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Composting, the Problem with Compostable Plastic and Possible Solutions

Introduction

It is clearly established that the world's population is growing exponentially and with that our emission of greenhouse gases and waste production along with the use of natural resources. These issues won't be solved by just one solution but a multitude and all will have to be done in a sustainable fashion. An answer to one of these problems has been replacing petroleum based plastics with compostable plastics based from plant material. These plastics would essentially curb our use of petroleum in plastics and switch to something that can be endlessly regenerated with the use of plants providing CO_2 sequestration and O_2 production. These plastics would be able to be disposed of in compost piles that would in-turn feed the plants growing the plastic. The problem is that the plastics developed thus far are not compostable by a composter's standards.

Composting Summary

Composting is the basic process of decomposition of organic material. The organic material is broken down into its basic continuants to be later used by other living organisms. A compost pile is created in the most basic form by piling organic waste, which is enough to begin the process. The process is dependent on a few factors like moisture, oxygen, size of the waste particles but also Carbon-Nitrogen Ratio (CN ratio) refers to the ratio of the pile's overall CN ratio from all added constituents. It is usually the most limiting to the productive compost pile because carbon and nitrogen are used for cell growth in organisms. Carbon is used for energy and cell proliferation while nitrogen is used in cell function (Proteins, enzymes, amino acids, etc.) and speeds proliferation. If the *ratio is too low* the pile will decompose quickly due to the relatively high availability of nitrogen but the microbes will not be able to use the nitrogen due to the lack of carbon as energy and be released as ammonia gas. It also runs a risk of heating too fast too quickly and possibly combusting. Low ratio substances include: Grass, fruits, leaves. If the *ratio is too high* the pile will decompose quickly due the lack of available nitrogen need to produce new cells and grow the colonies. The lack of microbes means the release of energy will be less and will not heat the pile. High ratio substances include: Wood, newspaper, lignin.
30 parts carbon to 1 part nitrogen is accepted ideal but changes due to bioavailability, heat, particle sizes, moisture content, and lignin content. Finished product is usually about 10:1.
To start the process microorganisms living on the waste and around the pile move in and begin to eat the waste starting a basic succession process. They eat the easiest to obtains sugars and grow exponentially. This growth and metabolism via aerobic respiration done by the vast array of microbes causes the pile to heat up to around 145^{o}C. In this high temperature new microbes move in breakdown different substances until there is no food available for these organisms, when the temperature drops again the original microorganism move in again to finish the job. The total process takes about 30 days in perfect conditions.

Polylactic Acid Summary

Poly-L-lactic acid (PLLA) is the main building block (a polyester) for the majority of compostable plastics. It has similar mechanical properties to the common petroleum based plastic, polyethylene terephthalate or PET, notably the hydrophobic nature of the polymer and relatively high heat capacity. PLLA is polymerized from purified starch obtained from plants with high amounts of starch (mainly corn in the US). First identified in its low molecular weight form over 80 years ago by a Dupont scientist its high molecular weight was then synthesized by Dupont. Initially it was not found to be biodegradable by the traditional standard of the substance being able to degrade into carbon and water at 20-25 degree Celsius in the natural environment.

In soil burial trial, one that is common to determine the biodegradability of a substance, PLLA did not do well. In a test done in Japan the plastic was still whole after 3 years and in another study 20 months, this made scientist come to the conclusion that it did not degrade well in the natural environment. This was thought to be because of the lack of PLLA degrading microbes in the soil. In controlled composting condition PLLA was shown to fully degrade though in natural landfill and wastewater treatment it took longer.

It was then reclassified as compostable then biodegradable due to a number of ISO and ASTM standards (namely ASTM D6400-12). These standards setup the base of the problem for why PLLA is not compostable in the traditional view of composter. Overall the standards look for *any* degradation after 40-100 days depending on the standard. The standards are also done in laboratory setting with small test amounts of PLLA in powder or film form. For these reasons more research has been done to find exactly which microbes and enzymes are responsible for degrading PLLA.

The microbes responsible for majority of PLLA degradation are those from the family *Pseudonocardiaceae* of the genus *Amycolatopsi*s which seem to be relatively common around the world. Some strains of *Amycolatopsi*s degrade silk has been speculated that because of the similar structure of PLLA's l-lactic units to the a-alanine units in silk fibers that this helps them degrade the plastic. Other *Pseudonocardiaceae* that have been found to degrade PLLA include those of genus *saccharothrix, Kibelosporangium, Lentzea,*and *Streptoalloteichus*.

Fungi, normal very successful decomposer only one, *Tritirachium album* (now known as *Engyodontium album*), has been found. It is relatively well known due to its use of proteinase K.

Proteinase K has been shown to greatly increase the degradability of PLLA though that decreases with increased crystallization of PLLA. This may be an issue for PLLA to be compostable due to the low glassing point of PLLA (60^{o}-65^{o}C) since a normal static compost pile will reach 60^{o}C (140^{o}F) internally, though this heat may also help with the thermophiles of *Pseudonocardiaceae* to break PLLA. Three enzymes (PLAase I,II,III) were isolated from *Amycolatopsis orientalis* that show it can degrade PLLA at temperatures from 50^{o}-60^{o}C.

There are a number of prospective enzymes dealing with known enzymes that hydrolyze polyesters but at this time there is no clear consensus on the biodegradation of PLLA.

Personal Ideas and Possible Experiments

It is quite apparent that the standards for what makes a compostable plastic have been skewed drastically. At this point it does not look as though the standard will change anytime soon so research of how to expedite the decomposition of PLA. Since the bacteria the do most of the decomposing found around the world it would seem that it should be able to breakdown. Most of the breakdown seems to happen in thet hemophilic stage of a compost pile and after it.

Experiments I would be interested in seeing

Holding a compost pile at a thermophilic temperature for longer with possible addition of more waste to promote growth of microbes

Using macerated PLA as a base or middle layer when building a compost pile where the pile will heated the most.

How PLA works in Bukashi composting.

Sources and Further Reading

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