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REVIEW ON BIO-PLASTIC

Miss.Walkunde Pratiksha Laxman[1], Mrs. Pagire.[2]

[1]*Final Year B Pharmacy Student, Pratibhatai Pawar College of Pharmacy Shrirampur, Dist – Ahmednager.422605 (MS) 2022-2023*
[2] *Prof. Department of Pharmacogncoy, Pratibhatai Pawar College of Pharmacy Shrirampur, Dist – Ahmednager.422605 (MS)*
E-mail – pratikshawalkunde123@gmail.com

ABSTRACT

The diminishing supply of petroleum along with the pollution caused due to the non- biodegradability of petroleum-based plastics, has led to an increased interest in the field of bioplastics. The initial sections of this review begin with the history of plastics followed by bioplastics. A brief economic study of bioplastic has also been discussed in this review. Applications, advantages and disadvantages are also mentioned to give the reader a broader understanding of the scenario.

The later section of the project endeavors to study a novel method in the production of biopolymers using waste banana peels. Variations in synthesis parameters like pH, plasticizer choice and hydrolysis times were extensively tested and the optimum combination was obtained.

Aim and Objectives:

- Production of bioplastics from banana peels as the replacement for the traditional petroleum based-plastics.
- To minimize pollution in the environmental by the use of bioplastics.
- To study and understand Bio-Degradation process of Banana Peel

Keywords: *Bioplastics, Biodegradable, Renewable, Plastics, Banana Peels, Starch*

1. INTRODUCTION

1.1 Plastics

History:

A plastic is a type of synthetic or man-made polymer; similar in many ways to Natural resins found in trees and other plants. Webster's Dictionary defines plastics as: any of various complex organic compounds produced by polymerization, capable of being molded, extruded, cast into various shapes and films, or drawn into filaments and then used as textile fibers.

The development of artificial plastics or polymers started around 1860, when John Wesley Hyatt developed a cellulose derivative. His product was later patented under the name Celluloid and was quite successful commercially, being used in the manufacture of products ranging from dental plates to men's collars.[6]

Over the next few decades, more and more plastics were introduced, including some modified natural polymers like rayon, made from cellulose products. Shortly after the turn of the century, Leo Hendrik Baekeland, a Belgian-American chemist, developed the completely synthetic plastic which he sold under the name Bakelite.[8]

In 1920, a major breakthrough occurred in the development of plastic materials. A German chemist, Hermann Staudinger, hypothesized that plastics were made up of very large molecules held together by strong chemical bonds. This spurred an increase in research in the field of plastics. Many new plastic products were designed during the 1920s and 1930s, including nylon, methyl methacrylate, also known as Lucite or Plexiglas, and polytetrafluoroethylene, which was marketed as Teflon in 1950.

Nylon was first prepared by Wallace H. Carothers of DuPont, but set aside as having no useful characteristics, because in its initial form, nylon was a sticky material with little structural integrity. Later on, Julian Hill, a chemist at DuPont, observed that, when drawn out, nylon threads were quite strong and had a silky appearance and then realized that they could be useful as a fiber.

Advances in the plastics industry continued after the end of the war. Plastics were being used in place of metal in such things as machinery and safety helmets, and even in certain high-temperature devices. Karl Ziegler, a German chemist developed polyethylene in 1953, and the following year Giulio Natta, an Italian chemist, developed polypropylene. These are two of today's most commonly used plastics. During the next decade, the two scientists received the 1963 Nobel Prize in Chemistry for their research of polymers.

2. PROBLEMS ASSOCIATED WITH PLASTICS

Despit their many uses and desirable properties, petroleum base conventional plastics have many disadvantages. The major reasons for looking at alternatives to plastics are because of the following drawbacks:

1. Production Problems

Plastics are derivatives of petroleum, natural gas or similar substances. They are transformed into a polymer resin, which is then shaped and formed into whatever object is desired. However, as a petroleum by-product, plastics contribute to oil dependency, and in the present times it is generally recognized that oil will not be available indefinitely. This points to a possible raw material crisis in the future.

