence of polyethylene glycol (PEG) on the films' hygroscopicity and solubility of keratins. The results revealed that these films have with lower solubility in water.

5. APPLICATIONS IN WOUND SUTURES SILK

The coating of silk fibroin fiber with waxes or silicone is done for enhancement material properties of the fiber to be used in biomedical applications. silk fibroin from the silkworm, *Bombyx mori*, has good properties for biocompatibility and biodegradation, therefore, can act as a biomaterial. The knot strength of silk and its and handling make it popular suture in cardiovascular applications where bland tissue reactions are desirable for the coherence of the sutured structures [20] Li et al.[20] studied the behavior of biomedical textiles such as silk and observed that due to processing, controllable degradability and mechanical properties. this material can be used for extracorporeal implants and soft tissue repair.

5.1 SCAFFOLDS TISSUE ENGINEERING FOR BIOMEDICAL APPLICATIONS

Chen et al. [21] studied the behavior of blast fibers by A basalt fiber by reinforcing them with poly(l-lactic acid) (PLLA) matrix as for fabrication of natural composites for hard tissue repair. Solution blending and freeze-drying were carried out for producing PLLA. The results showed that there was a significant improvement in the various properties of the PLLA matrix. which showed that these material have a potential future in promising hard tissue repair applications. Goswami et al.[22] fabricated the foams of the three-components material system consisting of (poly(lactic acid) (PLA), poly(ε&59;-caprolactone) (PCL) and wollastonite (W) for the fabrication of biocomposites for biomedical scaffold constructing using compressed CO2. The results showed that newly developed composites showed, show osteoblast cell attachment. Cao et al.[23] used a phase separation technique for studying the behavior of-of 3D porous poly(lactic-co-glycolic acid) (PLGA) scaffolds. The results revealed that these materials can be used for medical applications. Zhang et al.[24] studied the mechanical properties of composite prepared for bone scaffold prepared using, poly(l-lactic acid) (PLLA), and octadecyl amine-functionalized Nano diamond (ND-ODA). The dispersion of nanoparticles increased the hardness and Young's modulus of the composites. It was observed that the properties of newly formed nanocomposites close to that of the human cortical bone.

5.2. SILK-BASED BIOCOMPOSITES FOR BIOMEDICAL APPLICATIONS

Silk is used in the medical field as sutures from past centuries. This material is naturally obtained from silkworms. These days silk fibroin due to the biocompatibility of this material it is widely studied for biomedical applications. These material having a promising future in based tissue engineering.[25] Koyanagi et al.[26] developed silk fibroin fibers using calcium chloride for wet spinning and observed 96% degradation of new fiber within 4 days. The results revealed that with controlled biodegradability the new fiber can be used for bio-medical purposes. Altman GH et al.[27] studied the properties of the silk-fiber matrix for its use in tissue engineering anterior cruciate ligaments (ACL).it was concluded that silkworm fiber matrices can be a new option for the repair of ACL

Table-5.1 Examples of Silk's Utility as a Matrix Material in Tissue Engineering

Silk form	Supported cell type in vitro	Comments
Fibroin	L-929 Mouse Fibroblast	Comparable growth rates to collagen films
	SE1116(human Colon adenocarcinoma);KB (human mouth epidermoid	
Fibroin Film	Carcinoma; colo201(human colon adenocarcinoma);QG56(human lung carcinoma)	Comparable growth rates to collagen films as well as rates of protein production of carcinoembryonic antigen (CEA)
Fibroin film	Saos-2 (human osteoblast-like cells)	bone formation was evident on fibroin films, but was enchanced on RGD-coupled matrices
Fibroin film	HbMSC; human adult anterior cruciate ligament fibroblasts	supports ligament specific development in Vitro

5.3. CHICKEN FEATHERS WITH PLA BIOCOMPOSITES

Chicken feather fibers(CFF) with PLA as a matrix can form a biodegradable composite which can be used for plastic products and implant applications Cheng et a.l[31] studied mechanical properties of chicken feathers by treating it with alcohol for 25 hr and washing with a water-soluble organic solvent. The diameter of the CFF was 5lm and length was 10-30mm. It was observed that the elastic behavior of newly formed composite excellent. [31].Okoro et al.[32] investigated the mechanical properties of Brown chicken feather fibers for reinforcing high-density polyethylene. The feathers were mercerized with 0.5 M KOH solution. The fabrication of fibers was carried out with a compression molding method. The Morphological properties of the material were studied using SEM. Tensile and flexural testing of composites was also done. The results revealed that chemically modified chicken feather fibers exhibited the excellent tensile and flexural strength.

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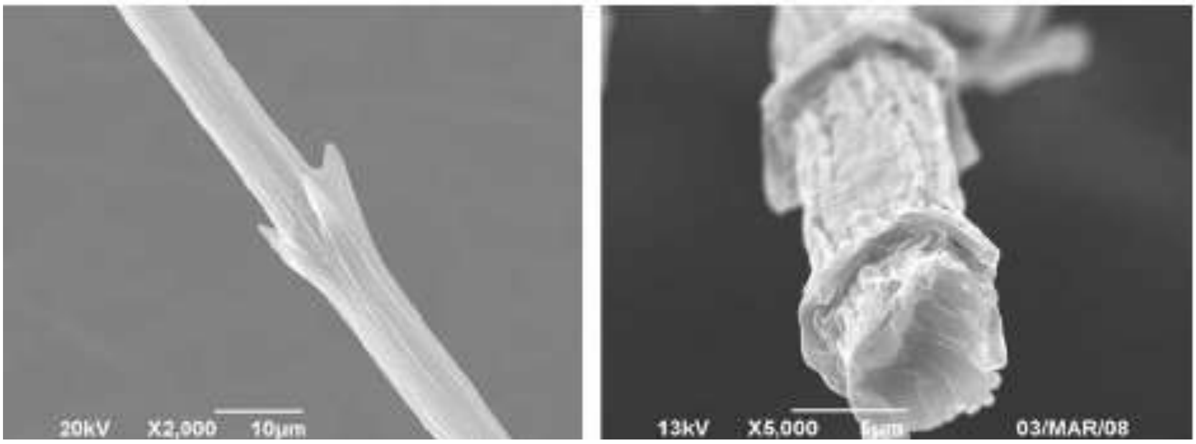

