BIOPLASTICS: AN ALTERNATIVE WITH A FUTURE

By

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(2018-11-047)

SEMINAR REPORT

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CERTIFICATE

This is to certify that the seminar report entitled **“Bioplastics-an alternative with a future”** has been solely prepared by **SAFNATHMOL P (2018-11-047)**, under my guidance and has not been copied from seminar reports of any seniors, juniors or fellow students.

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DECLARATION

I, Safnathmol P (2018-11-047) declare that the seminar entitled **"Bioplastics-an alternative with a future"** has been prepared by me, after going through various references cited at the end and has not been copied from any of my fellow students.

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Certified that the seminar report title entitled **"Bioplastics-an alternative with a future"** is a record of seminar presented by **Safnathmol P (2018-11-047)** on 03rd January, 2020 and is submitted for the partial requirement of the course SOILS 591.

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Bioplastics - an alternative with a future

1. Introduction

Plastic materials are widely used in our daily life and their usage in textiles, electronics, healthcare products, toys and in packaging applications are unavoidable. Synthetic plastic is made up of artificial or semi artificial organic compounds, which are flexible in nature. Synthetic plastics are derived from crude oil. Crude oil is a complex mixture of thousands of compounds and needs to be processed before it can be used. The production of plastics begins with the distillation of crude oil in an oil refinery. This separates the heavy crude oil into groups of lighter components, called fractions. Each fraction is a mixture of hydrocarbon chains (chemical compounds made up of carbon and hydrogen), which differ in terms of the size and structure of their molecules. One of these fractions, naphtha, is the crucial compound for the production of plastics. Since 1940s, synthetic plastics have reformed the society due to their fascinating properties like mechanical strength, lightness, flexibility and durability. These properties assigned to a material of low cost and ability to replace products made from other materials including paper, glass and metals.

Pollution due to plastic is one of the severe environmental problems that we are facing in this century. Plastics are considered to be the most widely used polymer in our daily life. Most of the synthetic plastics are produced from the non-renewable petroleum sources. Plastics are inexpensive and durable, and as a result levels of plastic production by humans are high. However, the chemical structure of most plastics renders them resistant to many natural processes of degradation and as a result they are slow to degrade. Together, these two factors have led to a high prominence of plastic pollution in the environment. Plastic pollution can afflict land, waterways and oceans. It is estimated that 1.1 to 8.8 million tonnes of plastic waste enters the ocean from coastal communities each year. Living organisms, particularly marine animals, can be harmed either by mechanical effects, such as entanglement in plastic objects, problems related to ingestion of plastic waste, or through exposure to chemicals within plastics that interfere with their physiology. Effects on humans include disruption of various hormonal mechanisms. As of 2018, about 380 million tonnes of plastic is produced worldwide each year. From the 1950s up to 2018, an estimated 6.3 billion tonnes of plastic has been produced worldwide, of which an estimated 9% has been recycled and another 12% has been incinerated. This large amount of plastic waste enters the environment, with studies suggesting that the bodies of 90% of seabirds contain plastic debris (Denoncour *et al*., 2014). They have adverse environmental impacts including high CO_2 emission and long period accumulation due to non-biodegradability, which demands a better sustainable alternative. Since the last two decades, the use of synthetic materials has increased and become more frequent in this capitalist system. Polymers used as raw materials are usually disposed very rapidly and considered serious damages when they return to the environment. Because of this behaviour, there was an increasing in the global awareness by minimizing the waste generated, in addition to the scientific community concern for technological alternatives to solve this problem. Bioplastics are attaining special interest due to their inherent properties, which have the ability to replace conventional plastics. These environmentally friendly biopolymers have excellent potential in domestic, agricultural, industrial and medical field; however their production on a large scale is still limited.

2. Bioplastics

Bioplastics refer either to bio-based plastics synthesized from biomass and renewable resources such as polylactic acid (PLA) and polyhydroxy-alkanoate (PHA) or plastics produced from fossil fuel including aliphatic plastics like polybutylene succinate (PBS), which can also be utilized as a substrate by microorganisms (Tokiwa *et al*., 2009). Bioplastics are not just one single substance, they comprise of a whole family of materials with differing properties and applications. According to European Bioplastics (EUB, 2019), a plastic material is defined as a bioplastic if it is either biobased, biodegradable, or features both properties. The term “biobased” means that the material or product is (partly) derived from biomass (plants). Biomass used for bioplastics are from e.g. corn, sugarcane, or cellulose. Biodegradation is a chemical process during which micro-organisms that are available in the environment convert materials into natural substances such as water, carbon dioxide, and compost (artificial additives are not needed). The process of biodegradation depends on the surrounding environmental conditions (e.g. location or temperature), on the material and on the application. English chemist Alexander Parkes, who in 1856 was granted the first of several patents on a plastic material that he called Parkesine. Parkesine plastics were made by dissolving nitrocellulose (a flammable nitric ester of cotton or wood cellulose) in solvents such as alcohol or wood naphtha and mixing in plasticizers such as vegetable oil or camphor (a waxy substance originally derived from the oils of the Asian camphor tree, *Cinnamonum camphora*).

3. Types of bioplastics

Based on source of origin there are four different types of bioplastics namely biomass based bioplastics, polylactic acid, polyhydroxy-alkanoate and petroleum based bioplastics. The origin of bioplastic are cellulose, starch, sugar etc., which are primarily renewable in nature. Source of biomass can be starch, cellulose, protein, lignin and biobased ethylene.