2. Plastic Recycling

Although many types of plastics could potentially be recycled, very little plastic actually enters the recycling production process. The most commonly recycled type of plastic is polyethylene terephthalate (PET), which is used for soft drink bottles. Approximately 15 to 27 percent of PET bottles are recycled annually. The other type of plastic which is somewhat commonly recycled is high-density polyethylene (HDPE), which is used for shampoo bottles, milk jugs and two thirds of what are called rigid plastic containers. Approximately 10 percent of HDPE plastic is recycled annually.

These figures show that most of the plastics manufactured do not get recycled and as production continues unabated, this poses a serious problem.

3. Landfill Disposal

The vast majority of plastics, especially plastic bags, wind up in landfills. The fact that available landfill space is becoming increasingly scarce and plastics are non- biodegradable poses special problems for landfills.

Compounding the issue is the survey (Zero Waste America. (1988-2008) which found that 82 percent of the surveyed landfill cells had leaks, while 41 percent had a leak larger than 1 square foot.

Also, these leaks are detectable only if they reach landfill monitoring wells. Both old and landfills are usually located near large bodies of water, making detection of leaks and cleanup difficult.

All these issues point to the fact that landfill disposal of plastics is not a sustainable solution.

4. 4. Incineration

Some industry officials have promoted the incineration of plastic as a means of disposal. A similar process of pyrolysis breaks plastic into a hydro-carbon soup which can be reused in oil and chemical refineries.[7] However, both incineration and pyrolysis are more expensive than recycling, more energy intensive and also pose severe air pollution problems. In 2007, the EPA acknowledged that despite recent tightening of emission for waste incineration power plants, the waste-to-energy process still "create significant emissions, including trace amounts of hazardous air pollutants."

Incinerators are a major source of 210 different dioxin compounds, plus mercury, cadmium, nitrous oxide, hydrogen chloride, sulfuric acid, fluorides, and particulate matter small enough to lodge permanently in the lungs. (U. S. Environmental Protection Agency. (2007, December 28). Air Emissions)

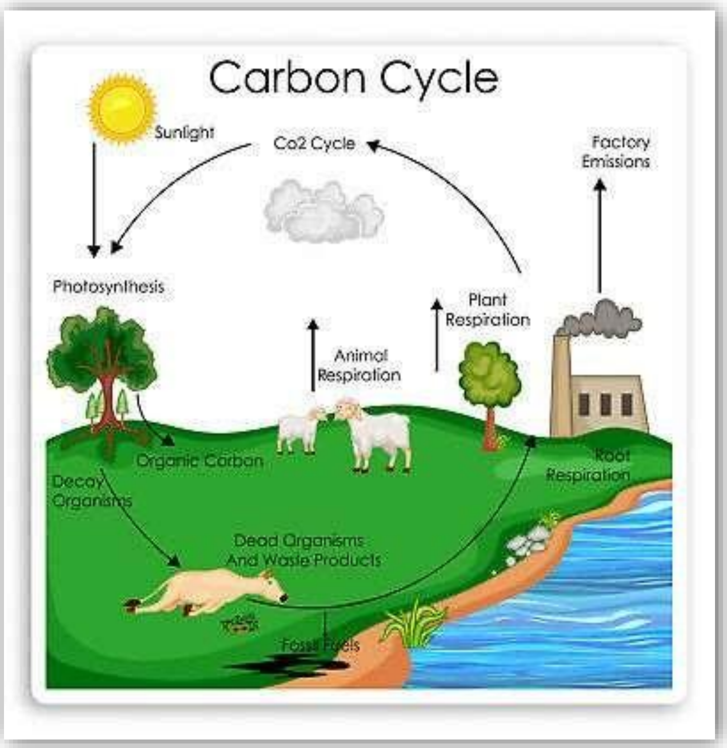
5. Adverse effect on Biodiversity

Plastic debris affects wildlife, human health, and the environment. Plastic pollution has directly or indirectly caused injuries and deaths in 267 species of animals (including invertebrate groups) that scientists have documented. These problems are because of various reasons which include poisoning due to consumption of plastics, suffocation due to entanglement in plastic nets etc.

