ISSN No.:2350-1146, I.F-5.11

Alternatives material: Bio-composites and Bio-plastics

DR.NIDHI JAIN

, 1Department of Applied Science, Bharati vidyapeeth college of engineering Lavale,

Savitribai Phule Pune University, India.

E-mail addresses: nidhijain1704@gmail.com

ABSTRACT:

Bio-plastics or biocomposite are the material which are now touching new horizons and replacing convention plastics. Biocomposite are the substance which eventually replace the petroleum based product. Due to the increase in the landfill and carbon foot print, world is in the need of new fabricated material. For green world and green tomorrow scientist and researcher are working day and night to bring biodegradable materials. In this article we try overview the various applications, morphology, mechanical properties and its application. We also try to review the nano-composite and various types of nano-composite derived from natural sources.

Keywords: Bio-composite, biodegradation, green technology, nano-bio-composites.

1. INTRODUCTION:

<u>Bioplastics:</u>

Bio-plastics are made from biodegradable materials and are bio-compliable which are not only saving environment and natural resources but also reducing green house emission(CO2 neutral) etc.(S.S. Ray, and M. Bousmina, 2005; V.A. Fomin, and V.V Guzeev, 2001; R.A. Gross et al., 2002; C. Bastioli, 2001;R. Leaversuch, 2002) Bio-plastics now a days are used in various fields like bio-medical,-structural and electrical products because of the better usability and performance .The world bioplastics consumption are increased from 15,000tons (in 1996) to 225,000tons(in2008)(4,7) R.A. Gross et al.,2002;C. Bastioli, 2001; R. Leaversuch.,2002;The demand of bio-plastics are increasing every year by 30 %(R. Leaversuch.,2002).Due to the increasing demand of bio-plastics which are some inferior in quality than synthetic counterparts.

Polymers blends and composites are commonly investigated to get the superior bio-plastics. Various organic and in organics fillers are added. Such as calcium carbonates nanoclay (inorganic) and wood and plant fibers(organics)(R. Andrews, and M.C. Wisenberger, ,2004.;T. Li et al., 2006;A.K. Mohanty,et al.,2000)The main forces reinforcement to form bio-composites is too decrease carbon foot print. Bio-composites made from bio-plastics and natural fibers are often termed as green composites. The major benefits of the green composites are

Bio-composites are the combination of natural fibers (bio-fibers) such as wood fibers (hard wood and soft wood) or non wood fibers (e.g. rice straw, hemp, banana, pine apple, sugarcane, oil palm, jute, sisal and flax) with polymer matrices from both of the renewable and non-renewable resources. The term 'bio-composites' broadly covers composite materials where at least one constituent should be bio-based. Polymer nano-composites are the upcoming technique in recent years. Nano-composites shows wide industrial application in various fields. They shows good performance and improved properties design flexibility, lower life costs etc. Antimicrobial material can combine together to form bio-composite which has huge advantages in the field of healthcare food active packaging, automotive and textiles to control harmful microorganisms (Hojatollah Bodaghi et al., 2013;Kuorwel et al., 2013; Manso, et al.,2013).

Silver is a powerful antimicrobial agent which is combining with the recent material like polymer matrix to form Polymer Nano-composites. (Fortunati et al.,2011 ; Nocchetti et al., 2013; Rinaldi et al., 2013). Silver ions are active against a very broad spectrum of bacteria, yeast, fungi and viruses even at very low concentration (Lara et al., 2010; Nocchetti et al., 2013) with negligible toxicity towards human cells at the same concentration range (Williams et al., 1989).Colloidal silver shows antimicrobial properties against Gram-positive and Gram-negativebacteria (Dallas, Sharma, & Zboril, 2011).Silver nitrates are also used as food additives in bottle water.

