

SUSTAINABLE SOLUTIONS USING BIO-BASED PLASTIC (USE OF POLYLACTIC ACID INSTEAD OF POLYCARBONATE)

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1. ABSTRACT

The escalating environmental concerns associated with synthetic, non-degradable plastics have intensified the search for sustainable alternatives in packaging applications. This study investigates the environmental impact and material performance of polycarbonate (PC) and polylactic acid (PLA) in bottle manufacturing, emphasizing the potential of PLA as a renewable substitute. Experimental data from industrial trials indicate that transitioning from PC to PLA significantly reduces greenhouse gas emissions and reliance on non-renewable energy sources. Additionally, the research explores the complementary properties of PLA and starch-based polymers, highlighting their limitations—such as PLA's brittleness and starch's moisture sensitivity—and the potential of blend and multilayer film strategies to enhance mechanical strength and barrier performance. The findings underscore the viability of PLA-starch composites as eco-friendly packaging materials, offering a promising path toward reducing plastic pollution and promoting circular material use in the packaging industry.

2. INTRODUCTION

Polylactic Acid (PLA) is a revolutionary bioplastic, derived from renewable resources such as sugary, starchy, or cellulosic feedstocks. Its versatility, biodegradability, and minimal environmental impact make it a beacon of sustainability in the plastics industry through Biomanufacturing. (Praj, 2025)

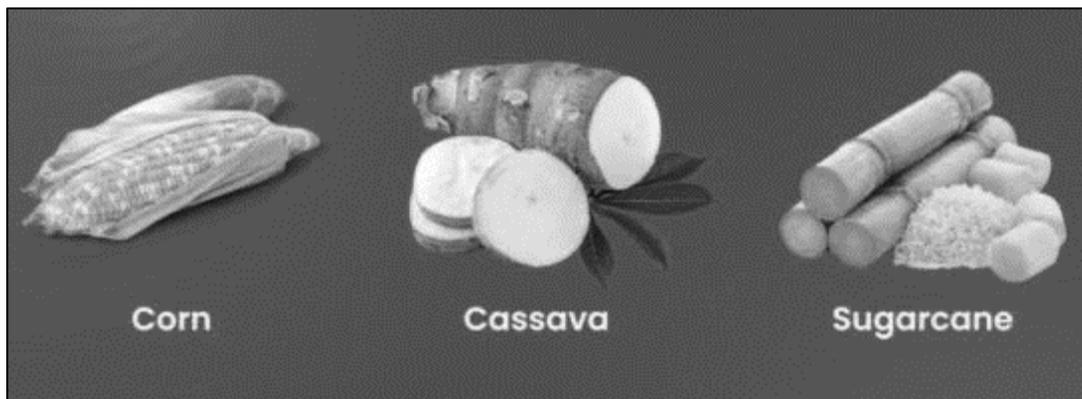
The increasing environmental concerns over petroleum-based plastics have driven the search for sustainable alternatives that reduce carbon footprints and dependence on fossil fuels. Among the most promising solutions is the adoption of bio-based plastics, particularly polylactic acid (PLA), as a substitute for conventional plastics like polycarbonate (PC).

Polycarbonate, widely used in packaging, electronics, and automotive industries due to its durability and heat resistance, poses significant environmental challenges. Its production relies on non-renewable resources, and its disposal contributes to long-term pollution due to its non-biodegradable nature. In contrast, PLA, derived from renewable resources such as corn starch or sugarcane, offers a biodegradable and compostable alternative with a lower environmental impact.

This research explores the feasibility of replacing polycarbonate with PLA in various applications, evaluating its mechanical properties, thermal stability, and environmental benefits. By analysing the strengths and limitations of PLA, this study aims to contribute to the development of sustainable material solutions that align with global efforts toward a circular economy and reduced plastic waste. The findings could offer valuable insights for industries seeking eco-friendly alternatives without compromising performance.

