Review on Fabrication and Application of Biodegradable Materials

Manmeet Singh[1], Nitin Waghmare[2]
[1]Dept of Industrial Engineering
[2]Faculty of Engineering and Technology, Asst. Professor
[1]Manav Rachna International University, Faridabad

Abstract- *The depletion of petroleum resources coupled with awareness of global environmental problem, global warming, the growing awareness of environmental and waste management issues: these are some of the reasons why bioproducts are increasingly being promoted for sustainable development. In recent years, there has been a marked increase in the usage of plastic because plastic can easily hold double the amount of weight, which is a plus point formost of the organizations but plastic is a non-biodegradable material and this increasing demand of plastic and mass production of same is affecting our environment.*

The reason behind non-biodegradable materials becoming global threat is because there is no proper way so to decompose them or reuse them, these ends up being taking space in our world, so conquer this industrialist are focusing in the field of developing biodegradable materials which could take place of these materials in the future.

This review aims to describe developments concerning environmental-friendly biodegradable polymers and composites carried out in recent years, based on several case studies.

Keywords- Bio composite, Bio material, Biodegradable

I. INTRODUCTION

Bio composites made from renewable natural resources gained much importance globally, because of their application in various fields due to their eco-friendly behaviour. This makes it imperative to understand about biodegradable composites and natural raw materials used in making such composites which are being used for household, biomedical, automobiles, packaging and other engineering applications[1].

Some Bio products have been used for thousands of years for clothing, furniture and food. Recent technological breakthroughs have substantially improved the properties of some bio-based polymers, such as heat resistant polylactic acid, enabling a wider range of applications. In addition to this, plants are also being optimized, so that they can provide bio-fibres with more enhanced and stable resource properties over time[2].

Also, the use of natural fibre for the reinforcement of the composites has received increasing attention both by the academic sector and the industry. Natural fibres have many significant advantages over synthetic fibres. Currently, many types of natural fibres have been investigated for use in plastics including Bamboo, jute straw, wood, rice husk, wheat, barley, oats, rye, sugarcane, grass, oil palm empty fruit bunch, water, hyacinth, banana fibre, pineapple leaf fibre and papyrus. Thermoplastics reinforced with special wood fillers are enjoying rapid growth due to their many advantages; lightweight reasonable strength and stiffness[3].

This review summarizes various case studies providing brief outline of mechanical properties of new biodegradable composites with importance and survey of proper selection of raw material to be used to produce Biodegradable composites along with materials used for reinforcement of those composites.

II. LITERATURE SURVEY

Advantages of Biocomposites –

Biocomposites are manufactured using bio binder and bio fibre which are fully bio degradable.

Biocomposites has many advantages, they are relatively cost effective, exhibit good thermal and dimensional stability, low coefficient of friction and low density. Bio composites are mainly used in high end use applications such as tissue engineering, automotive industries and aeronautical engineering, etc. It has been reported that bio-binders reinforced with bio fibres showed considerable improvement in tensile properties of biocomposites [4].

Bongarde U.S. and Shinde V.D. investigated that the natural fibre-reinforced polymer composite is rapidly growing both in terms of their industrial applications and fundamental research as they are renewable, cheap, completely or partially recyclable and biodegradable. Most importantly these composites comes with low density and low cost as well as satisfactory mechanical properties which makes the man attractive choice for manufacturing as they are easily available and renewability ofraw materials[5].

It is apparent from the work done so far on biodegradable composites that the tensile strength of fully biodegradable composites varied from 20-73 MPa and maximum tensile strength 73 MPa was recorded when the composites fabricated using PLA reinforced with Hemp and minimum tensile strength was found when Polycaprolactone bio binder was reinforced with flax fibre. The tensile modulus of biocomposites varied with addiction of different bio binders and bio fibres. The tensile modulus of such composites are shown in Fig. 3, where the maximum tensile modulus was 20 GPa reported in PLA with sisal fibre and lowest modulus reported in Polycaprolactone bio-binder reinforced with flax fibre [6].

