NatureWorks® PLA – Commercial Development of Biopolymers on a World Scale

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Overview
Polylactic acid (PLA) is a highly versatile aliphatic, compostable polymer derived from 100% annually renewable resources. Because annually renewable resources replace oil as the feedstock, PLA requires 20-50% less fossil resources than comparable petroleum-based plastics. With PLA, carbon dioxide is removed from the atmosphere when growing the feedstock crop and is returned to the earth when PLA is degraded. Since the process recycles the earth's carbon, PLA has the potential to reduce atmospheric CO_2 levels. Disposal of PLA fits with existing systems including the additional option of composting. Long-term, with the proper infrastructure, PLA products could be recycled back to a monomer and into polymers.

The landmass necessary for feedstock production is minimal. Producing one billion pounds of PLA requires less than 0.5% of the annual US corn crop. Since corn is an inexpensive dextrose source, the current feedstock supply is more than adequate to meet foreseeable demand. Compared to the escalating and volatile cost of petroleum-based feedstocks, long-term PLA will eventually reap the benefits of a more stable and lower priced feedstock.

In spite of PLA's excellent balance of properties and environmental benefits, traditionally the commercial viability of PLA has been limited by high production costs (greater than $2/lb). Until the last decade, PLA has enjoyed little success in replacing petroleum-based plastics outside of biomedical applications like sutures. Though development of PLA is at the early stages of commercialization versus more traditional, petroleum-based plastic, expansion of commercial adoption for applications like PLA bottles has been rapidly increasing as of late.

Packaging Applications and Performance

Packaging Overview

NatureWorks PLA represents a real breakthrough and significant step toward more sustainable packaging applications. PLA polymers exhibit a balance of performance properties that are comparable -- and in certain cases superior -- to traditional thermoplastics. There are three specific packaging areas that are receiving initial focus – rigid thermoformed containers, high valued films and bottles. Functional properties and their benefits are listed in the following table:

PLA Functional Properties

Functional Property	***Packaging Improvement***
Deadfold, twist and crimp	Improved folding and sealing
High Gloss & Clarity	Package aesthetics
Barrier Properties	Grease and oil resistance
Renewable Resource	Made from CO_2
Flavor and Aroma Prop.	Reduced taste/odor issues
Low temp. Heat Seal	Stronger seals at lower temperatures
High Tensile and Modulus	Wet paper strength, ability to downguage coating
Low COF, Polarity	Printability
GRAS Status	Food contact approved
Compostable	Compostable, Low “green” tax

Commercialization of PLA bottles:

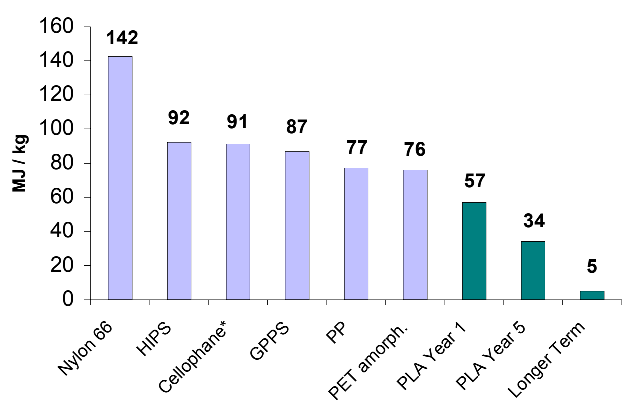
Marrying product and package, water and milk dairies commercially introduced new beverage brands in biobased PLA bottles. More beverage companies are increasingly evaluating and beginning to evaluate how they can used biobased packaging to help them vie for shopper attention on an over-crowded retail shelf space.

With an explosion of grab and go containers and bottles used for products like water, juices, teas, milk and a host of products crowding the beverage case, beverage companies feel its far too easy for new products to get lost in the clutter. Bottles made from NatureWorks PLA a crystal clear, easy to injection stretch blow mold help differentiate commodity products like water, milk and dairy at retail point of sale.

Packaging Conclusion
Polylactide, or PLA, is a new thermoplastic for packaging applications that is derived from annually renewable agricultural resources. PLA can be fabricated on a variety of familiar processes. It brings a new combination of attributes to packaging, including stiffness, clarity, deadfold and twist retention, low temperature heat sealability, and an interesting combination of barrier properties including flavor and aroma barrier characteristics. The combined attributes of this new thermoplastic make PLA a performance polymer that is environmentally and economically appealing. Table 4 summarizes PLA physical properties for packaging applications.

Environmental Sustainability

Annually renewable resources contribution to sustainability
Traditional, petroleum-based polymers rely on limited oil reserves for their feedstock source. Fossil resources not only take millions of years to regenerate, its price volatility as of late is especially well documented. In contrast, the monomer in PLA comes from annually renewal resources. Energy from the sun is harnessed in agricultural crops that are grown and harvested annually. So it takes roughly 100 days to regenerate the feedstock for PLA versus 1000's of years for petroleum-based plastics. However, like all polymer production facility, fossil fuels are required to process raw materials and produce PLA. The following table compares total petroleum use (feedstock + process energy) of pellet production for conventional plastics versus projected total petroleum use for production of PLA pellets. PLA year-1 data represents the production facility currently producing NatureWorks PLA. PLA year-5 and long-term data assume new product technology and alternative energy sources further maximize production efficiencies for PLA.



Total fossil resource use in common plastics measured in energy

Disposal of PLA

The compostability of PLA has generated a great deal of interest and discussion regarding new landfill diversion options. However, PLA fits all disposal routes available to traditional, petroleum-based plastics, including recycling and incineration.

Recent trials conducted by Recycle America Alliance, a subsidiary of Waste Management, Inc, in actual recycling facilities have demonstrated that PLA can be collected through normal plastic recycling channels and that the technology exists to efficiently separate PLA from other commonly recycled materials. In addition to its fit with the recycling stream, PLA has been successfully composted in applications where that disposal method is desired and commercial composting infrastructure is in place.

The Biodegradable Products Institute (BPI) for certification according to ASTM 6400-99 has independently reviewed and approved PLA as a compostable material. End products made with PLA will compost in municipal/industrial facilities according to ISO, CEN, ASTM, BPI and DIN regulations. It also meets the standards established in the EU (EN), Japan (JIS), Taiwan (CNS) and Korea (KS).

The multiple disposal alternatives of PLA means that it can play a key role in landfill diversion. In addition to its ability to be mechanically recycled and composted, it has shown favorable properties for use where incineration is the preferred waste disposal method. In addition, PLA may offer the potential landfill diversion option of being chemically recycled.

Summary

Low cost polylactic acid products are finding uses in many applications, including packaging films, thermoformed containers and even bottles. Polylactic acid is not being used in these applications solely because of its degradability, nor because it is made from renewable resources. PLA is being used because it works very well and provides excellent properties at a competitive price. The use of PLA as a cost-effective alternative to traditional, petrochemical-based plastics will lessen our dependency on volatile petroleum-based feedstocks.