The millions of tons of plastic bottles, bags and garbage in the world's oceans are breaking down and leaching toxins posing a threat to marine life and humans. Some marine species, such as sea turtles, have been found to contain large proportions of plastics in their stomach. When this occurs, the animal typically starves, because the plastic blocks the animal's digestive tract. In some case's small bits of plastics are accidently consumed by animals. Any such animal, if eaten by another will cause the plastics to travel up the food chain.[4] This may cause serious health hazards in a wide array of creatures.

3. THE CARBON CYCLE

When a plant grows, it takes in carbon dioxide, and when it biodegrades, it releases the carbon dioxide back into the earth – it's a closed loop cycle.[5] When we extract fossil fuels from the earth, we disrupt the natural cycle, and release carbon dioxide into the atmosphere faster than natural processes can take it away. As a result, the atmosphere is getting overloaded with carbon dioxide. Additionally, fossil fuels take millions of years to form, and are therefore non-renewable resources. In other words, we are using our fossil resources faster than they can be replaced. When we make products like plastics from fossil fuels, we are contributing to the imbalance in the environment while depleting valuable fossil resources, thereby increasing the carbon footprint of the product. Bioplastics, on the other hand, can replace nearly 100% of the fossil fuel content found in conventional plastics, and require considerably less energy for production.



Plastics are so vital to our lives and so versatile in their usage, their use cannot be completely stopped.[10] Hence alternative solutions to this problem are being looked into. The most promising answer seems to be coming in the form of bioplastics

4. BIO-PLASTICS

1. Introduction

Plastics that are made from renewable resources (plants like corn, tapioca, potatoes, sugar and algae and which are fully or partially bio-based and/or biodegradable or compostable are called bioplastics.[9]

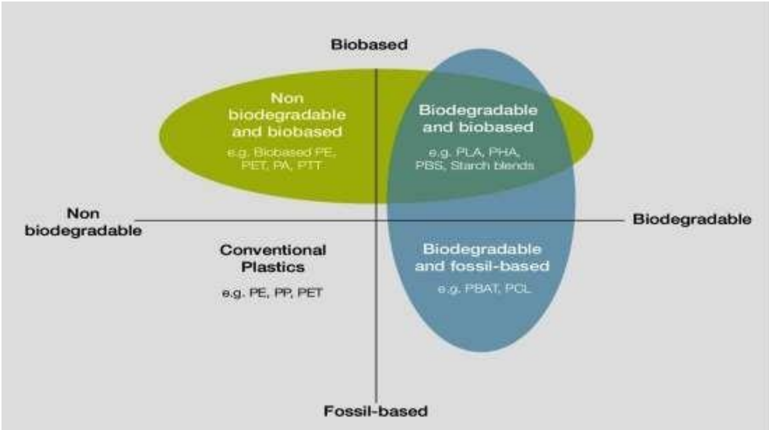
European Bioplastics has mentioned 2 broad categories of bioplastics:

1. **Bio based Plastics:** The term bio-based means that the material or product is (partly) derived from biomass (plants). Biomass used for bioplastics stems from plants like corn, sugarcane or cellulose.

2. **Biodegradable Plastics:** These are plastics which disintegrate into organic matter and gases like CO_2, etc. in a particular time and compost which are specified in standard references (ISO 17088, EN 13432/14995 or ASTM 6400 or 6868).

However, it should be noted that the property of biodegradation does not depend on the resource basis of a material, but is rather liked to its chemical structure. In other words, 100 percent bio-based plastics may be non-biodegradable, and 100 percent fossil-based plastics can biodegrade.

The figure below explains the broad categories into which bioplastics are divided.



