IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 2, August 2023

Poly Lactic Acid as Bio Plastic – An Overview

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Abstract: *The bio plastics are generating a growing interest as an alternative to petroleum based plastics that have caused many adverse impacts on the environment. The objective of this paper is to analyze Polylactic Acid (PLA) as a bioplastic. In fact, the market for PLA has grown up and will keep on expanding in the future. Overall, the PLA-based bio plastic would be an excellent substitute for the existing conventional plastics in various applications, hence will serve to protect the environment not only from pollution but also work as a sustainable and economical product. This paper highlights the works and literature on PLA as the biodegradable material regarding its synthesis, properties, usability and substitute.*

Keywords: Biodegradability, Bioplastics, Cellulose, Polylactic acid (PLA), Starch

I. INTRODUCTION

Commercial plastics such as polyethylene and polypropylene are economical, lightweight and versatile; however, they last for many years after being discarded, due to their properties of high resistance to corrosion, water and bacterial decomposition. It becomes waste that is difficult to eliminate and, consequently, a serious environmental problem due to its petrochemical origin [1].

The annual production of plastics exceeded 300 million tons in 2015, which generated 34 million tons of plastic waste throughout the world and 93% of them are disposed of in landfills and oceans [2].

Because of this, there is a huge need to promote the production of plastics from raw materials based on renewable sources, such as bioplastics, which are characterized by being made from organic materials and which are mostly biodegradable [3]. Thanks to the use of bioplastics, the remains of containers and wrappings that end up in sinks or oceans will be naturally degraded by contact with water and climatic agents, destroying and emitting organic molecules that do not have a harmful impact on the environment [3].

According to the International Standard Organization (ISO), bio plastics are defined as polymeric structures that use vegetable raw materials that are essentially derived from renewable resources [4]. Bio plastics can be classified according to their source, which can be divided into three subgroups, the first of which are the bio plastics generated directly from the biomass, that is, from the extracted starch, such as Polylactic Acid (PLA), the second are those generated from vegetable oils and the last, those generated from Polyhydroxyalkanoates (PHA) [4].

II. SYNTHESIS OF POLYLACTIC ACID

Poly lactic acid is one of the most promising biopolymers produced from nontoxic renewable and naturally occurring lactic acid. Lactic acid can be produced by fermentation of sugars obtained from renewable resources such as sugar cane, maize etc. Lactic Acid (LA), also named 2-hydroxy propionic acid, is the basic monomer of PLA. It has an asymmetric carbon that generates twoenantiomeric forms, L-LA and D-LA, that produces PLLA and PDLArespectively, and the combination of the two optical isomers creates PDLLA as shown in the figure .

The two main methods to produce LA are by bacterial fermentation of basic carbohydrates or by chemical synthesis. Chemical synthesis has many limitations, including limited production capacity, inability to produce only the desired isomer, and high manufacturing costs. The bacterial fermentation process to produce LA is preferred and can be classified as homofermentative or heterofermentative, depending on the bacteria used in the process. In the heterofermentative method, a lower quantity of LA is produced along with significant levels of other metabolites highlighting acetic acid, ethanol, glycerol and carbon dioxide; whereas in the homofermentative method a higher

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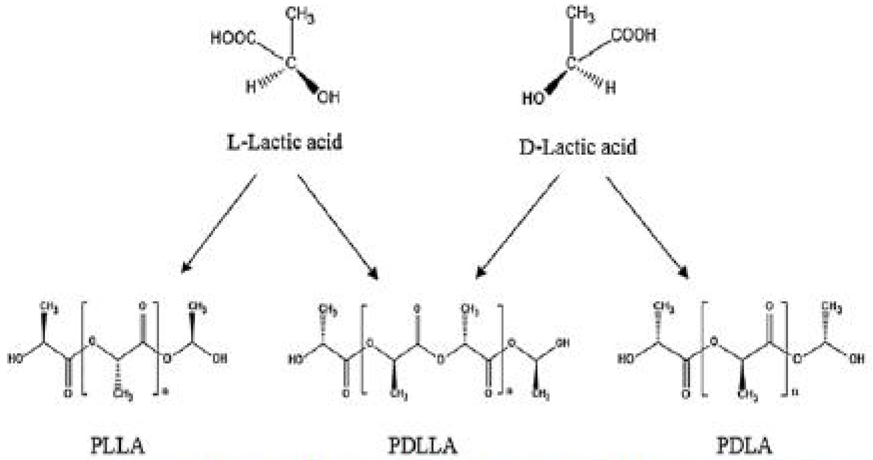
quantity of LA is produced with minor levels of other metabolites, which means a better yield. For the reasons mentioned, the homofermentative method is more frequently used by industry.



