IJASRM

International Journal of Advanced Scientific Research and Management, Volume 4 Issue 4, April 2019

www.ijasrm.com

ISSN 2455-6378

Bio-Plastics: A sustainable alternative to conventional petroleum based plastics

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Abstract

Bio plastics are plastics made from renewable sources such as biomass.Most common feedstock used to manufacture bioplastics are sugar, starch, cellulose, vegetable oils obtained from corn, potato, sugarcane, wood etc.While synthetic plastics is derived from petroleum based products. New economy bio plastics include Poly lactic acid, Polyhydroxyalkanoate, starch blends,biobased polyesters etc.while old economy bio plastics includes rubber,cellulose,Linoleum.Bioplastics can be broadly classified in to two categories Biodegradable plastics and Biobased plastics.Some common bioplastics include Poly Lactic acid(PLA),Poly hydroxyalkanoate (PHA),aliphatic polyesters and polysaccharides.Polycaprolactone (PCL),Polybutylene succinate(PBS) are derived from petroleum and are biodegradable.Bioplastics are finding its use as compostable bags,mulch,film,rigid packaging and in catering products.Bioplastics generation saves fossil fuel consumption and hence prevents greenhouse gas emissions. Recovery options for bioplastics includes thermal recovery,Mechanical recycling,landfilling and organic recycling.Biopastics are costly as biobased plastics industries are in nascent stage and bioplastic production is low.Bioplastics have potential to impact food supply and recycling options are still not much for bioplastics.In lines with core principles of circular economy, Bio plastics prevents waste generation and enhances recovery from waste.Bioplastics promote resource efficiency and adheres to low carbon economy.

Keywords: *renewable sources, new economy plastics, resource efficiency, circular economy*

1.Introduction

Bioplastics comprise of both biodegradable and bio based plastics.Generally plastics are composed of synthetic polymers hence plastics are non-biodegradable. Biodegradable plastics are plastics that decompose into Carbon di oxide, Methane, water, biomass and other inorganic compounds (Chen,2014). Compostable plastics are a category of biodegradable plastics that are biologically decomposed within a short period of time under suitable conditions. All compostable plastics are biodegradable but all biodegradable plastics are not necessarily be compostable (Stevens,2002). Microorganisms recognize these polymers as their food and decompose them through intra and extracellular enzymes through the process of hydrolysis and oxidation. Biodegradation of polymers comprises of fragmentation and mineralization (Naryan,2002). Fragmentation occurs through various living and nonliving factors which cause chemical breakdown of Polymers and cause mechanical disintegration. Partially degraded fragments produced through fragmentation process are metabolized into end products through the process of mineralization. During mineralization organic Carbon is converted in to Carbon di oxide. Polymers such as Polyesters and Polyamides which are formed through the process of condensation are decomposed through hydrolysis (Mohee et al.,2008). While polymers such as Polyvinylchloride (PVC) which contains only C atoms are decomposed through the process of Oxidation. Biodegradation occurs due to living and nonliving factors such as UV, heat, water and with the help of microorganisms.Expermentally the degradation process can be analyzed through measuring concentration of functional groups for ex. Infrared Spectroscopy can be used to determine concentration of Carbonyl group -(C=O)- produced as a result of oxidation process. Degradation process can also be measured by measuring molar mass by mass spectroscopy (Srikant,2011). Biodegradation through process of mineralization can be analytically determined by precisely measuring amount of Carbon dioxide produced or oxygen consumed in a closed system, if amount of Carbon in a poymer, its structure and mass is known. Naturally *Phanerochaete chyrosoporium* decomposes lignin in natural condition through the process of oxidation (Song,2009).Biodegradable plastics can be manufactured from renewable (Polylactic acid) or nonrenewable source (Polybutylenesuccinate,