3.1. Starch-based bioplastics - These are the most widely used bioplastics and these can also be manufactured at home. Starch can absorb humidity which makes it suitable candidate for drug capsule production. Starch can also be processed thermo-plastically as sorbitol and glycerine can also be added to starch. Starch based bioplastics are sometimes mixed with biodegradable polyesters to produce polycaprolactone. These blends are biodegradable. Other producers, such as Roquette, have developed other starch/polyolefin blends. These blends are not biodegradable, but have a lower carbon footprint than petroleum-based plastics used for the same applications. Due to the origin of its raw material, starch is cheap, abundant, and renewable. Starch based plastics are complex blends of starch with compostable plastics such as polylactic acid, polybutylene succinate, polycaprolactone and polyhydroxy-alkanoates. These complex blends improve water resistance as well as processing and mechanical properties. Starch-based films (mostly used for packaging purposes) are made mainly from starch blended with thermoplastic polyesters to form biodegradable and compostable products. These films are seen specifically in consumer goods packaging of magazine wrappings and bubble films. In food packaging, these films are seen as bakery or fruit and vegetable bags. Amylose and amylopectin are two types of starch based polymer which are produced from monomer glucose.

3.2. Cellulose based bioplastics - These are mainly the cellulose esters, including cellulose acetate and nitrocellulose and their derivatives, including celluloid. Cellulose can become thermoplastic when extensively modified. An example of this is cellulose acetate, which is expensive and therefore rarely used for packaging. However, cellulosic fibers added to starches can improve mechanical properties, permeability to gas, and water resistance due to being less hydrophilic than starch.

3.3 Protein based bioplastics - Bioplastics can be made from proteins from different sources. For example, wheat gluten and casein show promising properties as a raw material for different biodegradable polymers. Additionally, soy protein is being considered as another source of bioplastic. Soy proteins have been used in plastic production for over one hundred years. For example, body panels of an original Ford automobile were made of soy-based plastic. There are difficulties with using soy protein-based plastics due to their water sensitivity and relatively high cost. Therefore, producing blends of soy protein with some already-available biodegradable polyesters improves the water sensitivity and cost.

3.4. Biobased polyethylene - The basic building block (monomer) of polyethylene is ethylene. Ethylene is chemically similar to, and can be derived from ethanol, which can be produced by fermentation of agricultural feedstocks such as sugar cane or corn. Bio-derived polyethylene is chemically and physically identical to traditional polyethylene – it does not biodegrade but can be recycled. The Brazilian chemicals group Braskem claims that using its method of producing polyethylene from sugar cane ethanol captures (removes from the environment) 2.15 tonnes of CO_2 per tonne of polyethylene produced.

A number bioplastic classes have been synthesized from plant and animal derived fats and oils. Polyurethanes polyesters, epoxy resins and a number of other types of polymers have been developed with comparable properties to crude oil based materials.

3.5 Polylactic acid (PLA) - Corn and dextrose is used to produce polylactic acid which is transparent in nature. It carries same characteristics as petrochemical-based plastics and can also be produced using production method followed for conventional plastics. PLA is generally used in production of films, fibers, cups, and bottles. Superficially, it is similar to conventional petrochemical-based mass plastics like PS. It has the distinct advantage of degrading to nontoxic products. Unfortunately it exhibits inferior impact strength, thermal robustness, and barrier properties (blocking air transport across the membrane) PLA and PLA blends generally come in the form of granulates with various properties, and are used in the plastic processing industry for the production of films, fibers, plastic containers, cups and bottles (Jamshidian *et al*.,2010). PLA is also the most common type of plastic filament used for home fused deposition modelling.

3.6. Polyhydroxy-alkanoates (PHA) - These are linear polymers produced by bacterial fermentation of sugars and lipids. Bacteria produce it to store carbon and energy. At industrial level, the polymer is extracted from bacteria and is used in sugar fermentation. Bacteria include *Azotobacter, Ralstonia, Bacillus* sp. *Alcaligenes eutrophus, Enterobacter*. They are produced by the bacteria to store carbon and energy (Ojumu *et al*., 2004). In industrial production, the polyester is extracted and purified from the bacteria by optimizing the conditions for the fermentation of sugar. More than 150 different monomers can be combined within this family to give materials with extremely different properties (Coutinho *et al*., 2004). PHA is more ductile and less elastic than other plastics, and it is also biodegradable. These plastics are being widely used in the medical industry (Yadav *et al*., 2015).

3.7. Petroleum based bioplastics. Petroleum based plastics which are biodegradable are also considered as bioplastics. Polybutylene succinate, polycaprolactone, polyethylene are some examples for petroleum based bioplastics.

4. Properties of bioplastics

Bioplastic show following properties such as thermoplasticity, thermostability, elasticity, rigidity, gas barrier property, UV resistance and biocompatibility. Both PLA and PHA show all the properties except thermostabilty. Compared to PLA, PHA has more thermostability, hence PHA is considered as better bioplastic. Protein based bioplastics have less gas barrier property. Both starch based and cellulose based bioplastics are hydrophilic; their degradation is fast in soil. All the bioplastics are biocompatible (Karan *et al*., 2018).

5. Feedstocks of bioplastics

The first generation feedstock were the first crops and plants used to produce bioplastics. They're rich in carbohydrate and can be consumed by humans and animals. First generation feedstock are the most efficient to produce bioplastics as they require less land to grow, and have a higher yield and "efficiency" than other feedstock generations. Examples of first generation feedstock include corn, wheat, sugarcane, potato, sugar beet, rice and plant oil. Second generation feedstock refers to crops and plants not suitable for human consumption (food) or animal consumption (feed). Second generation feedstock can be either non-food crops (cellulosic feedstock) or waste materials from 1st generation feedstock (e.g. waste vegetable oil). Examples of second generation feedstock include: wood, short-rotation crops such as poplar, willow or miscanthus (elephant grass), wheat straw, bagasse, corncobs, palm fruit bunches and switch grass. Third generation feedstock is biomass derived from algae.