Classification of Biocomposites –

The materials called biocomposites result from a combination of a biodegradable polymer and biodegradable fillers, usually bio-fibres. Biocomposites can be classified into three main groups: (i) “bio1composites”, composites in which the production of raw materials is based on renewable resources, (ii) “bio2composites” which are bio1composites whose waste can be managed in an eco-friendly way at the end of their life (composting, biomethanation, recycling…), and (iii) “bio3composites”, which are bio2composites where the successive transformation processes from the raw materials to the final products are environmental-friendly (low energy consumption, low emissions). Nevertheless, a problem remains: while it is relatively easy to define a “bio1composite” by its content of renewable raw materials and a “bio2composite” by its service-life/end-of-life time ratio, how can environmental efficiency be defined for “bio3composite” transformation processes? With regard to the extrusion process, energy consumption can be evaluated from the specific mechanical energy (SME) and specific thermal energy (STE), which correspond respectively to the energy delivered by the screws per unit of mass of extruded biocomposite and to the total heat energy input through the barrel wall and the thermally regulated screws. A large number of energy efficiency indicators could be proposed for extrusion compounding such as the molten state viscosity of the extruded biocomposite and thermo-physical characteristics (transition temperature and enthalpy, heat capacity, thermal conductivity, density)[7,8].

Classification of Biodegradable Composites based on raw materials used in its preparation.

Pickering. K. L. et al. (2001) highlighted the advantages of using natural fibre composites which will help in improving the mechanical performance of the composites. He used composites like synthetic fibre composites which are low on impacting the environment and low on production cost with greater applications. According to the research done in this paper the performance of the composites improves with the proper Matrix Selection, Interfacial Strength, Fibre Dispersion, Fibre orientation, composite manufacturing process and Porosity, while he also added that the lower densities for NFCs lead to better comparison for specific properties which could become handy for some specific applications[9].

SAHEB D. N. and JOG J. P. showed that Natural fibre reinforced composites are very much emerging in a field of polymer science because these natural fibres from being low cost fibres with low density and high specific properties also comes with the property of being biodegradable and non-abrasive in nature. The major highlight of this research work was to show the properties of Natural Fibres Depending upon the Types of Natural Fibres selection, Microstructure of the Fibres, Chemical Composition of Natural Fibres and Natural Fibres Composite. Addition to the overall property highlighting research also shows the thermal stability of natural fibres, Moisture content of the fibres, Biodegradation and Photo degradation of Natural Fibres, Processing of Thermo set Composites, Dispersion of the fibres in the matrix, Processing of thermoplastic composites, Fibre-matrix Interface and Modification of Natural Fibres[10].

Jahagirdar M. and Kulkarni S. R. presented that Addition to the benefits of using natural fibres for reinforcement of the composite, researcher added vinyl ester and coconut fibbers and rubber particles which helped in improving the bending of the tensile and bending test. According to the results from the test performed by the researcher Coconut fibres and rubber particles based composites are more suitable for bending applications and addition to this it was also highlighted vinyl ester is a good choice because it helped in improving the more properties like impact, density,hardness, wear, dynamic,etc.[11]

Calabia B. et al. used cotton fibre formal named as CG as a filler in poly (butylenes succinate) (PBS) and the effect of silane treatment on the mechanical properties,thermal stability, and biodegradability of PBS/CF composites are investigated. The results showed that the tensile strength of PBS was improved (15%–78%) with the incorporation of CF

(10–40 wt%) and was further increased (25%–118%) when CF was treated with a silane coupling agent. Scanning electron microscopy (SEM)observation of the fracture surfaces of PBS/CF composites showed that there was slight improvement in fibre-matrix compatibility. Thermo gravimetric (TG) analysis showed that the thermal stability of the composites was lower than that of neat PBS and decreased with increasing filler loading. The bio-based carbon content of the composites increased with increasing CF content. The incorporation of CF (with and without silane treatment) in PBS significantly increased the biodegradation rate of the composites[12].

Mohanty A. K. et al. performed the chemical surface modifications with the help of jute fabrics involving bleaching, dewaxing, alkali treatment, cyanoethylation and vinyl grafting were made in the view of their use as reinforcing agents in composites. Addition to this various mechanical property of composites like tensile and bending strengths which results in improved properties of the composites. Then the degradation studies were also done and finding of the same shows that after 15 days of compost burial about 6% weight loss is observed and loss of mechanical strength was also observed[13].

Malathi A. N. et al. highlighted that the synthetic polymer which are produced in undesirable influence on the environment will cause problem and waste deposition and utilization. The main points was on food packaging industry as various classification of biodegradable polymer and mainly concentrated on Biodegradable polymers from biomass products. Addition to this the application of nano technology in food packaging was also expand with the use of edible and biodegradable films that reduce the packaging waste associated with processed foods this supports the preservation of fresh foods by extending their shelf life[14].

