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Food Science and Nutrition Technology
ISSN: 2574-2701

Poly (Lactic Acid) Films in Food Packaging Systems

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Mini Review

Volume 2 Issue 4
Received Date: October 10, 2017
Published Date: October 28, 2017

Abstract

Poly (lactic acid) (PLA) is a non-toxic, compostable bio based material derived from starch and/or sugar and has high mechanical strength and plasticity. It is accepted as GRAS (Generally Recognized as Safe) by the Food and Drug Administration (FDA) and suitable for using in food and beverage packaging. PLA is primarily obtained from lactic acid which can be produced from renewable substances such as potato, wheat and corn starch. Petroleum based polymers cause an increase in fuel energy utilization and greenhouse gas emissions, however PLA is environmental friendly. Various polymers (protein, polycaprolactone (PCL) and polyhydroxy butrate (PHB)), fillers (wood, flax, and ramie) and additives have been combining with PLA in order to develop the performance of film and reduce the cost. On the other hand, PLA plays an important role in nanotechnology applications. Nan fillers like clay, montmorillonite and silica can be used for fortifying PLA composites. As a packaging material, PLA has a potential for manufacturing flexible films, extruded packages, containers of yoghurt, bottled water and juices, cups and lunch boxes. Moreover, in antimicrobial packaging, PLA is an excellent material which is able to be successfully incorporated with plant extracts (e.g. lemon), essential oils (e.g. oregano oil), enzymes (e.g. lysozyme) and metals (e.g. silver) in order to develop antimicrobial characteristics. In this mini review, the significance of PLA based packaging systems in food applications is discussed.

Keywords: Poly (lactic acid); Food packaging; Starch

Abbreviations: PLA: Poly Lactic Acid; FDA: Food and Drug Administration; PCL: Poly Capro Lactone; PHB: Poly Hydroxy Butrate

Introduction

Recently, biopolymers have considerable interest as a replacement for petrolic synthetic polymers. Poly (lactic) acid (PLA) is biodegradable aliphatic polyester, which can be fabricated by fermentation of renewable resources such as corn, cassava, potato and sugarcane [1,2]. Comparison to other aliphatic polyesters, PLA has perfect attributes such as high mechanical strength, high modulus, biodegradability, biocompatibility, bio absorb ability, transparency, energy savings, low toxicity and easy process ability [3,4]. Moreover, PLA has a wide range of applications such as in agricultural films, biomedical devices, packaging, and automotive industries due to its great properties [5-7]. Furthermore, PLA has given significant attention in food packaging applications with films or coatings. The potential for PLA to be used in antimicrobial packaging has been known by a number of researchers [5,6]. So, this mini review points on the use of PLA in antimicrobial systems for food packaging applications and explores the engineering characteristics and antimicrobial activity of PLA films in corporate and/or coated with antimicrobial agents.

Synthesis and Properties of PLA

The synthesis of PLA is a complex and multistep process (Figure 1). Rigorous control of conditions (temperature, pressure and pH), the use of catalysts and long polymerization times are needed for this process. PLA could be obtained by different polymerization process as poly- condensation, ring opening polymerization and by direct methods (azeotopic dehydration and enzymatic polymerization). Nowadays, the most used production techniques are direct polymerization and ring opening polymerization [8].

PLA has excellent properties compared to other biopolymers, including [8,9]

a) Environment friendly, PLA is biodegradable, recyclable and compostable.
b) Biocompatibility, PLA should not produce toxic or carcinogenic effects in local tissues
c) Processibility — PLA has better thermal processibility
d) Energy savings — PLA requires 25–55% less energy to produce

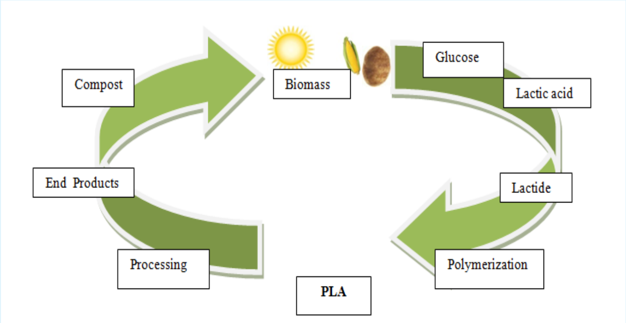

Figure 1: PLA life cycle starting with corn and sugar-beet; the biological systems use the solar energy by the process of photosynthesis [9].

Biodegradation of PLA

PLA degradation consists of through scission of ester bonds primarily. PLA has not biodegradable completely, but also not pollute environment after biodegradation. Some studies have identified the biochemical processes and microbial compound in biodegradation of PLA by using the modern molecular biological techniques (e.g., PCR, high- throughput sequencing technology) and analytical techniques (e.g., 1H NMR, ESI-MS, IR, DSC, X-ray, SEM, FTIR-ATR, GPC) [10,11].

Biochemical and Microbial Degradation of PLA

Biochemical processes of PLA degradation contain chemical hydrolysis and biodegradation in the natural soil microcosm. The ester bonds of PLA fragment into carboxylic acid and alcohol by chemical hydrolysis because of dehydration, however the advance of complete hydrolysis need much time and energy. For this reason, analysis of biochemical processes of PLA biodegradation is a key factor for discovering the effective methods of PLA biodegradation [12].

Compared to other degraders of biodegradable polyesters, PLA materials are less sensitive to attack of microbial in the native environment. Hence, the studies on pure isolation of PLA-degrading microorganisms have been increased in recent years. Nowadays, a lot of types of microbes that are able to degrade PLA have been isolated from soil or water [6,12].