Polycaprolactone).As susceptibility of a polymer to biodegradation depends upon its chemical structure not on what is its source. Biodegradable plastics can be manufactured from Starch,Polylactic acid (PLA),Poly hydroxyl Butyrate (PHB).On the other hand Bio composites are combination of two or more polymers natural or synthetic (Zhang and Sun,2005).Biocomposites have properties of matrix and fibres with higher material strength.Biocomposites can be synthesized by reinforcing gluten,soy protein with jute, bamboo fibres,hemp.Egg albumin and starch composites derieved from potatao and corn are suitable for packaging (Plackett,2005).Oxo degradable polymers are polymers with which have a metal element added to it to catalyze or act as prooxidant to enhance fragmentation and breakdown (Lee,1996).One important concern regarding bio plastics is that they are biobased polymers and are generally costly.

Table.1Natural polymers and their uses

Polymer	Source	Uses
Cellulose	Cell wall of plants and algae	Paper cellophane rayon, fuel
Lignin	Cell wall of plants	Construction timber, News print,fuel
Chitin	Exoskeleton of crustaceans, insects, cell wall of fungi	Medical, agriculture
Polyesters	Plant cuticle	Clothing
Fibre	Wool,silk	Clothing

2. Categories of Bio-plastics

Biobased plastics can be produced from plant based raw material such as sugars, polysaccharides,fatty acids,protenis and lignin.Most common biopolymers are polysaccharides found in cellulose and starch.Proteins are polymers of aminoacids most common examples are gluten,collagen and casein present in milk.Lignin is cross linked polymer found in cell walls of plant and leads to formation of wood.Biodegradble plastics being produced commercially and available in market can be classified in to fallowing categories;

1.Polysaccharides based:Starch and cellulose are abundant in nature are very common polysaccharides.D-glucose is a monomer present in starch.Starch is composed of amylose and amylopectin.Amylose and amylopectin are linked by stron intermolecular and intramolecular hydrogen bonding.Plasticizers like sorbitol and glycerol at temperature 90-180 ^{0}C converts Native starch to thermoplastic starch.First bioplastic manufactured was celluloid was made from cellulose nitrate.cellulose derivatives can be classified in to two groups mainly cellulose ethers and cellulose esters. Cellulose esters are produced by esterification of cellulose by organic acids. Examples of cellulose esters includes cellulose acetate, cellulose propionate, and cellulose butyrate.

2.Protein based:Casein formaldehyde is most common example of protein based plastics.Casein is cross-linked by formaldehyde and dewatering. Another example is gelatin produced from collagen used in pharmaceutical industry.

3.Lignin based:Lignin can be used to manufacture both thermosets and thermoplastic polymers.It cabn also be blended with PE,PVC,PA and with natural fibers.Most common lignin based bioplastic is liquid wood and used in injection molding machines.

4.PHA: (Polyhydroxyalkanoates) Polyhydroxyalkanoates are produced by fermentation of carbonate through action of microbes. PHA includes PHB(Polyhydroxy butyric acids),polyhydroxybutyrate,PHV (Polyhydroxy valerate).PLA is transparent and rigid and used as film,pot and cups.PLA is also used to pack vegetable and fruits to its permeability.

5.PLA(Polylactide,polylactic acid):It is manufactured from natural acid lactic acid produced from fermentation of sugars or starch by microbes.

6.Biobased polysuccinates (PBS): Polybutylene succinate (PBS) is a biodegradable bioplastic produced from Butanediaol and succinic acid.

7.Biobased Polyamides:Polyamides are suitable for technical application and as fiber.Most common examples are Nylon,Perlon.Biopolyamides are manufactured from dicarboxylic acid,diamine produced from renewable feedstock.

8.Biobased Urethanes:Biobased polyurethanes are produced by reaction between Polyols and diisocynates.These can be hard,brittle,eleastic,foamed or compact.Polyols are obtained from soya, castor,rapesees,sunflower oil.

9.Biobased Polyacrylates: Acrylicplastics PMMA (Polymethyl methacrylate) commonly known as plexiglass. Methyl methacrylate have been recently discoverd to get produced from an enzyme, based on a biotechnological process using sugars, alchol and fattyacids.