6. Production of bioplastics

6.1. Biomass based bioplastics - Samer *et al*. (2019) produced starch based bioplastics from agricultural crop residues. In this study, potato peels were used as an example of starchy agricultural crop residues which can be processed for the production of bioplastics. Potato peels were boiled and a milky white water was formed, where starch was extracted from that water by filtration. Weighed the starch and then poured into the flask. Determined the required volume of water using the graduated cylinder and then pouring the water into the flask which contains the starch. The magnetic hot plate stirrer to mix the water and the starch at 105ºC where the time was recorded using a stopwatch. Adding the vinegar,then the glycerin to the mixture. Stirred the mixture until being cohesive then measuring the temperature of mixture. Poured the mixture onto oil greased foil paper or oil greased Petri dish, where the oil will ease removing the bioplastic once it dries. At this stage the bioplastic can be shaped as required. Kept the petridish in an oven at 65ºC for one to two hours. On the other hand, the produced bioplastics were tested at the laboratory for biodegradability. Amylase enzyme was added to water, where the mixture was stirred. Afterwards, the bioplastic was added to the mixture. The sample was left overnight along with the control sample which consists of water only. This test was conducted to ensure that the produced bioplastic is biodegradable. Glycerin makes the chains of starch slip along each other which makes the bioplastic material more flexible. Therefore, the more glycerin is used the more flexible bioplastic is produced, and vice versa the less glycerin is used the harder bioplastic is produced. Vinegar breaks the starch chains into smaller sizes which make them more manageable while creating the bioplastic.

6.2. Polylatic acid (PLA) - PLA is commercially produced by carbohydrate fermentation (Aguirre *et al*., 2016). The fermentation, technology can make a desired stereoisomer of lactic acid. The existing commercial production processes use homolactic organisms, such as *Lactobacillus delbrueckii*, *L. bulgaricus, L. leichmanii*. A wide variety of carbohydrate sources can be used (molasses, corn syrup, whey, dextrose, cane, or beet sugar). The use of a specific carbohydrate feedstock depends on its price, availability, and purity. Proteinaceous and other complex nutrients required by the organisms are provided by corn steep liquor, yeast extract, for example. Excess calcium carbonate is added to the fermenters to neutralize the acid produced and produce a calcium salt of the acid in the broth. The fermentation is conducted as a batch process, requiring 4 to 6 days to complete. Lactate yields of approximately 90% (w/w) from a dextrose equivalent of carbohydrate are obtained. Keeping the calcium lactate in solution is desirable so that it can be easily separated from the cell biomass and other insoluble, and this limits the concentration of carbohydrates that can be fed in the fermentation and the concentration of lactate in the fermentation broth, which is usually around 10% (w/v). The broth containing calcium lactate is filtered to remove cells, carbon treated, evaporated, and acidified with sulphuric acid to convert the salt into lactic acid and insoluble calcium sulphate, which is removed by filtration. The filtrate is further purified by carbon columns and ion exchange and evaporated to produce technical and food-grade lactic acid, but not a heat stable product, which is required for the stearoyl lactylates, polymers, and other value-added applications. The technical-grade lactic acid can be esterified with methanol or ethanol, and the ester is recovered by distillation, hydrolyzed by water, evaporated, and the alcohol is recycled. Lactic acid can be used to produce the PLA of variable molecular weights; however, usually only the high molecular weight PLA has major commercial value in the fibre, textile, and packaging industries. There are two main methods available to produce high molecular weight PLA from LA by direct condensation polymerization and polymerization through lactide formation.

6.3. Polyhydroxy-alkanoates (PHA) - The industrial PHA production starts with reactivation and adaptation of the bacterial cells that are induced to the growth through the culture in a complex nutrient medium without limiting nutrients, under constant stirring around 200 rpm and temperature of 30◦C (in average).The growing cells are transferred to a new culture with a larger volume of medium and similar composition to that used in the fermentation process. In order to increase the number of cells, the above mentioned step is repeated few times, being performed in fermenters with successively larger volumes and the same fermentation medium. It is important to guarantee the availability of macronutrients (Fe, B, Mo, Ni, Cu, Mn, Co, Zn and Ca salts), potassium phosphate or calcium phosphate as phosphorus source and hydroxide ammonium as nitrogen source, as well as pH in equilibrium. This first fermentation step lasts around 16 h at a basic pH with no PHA accumulation by the bacterium. During the second step, PHA synthesis is induced by limiting the nutrients required for cell growth, for example phosphorus or nitro-gen, whilst an excess carbon medium is provided. Several carbon sources can be used to produce different types of PHAs, including carbohydrates, mono, di or polysaccharides such as glucose, sucrose, lactose, starch and lignocelluloses, triglycerides, fatty acids, glycerol, animal fat, vegetable oils, frying oils and methanol residue from the biodiesel industry; and hydrocarbons such as methane and hydrocarbons derived from plastic wastes. At this step, satisfactory levels of oxygen must be guaranteed by controlling conditions such as stirring and aeration; it is necessary due to the aerobic fermentation process occurred, in which the concentration of oxygen dissolved in the medium directly influences the kinetic parameters. The carbon source provided at the beginning of the fermentation is depleted around 12 h and must be continuously added, keeping a constant concentration in the medium; the dissolved oxygen must also be kept constant, increasing the constant stirring and the aeration of the system. This step lasts around 14 h while the other nutrients in the medium, mainly phosphorus and nitro-gen, are depleted, then raising the cell concentration. The depletion of nutrients and the abundant carbon source discontinue the cells growth, thus initiating the final fermentation step, in which polymer accumulation occurs. The accumulating step increases the polymer content into the cell to around 80%. The transition between growths and accumulating steps could be easily observed. The nutrients depletion is associated with a spontaneous elevation of the pH of the medium and few hours later, the demand for oxygen decreases, decreasing the need for stirring and aeration; the rate of carbon source consumption also decreases and its addition must be reduced. In addition, changes in cell morphology can be attributed to the polymer storage. At the end of the accumulation step, the cell enzyme complex must be deactivated rapidly because the bacterium is directed to consume the accumulated polymer when the carbon source is depleted. The deactivation is usually done by pasteurizing, raising the temperature around 80◦C for 15 min. The fermented medium is then conducted to the extraction and purification steps, with disruption of the cells and elimination of the cell debris by solvents and other chemicals. These steps, known as downstream, contribute significantly to the increase in the production costs of the biopolymers (Ojumu *et al.*, 2004).