Biopolymers reinforced with bio-fibers are generally considered to be green composites, for the formation of the composites at least one component of the composites either the fibers or the resin has been biodegradable. Such semi biodegradable composites have problem in disposable. Generally these semi green composites have moderate tensile strength and stiffness in the range of 100MPa or 200 Mpa and 1Gpa or 4GPa respectively

As a result, their applications are restricted only non-critical and non-load bearing parts, such as packaging, casings etc. they cannot be used in load bearing applications where high strength and stiffness are required (Chabba, S. & Netravali, 2004; Lodha, P. & Netravali, 2005; Chabba, S.,2003; Lodha, P. 2003; Mohanty, A.K et al., 2000; Ochi, S., 2002; Netravali, A.N. 2004; Chabba, S.C et al.,2004; Nam, S. 2002; Fujii, T.et al., 2004; Netravali, A.N. 2004; Mohanty, A.K., 2005; Huang, X. & Netravali, 2006; Mohanty, A.K., 2005; Huang, X., 2006; Lodha, P. & Netravali, A.N.,2005; Mohanty, A.K et al., 2005; Nabi Saheb, D. & Jog, J.P. 1999; Klempner, D.; 1994; Finnefrock, A.C., 2003; Shah, D. 2005; Helbert, W.; 1996; Nishino, T.; 1995; Nakagaito, A.N. & Yano 2003; Turner, I. & Karatzas, C. 2004; Grubb, D.T. & Jelinski, L1997; Borstoel, H 1998; Salmon, S. & Hudson, S.M. 1997)

Polyflax is 100 % renewable bio-composites are now available which has fibers and resins derived from sugarcane (Can et al., 2014).

Recyclability of biodegradable polymers:

Recycling of the polymer in the process where polymer are reused when its service life was over, Recycling is done to increase the life of the polymer before its discarded.

These polymer wastes can be recycled in two ways (1) Mechanical one (2) Chemical one

In mechanical recycling the waste are remolds, reprocessed into desired products through various processing techniques and in chemical recycling the polymer is converted into monomer, the monomer is used as raw materials for further polym-erization process (Soroudi and Jakubowicz, 2013). Examples of the recycling products are PLA/PHBV blend (Zembouai et al., 2014), and PLA (Żenkiewicz et al., 2009).After processing PLA for 10 times, the various physical properties such as tensile strength reduces to 5.2%, , tensile strain reduces to 2.4%, , and impact strength reduces to 20.2%..

But we can see the mark difference in melt flow rate, and oxygen and water vapor permeability rates were increased .We can see the several other examples where we find similar types of changes.

Durability of biodegradable polymers:

Durability of the polymer decides the suitability of the polymer for various applications. It decides the suitability of the polymer for various applications. The durability of the polymer can tested by the by subjecting it into environmental variables such as temperature and humidity. Scientist studied the durability of the polymer and reported that the durability of the polymer decrease at high elevated temperature and humidity with respect to time(Harris and Lee (2010, 2013)).For example when we study the durability of PLA polymer. It was reported that, it's not suitable for the automobile industries, as it exposed to 70 °C temperature with 90% relative humidity in 8 days, it shows sever degradation in mechanical properties. In the same way PHBV polymer also studied in water and marine environments at different temperatures (Deroiné et al., 2014a,b, degradation is reported. In case of the polyesters its mainly depends on chemical structure (Kim and Kim, 2008). PBS and its composites durability is improved by addition of trimethylolpropane triacrylate (TMPTA) as an anti hydrolysis agent.

Biocomposite:

Bio-composites have the capacity to replace traditional petroleum based composites, which produces a serious problem in the environment .The mechanical properties of the bio-composites are inferior than the synthetic made B. V. Ramnath, 2013; D. U. Shah 2013; T. T. Ngo, 2013; M. Fejos, J. 2013; R. Wang and T. P. Schuman 2013; H. Cui and M. R. Kessler2012).The mechanical properties of the bio-composites are improved by altering the natural fibers and thermal matrix. The silane treatments were tested by Cris and Kessler in 2012.Thid study was aim to modify the mechanical strength and ductility of several fibers reinforced thermostat composite by modification of either the fibers or the polymers matrix.

Polymer nano-composites are new field of nano-composites which are widening the scope of biocomposite in recent years because of the good performance better properties, greater flexibility, cheap prices and wide range of application. They are used in the field of health care, packaging industries textiles, agriculture transport etc. (Hojatollah Bodaghi, H., 2013)

Some bio-based polymer composites are used in industries for the following purpose

1. to minimizing the petroleum product consumption

2. Save the renewal resources.

3. Minimize the green house emission.

4. Minimize the harmful solid waste deposition.

5. Reducing the deposition of non-renewable resources in water.

6. Help in cleaning the water bodies.

7. The waste product regenerated can be recycled again.

8. Provide boast in the agriculture sector by increase employment in the agriculture sector.

9. High specific mechanical properties, thermal and acoustic insulation. (Lodha, P. & Netravali, A.N. 2005; Bledzki, A.K. & Gassan, J. 1999; Stamboulis, A, Baille, C.A. & Pejis 2001)

Nano-composites can be made from two types of reinforcement: Particle based nano-composites and fiber based nano-composites.