PLA as a Packaging Material

PLA has been approved for use in food packaging, including direct contact applications with its classification being generally as safe (GRAS). Lately, thermoformed and/or extruded PLA packages has been developed convenient for widespread practices such as cups, overwrap, blister packages, food and beverage containers [13,14].

PLA, which is claimed to be biodegradable for yoghurt cups that is produced from high-impact polystyrene has been used by a Danish dairy company [15]. Lunch boxes and fresh food packaging [16] and containers for packaging of bottled water, bottled juices and yogurts [17] are other commercial examples for uses of PLA. In order to improve fully renewable and degradable packaging materials, blends of PLA with starches, proteins, and other biopolymers have also been investigated [18,19].

PLA as an antimicrobial packaging

The potential of PLA for use in antimicrobial packaging applications has been studied by many researchers [20-25]. Also, there are patents worldwide on PLA-based materials including antimicrobial agents [26-29].Organic acids, bacteriocins (e.g. nisin), plant extracts (e.g. lemon extract), essential oils and extracts (e.g. thymol), enzymes (e.g. lysozyme), chelating agents (e.g. EDTA), metals (e.g. silver) have been incorporated into PLA to improve antimicrobial activity. PLA with the addition of natural antimicrobial agents such as nisin, lysozyme, and silver zeolite has shown inhibitory effects against selected microorganism such as *Listeria monocytogenes, Escherichia coli, Staphylococcus aureus* and *Micrococcus lysodeikticus*. Native antimicrobial substances have been incorporated into coatings on the surface of PLA and these were displayed to be effective against spoilage and pathogenic microorganisms [23,30,31]. Several studies have examined the potential of PLA in general AP applications even though there are a number of examples that use PLA in antimicrobial food packaging applications [20,22].

The choice of consumer for natural food products with a little or no preservatives, with minimum microbial contamination while using sustainable packages has achieved a growing popular in the use of PLA in antimicrobial packaging [32]. Antipack TM produced by Handary in Belgium is an example of a commercial antimicrobial PLA packaging product, which is a film manufactured from a PLA-/starch-based material incorporated with an antifungal substance. This product is claimed to delay the growth of yeast and mold during the shelf life by releasing chitosan-including natamycin onto the surface of solid foods such as cheese, fruits, vegetables, meat, and poultry [33]. According to other study the authors incorporated both 5% (w/w) loadings of nisaplin and EDTA into plasticized PLA/GTA films and found an importance decrease in the elongation at break (from 108.5% to 62.5%) and in the impact strength (from 5.4 to 3.4 J/cm3) when compared to the plasticized only PLA. In spite of the PLA elasticity increased by adding GTA, the decrease in the mechanical features of plasticized PLA incorporated with antimicrobial compounds may be attributed to the “filler effect”. They reported that were unable to resolve the contradiction of the effect of the antimicrobial substance on the engineering [28]. Lately, Prapruddivongs & Sombatsompop [34] analysed the effects of incorporating natural fibers such as wood floor on the mechanical properties of antimicrobial films. They found that the addition of 1.5% (w/w) triclosan produced a thin effect on the mechanical features of decent PLA. In addition, Liu, et al. [28] extruded a thin membrane of PLA/pectin–nisaplin micro particles with 1% (w/w) and 9% (w/w) concentrations of nisaplin/pectin. They found that the extruded PLA films impregnated with solvent-cast pectin–nisaplin significantly reduced the tensile strength (by 49%), tensile modulus (by 41%), and toughness (by 51%) but no significant different in the flexibility happened when compared to PLA/pectin membranes. They reported that this fact happened due to the contrast between the inactive components in the Nisaplin (e.g. 2.5% nisin, milk solids and salt) with the PLA.

On the other hand, nonmaterials such as nanoclays, carbon nanotubes, and silica nanoparticles (NPs) can widen the use of bio-based films like PLA films [35-37]. Thus, nowadays there are only a limited number of commercially produced packaging materials that incorporate NPs, there is an increasing interest of the potential use of NPs in antimicrobial packaging systems for the protection of food products against microbial contamination and for the extension of the shelf-life of the packaged products [38]. Several researchers have examined the antimicrobial activity of NPs incorporated into PLA-based films. Busolo, et al. [39] incorporated 1% (w/w) silver-nano clay into PLA film and found a 99.8% reduction in the population of Salmonella spp compared with the control film. Jin & Gurtler [40] showed that PLA and ZnO coated onto a glass jar decreased the growth of Salmonella enteric against liquid egg. Pantani, et al. [41] advanced an antimicrobial film based on PLA incorporated with ZnO at different concentrations and observed a significant reduction of E. coli and S. Aureus in liquid culture. Darie, et al. [42] developed PLA nanocomposite films containing the nanoclays Cloisite 93A and Cloisite 30B and found that these nanoclays successfully reduced the growth of E. coli, P. aeruginosa, and S. aureus during in vitro experiments.

Conclusion

The researchers explore new and different materials due to the consuming of fossil fuel sources and the negative environmental effects resulting from the weak degradability of conventional ones. Since the new generation bio-based plastics are manufactured from renewable resources such as crops and agricultural wastes and their usage is considered to be advantageous. But there is a need to address any potential negative environmental impacts. In these days, many studies have been conducted for determine and discuss the biodegradation of bioplastics in different environments. The biodegradation of PLA bioplastics was examined more than the other biopolymers due to their bio-based and specific mechanical features.

The improvement of antimicrobial PLA films with developed physical and mechanical attributes and due to its antimicrobial activity the natural brittleness and hydrophobicity of this polymer is still a problem. Some of these material limitations can be accomplished with the application of modern and advanced technologies such as nanotechnology. In the near future, antimicrobial PLA materials selected for food contact packaging applications may compete conventional petroleum-based polymeric materials, the former having significant environmental utilities.

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