The industrial methods of manufacturing of various plastic products using this polymer carried out by injection moulding, foil extruding and bottle blowing.

7. Biodegradation of bioplastics

The biodegradation of polymers consists of three important steps: (1) Biodeterioration, which is the modification of mechanical, chemical, and physical properties of the polymer due to the growth of microorganisms on or inside the surface of the polymers. (2) Biofragmentation, which is the conversion of polymers to oligomers and monomers by the action of microorganisms and (3) Assimilation where microorganisms are supplied by necessary carbon, energy and nutrient sources from the fragmentation of polymers and convert carbon of plastic to CO_2, water and biomass. The important factors that affect the plastic's biodegradation in the environment are the chemical structure, the polymer chain, crystallinity and the complexity of polymer formula (Emadian *et al.,* 2017). In fact, the specific functional groups are selected by enzymes and can be processed. Generally, polymers with a shorter chain, more amorphous part, and less complex formula are more susceptible to biodegradation by microorganisms. Moreover, the environment, in which the polymers are placed or disposed of, plays as a key factor for their biodegradation. The pH, temperature, moisture and the oxygen content are among the most significant environmental factors that must be considered in biodegradation of polymers previously, the non-biodegradability of synthetic plastics resulted in the accumulation of millions of tons of plastic wastes. However, by developing bioplastics as a substitute material for conventional plastics, certain applications have become mandatory for the production of real biodegradable polymers.

Degradation of three kinds of bioplastics and their effects on microbial biomass and microbial diversity in soil environment were analyzed by Adhikari et al (2015). Scanning electron micrograph of plastics was carried out after 28 days and 2 years (Plate.1).

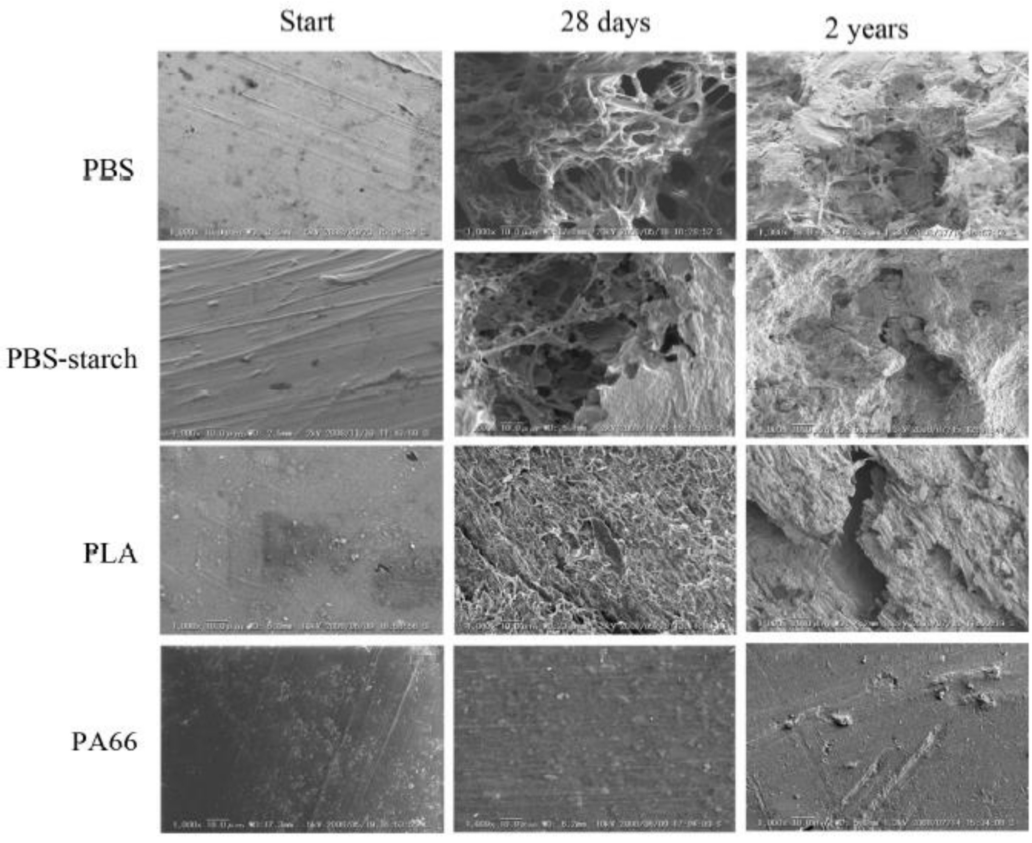

Plate 1. SEM analysis of surface of PBS, PBS-starch, PLA and conventional plastic PA66

The degradation rate of bioplastic in soil was closely related to the main components in the bioplastics. Polybutylene succinate-starch (PBS-starch) and polybutylene succinate (PBS) were degraded by 1% to 7% after 28 days in a soil with an initial bacterial biomass of 1.4×10^9 cells/g-soil; however poly lactic acid (PLA) was not degraded in the soil after 28 days (Figure 1.).When the powdered bioplastics were examined for the degradation in the soil, PBS-starch also showed the highest degradability (24.4% degradation after 28 days), and the similar results were obtained in the case of long-term degradation experiment (2 years).