Fig. 5.1 SEM images of the CFF [9]

6. PROCESSING TECHNOLOGIES

The fabrication of natural composites is a challenging task as the intrinsic properties of these fibers are very different from inorganic fibers. The major considerations for processing of these fibers are their hygroscopic nature and low resistance to high temperature due to which only limited resins could be used as matrix. The techniques and equipment used for fabrication of these fibers are similar to that of conventional inorganic fiber composites. The processing method of these fibers usually depends upon the matrix resins and processing conditions depend on the type of natural fibre used. Therefore low viscosity thermosetting resins are mostly used as a matrix as these can easily impregnate the natural fibers and do not cause any damage related to thermal degradation. The common processing methods used for the fabrication of these fibers are compression molding, Injection molding, (RTM) and (VARTM). The fibers can be used in the form of mats or in woven form. Compression and injection moulding methods are preferred technologies for mass production of plastics and natural composites parts due to their high precision and fast cycle times. Rajendran et al.[33] fabricated the biocomposites using injection molding process for mechanical characterization. new biodegradable polymer blend based matrix system was used for fabrication and effect of melt processing parameters on the impact strength of the bio composite was studied by designing full factorial experimental design. The results revealed that processing parameters, fibre length significantly affected the impact strength of the bio composites. Cho et.al [34] fabricated the natural fibers (jute, kenaf and henequen) reinforced thermoplastic (poly(lactic acid) and polypropylene) and thermosetting (unsaturated polyester) matrix composites using compression moulding process and investigated the mechanical properties of manufactured fibers moreover surface treatment of fibers was also carried using tap water by static soaking and dynamic ultra sonication methods. The results revealed that there was a significant improvement in the mechanical properties of the composite. H.Park et.al[35] fabricated and investigated the mechanical properties of natural fibers of flax using A Vacuum Assisted Resin Transfer Moulding(VARTM) process. The comparison of manufactured fibers was done with data from references. The results revealed that there was a good improvement in the mechanical properties of the fabricated fiber. Xi Peng et al.[36] observed the mechanical properties of the pultruded composite rods made from hemp and wool fibre reinforcements. The mechanical and morphological characterization was done. The results showed that there was an improvement in the mechanical properties of the that using the polyurethane resin the composites can achieve has higher specific tensile and compressive strength.

CONCLUSION

Using natural fibers to develop biocomposites offer multiple advantages; it helps generate more economic opportunities for the agricultural sector. It helps reduce carbon dioxide emissions as compared to other sources. Further, it allows moving on from petroleum-based composites, which use imported oil to more readily available natural materials. Biocomposites are more energy efficient, have higher sound absorption and higher insulation. Further, since biocomposites are bio-renewable, durable, environment-friendly and low cost, they are extremely suitable for application in the biomedical sector. However, more research is still needed on biocomposite materials to overcome issues such as photochemical degradation, when exposed to UV radiation as well as moisture absorption. One of the main considerations in design criterion for implants based on composite biomaterials is anisotropy of elastic properties of biological tissues. This criterion can be fulfilled by using porous ceramic-polymer biocomposite, with similar mechanical properties as well as morphology to cancellous bone. It also provides surgeons with the ability to cut the graft and moulding the shape of the composite to the shape of defect directly in the surgery room. They offer the flexibility to change the percentage of reinforcing and continuous phase and tailor the implant to be more coherent with the mechanical and physiological conditions of the host tissues. And they are very suitable for orthopaedic applications because of their high strength and low elastic modulus. This composite is less susceptible to fatigue failures and has high fracture toughness. Problems such as corrosion and release of allergic nickel and chromium ions have also been eliminated. Moreover, biocomposites are well suited to modern medical diagnostic techniques, such as X-ray, magnetic resonance imaging (MRI) and computed tomography (CT) scan. However, biopolymers are more suited to some dental applications such as dental implants, since they have more aesthetic appeal. Comparatively, biocomposites have greater application in case of hard tissue such as a prosthetic socket, dental post, bone plate, orthodontic arch-wire, bracket, and composite screws and pins. The successful application of biocomposites in the medical field can be demonstrated by cages used for spinal fusion they are less susceptible to pathogen transfer and offer less painful, quicker and affordable surgery as compared to the allograft. The processes used for thermosetting polymers, compression molding and LCM (e.g. RTM and resin infusion) are the most extensively used for research and applications. The variability of natural fibers extends to their capability of absorbing resin and consequently swelling during processing, and this makes a characterization of permeability more problematic. Natural fibers are widely used, especially in automotive applications, in combination with thermoplastics – here, however, the choice of polymer is limited by the maximum processing temperature at which fiber degradation occurs. A moisture removal stage is considered an essential part of the manufacturing cycle.

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