2.1. Raw Materials Used in Polylactic Acid Production

PLA plastic is made from plant materials like corn, sugarcane, cassava. (EUP Egypt Industries, 2025)



3. THE MAIN CHARACTERISTICS OF PLA MATERIALS

PLA is derived from lactic acid (LA), a linear aliphatic thermoplastic polyester. It is recognized and classified as one of the aliphatic polyesters, like polyglycolic acid (PGA), and is commonly made from hydroxyl acids.

Due to the asymmetric carbon atom in its molecule, LA exists in two forms, L-LA and D-LA, as illustrated in Fig. 1. These two forms are mirror images of each other. They have identical physical and chemical properties in their pure forms. The only differences are that plane-p. The plane-polarized light direction of rotation that is generated by a chemical is shown by the sign of (+) and (-). Polarized light rotates similarly in opposite directions, and that other asymmetric (chiral) reagents such as most enzymes in biological systems, have different reactions. The plane-polarized light path or like PETE polymer, but in term of temperature control condition, it has a significantly lower maximum continuous use of temperature.

Additionally, via chemical conversion, PLA can be re-polymerized when it is recycled back to lactic acid. Fig. 2 below shows the PLA cycle in the nature. (Taib, 2023)

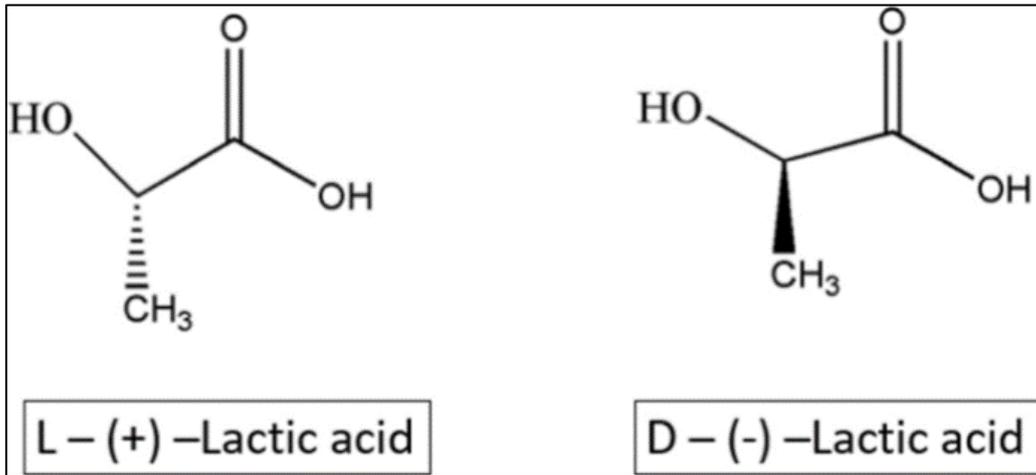


Fig.1 Enantiomeric forms of lactic acid (Casalini, 2019)