Thus, all the highlighted regions in the graph represent bioplastics. They can thus be bio-based biodegradable, non-bio-based biodegradable and bio-based non- biodegradable.[3]

The table below gives a short comparison of various properties of both the plastics.

Bioplastics Vs Petroplastics

	Bioplastics	Petroplastics
Renewable	Yes or partially	No
Sustainable	Yes	No
Break down in the environment	Biodegradable and/or or compostable	Some degradable by polymer oxidation
Polymer range	Limited but growing	Extensive
GHG emissions	Usually low	Relatively high
Fossil fuel usage	Usually low	Relatively high
Arable land use	Currently low	None

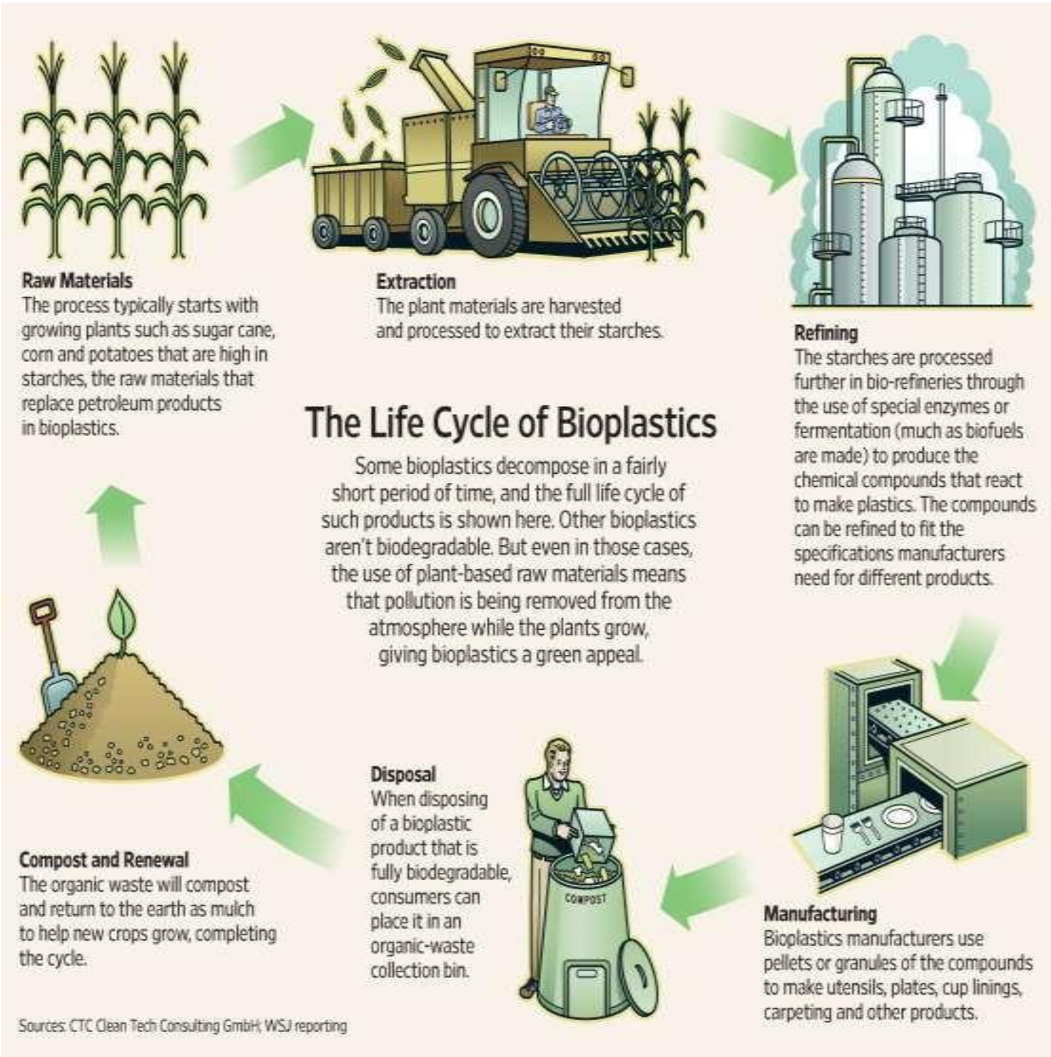
History

Sr.	Event Date:	Event:
1	1st Jan, 1862	**The First Man-made Plastic (Bioplastic):** At the Great International Exhibition in London, Alexander Parkes (1813-1890), a chemist and inventor, displayed a modulable material made of cellulose nitrate and wascalles called Parkesine. Parkesine was greeted with great public interest, so Parkes began the Parkesine Company at Hackney Wick, in London. However, it wasn't very successful commercially.[11]
2	8th Aug, 1869	**Reinvention:** After the fall of the Parkesine Company, a new name in bioplastics surfaced. In 1869, John Wesley Hyatt, in an effort to find a new material for billiard balls other than ivory, invented a machine for the production of stable bioplastic. He

		was able to patent the material as Celluloid.[2]
3	28th Mar, 1907	**Discovery of Conventional Plastics:** The discovery of petroleum plastics. The beginning of a long road that is coming to a dead end.
4	8th Sep, 1924	**Ford Goes Bioplastic:** In the 1920's, Henry Ford, in an attempt to find other non- food purposes for Agricultural surpluses. Ford began making bioplastics for the manufacturing of automobiles. The bioplastics were used for steering wheels, interior trim and dashboards. Ford has been using them ever since.[14]
5	12th Jun, 1933	**The Discovery of Polyethylene:** In 1933, two chemists, E.W. Fawcett and R.O. Gibson discovered polyethylene on accident. While experimenting with ethylene and benzaldehyde, the machine that they were using sprang a leak and all that was left polyethylene. They were credited with the discovery of the polymerization process.[12]