Fiber based nano-composites: Natural fibers are those fibers which are originated either from vegetables or they are obtained from animals. The plants fibers are cotton jute coir etc, protein fibers are wool and silk. Natural fibers can be divided into three types (1) seed hairs Ex Cottin and coirs etc and protein fibers are wool and silk. Natural fibers can be divided into three types.

(1)Seed Hairs Ex Cotton and coir’s

(2) bast fibers Ex Kenaf and sisal etc.

(3) Leaf fibers Ex sisal abaca

Out of all these types of fibers jute flax, hemp and sisal are predominately used in the formation of composites. (Nabi Saheb, D. & Jog, J.P,1999)Major animals’ fiber comes under (eg wood feather, angora fibers and silk fibers).

Role of matrix in formation of bio-composites:

Matrix plays a role of backbone in the formation of bio-composites; it provides stiffness-toughness and desired properties for the resulting bio-composites. Some the publication already review the matrix using sin-gle polymer matrix-based biocomposite (Satyanarayana et al., 2009; Wahit et al., 2012; Dicker et al., 2014; Ahmad et al., 2015; Shah, 2014.Recently there is a growing trend for the blend matrices. Researcher find out that multiphase polymer blend are very effective and providing a new route for developing polymer matrix system for NFCs. Zhang et al. (2012) worked of ternary blend of various polymer composite like PHBV, PLA, and PBS. Muthuraj et al. (2014) found good result in various mechanical, thermal and thermo-mechanical properties with binary blend of PBS and PBAT

Nature of Natural fibres and its behaviour

Strength of plant fibres’ depends on its internal structure, chemical composition, micro fibril orientation angle etc, (Ahmed et al, 2015 table 5.5.)When we study the natural fibers constituents, cellulose are highly crystalline nature and lignin is amphorus in nature with highly aromatic structure, Lignin acts as a protective barrier for cellulose in plants because of its stiffness. Degree of polymerization10-1000 lower in Hemi cellulose. Cellulose has strength.2 Gpa and stiffness of 138GPa (shah2013).Pectin act as hydrophilic component in plant fibers.

Cellulosic fibers are renewable resources mostly used for the production of biocomposite. These cellulobasic fibers have low cost and easily available production requires little energy. They decrease the CO2 content and increase the O2 production. Generally all plants based fibers are short length to increase the length they are converted into yarns. Yarns are woven or knitted in two direction leading to higher failure strength(Chabba, S. & Netravali, A.N. ,2004,Chabba, S. & Netravali, A.N2005,Naik, N.K. & Kuchibhotla, R. 2002).The woven fibers have large spectrum of advantage such as higher impact strength, high tolerance toughness ease of manufacture(38,39,41,43) Chabba, S. & Netravali, A.N2005,. Naik, N.K 1996, Brouwer, W.D.The y have lower density then glass fibers and therefore comparable specific strength.(Nabi Saheb, D. & Jog, J.P,1999)

Mechanical properties of composites can vary with the constituents' fibers, the matrix and the fibers/matrix interfacial shear strength (IFSS). IFSS is a factor that decides the toughness transverse mechanical properties and inter-laminar shear strength (ILSS) of the composite materials.

Epoxy and a linseed oil-based (UVL) resin were used for the polymer matrix, while fiberglass and hemp were used for the reinforcing agent in a fabric form.

Mechanical properties of biocomposite:

Biocomposite can be made by unique properties and can be generated from natural occurring material. These properties of biocomposite cannot be obtained naturally. Because of its unique properties they can be used in different sectors construction, electronics devices, hips and marine equipments and many more. In 1941 Henry ford first introduced biocomposite which is made up of hemp, sisal and cellulose based plastics.Hence biocomposite and synthetic plastics are blended together.