10.Biobased PVC:Ethylene from bioethanol is used to produce partially biobased Poly Vinyl chloride

IJASRM International Journal of Advanced Scientific Research and Management, Volume 4 Issue 4, April 2019
www.ijasrm.com
ISSN 2455-6378

Table.2 Types of Bio-plastics

Bio-plastics	
Biodegradable plastics	*Derived from Non renewable sources* PCL(Polycaprolactone) PBS Poly(butylene succinate) *Derived from Renewable sources* PHB (Polyhydroxybutyrate) PLA(Polylactide acid) Starch blends
Bio-based Plastics	*Degradable* PHB (Polyhydroxybutyrate) PLA(Polylactide acid) Starch blends Cellophane Chitosan Rayon *Non-biodegradable* Nylon-11(NY 11) Polyethylene (PE) Acetyl cellulose (AcC)

3.Global production and Consumption

According to Institute of Bioplastics and Biocomposite global production of bio plastics was 2.27 million tonnes in 2017 and is expected to grow to 4.31 million tonnes by 2022 (Bioplastics facts and figures, 2018).Bioplastics production uses .01%(.6 million hectares) of global agricultural area of about 5 billion hectares.

Table.3Feed stock for Bio-based plastics

Feedstock	**crop**
Sugarcane	Sugarcane without cane tops
Sugarbeet	Beet without leaves
Corn	Maize kernel
Potatoes	Potato tuber
Wheat	Wheat grains
Wood	Standing timber,residual wood
Castor oil	Castor beans (seeds)

4.Application of Bio-plastics

1.Packaging:Bioplastics can be used for packing chocolates,fruits,vegetables,meat and eggs.Jars and bottles can also be manufactured to store juice, milk and water.Bioplastics once used can be composted in sound ecological manner.

2.Agriculture/horticulture:Due to its biodegradable nature bioplastics can find extensive role in gardening and agriculture. Mulch made from biopolymers can be ploughed in field after use.Pots and trays made from bio plastics can get decayed in to soil easily.

3.Personal care products and medicine:PLA(Polylactic acid) is used in surgery as thread.Thermoplastic starch is used to make pills and capsule.Dental implants,disposable gloves,nappies,women hygiene products can also be manufactured from bioplastics.Biobased polyethylene products are used as casing for cosmetics such as lipsticks and sampoo bottles.Biodegradable pins,screws are used in broken bones,ligaments and reconstructive surgery on knees and ankles.

4.Electronics: Computer mouse, keyboard, headphones components can be manufactured from bio based plastics.

5.Automobile: Soya based polyols are used to manufacture Poyurethanes for making seats,head rests,armrests in automobiles.Sapre wheel cover,surface covering,seat covers and carpet can be made from biobased plastics.The idea of bioconcept car is gaining momentum which uses biobased components such as fuel line,connectors, made of polyamides,steering wheel with airbags etc.

6.Textile: Children dress,shoes,swim wear,suits,wedding dress can be made from biobasd polyesters.

7.Construction and Housing:Carpets, biobased foams such as polyurethanes for furniture,cellulose based building insulation,wood plastics composites,Bio PVC also biobased polymers can also be found in paints ,varnishes and wall papers.

Table 4.Comaprison of Bio-plastics with conventional plastics

Conventional plastics	**Bio plastics**
Technically mature	Early stage of development
High quality products	Production and recycling processes not yet optimized
More consumption of energy during production	Less consumption of energy during production
More greenhouse gas emission	Less greenhouse gas emission
Treatment option includes thermal recovery, mechanical recycling and landfilling	Also has option of Organic recycling
Long times usually hundreds years to degrade	Can be degraded and composted