6	13th Aug, 1941	**The First Bioplastic Car:** Henry Ford unveiled the first plastic car in 1941. This car had a bioplastic body and parts consisting of 14 different bioplastics. There was a lot of interest, but soon after, WWII started and attentions were diverted.
7	9th Aug, 1990	A British Company, Imperical Chemical Industries, developed a bioplastic, Biopol, which is biodegradable. This was the beginning of the bioplastic revolution.

5. LIFE CYCLE

The figure below shows the lifecycle of a generic bioplastic.



Application of Bio-Plastic-In Pharma-Industry(PLA-Poly lactic acid)

(a) PLA in Tissue Engineering: The PLA is most widely used biopolymers in medical applications because of its biocompatibility as well as its biodissolvability in the human body by the hydrolysis of the ester backbone to obtain non-harmful and

non-toxic compounds after degradation.[8] Hydrolysis is the most important degradation mode for PLA polymers used for medical applications. BMPs are biologically active molecules that have the ability of initiating new bone formation, and they used for clinical applications in combination with biomaterials, such as bone-graft replacements to stimulate bone repair. On the contrary, the bone that is forming by degradation of PLA was in very small quantity.

(b) PLA in Wound Management: PLA and their copolymers used in various applications of wound management, like for making surgical sutures, healing dental wounds, and preventing postoperativeadhesions. Li et al., (2011) analyzed the capability and contingency of PLA ureteral stents used for treating the ureteral injuries. PLA stents are degradable type that later can be removed from human body 25. Consequently, PLA stents displayed a promising future in the treatment of

ureteral injuries. Qin et al., (2006) in his work used PLA polymer blends to prevent postoperative adhesions. The PLA blends are more flexible as compared to pure PLA because the mechanical properties of pure PLA such as tensile strength,Young's modulus and glass transition temperature were higher as compared to the PLA blends.[13]

