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Comparative Study of Biodegradable Matrix Materials for Green Composites: A Review

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Abstract — *The green composite is rapidly growing in terms of their industrial applications. They are renewable, cheap, completely or partially biodegradable. These composites are having low density and cost with good mechanical properties. Green composites are most suitable material profound in nature for their use in various fields due to their environment friendly advantages. The scope of the review is to bring the properties of different biodegradable matrix materials that would attract many researchers attention to focus on future need and importance of fully green composites. This review gives pathway for designers on the specific application of green composites. A concise summary of the major attributes of biodegradable materials are provided with their mechanical properties.*

Keywords- *Green Composite, Biodegradable*

I. INTRODUCTION

Very recently, biodegradable polymers are being used to produce composite materials together with biodegradable fibers as reinforcement. There are many varieties of biodegradable resins available for making such kind of composites called green composites. Manufacturing of green composite from biodegradable sources is a challenging task for researchers to meet the future demand for eco-friendly materials [15]. This paper deals with review of different biodegradable matrix materials with its characterization.

Green composites are defined in this review as biodegradable polymer with natural fibers. Green composites include nature fiber as a reinforcement material like coir, jute, cotton, bamboo, hemp and biodegradable matrix materials. Natural fibers are eco-friendly, light weight, string, renewable and cheap. Natural fibers and binders provide sufficient mechanical properties in particular stiffness and strength at low price levels. Green composites are gaining importance due to their non-carcinogenic and biodegradable nature [2,8,17]. However the main disadvantages of green composites are the relative high moisture absorption.

II. BIODEGRADABLE MATRIX MATERIALS

Materials are defined as biodegradable if degradation is caused by biological activity, such as enzyme action, which leads to major changes in the chemical structure in a given time period into simple molecules, such as carbon dioxide and water. Biodegradable is a desired quality because it prevents accretion of solid waste, which is a foremost consideration for green composites [2,17]. There are wide ranges of biodegradable matrix materials which include thermosetting and thermoplastic polymer. Generally bio thermoplastic are commonly used in green composites.

2.1 Poly Lactic Acid (PLA):

PLA is obtained from natural resources through ring opening polymerization of lactides, where the lactic acid monomers are obtained through fermentation of carbohydrate material, usually glucose derived by hydrolysis from starch. PLA has greater tensile strength and modulus than polypropylene. Oksman et al. [19] observed that with triacetin glycerol triacetate ester as plasticizer, tensile stress and modulus reduced to 43.2MPa and 7.3GPa respectively for 5% plasticiser to 29.5MPa and 5.4GPa for 10% and to 19.6MPa and 2.4GPa for 15% plasticiser. Bax and Mussig [4] studied the tensile properties of PLA based flax and rayon composite and they found that For flax maximum tensile strength and modulus were 54.15MPa & 6.31GPa respectively for 30 wt% reinforcement and For viscose rayon maximum tensile strength and modulus were 57.97MPa & 4.85GPa respectively for 30 wt% reinforcement. Ochi et al. [18] studied the mechanical properties of kenaf PLA composite. They found that the tensile strength increased linearly up to a fiber content of 50 vol% and get maximum strength of 223MPa at 70 vol%. Iovino et al. prepared coir and PLA/TPS based biocomposite. In the standard matrix, they observed that the TPS granules acted as a stress concentrator in the blend.

2.2 Polyhydroxyalkanoates (PHA):

In PHA, PHB is frequently used which is composed of monomeric units of 3-hydroxy butyric acid. Due to its biodegradable nature it has wide applications in area of medical applications and packaging material [2].

2.3 Soyabin Oil Matrix:

Liu et al. [12] studied that tensile modulus increased linearly with fiber length volume fraction until at 55 vol% of reinforcement it reached approximately 6GPa but with changing fiber length the modulus increased steeply up to a fiber length of 6mm then stabilized concluding that 6mm is the critical length for Kenaf Soyabin based composite. Thielemans and Wool [24] added that butyrated kraft lignin to an unsaturated thermosetting resin, consisting of a mixture of Acrylated Epoxidised Soyabin oil (AESO) and styrene and prepared composite materials from resin mixture with flax fibers and short wheat straw fibers by vacuum assisted resin transfer moulding. They observed that as the amount of butyrated lignin in the resin was increased both tensile modulus and strength decreased.