Biocomposite are the substance which is made up of two or more different constituents having different physical and chemical properties. Composites materials are two phase interface on is matrix or continuous phase and second one is reinforcements or discontinuous phase as reinforcement. Mechanical performances of the matrix are also affected by reinforcement. Matrix may be metal, ceramic and polymer and reinforcement can be fiber (short or long) and particulate (powder, flacks and spherical) composites. Biocomposite are generally have better mechanical properties, light in weight and can be molded in shapes, means design flexibility, non abrasive and good in strength. (Akil et al.,2011).

Applications of biocomposite:

Fiber reinforce polymer composites are having wide range of application in the field of automotive interior parts, a packaging construction, electrical and musical instrument etc.

(a) Bio-plastics and Bio-composites in packing materials:

In food industries packing has the major contribution and its share around 20 % of the food industries .These packaging materials are generally non renewable and non degradable and contribute heavily in creating waste.(S. Pilla, 2009).Lot of health related issues are also consider during designing of packaging materials, which maintain the food natural flavor and vitamins. Keeping in this mind packaging materials should be such that possess certain properties such are permeability (gas and vapor), air tight, resistance to chemicals, UV and light, transparency etc. It should be meticulously design engineering materials, with lower cost. Designing of biocomposite is a 'cradle to grave' cycle. Use of biocomposite and bio-plastics in packing field will definitely leverages the industry and reduces the increase of landfill.

Companies that have been developing bio-plastics are Dow chemical’s (EcoPLA), DuPont (Sorona and Hytrel), BASF (Ecoflex and Ecovio) etc. Basf worked meticulously in developing biobased and biodegradable plastic lines based on starch, PLA, PBAT etc.

V.A. Fomin, 2001].

Several researcher worked on the development of Biocomposite from renewable biomass for food packaging applications. Venkata S.et al used Poly (lactic acid) was compounded with 10 – 30 wt. % hemp hurd to produce rigid plastic biocomposite. Biocomposite are cost-effectiveness and equivalent mechanical properties, and have antimicrobial materials with the inclusion of silver nanoparticles.

(b) Bio-plastics and Bio-composites in Civil Engineering

Bio-plastics and Bio-composites in Civil Engineering as added advantage due to unique properties such as light-weight, low material costs, high specific properties.(A.K. Mohanty et al

2000,W.D. Brouwer, 2000).Biocomposite and bio-plastics offer great help to the people in providing temporary houses for protecting their life .Countries like India, where large number of the people are poor, difficult to make concrete house for survival. People usually make temporary house which are cheap and easily made from natural occurring materials such as wood, dry big leaves and other natural biocomposite. Some of the other applications of bio-composites in civil engineering, construction field are formwork, doors, flooring walls and wallboard ceiling panels etc. These houses are also made due to a major catastrophe occurs such as earthquake, hurricane etc

These aforementioned advantages are not sufficient to replaceable non renewable continents to renewable biocomposite because of some deficiencies. The major deficiencies are hydrophilicity of natural fibers and weak interfacial bonding. These composites are not widely exploited as far as structural part is concern such as beams and columns.

(c) Bio-plastics and Bio-composites in Bio-médical Applications:

Bio-medically Bio-plastics and Bio-composites are used for the implants, tissue engineering, drug delivery etc.-They are bio-based, biodegradable and biocompatible. These bio-composites are best suitable for the critical aspects of the biomedical field. They are close to the nature that is why they are compatible with the tissue and other related organs in which they are implanted.-These bio-plastics offer a feasible solution the implants, tissue engineering, drug delivery etc.-The advent of the new invention in the field of the nano-compoite open varied range of the application in the biomedical industries. Bio-nanocomposites are principal and foremost application can be seen in the field of damaged tissues and in implants [. M. Darder,et al, 2007.]. Bionanocomposites not only provide mechanical stability but also provide macroporosity for the transportation of nutrients and waste [V. Thomas, 2006,M.S. Widmer, and A. G. Mikos,2009].

(d)Bio-plastics and Bio-composites in automotive applications:

Economics development and automobile sector go hand to hand in the development of the country. Movement of the human resources takes place by the transportation network work system and construction of the infrastructure. Due to the increases in the demand of the automobiles there is a need of the new fabricated materials in this sector. For sustainable growth of the automobile sector there is a need of new innovative materials. These materials helps us to achieve various goals such as

(a) Saving of non renewable fuels

(b) Decrease cost

(c)Decrease environmental pollution by reducing emissions

(d) Recycle the waste.