(c) PLA in Drug Delivery System: In drug delivery systems, the drug could release persistently for different period up to one year. PLA are using in drug delivery system because it is completely biodegradable, it has better encapsulation capacity, biocompatible and less toxic. Polymeric drug release occurs in three ways: erosion, diffusion and swelling. The degradation occurs. when water enters the biodegradable polymer containing monomers connected by ester bonds with each other. The ester bonds breaks randomly by hydrolytic ester cleavage, leading to subsequent erosion of the device. For degradable polymers, erosion occurs by two methods, which are homogeneous / bulk erosion and heterogeneous /surface erosion 28. PLA and their copolymers in the form of nano-particles were in the encapsulation process of many drugs, such as psychotic, restenosis, hormones, oridonin, dermatotherapy, and protein (BSA) 29. Methods to obtain these nano-particles are solvent evaporation, solvent displacement, salting out, and emulsion solvent diffusion. Ling and Huang 30 used the poly (lacticco-glycolic) acid nano-particles for loading the drug, paclitaxel.

2.Polylactic-co-glycolic Acid (PLGA): PLGA is one of the most beneficial synthetic biodegradable polymers used in the biomedical field and has been approved by FDA (US Food and Drugs Administration) and European Medicine Agency) 36. PLGA has attracted significant interest as a principle material for medical applications because of its biocompatibility and biodegradation rate depending upon the molecular weight of polymer and ratio of its copolymer. According to FDA, PLGA is safe to use in human body, provided better interaction with biological materials by modifying its surface properties.PLGA is a hydrophilic, crystalline polymer with

comparatively fast deterioration rate as compared to other biodegradable polymers. Typically, the PLGA co-polymers are preferable compared to its constituent homo-polymers for the mixture of bone replacement constructs, as PLGA recommend highgrade control as compared to its degradation properties by differing the ratio of its monomers. The PLGA offers broad range of degradation rates, controlled by amalgam of the chains, both hydrophobic / hydrophilic and crystalline nature of the polymer 37. PLGA is usually used in conjunction with other materials including ceramics, biologically active glass, in order to provide PLGA more bionics and able to intensify bone reformation 38. Hence, PLGA - based bone replacements have classified according to their types and application: such as scaffolds, fibers, hydrogels or microspheres.

3. Poly (ε- caprolactone) (PCL):

a) Biodegradation: PCLs can be biodegraded with the help of bacteria and fungi that are outdoor living organisms, but they cannot biodegrade in the bodies of animal and human because they have the lack of suitable enzymes 84. However, that has not to say that they are not bioresorbable, but preferably,that the procedure takes much longer, propagate through hydrolytic degradation. It is broadly accepted that hydrolytic degradation of poly (-hydroxy) esters begin through either surface or bulk degradation pathways. Surface degradation or erosion implies the hydrolytic scission only at the surface of the polymer backbone 85. This situation appears when the rates of hydrolytic cleavage of chain and the making of oligomers and monomers, which disperse into the surroundings, is rapid than the rate of water intrusion into the polymer bulk. This generally results in thinning of the polymer with respect to time without influencing the molecular weight of the inner bulk of the polymer, which would usually remain unchanged over the period of degradation 86. When the water enters the entire polymer bulk degradation occurs, that because the hydrolysis all over the entire polymer matrix due to random hydrolytic chain scission, an overall reduction in molecular weight takes place. When the water molecule diffuses into the polymer bulk, hydrolysis of the chains enables the monomers or oligomers to diffuse out of the polymer bulk, slowly erosion will occur and equilibrium for the diffusion - reaction would attained. The internal autocatalysis was provoked by the degradation mechanism through the carboxyl and hydroxyl end group by-products when the equilibrium of diffusion reaction was disturbed. Because the surface oligomers and carboxyl groups may freely diffuse into the surroundings (during the surface erosion condition), while in the case of bulk degradation an acidic gradient can be produced in the form of the newly generated carboxyl end group formed during the cleavage of ester bonds by the internal concentration of autocatalysis products. This, in turn, increases the internal degradation as compared to the surface, resulting in as an outer layer of higher molecular weight skin along with a lower molecular weight, degraded, interior. When the internal oligomers become small enough that quickly diffuses via the outer layer, followed by the beginning of weight loss, and decreased rate of chain scission producing a hollow structure having the higher molecular weight. The quick release of acid by - products and these oligomers can result in inflammatory reactions in vivo, as described in the literature of bioresorbable device 87. In addition to poor vascularization or low metabolic activity, local and temporary disturbances may arise to the surrounding tissue unable to buffer the pH change this has been observed from an example of fiber-reinforced PGA pins used in the orthopedic surgery due to which osmotic pressure is increased by the local fluid accumulation at the time of rapid degradation.[11]