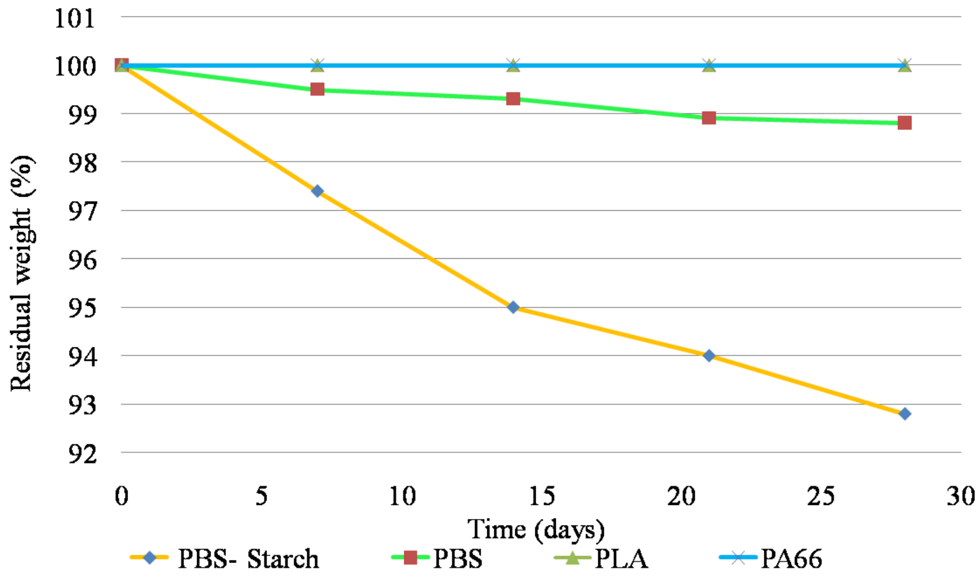

Figure 1. Shorterm degradation of bioplastics and PA66

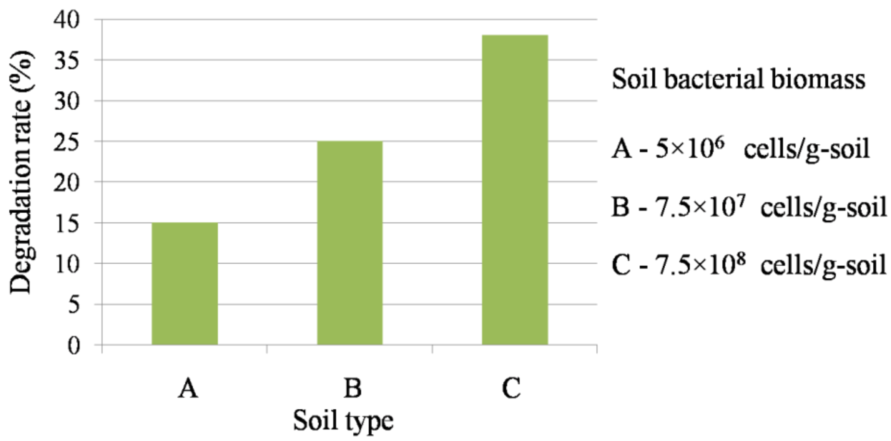

Figure 2. Effect of soil bacterial biomass on degradation of PBS-starch

To investigate the effect of bacterial biomass in soil on biodegradability of bioplastics, PBS-starch was buried in three kinds of soils differing in bacterial biomass (7.5×10^6, 7.5×10^7, and 7.5 × 10^8 cells/g soil). The rate of bioplastic degradation was enhanced accompanied with an increase of the bacterial biomass in soil (Figure 2.) 16S rDNA PCR-DGGE analysis indicated that the bacterial diversity in the soil was not affected by the degradation of bioplastics. The products of degradation of bioplastic do not affect the bacterial biomass in the soil instead they increased bacterial biomass. In case of conventional plastic, the microbial biomass decreased in soil (Figure 3.)