Nishino T. et al. Used kenaf fibres as the natural reinforcement for the composite. During the whole investigation process it was found that using kenaf fibres definitely improve the mechanical properties[15].

Sahar J. and Sapuan S. M. have carried out the development and properties of natural fibre reinforced biodegradable polymers which are fully degrade and compatible with the environment. Natural fibre reinforced of biodegradable polymer composites appear to have very bright future for wide range of applications, which are helpful and the main key point here is its biodegradability in nature[16].

Lu D. R. et al. discussed the all properties of starch as a natural polymer which help in many new shortcomings simultaneously. Some synthetic polymers are biodegradable and can be tailor-made easily but by combining the individual advantages of starch and synthetic polymers, starch-based completely biodegradable polymers (SCBP) are potential for applications in biomedical and environmental fields. This results in great attention and was extensively investigated in the biodegradable composites. Finally the researches show cased most of the properties of starch which helps in reducing the use of the petroleum based composites[17].

Ku H. et al. explored the The tensile properties of natural fibre reinforce polymers(both thermoplastics and thermo sets) are mainly influenced by the interfacial adhesion between the m atrix and the fibres. Several chemical modifications are employed to improve the interfacial matrix-fibre bonding resulting in the enhancement of tensile properties of the composites. In order to get desired results Hemp fibres were used, with conducted experiment it shows that the strength and stiffness of the natural fibre polymer composites is strongly dependent on fibre loading[18].

Barkoulaa N.M. et al. focuses on short flax fibre reinforced composites based on polyhydroxy butyrate (PHB) and its copolymer with hydroxyvalerate (HV). The effect of the fibre and copolymer content on the mechanical properties of the composites was discussed. Then the biodegradability of the composites expressed as weight, stiffness and strength loss as a function of burrier time is presented on the example of injection moulded flax/PHB/HV composites. The final conclusion shows that addition of flax fibres along with controlled processing conditions seems to be a convenient way of toughening of the PHB matrix. Composites manufactured through injection moulding exhibited lower impact strength than those manufactured through compression moulding[19].
Oregan State University Performed a series of experiments which was done to show the group of students, how to create biodegradable plastic using microwave. Students used Substrate (Gelatin substrate tends to produce the strongest material. Results can vary depending on the brand of gelatin used.), Plasticizer(Increasing the amount of plasticizer increases the flexibility of the final product. If no plasticizer is added, thesubstrates produce brittle material. The amount of plasticizer necessary to make the best bioplastic depends on the brand of the substrate and the drying conditions), Non-stick spray (It is extremely important to use the non-stick spray; otherwise the aluminium foil molds cannot be removed from the bioplastic.) and Drying (While you can dry the moulds in the open air, drying the moulds in a controlled temperature environment is faster and gives more repeatable results. Good drying methods are to set an oven at 150° F or use a food dehydrator), were the main points to learn from this experiment[20].

Natural fibres as reinforcement of Composites

R. Siva Shankar and S.A. Srinivasan state that Natural fibres as reinforcement have currently attracted the attention of researchers because of their benefits over other established materials. Natural fibres are

- Environmentally friendly
- fully biodegradable
- abundantly available
- Renewable and cheap and
- have low density

Plant fibres are light compared to glass, carbon and aramid fibres The biodegradability of plant fibres can contribute to a healthy ecosystem while their low cost and high performance fulfils the economic interest of industry. When natural fibre reinforced plastics are subjected at the end of their life cycle to combustion process or landfill, the released amount of CO_2 of the fibres is neutral with respect to the assimilated amount during their growth.

Natural fibres are renewable resources in many developing countries of the world; they are cheaper, pose no health hazards and finally, provide a solution to environmental pollution by finding new uses for waste materials. Furthermore, natural fibre reinforced polymer composites form a new class of materials which seem to have good potential in the future as a substitute for scarce wood and wood based materials in structural applications[21].

III. CONCLUSION

The progress made in the field of environmental-friendly biodegradable polymers and composites over the past ten years has been spectacular. A large number of corporations are now involved in this area, manufacturing a wide range of products. There are also major ongoing advances in research and development, contributing to the increased attractiveness of chemical sciences and technology for a new generation of scientists and engineers. All in all, these developments have converted bio-based polymers and composites from a minor niche into a mainstream activity. However, the challenges that need to be successfully addressed in the years and decades to come are the lower material performance of some bio based polymers, the control of the lifetime during in-service life regardless of their end-of– life biodegradation, their relatively high production and processing costs, and the need to minimize the use of agricultural land and forests, thereby also avoiding competition with food production and adverse effects on biodiversity and other environmental impacts.