5.Disposal of Bio- plastics

Recycling is top priority in any waste management strategy. How bio plastics will be recycled and managed depends upon type of product and type of plastics.Once end product is generated it is collected, it can either be recycled, biodegraded or utilized for energy generation.Bioplastics can also be composted which can used for gardening and farming. From farms renewable resource in form of biomass can be generated which can be used to extract and process raw materials like starch,oils,sugars, fibers to again manufacture bio plastics.In recycling products not in use are converted in to secondary materials.Material recycling includes shredding, cleaning, melting, granule formation of plastic waste.During material recycling chemical characteristics of plastic waste remains unchanged (Sivan,2011).While feedstock or chemical recycling involves breaking up of plastic in to its monomers.For example during chemical recycling of biplastics like PLA(Polylactic acid) is converted in to lactic acid which can be used for other purposes.Bioplastics which have been recycled several times can also burned to extract energy. Many European countries incinerate plastic waste to generate heat to produce electricity. Incinerating plastic makes it ideal substitute for coal and oil.Bioplastic waste can be treated biologically which involves composting and fermentation. During composting bioplastic waste is completely broken down in to CO_2 and H_2O.Fermentation involves bio gasification through anaerobic digestion. Methane gas generated during fermentation can also be used as energy.

Table.5 Management options for Bio plastics

Recycling	Technically feasible but depends upon quality of feedstock and continues supply
Waste to energy	Energy recovery by incineration is suitable option although has low calorific values
Composting	Microorganisms such as bacteria,fungi, degrade bioplastic waste in to humus, carbondioxide and water
Anaerobic digestion	Bioplastic waste is converted in to biogas and biodigestate by microrganisms in absence of air

6.Benefits of Bio-plastics

Bioplastics are produced from renewable sources like biomass.Bioplastics hence during manufacturing doesn't involve fossil fuel fuels.Bioplastics are seen as alternative to petro based plastics.Bioplastics are superior to conventional plastics in terms of energy efficiency and carbon emissions (Future of bioplastics,2013). Around 4% of petroleum consumption is devoted for plastic manaufacturing.In United States alone plastics manufacturing is responsible for 2% of greenhouse gas emissions (British petroleum,2009). Also petroleum based plastics are resistant and doesn't degrade in environment for very long periods.Bioplastics can be safely recycled, reused, composted or burnt without producing any harmful toxins. During production, Bio plastics consume less fossil fuels and emit less greenhouse gases.Bioplastic do not have any health issue like that of conventional plastics and upon degradation doesn't leach any harmful chemicals to soil (UNEP,2015). However production of bio plastics from renewable feed stock such as corn, soy, sugarcane and other food crops is thought to affect world food supply.

7.Conclusion

Plastics are pillars of modern economy and find its use in every sphere of life. Plastics accounts for about 40 % of global market for consumer packaging products including food and nonfood items.No doubt plastics are incredible human invention but petroleum based plastics are non biodegradable and creates numerous ecological,health and asthetic probems.There is an urgent need to find alternative solution to plastics which is not only ecologically sound but also is economical viable.Due to Ecological concern, limited availability of fossil fuels and Lower carbon footprint, Bio plastics are suitable options for replacement of Petro based plastics.Bioplastics are energy efficient, it doesn't contain health damaging chemicals like phthalates and bisphenols,can be safely used to pack food items.However bioplastics need to be collected and recycled separately and properly disposed off. It has been estimated that if all of world plastics is switched over to use of bio plastics then around 4-7% of world arable land would be required to grow crops to produce raw material to manufacture bio plastics.Biobased polymers with unique properties can be used to produce bio based plastics. The strength and durability of bio based plastics can be improved to great extent by combination of various sets of biocomposites.Presently bioplastics market remains small as compared to convention plastics.Hence there is a need to promote research in industrial biotechnology to produce raw materials to produce bioplastics.There is a need to screen microorganisms which have ability to synthesize biopolymers. The most important benefit of the biodegradable plastics is that they decompose naturally.As part of collection system they should be treated aerobically and anaerobically with organic waste.

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