Representation of the enantiomers for the LA and the possible outcomes for PLA

Polylactic Acid (PLA), finally, is a thermoplastic biopolymer. Its crosslinking of chains gives rise to biodegradable plastic sheets that serve as the basis for the production of numerous nonpolluting plastic products.

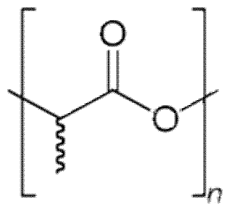


Figure 5: Structure of polylactic acid [6].

III. STRUCTURE OF POLYLACTIC ACID

PLA is one of the most common bioplastics used today, however, the process for this material to be degraded is very specific and has to occur in the appropriate facilities, that is, if it ends up in a landfill, it will remain there for thousands of years like a normal plastic.

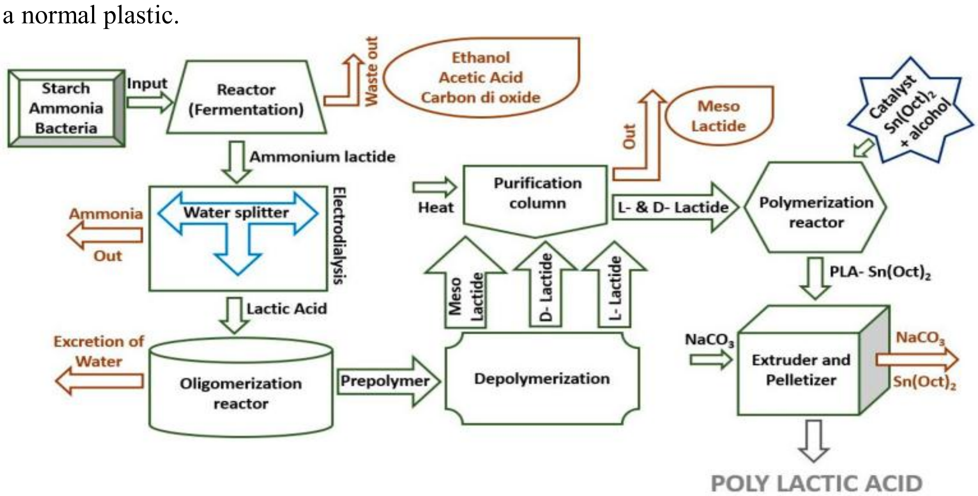


Fig. 1: Process of making poly lactic acid.

IV. PROPERTIES OF PLA:

Property	PLA	PP	PET	Nylon
Density (g/cc)	1.25	0.9	1.4	1.2
Tensile strength (MPa)	109.97	189.95	204.95	249.94
Tensile modulus (MPa)	3299.26	2399.46	3799.15	1824.59
Ultimate elongation (%)	160	110	140	125
Tear resistance (g/mm)	0.3810	0.1316	0.4572	0.3302

Table 1: Mechanical properties of PLA and petroleum-based polymers .

PLA possesses attractive mechanical properties such as a low haze or turbidity, which is the cloudiness of a fluid and is measured by the percentage of light that it deflects, a high tensile strength that represents the maximum stress that a polymer can withstand before breaking under pulling, expressed in MPa. Elongation at break, also known as fracture strain, is the ratio between changed length and initial length after breakage of the polymer, reported as percentage, and tear resistance is used to determine how well a material behaves the effect of tearing in g/mm [8]

Abbreviations: PET (Polyethylene Terephthalate), PP (Polypropylene).

Property	Values
Specific Gravity	1–1.5
Surface Energy (dynes)	36–40
Melting Temperature (°C)	140–210
Molecular Weight (Daltons)	Approx. 1.6×10^5
Melt Flow Index (g/10 min)	4–22
Crystallinity (%)	5–35
Glass Transition Temperature (°C)	50–75

Table 2: Physical properties of polylactic acid

V. APPLICATIONS OF PLA AS BIO PLASTIC

Poly lactic acid (PLA) is one of the most demanded biopolymers, representing 13.9% of the global production of bio plastics, owing to its versatile characteristics, which make it applicable for packaging, textile, construction, and automotive applications. Specifically, in the textile industry. PLA finds applications in various industries, particularly in areas where its biodegradability and low Carbon footprint are advantageous are listed below:

- **Packaging Materials:** PLA is commonly used to produce food packaging, disposable cutlery trays, cups and films. It's transparency, flexibility and ability to form complex shapes make it suitable for packaging applications. PLA packaging can help reduce the environmental impact of single use plastics
- **Textiles and Apparel:** PLA fibers can be used to produces sustainable textiles and clothing. These fibres can be blended with other materials like cotton or polyester to create fabrics with improved breathability and moisture-wicking properties.
- **3D Printing:** PLA is a popular material for #D printing due to its ease of use, low warping tendency and biodegradability. It's used to create a wide range of objects, from prototypes to functional parts.
- **Medical Devices:** PLA can be used in medical applications such as sutures, drug delivery systems and tissue engineering scaffolds. Its biocompatibility and ability to break down in the body over time make it suitable for temporary medical implants.
- **Agricultural Films:** PLA films can be ueds in agriculture for applications like mulching and soil erosion control. These films eventually biodegrade in the soil, reducing the need for cleanup and disposal.
- **Disposable Tableware:** PLA –based disposable plates, bowls and cutlery are commonly used in events and gatherings. They offer a more sustainable alternative to traditional plastic tableware.
- **Biodegradable Films:** PLA films can be used for agricultural and industrial applications, such as mulch films, greenhouse films and packaging films. These films can break down into non-toxic components, reducing environmental pollution.

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- **Electronics and Electrical Components:** PLA can be used to produce casings and components for electronics, such as smartphones cases and connectors. Its thermal and mechanical properties make it suitable for various electronic applications.
- **Promotional Items:** PLA based promotional items like key chains, pens and other branded merchandise offer an eco-friendly alternative to traditional plastic.
- **Construction Materials:** PLA can be used to create environmentally friendly construction materials such as biodegradable films for temporary protection, acoustic panels and insulation.

VI. ADVANTAGES & DISADVANTAGES OF PLA AS BIO PLASTICS

6.1 Advantages

A. 100% biodegradable, compostable eco-friendly material

Polylactic acid (PLA) has good biodegradability and can be completely degraded by microorganisms in nature after use, and finally carbon dioxide and water are generated without polluting the environment. This is very beneficial to environmental protection and is recognized as an environmentally friendly material.

Ordinary plastics are still treated by incineration and cremation, causing a large amount of greenhouse gases to be discharged into the air, while polylactic acid plastics are buried in the soil to degrade, and the carbon dioxide produced directly enters the soil organic matter or is absorbed by plants, and will not be discharged into the air will not cause the greenhouse effect.

B. Good mechanical and physical properties

Polylactic acid is suitable for various processing methods such as blow molding and thermoplastic and is used to process various disposable plastic tableware from industry to civilian use, such as cutlery, spoons, dishes, plastic products, packaged food, non-oven fabrics, industrial and civil cloth. And then processed into agricultural fabrics, health care fabrics, wipes, sanitary products, outdoor anti-ultraviolet fabrics, tent fabrics, floor mats, and so on.

A. Good compatibility and degradability

Due to its good compatibility and degradability, polylactic acid is also widely used in the medical field. For example, polylactic acid can be used to produce disposable infusion equipment, non-dismantling surgical sutures, and low-molecular-weight polylactic acid as a drug sustained-release packaging agent.

D. Good gloss and transparency

The basic physical properties of polylactic acid (PLA) and petrochemical synthetic plastics are similar, that is to say, it can be widely used to manufacture various application products. Polylactic acid also has good gloss and transparency, which is comparable to films, made of polystyrene, and cannot be provided by other biodegradable products.

E. Best choice for 3D printing

PLA has a lower melting point than many petrochemical plastics and requires less energy for conversion. Because of its low melting point, cheap, easy to print, and smokeless characteristics. PLA has become the best choice for 3D printing

6.2 Disadvantages :

A. High price

PLA is more expensive than petrochemical plastics.

B. Compostable but not fast enough

For industrial composters, the speed of composting is not fast enough. The residue is not compost. It will not improve soil quality. No nutrition. It changes the pH of the soil, and it makes the soil more acidic.

C. Low melting point

PLA has a low melting point and is not suitable for high temperature environments, nor can it be mixed with other plastics for recycling.

D. High permeability

PLA has higher permeability than other plastics. Moisture and oxygen pass more easily than other plastics. This will lead to faster food spoilage, so PLA is not recommended for long-term food storage applications.

VII. CONCLUSION

Bio plastics made of Polylactic acid are a positive alternative that can decrease the excessive consume of non-biodegradable plastics created from petroleum.

Compared to plastics made from petroleum, Polylactic acid is biodegradable, but it is significant to know that this is true under certain conditions and with the presence of specific microorganisms, so it is important to inform consumers so these biodegradables bio plastics can be properly disposed.

It is evident that Polylactic acid has many applications in the field of medicine, however, for us the greatest focus should be given to the commercial applications that this bio plastic could have specifically in packaging, since the plastics are currently used a lot for packaging and this is one of the largest sources of existing pollution.

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