PCL in Drug-Delivery Systems:PCL is suitable for controlled delivery of drug due to various advantages: high permeability for several drugs, excellent biocompatibility and it can completely excrete from the body once get bio-resorbed. PCL is suitable for long-term drug delivery system expanding up to more than 1 year because the rate of its biodegradation is slower than that of other polymers. PCL also has the capability of making compatible blends by using other polymers, which can influence the degradation kinetics; it can also ease the altering to fulfill desirable drug release profiles 101

The rate of drug release from PCL based on factors such as the type of formation, techniques of preparation, the content of PCL, percentage, and size of the drug loaded within the microcapsules. Because PCL has higher permeability so it has mixed with other polymers for improving stress, resistance against cracks and for controlling the release rate of the drug. In last few years, PCL have become a major area of research in order to develop controlled drug delivery systems mainly used for proteins and peptides.[15]

PCL Applied in Tissue Engineering: : An interdisciplinary field of science that use the principles of life sciences and engineering in order to obtain biological replacements that helps in replacing, retaining, or improving the functions of whole organs or tissues (including bone, cartilage, and blood vessels) is known as tissue engineering 104. Certain structural and mechanical properties required by the tissues involved in the repairing process of tissues for appropriate functioning. The term tissue engineering is also being involved in performing specific biochemical functions employing cells inside a support system that artificially created (including an artificial liver, or pancreas). In tissue engineering, some powerful developments

made that helps in yielding a unique set of implementation strategies and tissue replacement. A unique opportunity has been create for fabricating tissues in the lab from the blends of engineered extracellular matrices (also known as “scaffolds”), biologically active molecules and cells by making scientific advancements in stem cells, growth and differentiation factors, biomaterials, and biomimetic environments. [1]

6. ADVANTAGES OF BIOPLASTICS

1. Eco Friendly

Traditional plastics are the petroleum-based plastics which depend on fossil fuels which is an unsustainable source.[5] Also acquiring fossil fuels does a lot of harm to the natural environment. Bioplastics on the other hand are made from bio mass like trees, vegetables, even waste which is completely bio degradable. So, bioplastics are made from completely renewable source. Even during the manufacturing of plastics, a lot of pollution occurs, for example, during production, PVC plants can release dioxins, known carcinogens that bio-accumulate in humans and wildlife and are associated with reproductive and immune system disorders Require less time to degrade.[16]

Traditional plastics take thousands of years to degrade, these plastics lie in the environment, most notably on the ocean floor where they do the maximum damage for years. These plastics hamper the growth and kill the natural habitats.

Bioplastics on the other hand, require considerably less time to biodegrade. This degradation can be carried out at home for some bioplastics and even for the bioplastics which require specific conditions, time required to degrade completely is considerably less. This reduces the huge pressure on our existing landfills.

2. Toxicity

Some of the plastics degrade rapidly in the oceans releasing very harmful chemicals into the sea, thus harming the animals, plants and also harming the humans by entering the food chain.

Biodegradable plastics are completely safe and do not have any chemicals or toxins. This plastic harmlessly breaks down and gets absorbed into the earth. Such advantages of bioplastics are of extreme importance, as the toxic plastic load on the earth is growing and at this rate will cause a whole range of problems for future generations.