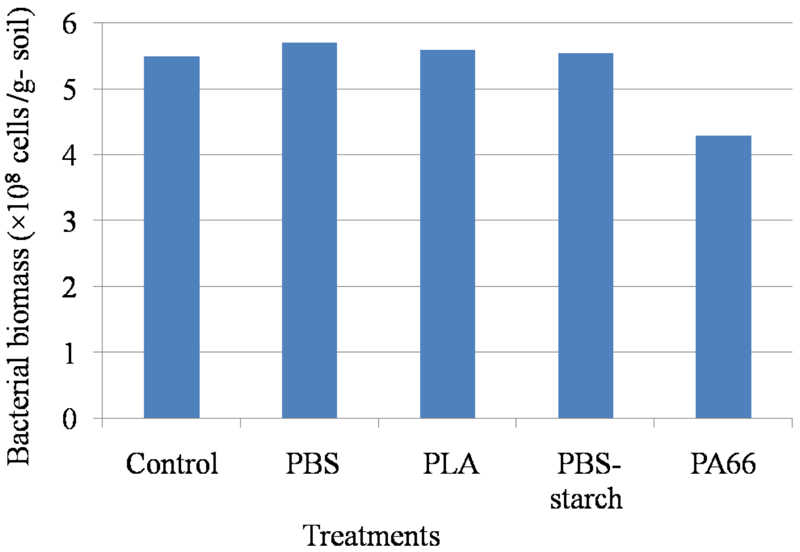

Figure 3. Effect of bioplastic degradation on bacterial biomass in soil

8. Bioplastics and nanocomposites

In recent years, significant attention has been given to a new class of bioplastic materials represented by nanocomposites as the promising alternative to conventional plastics due to their superior properties. Nanocomposites consist of a polymer matrix reinforced with nano dimensional particles instead of the conventional micro dimensional fillers. The interest in nanocomposites has been inspired by the pioneering work conducted by researchers at Toyota company inthe 1980s where it was reported that presence of nanoparticles in the matrix contributed to significant improvement in both physical and mechanical properties. In the years that followed, there was a great deal of research efforts aimed at improving the performance of materials through use of nanoparticles. Clay particles such as montmorillonite, hectorite, saponite and laponite can be effectively used as nanocomposites due to their unique structure and properties. When added to form nanocomposites, the clays significantly enhance the mechanical performance of bioplastics, improve their moisture resistance and significantly reduce the release of plasticizer from starch.

One of the most important is carbon fiber microelectrode (CFME) materials, which has a diameter of 7 μm and improves the mechanical properties of nanocomposites. The Fourier transform infrared-attenuated total reflectance (FTIR) image indicates that the peak at 3273 cm^{-1} belongs to O-H bond stretching (Ozdamar and Ates, 2018). The peak at 1416 cm^{-1} refers to C-C bond stretching and the peak at 1151 cm^{-1} shows C-O bond stretching. In addition, the peak at 2931 cm^{-1} has C-H bond stretching. This FTIR image (Figure 4.) shows increased bonding between CFME and starch based bioplastics.

9. Applications of bioplastics

The use of bioplastics is as diverse as that of conventional plastics. As an emerging innovative material, these are increasingly used in many industries, from packaging to building materials and agricultural products to electronic and biomedical devices. Bo Gu *et al* (2007) observed that the effect of corn starch based bioplastic mulch on water use efficiency was comparable to that of polyethylene plastic mulch (Figure 5.

Therefore, bioplastics are recommended as a viable option to replace conventional polyethylene plastic. In agriculture, bioplastics have various applications like mulch film, food packaging, seed coating and construction of greenhouse.

There is a high demand for packaging made from bioplastics to be used for wrapping organic food as well as for premium and branded products with particular requirements. In 2019, global production capacities of bioplastics amounted to about 2.11 million tonnes with almost 53 percent (1.14 million tonnes) of the volume destined for the packaging market – the biggest market segment within the bioplastics industry.

Biodegradable polymers offer specific advantages in agriculture and horticulture. Mulching films - the most important example - are generally making rapid advances in these sectors: production of pure foods with a minimum use of pesticide is a powerful sales argument in vegetable-growing or organic farming. Ploughing-in of mulching films after use instead of collecting them from the field, cleaning off the soil and returning them for

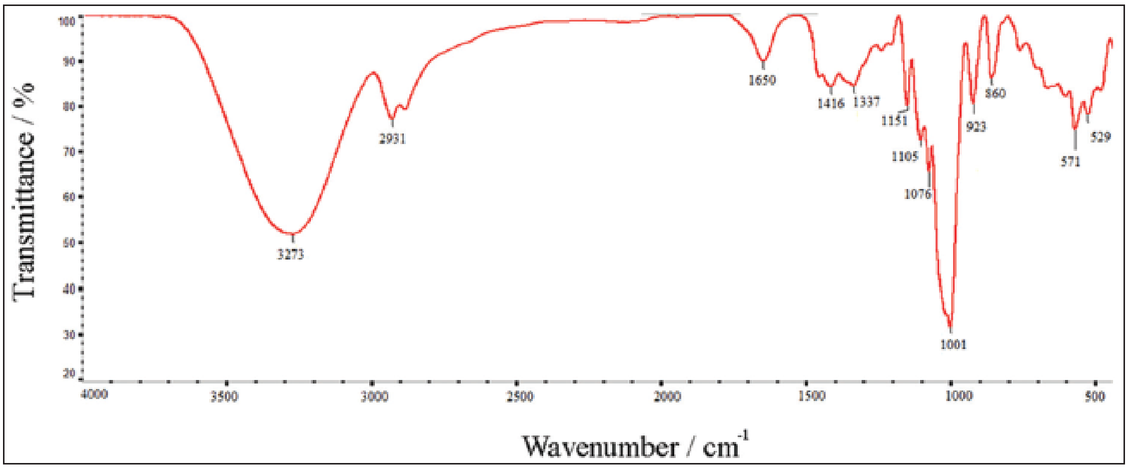

Figure 4. Fourier transform infrared-attenuated total reflectance (FTIR) image of bioplastic with 0.5% carbon fiber microelectrode nanocomposites

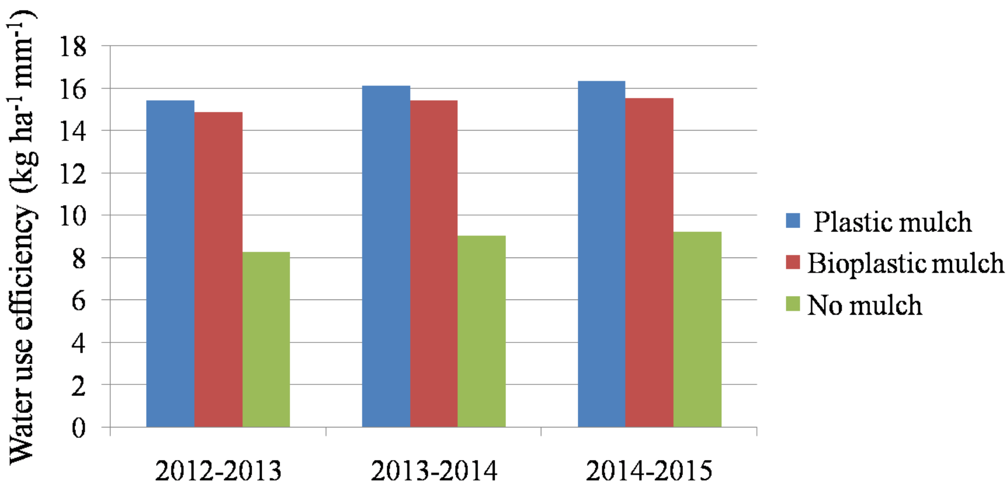

Figure 5. Effect of biodegradable mulch on water use efficiency

recycling, is practical and improves the economics of the operation. Biodegradable mulching films today are very well adapted to the location and fruit.