(e) Helps in the biodegradable of the materials

The emergence of bio-plastics and bio-composites serves has a alternative sources in all the fields that not reduce carbon footprint on the environment but also helps us to achieve pollution environment and society.

Bio Nano-composites

Polymer clay nano-composite has gain large scale improvement in physical and mechanical properties when compared to conventional composites or normally used pure composite. Some of the changes seen in the properties like increase in strength and modulus, heat resistance and decreased gas permeability and flammability (Giannelis, 1998).

For about half a century, numerous amount of research is being carried in the field polymer-clay nano-composites , which illustrates their significance of synthetic thermosetting(Park, J.H. & Jana, S.C. 2003; Chen C. & curliss,2003,Messersmith, P.B. & Gianelis, E.P. 1994) as well as thermoplastics polymers. The materials prepared synthetically have more strength than the naturally produced.

Some of the different types of nano-composites are:

Nano-composites generated from starch:

Natural Starch can be converted into into a plastic-like material called thermoplastic starch (TPS).Natural biopolymers used to developed renewable sources of packaging materials. These renewable sources of packaging materials are environment friendly and help to decrease carbon foot print. Natural starches are generally water-sensitive and have poor mechanical properties, to increase the mechanical properties and strength reinforcement of starches were madby nano-scale materials without effecting its biodegradablility. De Carvalho, et al.2001 Park, et al.2002 obtained well-ordered nano-composites because of the dispersion of the clay in the TPS matrix. TPS matrix, the increase the mechanical, thermal, and barrier properties. Withelm, et al,2003 made glycerol-plasticized starch reinforced with Ca2+-hectorite clay which shows great change in the properties of the materials in terms of storage modules which is a measure of elastic response of a materials. McGlashan and Halley 2003 increases the blow ability of the materials using starch/polyester blends,Xu, et al. worked on starch acetate nano-composites which increase glass transition temperature (Tg) by 6 °C -14 °C depending on the type of clay, Huang andYu,2006 worked on thermoplastic corn starch and find huge differences in the Tensile strength and Youngs modulus used to prepare starch/MMT nanocomposites.

Nano-composites generated from Cellulose:

Cellulose are high molecular weight polymer which are abundant available naturally in bio-polmers. Cellulose acetate is mostly used in large volume applications such as fiber, film and also in injection molding thermoplastics. Several scientists reported on the various properties of the cellulose and its derivatives Cho et al.,2004; Ruan,2003. Nano composites made from cellulose based materials have improved mechanical and thermal properties and permeability of films, which can be reinforced by organo clay.

Nano-composites generated from Chitosan

Chitosan structurally composed of β-(1-4)-linked d-glucosamine and N-acetyl-d-glucosamine. Its is a type of fiber derived from chitin. Chitosan is sugar like that is found in the hard outer shells of crustaceans such as crab, crayfish, shrimp and squid. It contains all the properties of the fibers like, not absorbed in the gastrointestinal system. It can be used to lose weight as dietary suppliements. It is nontoxic, biocompatible, biodegradable readily available. It was found that the tensile strength of chitosan film was enhanced by addition of clay. Various researches confirmed these facts such Xu et al., 2006 prepared Nano-composites film generated from Chitosan Na-MMT and Cloisite 30B using a solvent casting method. In the same way R. Wang 2013, et al. prepared chitosan /MMT nano-composite, by the dispersed of clay which increase the hardness and elastic modulus of the matrix

Protein based Nano-composites

Clay contains native inorganic ions inside the cavities which are replaced by heavier ammonium ions linked to hydrocarbon chains. This inculcation modifies the properties of the clay such as thermo-mechanical properties, dimensional stability, barrier characteristics and flame retardancy. This can be used for wide range of technology advancement. Soy protein is used (Otaigbe and Adams,1997)to obtained better mechanical properties and water resistance with polyphosphate fillers Clay nano-composites based on poly (vinylidene fluoride-co-hexafluoropropylene).With MMT clay glatin is used which is a form of animal protein which improves the mechanical and water resistance properties of the polymer208. Banerjee, M.;et al 2012 .It also shows enhancement in the tensile strength and Young's modulus

Conclusion: Bio-composites offer a huge opportunity to cater a large number of fields by offering new agricultural, environmental, manufacturing and consumer benefits. Bio-based composites materials are providing promising materials to design biocomposite of general and of special interest. There were various issues regarding structure which need to resolve for varied application of the product. Bio-nano-composites have immense potential to enhance the quality and safety in food packaging by providing antimicrobial activity. In all bio-composites are cost effective, renewable resources, commercially viable and bio-degradable solution for the men kind.