3. Lower energy consumption

Companies still use fossil fuels for the manufacture of bioplastics; however, many bioplastics use considerably less fuel for their manufacture.[17] For example,

Polylactic acid production requires less energy than other plastics

4. Environmental protection

Burning fossil resources increases the share of CO_2 in atmosphere, which causes an increase of the average temperature (greenhouse effect). Scientists see a distinct connection between CO_2 increase in atmosphere and the increase of number of thunderstorms, floods and aridity. Climate protection is nowadays a central part of environmental policy, due to the fact that climate change can create far-reaching negative consequences. Governments and organizations work against this threat with targeted measures.

7. CHALLENGES FOR BIOPLASTICS

1. Misconceptions

Even through bio-degradable plastics are considered to be good for the environment, they can harm the nature in certain ways. Emission of Greenhouse gases like methane and carbon dioxide, while they are degrading, is very large at landfill sites.[3]

This can be handled by designing plastics so that they degrade slowly or by collecting the methane released and use it elsewhere as fuel.

2. Environmental Impact

Starch based bioplastics are produced generally from plants like corn, potatoes and so on. This puts massive pressure on the agricultural crops as they have to cater the need of ever-growing population. To make plastics, crops have to be grown and this could lead to deforestation.

Bioplastics are generally produced from crops like corn, potatoes, and soyabeans. These crops are often genetically modified to improve their resistance to diseases, pests, insects etc. and increase their yield. This practice however carries a very high risk to the environment as such crops can be toxic for humans as well as for animals.[20]

3. Cost

Bioplastics are newer technology and require still more research and development to get established. Bioplastics are not thus, comparable to plastics with respect to cost

8. FUTURE SCOPE

- Further Research can be carried out for better understanding of the Process and thereby improving the Quality of the product.

- Other commonly available starch sources can be explored. Food wastes like mango seeds and corn kernels also have high starch content. Hence, these can also be utilized as a raw material for synthesis of polymeric films.
- So, far we have conducted the experiment using only one set of concentrations (0.5 N NaOH & 0.5 N HCl). Varying the concentration of the reagents might alter the properties of the polymeric films obtained.
- This project focused primarily on tensile strength measurement. Other standard tests like Izod Impact Test, Dart Impact Test etc. should also be conducted.
- Synthesis of polymeric films can also be carried out after extraction of starch from banana peels instead of processing it as a whole to see if improves the polymeric properties.
- The banana peels consist of many different components apart from starch. Currently only the reaction with starch has been considered. The interaction of all the other components with the reagents may also have an effect which must also be quantified.[18]
- Bioplast its can help reduce reliance on fossil fuels, support sustainability in the industry and a manufacturers to diversify feedstocks.
- Biodegradable plastics and packaging derive from natural substances, there are no chemicals or toxins in these items.
- Degrade in the environment .by microbes which ooze out the acid and cat the plastic in 10 years. There are various additives which arc used to increase the biodcgradability without affecting the shelf-life and physical properties of product.[19]
- The improvement of pharmaceutical packaging for natural responsibility, sustainability and certain appropriate ecological and recycling regulations; more consideration has been paid to the removal and recycling of packaging waste in numerous nations.

9. CONCLUSION

The tensile strength for sample keeps increasing when the residence times are increased from 5 minutes to 15 minutes and reaches a maximum at 15 minutes and then starts decreasing when the time is increased to 20 minutes. This suggests that the optimum hydrolysis times is 15 minutes for this sample set.

Bioplastic film can sustain the weight near about 2 kg and which have enough tensile strength Glycerol is added as plasticizer that increases its flexibility.

To prevent of bacteria and fungi sodium meta bisulfide is used.

Based on advantages of bioplastics, there are certainly an abundant number of materials and resources to create and find more use of bioplastics.

Based on disadvantages of bioplastics, for the sustainability, several parameters are considered.

Microorganisms have immensely contributed in biodegradation through their inbuilt mechanism of enzyme secretion and digestion of polymers completely.

Another sustainable solution to reduce plastic is generation of Bioplastics which are biodegradable plastics that are produced from renewable sources.

Bioplastics can either produce from agro-wastes using some chemical treatment in order to manufacture eco-friendly biofilms that have various applications.

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