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CHARACTERISTICS AND MEDICAL USES OF PLA POLYLACTIC ACID

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Abstract: *The biopolymer (PLA) is a completely bioresorbable biopolymer obtained from the lactic acid monomer LA. The biopolymer is characterized by exceptional biocompatibility and availability to be used in a wide range of medical applications. Added to these is easy processing for the manufacture of medical components.*

Keywords: *lactic acid LA, polylactic acid PLA, biocompatibility, medical applications.*

INTRODUCTION

Polylactic acid PLA, also known as lactides, is a biopolymer obtained from the monomer lactic acid (LA), a naturally occurring organic acid [1]. The polylactic acid (PLA) is also known as poly(lactide), the two terms being used interchangeably although they have different chemical manufacturing routes [2], [3].
Lactic acid (LA), known as α-hydroxypropionic acid, or 2-hydroxypropanoic acid [1] is the simplest 2-hydroxycarboxylic acid (or α-hydroxy acid). It has the chemical formula C3H6O3 (Fig.1a) and the structural formula CH3-CHOH-COOH [1].

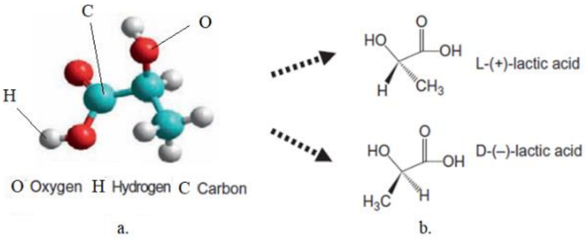

Figure 1: Lactic acid LA: a. Lactic acid molecular structure; b. Stereoisomers of lactic acid, from [2]

Each molecule of LA is an organic molecule with a chiral center that contains an asymmetric (chiral) carbon atom, to which four different atoms or radicals are connected such as methyl group, hydrogen atom, hydroxy group, and carboxylic acid group. In this chemical configuration, the LA molecule is optically active with the property of optical isomerism (enantiometry) [1].
Lactic acid LA exists as two chiral stereoisomers forms, namely L- (+) (Dextrorotatory) lactic acid and D- (-) (Levorotatory) lactic acid (Fig.1.b), which are optically active and a form of mixture between (-D) and (+L)-meso-lactic acid, or racemic mixture, equimolar mixture of (L,D), the form that is optically inactive by intermolecular compensation [1], [4], [3].
The polylactic acid PLA can be of natural origin, obtained from natural resources such as wheat, corn, biomass, etc. [1] or it can be obtained from lactic acid by three main chemical synthesis routes such as by "direct polycondensation" of lactic acid, by "ring-opening polymerization" (ROP) of lactide and by "azeotropic dehydration polycondensation" [2], [3].
The PLA biopolymer has three distinct stereoisomers namely [2], [3]: poly(L-lactic acid) or PLLA, produced from % the pure L-isomer (PLLA is widely used in medical applications because it is metabolized by the human body); poly(D-lactic acid) or PDLA, produced from % the pure D-isomer and poly(D,L-lactic acid) or PDLLA, produced from both L (+) and D (-) lactic acids.
The biopolymer (PLA) is a highly versatile biodegradable linear aliphatic thermoplastic polyester because the monomer units of polymer backbone are joined by ester bonds, thus being part of the family of biodegradable polyesters [1], [3]. The physical, chemical, mechanical, biological properties, etc. of polylactic acid (PLA) are described in numerous works such as [2], [3], [1], [4], [5], [6].
Table 1 summarizes the general properties of lactic acid.

Table 1. General properties of PLA, from [5], [4], [6]

Physical properties		Mechanical properties	
Specific Gravity	1,24	Tensile Strength (MPa)	62,1
Glass Transition Temperature (K)	328	Ultimate Tensile Strength (MPa)	59
Melting Temperature (K)	428	Elastic modulus (GPa)	3,8
Heat Distortion Temperature (K)	328	Tensile Elongation (%)	3,5
Heat deflection (^{0}C)	55	Flexural Strength (MPa)	108
Clarity	transparent	Flexural Modulus (MPa)	3600
PLLA and PDLA	crystalline state	Max Elongation (%)	4-7
PDLLA	amorphous state	Ductility	low
		Toughness	low
		Impact Strength-Izod notched (J/m)	26

1. MEDICAL USES

PLA biopolymer is a versatile, biocompatible, bioresorbable, and environmentally friendly polyester and its degradation products are not toxic to living tissue, being eliminated through metabolic processes [1], [2], [3], [4].
Being a bioresorbable polyester, polylactic acid is characterized by the main medical uses specific to bioresorbable polyesters, presented synthetically by Ikada and Tsuji [7] and repeated in table 2

Table 2: Medical application of bioresorbable polymer, from [7]

Function	**Purpose**	**Examples**
Bonding	Suturing	Vascular and intestinal anastomosis
	Fixation	Fractured bone fixation
	Adhesion	Surgical adhesion
Closure	Covering	Wound cover, Local hemostasis
	Occlusion	Vascular embolization
Separation	Isolation	Organ protection
	Contact inhibition	Adhesion prevention
Scaffold	Cellular proliferation	Skin reconstruction, Blood vessel reconstruction
	Tissue guide	Nurve reunion
Capsulation	Controlled drug delivery	Sustained drug release

The numerous medical uses of polylactic acid arising from the exceptional characteristics of this excellent biocompatible and biodegradable biopolymer are presented, in summary, by several researchers, such as Manavitehrani et al. [8], Li et al. [9], Kroczek et al. [10], Lopes et al. [11], Pawar et al. [12], Hamad et al. [13], DeStefano et al. [14]: biodegradable sutures, resorbable prostheses, scaffolds for tissue engineering, orthopedic applications and interventions, cardiovascular and ureteral implants, cancer therapy, oral and maxillofacial surgery, drug delivery systems in the form of microcapsules, microspheres, pellets, etc. In summary, Singhvi et al [6] the main fields of use in medical applications of polylactic acid PLA, such as tissue engineering, implants, drug delivery and others such as
In order to improve the mechanical properties of PLA polylactic acid, Islam [15] reports the possibility of reinforcing it with non-resorbable biomaterials such as carbon fibers.
In conclusion, Alizadeh-Osgouei et al. [16] reports that PLA biopolymer is one of the best options to be used in numerous medical applications.

2. CONCLUSIONS

Polylactic acid is part of the biodegradable polyester family. It is characterized by physical, mechanical, and biological properties, in which exceptional biocompatibility, bioresorbability and a good processing ability are noted. The set of these properties make it possible to use polylactic acid in a wide range of medical applications such as sutures in dermatology and cosmetics applications.

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