PLA (Polylactic Acid): New Era of Textiles

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Abstract

Non degradable synthetic era leads to the environment pollution. So, various efforts have been done to make products ecofriendly. Many researches have been conducted to make the polymers biodegradable.

This paper provides the brief review on PLA (Polylactic acid) fibres. PLA is the biodegradable natural polymer which has wide applications in textiles. PLA not only as a product is biodegradable it's raw materials available in nature in the form of corn, sugar beets, wheat and other starch rich products are also biodegradable. PLA degradation is due to hydrolytic cleavage of ester linkage included by the water molecules and depolymorisation process. PLA exhibit mechanical properties closer to polyethylene and polystyrene. It is a special type of aliphatic polyster. It can be processed like other thermoplastic materials to filament or can be molded or blown to produce different plastic products. Since it is biodegradable and can be processed to different products with variety of properties, it can be used for a wide range of uses from packaging to surgical sutures.

Introduction

Globally the trend is to go back to nature and patronize the natural product. Green marketing is the most commonly seen in post industrial affluent societies. Consumers are also much more aware and conscious of what they buy & its real impact. Today we are inscribing alarm about nature so this becomes our duty to nurture it.

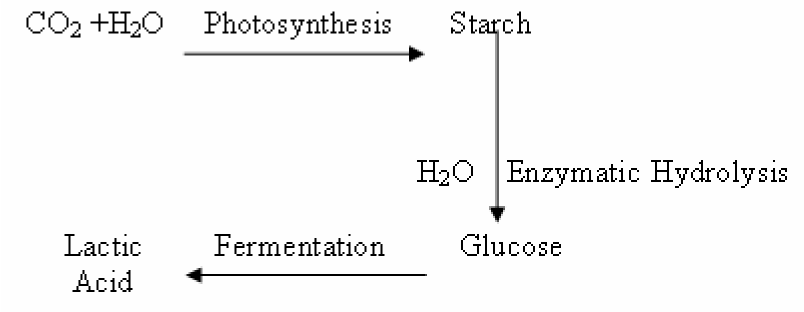
Synthetic polymers depend upon the resources of oil, gases for their monomer source. These resources take millions of years to regenerate. Regular uses of these resources have created a problem of energy crisis. Also most of synthetic polymers are not biodegradable. Biodegradable polymers are those which are completely converted by microorganism to carbon dioxide, water or methane.

So, attention is focused on synthetic fibres is based on natural renewable resources. PLA (Polylactic Acid) polymer is one of them. PLA belongs to the family of Poly (α hydroxy) acid. Monomer used for the manufacturing PLA is obtained from renewable crops.

Manufacturing of PLA

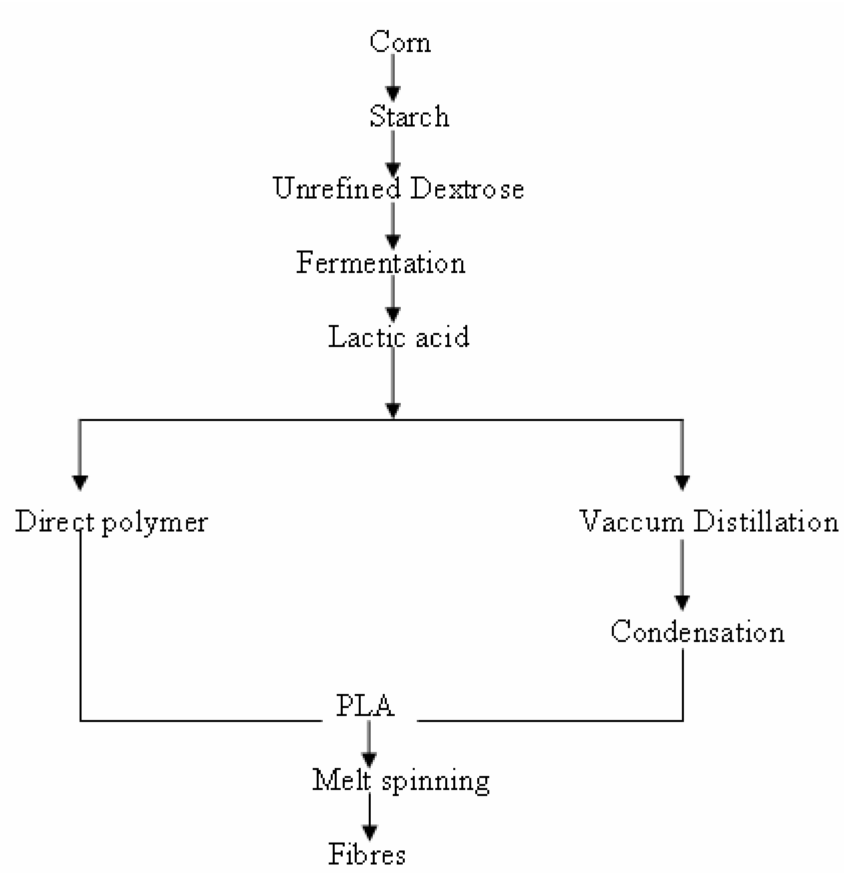
PLA is composed of lactic acid which is produced by converting corn starch into sugar and then fermenting it to yield lactic acid.