Other promising applications in agriculture and horticulture include: films for banana bushes, which have to be protected from dust and environmental influences; fastening technology; plant pots for propagation/cultivation; fertiliser rods; or pheromone traps, which no longer have to be removed after use. Biodegradable plastics also offer opportunities for pot-plant marketing. Herb pots are a good example. Once the herbs are harvested, everything including the film can be composted. Alternatively, products can simply be planted into their pot, which is very convenient for hobby gardeners. Flower bulbs that can directly be planted into the soil in their packaging are also available. The packaging disperses quickly and then plant growth can begin.

A large proportion of consumer electrical appliances are made of plastics. Today, casings, circuit boards and data storage are made of plastic to ensure the appliances are light and mobile whilst being tough and, where necessary, durable. An increasing range of bioplastic products is introduced in the fast-moving consumer electronics sector: touch screen computer casings, loud speakers, keyboard elements, mobile casings, vacuum cleaners or a mouse for a laptop.

In the automotive industry manufacturers have turned to biobased or partly biobased durable bioplastics to produce sturdy dashboard components as well as solid interior and exterior features. Components made completely or partially from bioplastics can provide a standard of safety that is of ultimate importance in the transportation sector. The products include seat and airbag covers as well as steering wheels.

10. Advantages and disadvantages of bioplastics

The future of biodegradable plastics shows great potential. Here are the advantages of bioplastics:

- Lower carbon footprint - It should be pointed out that the carbon footprint of a bioplastic is crucially dependent on whether the plastic permanently stores the carbon extracted from the air by the growing plant. A plastic made from a biological source sequesters the CO_2 captured by the plant in the photosynthesis process. If the resulting bioplastic degrades back into CO_2 and water, this sequestration is reversed. But a permanent bioplastic, made to be similar to polyethylene or other conventional plastics, stores the CO_2 forever. Even if the plastic is recycled many times, the CO_2 initially taken from the atmosphere remains sequestered (Boonniteewanich *et al.*, 2014).

- Independence - Bioplastic is made from renewable resources: corn, sugarcane, soy and other plant sources as opposed to common plastics, which are made from petroleum.
- Energy efficiency - Production uses less energy than conventional plastics. On the other hand, plastics are made from about 4% of the oil that the world uses every year. With oil scarcity, the manufacture of plastics becomes increasingly exposed to fluctuating prices (Schulze *et al.*, 2017).
- Eco-safety - Bioplastic also generates fewer greenhouse gasses and contains no toxins. Bioplastics contribute clearly to the goal of mitigating GHG emissions with only 0.49 kg CO_2 which is being emitted from production of 1 kg of resin. Compared with 2~3 kg CO_2 of petrochemical counterparts, it is about 80% reduction of the global warming potential (Philip *et al.*, 2013) (Figure 6).

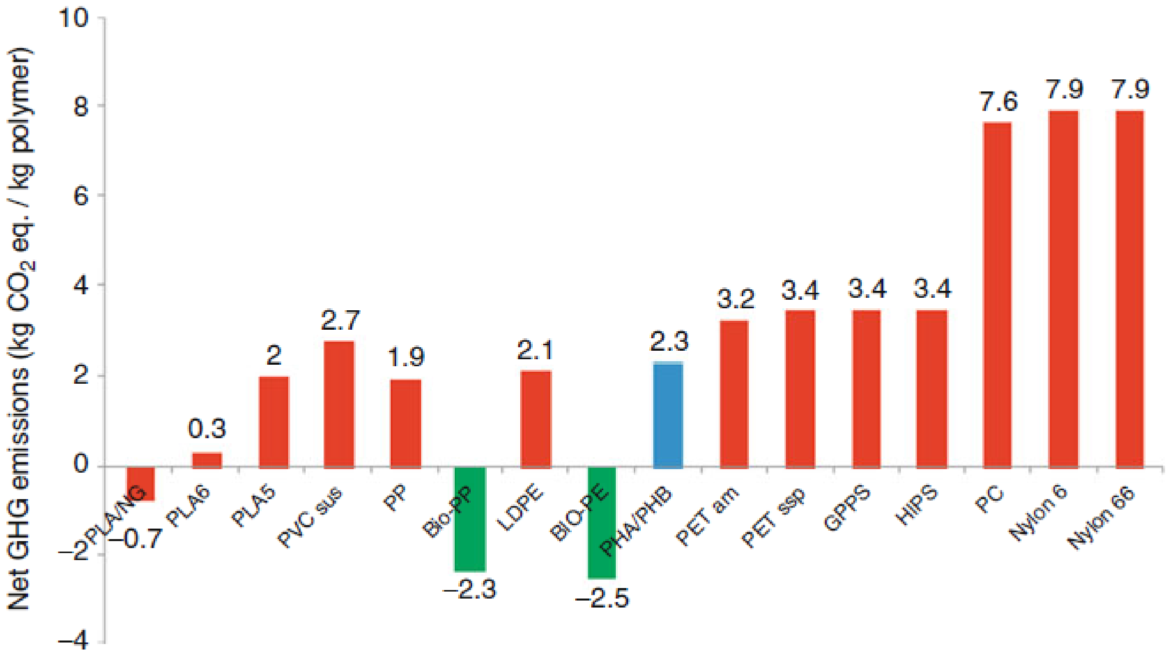

Figure 6. Greenhouse gas emissions by different plastics and bioplastics.