References

1. HojatollahBodaghi, H., Mostofi, Y., Oromiehie, A., Zamani, Z., Ghanbarzadeh, B.,Costa, C., et al. (2013). Evaluation of the photocatalytic antimicrobial effects ofa TiO2nanocomposite food packaging film by in vitro and in vivo tests. LWT –Food Science and Technology, 50, 702–706.
2. Kuorwel, K., Kuorwel, K. K., Cran, M. J., Sonneveld, K., Miltz, J., & Bigger, S. W. (2013).Migration of antimicrobial agents from starch-based films into a food simulant.LWT – Food Science and Technology, 50, 432–438.
3. Manso, S., Cacho-Nerin, F., Becerril, R., &Nerín, C. (2013). Combined analytical andmicrobiological tools to study the effect on Aspergillusflavus of cinnamon essen-tial oil contained in food packaging. Food Control, 30, 370–378.
4. Fortunati, E., Latterini, L., Rinaldi, S., Kenny, J. M., &Armentano, I. (2011). PLGA/Agnanocomposites: In-vitro degradation study and silver ion release. Journal

ofMaterial Science: Materials in Medicine, 12, 2735–2744

5. Nocchetti, M., Donnadio, A., Ambrogi, V., Andreani, P., Bastianini, M., Pietrella,D., et al. (2013). Ag/AgCl nanoparticle decorated layered double hydroxides:Synthesis, characterization and antimicrobial properties. Journal of MaterialChemistry B, 1, 2383–2393.
6. Rinaldi, S., Fortunati, E., Taddei, M., Kenny, J. M., Armentano, I., & Latterini, L.(2013). Integrated PLGA–Ag nanocomposite systems to control the degrada-tion rate and antibacterial properties. Journal of Applied Polymer Science, 130,1185–1193.
7. Lara, H. M., Ayala-Nu˜nez, N. V., Ixtepan-Turrent, L., & Rodriguez-Padilla, C. (2010).Mode of antiviral action of silver nanoparticles against HIV-1. Journal ofNanobiotechnology, 8, 1–10.
8. Williams, R. L., Doherty, P. J., Vince, D. G., Grashoff, G. J., & Williams, D. F. (1989). Thebiocompatibility of silver. Critical Reviews in Biocomposites, 5, 221–243.
9. Dallas, P., Sharma, V. K., &Zboril, R. (2011). Silver polymeric nanocompositesasadvanced antimicrobial agents: Classification, synthetic paths, applications, andperspectives. Advances in Colloid and Interface Science, 166, 119–135
10. L odha, P. & Netravali, A.N. Characterization of stearic acid modified soy protein isolate resin and ramie fiber reinforced 'green' composites. Compos. Sci. Technol.,2005, 65(7-8), 1211-25.
11. Bledzki, A.K. & Gassan, J. Composites reinforced with cellulose based fibers. J. Prog. Polym. Sci., 1999, 24(2),221-34.
12. Stamboulis, A.; Baille, C.A. & Pejis, T. Effects of environmental conditionson mechanical and physical properties of flax fibers. Compos. Part A-Appl. S., 2001, 32(8), 1105-15.
13. Chabba, S. & Netravali, A.N. 'Green' composites using modified soy protein concentrate resin and flax fabrics and yarns. Jpn. Soc. Mech. Engg., 2004, 47(4), 556-60.
14. Lodha, P. & Netravali, A.N. Characterization of stearic acid modified soy protein isolate resin and ramie fiber reinforced 'green'

composites. Compos. Sci. Technol., 2005, 65(7-8), 1211-25.

15. Chabba, S. Characterization of environment friendly green composites with modified soy protein concentrate and flax yarn and fabric. Cornell University, USA, 2003.
16. Lodha, P. Fundamental approaches to improving performance of soy protein isolate based ‘green’ plastics and composites. Cornell University, USA, 2003. PhDThesis.