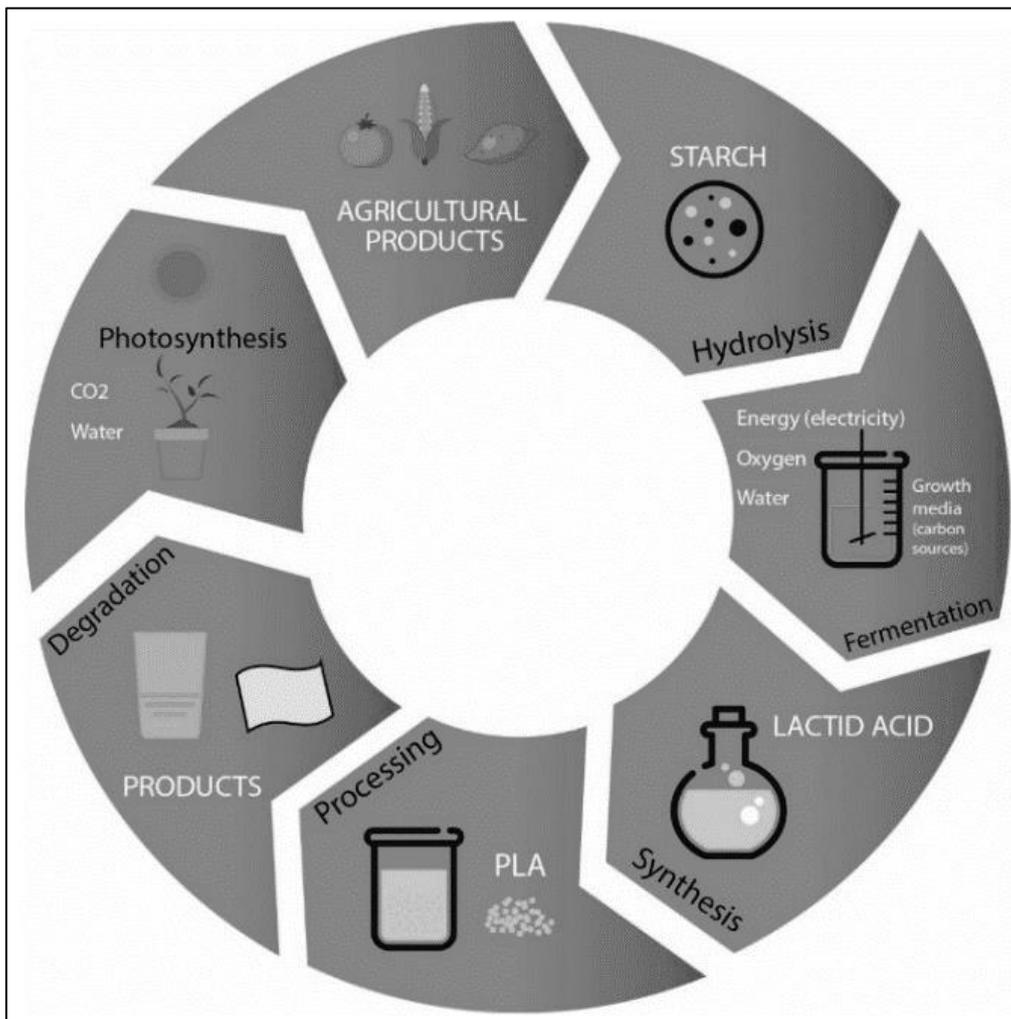


Fig. 2 PLA cycle in nature (Auras, 2004)

Table 1. Tensile properties of neat PLA films reported by different authors. Tensile strength (MPa) and Elongation at break (%). (Muller, 2017)

PLA	Processing	TS (MPa)	E (%)	Ref.
120 kDa	Extrusion Compression moulding	55.1	3.8	(Acioli-Moura, 2008)
2002D® 4% D-content 235 kDa	Extrusion Injection moulding	60	2	(Huneault, 2007)
4042D® 6% D-content 130 kDa	Melt blending Compression moulding	56.3	3.6	(Hwang, 2012)
4042D® 6% D-content 130 kDa	Melt blending Compression moulding	70.2	7.4	(Phetwarotai, 2012)
125 kDa	Extrusion Compression moulding	55.4	2.6	(Teixeira, 2012)
120 kDa	Compression moulding	62.7	6.1	(Wang, 2002)
2002D® 4% D-content 235 kDa	Melt-blending Compression moulding	55	4.5	(Wokadala, 2014)
4032D®	Extrusion Injection moulding	65	5	(Xiong, 2013)

4. USE OF PLA IN ESCALATOR

4.1. Lubrication System Container

Escalator Downdraft Lubrication and Automatic Lubrication Systems use containers made from polycarbonate; a durable but non-biodegradable plastic associated with environmental concerns which can be replaced with the containers made out of Polylactic acid.