Here are the disadvantages of bioplastics:

- High costs - It is acclaimed that bioplastics costs two times more than conventional plastics. However, the amount of large-scale industrial production of bioplastics which are more common in the future with the implementation of cost reduction is expected.
- Reducing raw materials - Bioplastics produced from renewable sources might reduce raw material reserves. Moreover, in order to reduce energy consumption during the production of bioplastics and potential competition with agricultural resources for foods and also to provide additional raw material sources, the exploitation of food by-products is also the current trend.
- Lack of production infrastructure
- Non degradability in landfills

11. Conclusion

Bioplastics , a better alternative for sustainable development, have evolved into an innovative area of research for scientists around the world. The potential market for agricultural materials in bioplastics is driving a push towards expanding the bioplastics industry (Hottle *et al*., 2013).

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13. Discussion

a) What is the difference between nanoparticle and nanocomposites?

Nanoparticles are material with a dimension of 1 to 100 nm. Nanocomposites are multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nm. Hence nanoparticles and nanocomposites are not same

b) What is plasticizer? Explain its role in bioplastic production.

Plasticizers are small, relatively non-volatile, organic molecules that are added to bioplastic to reduce brittleness and impart flexibility. They reduce contact between polymers and reduce crystallinity. Sorbitol, glycerol, xylitol are some examples

c) Examples for compostable bioplasics?

PLA is a very well-known compostable bioplastic. Starch based bioplastics and PHA are also compostable bioplastics

d) Price of bioplastics in market

Price may vary according to the type of bioplastics. PLA have a price of 120-160 rupees/Kg. Where PHA has 400 rupees/Kg. Starch based bioplastics have comparatively more price, about 500 rupees/Kg

e) What is the role of bioplastic when it is used as a coating for seeds?

Seed coating using bioplastic act as a protective layer. Use of bioplastic along with biocontrol agent improves their activity. It also act as a carbon source for biocontrol agents.

f) Which country rank first in production of bioplastics?

United States of America

g) Compare the cost of bioplastic against conventional plastic

The cost of production of bioplastic is much more than conventional plastic. High density polyethylene cost about 80 rupees/Kg and PVC have a higher cost about 160 rupees/Kg

14. Abstract

KERALA AGRICULTURAL UNIVERSITY

COLLEGE OF HORTICULTURE, VELLANIKKARA

Department of Soil Science and Agricultural Chemistry

SOILS 591: MASTER'S SEMINAR

Name	: Safnathmol P.	Venue: Seminar hall
Admission No	: 2018-11-047	Date : 03-01-2020
Major Advisor	: Dr. Rajalekshmi K.	Time : 9.15 am

Bioplastics - an alternative with a future

Abstract

Pollution due to plastics is one of the severe environmental problems that we are facing in this century. Plastics are considered to be the most widely used polymer in our daily life. Most of the synthetic plastics are produced from non-renewable petroleum sources. They have adverse environmental impacts including high CO_2 emission and long accumulation period due to non-biodegradability, which demands a better sustainable alternative. Recently, bioplastics are attaining special interest due to their inherent properties and the ability to replace conventional plastics.

Bioplastics refer either to bio-based plastics synthesized from biomass and renewable resources or plastics produced from fossil fuel including aliphatic plastics like polybutylene succinate (PBS), which act as a substrate for microorganisms (Tokiwa *et al.*, 2009). According to European Bioplastics (EUB, 2019), a plastic material is defined as bioplastic if it is either biobased, biodegradable or features both these properties.

Based on source of origin, there are four different types of bioplastics namely biomass based bioplastics, polylactic acid (PLA), polyhydroxy-alkanoate (PHA) and petroleum based bioplastics. Biomass used for bioplastics can be obtained from agricultural crops, crop residues and animal protein. Polylactic acid is obtained from the monomer lactic acid, which is produced from the microorganism catalyzed fermentation of sugar or starch, whereas PHA is produced inside the cell of bacteria as a storage polymer.

The biodegradation of bioplastics consists of three important steps namely biodeterioration, biofragmentation and assimilation, which are carried out by various microorganisms in the soil. Adhikari *et al.* (2016) studied the degradation of three kinds of bioplastics and their effects on microbial biomass and microbial diversity in soil environment. The degradation rate of bioplastics in soil was found to be closely related with the main components present in it. Further they reported that the bacterial diversity in soil remains unaffected due to bioplastic degradation.

The use of bioplastics is as diverse as that of conventional plastics. As an emerging innovative material, these are increasingly used in many industries, from packaging to building materials and agricultural products to electronic and biomedical devices. In agriculture, bioplastics have various applications like mulch film, food packaging, seed coating and construction of greenhouse. Bo Gu *et al*. (2007) observed that the effect of corn starch based bioplastic mulch on water use efficiency was comparable to that of polyethylene plastic mulch. This manifests bioplastics as a viable option to replace conventional polyethylene plastic. Bioplastics have potentially much lower carbon footprint, good compostability and are eco-friendly. However, they have limitations such as high production cost, variability in properties and lack of production infrastructure.

Bioplastics have evolved into an innovative area of research for scientists all over the world. The potential market for agricultural materials in bioplastics is driving push towards expanding the bioplastics industry. Bioplastics provides better alternatives for sustainable development.

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