REFERENCES

[1] A.S. Singha, A. Sharma and B.N. Misra // J. Polym Mater. 25 (2008) 91

[2] Febles C. I, Arias A, Hardisson A, Rodrı´guez-Alvarez C and Sierra A. Journal of Cereal Science 2002, 36, 19–23.

[3] Blandino A, Dravillas K, Cantero D, Pandiella S.S and Webb C. Process Biochemistry 2001, 37, 497–503.

[4] BergeretAnne, Environmental-Friendly Biodegradable Polymers and Composites. Integrated Waste Management, ed. by Sunil Kumar (InTech, 2011).

[5] Bongarde U.S., Shinde V.D., "Review on natural fibre reinforcement polymer composites‖", International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 3, Issue 2, March 2014.

[6] A. Arbelaiz, B. Fernandez, A. Valea and I. Mondragon // Carbohydrate Polymers 64 (2006) 224.

[7] Thimothy Thamae, Shanil Vaja, Yiyi Shangguan, Claire Finoro, Nick Stefano and Caroline Baillie. ISBN: 978-1-60741-301-1, 2009.

[8] Jean Marc Saiter, Larisa Dobircau, and Nathalie Leblanc. International Journal of Polymer Science 2012.

[9] Pickering K.L., Aruan Efendy M.G., Le T.M. , "A review of recentdevelopments in natural fibre composites and their mechanical performance‖",Elsevier, 9 september, 2015.

[10] SAHEB D. NABI and JOG J.P., "Natural Fibre Polymer Composites: AReview‖", 19 may, 1999.

[11] Muneerabibi S. Jahagirdar, Shreenidhi R. Kulkarni, "BiodegradableComposites: Vinyl Ester Reinforced With Coconut Fibres and Vinyl EsterReinforced With Coconut Fibres and Rubber Particles‖", International Journal ofInnovative Research in Science, Engineering and Technology, 8 August, 2014.

[12] Buenaventurada P. Calabia, Fumi Ninomiya, Hisaaki Yagi, Akihiro Oishi,Kazuhiro Taguchi, Masao Kunioka and Masahiro Funabashi, "BiodegradablePoly (butylene succinate) Composites Reinforced by Cotton Fibre with SilaneCoupling Agent‖ from ISSN 2073-4360" MDPI, 29 January 2013.

[13] Mohanty A.K. & Khan M.A., Hinrichsen G., "Influence of chemical surfacemodification on the properties of biodegradable jute fabrics—polyester amidecomposites‖", from Elsevier, 8 july 1999.

[14] Malathi A. N., Santhosh K. S., Udaykumar Nidoni, ―Recent trends ofBiodegradable polymer: Biodegradable films for Food Packaging and applicationof Nanotechnology in Biodegradable Food Packaging‖ from Current Trends inTechnology and Science ISSN : 2279-0535. Volume : 3, Issue : 2.

[15] Takashi Nishino, Koichi Hirao, Masaru Kotera, Katsuhiko Nakamae, HiroshiInagaki, "Kenaf reinforced biodegradable composite‖", Elsevier, 21 February,2003.
[16] Sahari J. and Sapuan S.M., "Natural fibre reinforced biodegradable polymercomposites‖", 8 August, 2011.
[17] Lu R., Xiao C. M., Xu S. J., "Starch-based completely biodegradablepolymer materials‖", Express Polymlett, 30 March 2009.
[18] Ku H., Wang H., Pattarachaiyakoop N., Trada M., "A review on the tensileproperties of natural fibre reinforced polymer composites‖".
[19] Barkoul N.M., Garkhail S.K., Peijs T., "Biodegradable composites based onflax/polyhydroxy butyrate and its copolymer with hydroxyvalerate‖", Elsevier, 19August 2009.
[20] University Oregan State, "Experiment reference of referencing differentsubstrate and preparation with fork it as titled".
[21] R. Siva Shankar1, S.A. Srinivasan1, Dr.S. Shankar2, Dr.R. Rajasekar3, R. Naveen Kumar4, P. Sathish Kumar; Review article on wheat flour/wheat bran/wheat husk-based bio composites; International Journal of Scientific and Research Publications, Volume 4, Issue 4, April 2014