Energy from the sun promotes photosynthesis within the plant cells .CO_2 & water from atmosphere is converted into starch. This starch is readily extracted from plant matter and converted to a fermentable sugar by enzymatic hydrolysis. Carbon & other elements in these natural sugars are then converted to lactic acid through fermentation.



Polylactic acid is formed by two methods from lactic acid:

1) By direct condensation of lactic acid: It involves removal of water and the use of solvent under high vacuum & temperature. From this only low to moderate molecular weight polymers can be produced.
2) By ring opening polymerization via the cyclic intermediate dimmer (lactide). It is based on removing water under milder condition without solvent to produce cyclic intermediate dimmer as lactide. Before ring polymerization, lactide stream is split into low D lactide and high D meso lactide stream. Ring opening polymerization of optically active type of lactide can yield a family of polymers with a range of molecular weight by varying the amount and sequence of D lactide in polymer backbone. Fibres are extruded through melt spinning process. PLA polymer can be processed on conventional m/c with following criteria:
   - Extruder: General purpose single screw extruder with L/D ratio of 24:1 to 30:1 & 3:1 compression ratio.
   - Spinning: It is done in temp. range of 220-240°c.Spinning speed for FDY 9000 m/min.



Comparison of Fibre:

Property	PLA	PET	Nylon	PP
Density (gm/cm3)	1.25	1.38	1.14	0.9
Melting point (°C)	215	260	220	163-171
Tenacity (cN/tex)	50	35-65	23-60	25-35
Elongation (%)	35	15-40	25-65	55-70
Moisture regain (%)	0.4-0.6	0.4	4	0.01-0.1

Dyeing of Fibre:

PLA processes & products are comparable with PET. Both available in filament and staple form, they are melt spun, weaving and knitting set ups are similar, fabrics can be heat treated to give dimensional stability and both are dyed with disperse dyes.

Before dyeing conditions should be considered as:

- Melting point is 170°c which is important for determining heat setting conditions and fabrics can be stabilized at 125°c for 30 sec.
- Hydrolytic degradation of polymer will occur particularly under combined high temperature & alkaline conditions.

Pretreatment processes:

- Scouring: Mild scouring with 1-2gpl soda ash at 50-60°c for 15 minutes & rinse at 50°c.This removes spinning oils, lubricants etc.

- Bleaching: It is done by using soda ash & hydrogen peroxide.
  Conditions:
  3gpl soda ash
  3ml/l H_2O_2
  0.5gpl Baystabil
  30 minutes at 95°c.

- Dyeing conditions: Dye selection is crucial as individual dye behaviour is quite different from PET dyeing. PLA can be dyed with disperse dye at 110-115°c for 15-30 minutes at PH4.5-5.
- Dye uptake: Diffusion coefficient in PLA fibre was much higher than that in the PET. Dye uptake for PET fibre increases in proportion to the dye bath concentration. Over the whole concentration range. On the other hand in med. /higher conc. range there was no increase in dye uptake with PLA owing to low saturation value.
- Depth of colour: Better depth of shade obtained on PLA compared to PET.

- Light fastness: PLA fibre shows poor light fastness ratings compared to PET.
- Wet fastness: Higher diffusion of dyes in PLA fibres than in PET results in migration to the fibre surface by thermo migration leading to lower wetting fastness.
- Reproducibility: Reproducibility of disperse dyeing on PLA fibres is considered to be inferior to that on PET fibres.
- Reduction clearing: It can be done using Sodium hydrosulphite and soda ash at tep.60°c for 15min.

Blends of PLA:

Generally it is blended with cotton. So, care should be taken while treating these fabrics at high temperature with alkali. For dyeing these blends reactive and disperse dye can be used.

PlA also can be blended with wool because of their good physical stretch and recovery properties. Such blends can be processed using acid and disperse dye in one bath.

- **Applications:**

Medical Applications:

It is used for the development of an improved suture. Due to its high strength it has been investigated as scaffolding material for developing ligament replacement or augmentation devices to replace nondegradable devices to replace nondegradable fibres such as Dacron. Injectable form of PLA has recently been approved for restoration or correction or correction of facial fat loss.

Other applications:

Because of better wicking, drape & excellent crease resistance fibres can be used in agricultural applications, wipes, diapers, geotextiles etc. Fibre has a good UV resistance & superior resilience which brings its application in furnishing like carpet tiles, industrial wall panels, automotive furnishing. By controlling the ratio & distribution of D & L isomers in the polymer chain, it is possible to induce different crystalline melting point during melt processing. This feature offers distinct benefits manufacturing bicomponent fibres.

Nonwovens:

PLA is used for agricultural applications and geotextiles because of its good degradability, enhanced wicking and being natural based fibre.

Conclusion

PLA is one of the major substitutes for existing synthetic non-degradable fibres. Source for PLA polymer is corn which is renewable & cheap. PLA is first melt processable natural based fibre. But low degradation rate, low abrasion resistance, less moisture regain than cotton & other hydrophilic fibres, dropping of strength up to 70% during melt spinning due to degradation puts the limit to use of PLA. Its excellent features may lead to the increased demand in future.