2.4 Thermoplastic Starch (TPS):

Shibata et al. [23] studied the effect of fiber loading and fiber length in kenaf and bagasse fiber reinforced corn starch based matrix random composites. They found that flexural modulus and strength increased up to a fraction of 60 vol% for kenaf fiber and 66% for bagasse fiber. Curvelo et al. [7] studied the mechanical properties of regular corn starch with wood fiber reinforced composite. They observed that the tensile strength and modulus were improved to 11MPa and 0.32GPa respectively for composite compared with 5MPa and 0.13GPa for TPS. Takigo and Asano [25] studied the effect of processing on TPS based composite with microfibril nanofibers prepared by hot pressing at 1400C. They found that flexural strength and modulus reached approximately 65MPa and 7GPa for composites prepared at 50MPa pressure compared with 22.3 MPa and 0.95GPa for the neat resin materials.

2.5 Natural Rubber:

Wang and Huang [27] prepared composites from natural rubber as the matrix material combined with coir fiber from ripe coconut as reinforcement by heat pressing. They found that tensile strength of the 60 vol% reinforced composites to be in the range of 140MPa with no significant influence of processing temperature. Geethamma et al. [9] concluded that alkali treatment is an important step for improvement of interfacial bounding because of the removal of cuticle and the creation of a rough surface. Jacob et al. [10] prepared natural rubber composites with a 50:50 hybrid reinforcement of sisal and oil palm using two roll milling and curing at 150^0C. They observed by a rheometric study of vulcanization that the mix with bonding agent and chemically treated fiber yielded maximum torque. They observed that the tensile strength in the fiber direction increased up to 7.5MPa.

2.6 Cashew Nut Shell Liquid (CNSL):

The main constituents of CNSL are anarcadic acid, cardanol and cardol. Mwaikambo and Ansell [16] studied the mechanical properties of CNSL resin with unidirectional continuous hemp fiber. They observed that as the moulding pressure was raised, tensile strength increased for the untreated hemp composite but decrease for the alkali treated hemp composite. Aziz and Ansell [3] have made long straight and random fiber composite from kenaf and hemp fibers. They observed that alkali treated fiber composite gave better flexural strength compared to untreated fiber composite.

2.7 Castor Oil Matrix:

Silva et al. [22] produced castor oil polyurethane composites reinforced with Sisal and coir random fiber by compression moulding to study the effects of different types of reinforcements on the performance of composites. For matrix preparation they used polyol synthesized from castor oil mixed with tri-functional polyester with hydroxyl.

III. PROPERTIES OF BIODEGRADABLE MATRIX MATERIALS

Biodegradable matrix materials vary among their mechanical properties such as tensile strength, tensile modulus, flexural strength, density and elongation. There are wide range of composites are used for different types of applications and density is one of the vital factors to consider the material for a specific application. Tensile modulus is another essential mechanical property of biodegradable matrix which measures stiffness of materials. Elongation determines how much deformation occurs in the materials under stress [1, 2]. It is observed that there is considerable variation in densities and elongation of different biodegradable matrix materials. There is a wide scope for further improvement of quality to meet the needs of tomorrow

IV. ADVANTAGES OF GREEN COMPOSITE

Green composites are relatively cost effective, exhibit good thermal & dimensional stability, low co-efficient of friction and low density. It has low specific weight which results in a higher specific strength and stiffness than glass. It can be produce with low investment which makes the material an interesting product for low wage countries. Thermal recycling of green composite is possible where glass causes problems in combustion furnaces.[15,17] Green Composites are mainly used in high end applications such as automotive and aeronautical engineering etc.

V. CONCLUSION

This review has provided a succinct summary of the main biodegradable matrix materials. Biodegradable matrix materials are mostly synthesized from bio-sources like wheat, soybean, rice, sunflower, corn etc. and its properties varies depending on their chemical structure grade and quality. Nowadays glass fiber, carbon fiber and petroleum based synthetic fibers have been frequently used. Exploitation of non renewable resources become a prime concerns which prioritizes the need of exploitation of renewable resources for the development of bio materials that could be used as an alternative to the conventionally used composite for automobile, biomedical, packaging and other commercial purposes. The present study shows that there is a wide range in the mechanical properties of green composites and therefore it is essential to carry out advanced research on the engineering of natural fibers and biodegradable matrix materials for targeted applications.

The main drawback of natural fibers used in composites is their moisture absorption property. Hence the recent research on the natural fiber composites has been directed towards fiber surface modification and matrix adjustments to enhance mechanical property of the finished composite material.

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