4.2. Other areas of applications of PLA in escalator

- Handrail Caps (End Caps)
- Rigid Parts of Skirt Deflectors (Mounting Brackets, Clips, Non-Impact Sections)
- Electrical System Brackets (Cable Management, Sensor Mounts, Low-Heat Junction Boxes)

5. APPLICATIONS OF PLA

- **Sustainable Packaging:** PLA is extensively used in the packaging industry for food contact materials due to its safety and biodegradability. It is FDA approved for use in products such as containers, cups, trays, bottles, straws, and flexible films. PLA packaging is especially favoured for short shelf-life products like fruits and vegetables and single-use items, offering a premium, eco-friendly alternative to traditional plastics like polystyrene or polypropylene. This helps reduce plastic waste and environmental pollution significantly.
- **Medical and Healthcare Applications:** PLA's biocompatibility and biodegradability make it invaluable in medical fields. It is used for manufacturing surgical implants, fixation rods, plates, screws, sutures, drug delivery systems, and tissue engineering scaffolds. PLA implants naturally degrade over time, eliminating the need for secondary removal surgeries. Its role in modern medicine also extends to 3D printed customized implants and personal protective equipment (PPE), enhancing patient-specific care and safety.
- **Automotive Industry:** In automotive manufacturing, PLA and its composites are used to produce interior components such as door trims, floor mats, pillar covers, and ceiling panels. PLA-based materials contribute to vehicle lightweighting, improved tensile strength, and impact resistance while delivering environmental benefits by replacing petroleum-derived plastics. PLA composites are also proposed for innovative automotive parts like translucent roofs and spare wheel covers in hybrid concept vehicles.
- **Textiles and Fibers:** PLA fibres are employed in producing breathable, lightweight, and recyclable fabrics used in clothing, upholstery, carpets, mattresses, and sportswear. PLA textiles offer low moisture absorption and UV resistance, making them good alternatives to petroleum-based synthetic fibres. This sector leverages PLA to provide sustainable and comfortable textile products with reduced carbon footprints.
- **3D Printing:** PLA is the most popular filament material for Fused Deposition Modelling (FDM) 3D printing due to its low melting point, ease of use, dimensional accuracy, and biodegradability. It enables rapid prototyping and manufacturing of functional parts, educational models, medical implants, toys, and decorative items. Its wide availability in diverse colours and blends adds to its versatility in additive manufacturing.
- **Agriculture:** PLA is used for producing biodegradable mulch films, seed trays, and plant pots that help reduce plastic pollution in agricultural environments. These materials decompose naturally under composting conditions, supporting eco-friendly farming practices.

6. PLA'S KEY ADVANTAGES IN INDUSTRIAL APPLICATIONS

- **Biodegradability and Composability:** Minimizes environmental impact compared to conventional plastics.
- **Renewable Resource Base:** Derived from corn, sugarcane, cassava, and other plant starches.
- **Biocompatibility:** Safe for medical use and human contact.
- **Versatile Processing:** Compatible with injection moulding, extrusion, thermoforming, and 3D printing.
- **Mechanical Properties:** Good tensile strength and flexibility, adjustable through blends and additives.
- **Eco-Friendly Manufacturing:** Requires less energy and generates fewer greenhouse gases during production.

7. CONCLUSION

The integration of polylactic acid (PLA) into escalator components symbolizes a thoughtful convergence of sustainability, design, and innovation in modern public infrastructure. Derived from renewable sources such as corn starch and sugarcane, PLA is both bio-based and compostable, offering a low-carbon alternative to petroleum-based plastics. Its lightweight nature makes it particularly suited for non-load-bearing parts, contributing to energy efficiency and ease of installation. Additionally, PLA's smooth finish and natural translucence support aesthetic flexibility, enabling designers to create escalators that blend functionality with a modern visual appeal.

As material science continues to evolve, PLA's heat resistance and durability have significantly improved, broadening its application in high-use transit systems. Its adoption reflects a growing environmental consciousness among urban planners, transit authorities, and manufacturers—signalling a shift toward reducing environmental impact without compromising design or performance. Beyond its physical utility, incorporating PLA into escalators sends a clear message of public environmental responsibility, transforming everyday infrastructure into quiet champions of sustainability. With each PLA-based step, cities embrace a future where innovation and eco-awareness walk side by side—elevating not just people, but ideals.

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9 BIOGRAPHICAL DETAILS



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