# Degradation of Biodegradable, UV-degradable and Oxodegradable Plastics in MSW In-vessel Composting Environment.

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## Abstract

Biodegradable and oxodegradable plastics degraded in an in-vessel Engineered Compost System (ECS) along with municipal solid waste (MSW) from Mariposa County, California. Biodegradable plastics included, corn starch based biobag, Mirel PHA bag, BioTuf Ecoflex bag, Husky Eco-Guard plastic bag, PLA lids, sugar cane lids, and Kraft paper. Also buried were polyethylene shrink-wrap, UV degradable plastic bag, and oxodegradable plastic bag. The samples were placed in burlap sacks and mixed with solid waste. After 45 days, the biodegradable plastics demonstrated biodegradation with fragments of Kraft paper, sugar cane lids, PLA lids, corn starch bag, Mirel bag, and Ecoflex bag. The samples were removed from the in-vessel compost and placed in a static pile in Vacaville for 120 days. The Husky Eco-Guard plastic bag, PLA lids, Ecoflex bag and Mirel bag degraded fully. The sugar cane lids and Kraft paper were significantly degraded. Several pieces of each were observed. The sugar cane lids had similar biodegradation rate the Kraft paper control. The oxodegradable and UV-degradable plastics had some holes in the bags and had some discoloration, but did not fragment into smaller pieces and did not degrade in the compost environment.

## Introduction

Plastics can be produced from natural or synthetic materials. Traditional plastics, with an annual world production of approximately 140 million tones,[1] are typically made from petroleum based products. Alternatively, biobased polymers are produced from natural materials, e.g., starch from corn, potato, tapioca, rice, wheat, etc., oils from palm seed, linseed, soy bean, etc., or fermentation products, like polylactic acid (PLA), polyhydroxyalkanoate (PHA), and polyhydroxybutyrate (PHB). Most biobased materials are biodegradable, though some are not biodegradable. For example, polyesters can be made from soybean oil, though they are not biodegradable since the polymer is not consumed by microorganisms. Polyurethane can be made by reacting organic alcohol with isocyanate, but it is not biodegradable since it is not consumed by microorganisms, either. Some petroleum-based are considered biodegradable polymers since they are consumed by microbes in the soil and biodegrade in compost environments. Aliphatic-aromatic co-polyester polymers from BASF and ε-caprolactam are made from petroleum materials and are consumed by microorganisms.

## Background

Compostable plastics degrade in composting facilities and break down into water, methane, carbon dioxide and biomass. Micro-organisms in the soil or compost degrade the polymer in ways that can be measured by standard tests over specified time-frames. Compostable plastics are defined according to the ASTM D6400 standard as materials that undergo degradation by biological processes during composting to yield carbon dioxide, water, inorganic compounds, and biomass at a rate consistent with other known compostable materials and leave no visible distinguishable or toxic residue. Biodegradable plastic is defined according to the ASTM D6400 standard as a degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi, and algae. Biodegradable plastics can be made into different commercial products, including, trash bags, food containers, packaging trays, plastic utensils, and packaging containers and bags. The use of biodegradable polymers is increasing at a rate of 30% per year in some markets worldwide. [2]

Several organizations are involved in setting standards for biodegradable and compostable plastics, including, US Composting Council (USCC), American Certification System of Biodegradable Products Institute (BPI), Environment & Plastics Industry Council, American Society for Testing and Materials (ASTM), European Committee for Standardization (CEN), Japan's GreenPla program, and British Plastics Federation. The standards from these organizations have helped the industry create biodegradable and compostable products that meet the increasing worldwide demand for more environmentally friendly plastics. [3] If a biodegradable polymer does not meet the requirements listed in ASTM D6400 or EN13433, then it is not considered compostable. It must degrade in a specified time frame without leaving any residuals in the compost. [4]

Biodegradable polymers are those that are capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds or biomass by the actions of microorganisms. The rate of decomposition, residuals, and by-products can be measured in standardized tests. Compostable polymers are those that are degradable under compositing conditions, which include actions of microorganisms, i.e., bacteria, fungi, and algae, under a mineralization rate that is compatible with the composting process. Polyethylene plastic bags that are produced with starch additives are not certified as compostable plastics since they do not meet he ASTM D6400 standards. The plastics do disintegrate but leave small plastic fragments in the compost, which violates the ASTM D 6400 standards. The ASTM D6400 standard differentiates between biodegradable and degradable plastics. Some synthetic polymers, e.g., Low Density Polyethylene (LDPE), can erode over time if blended with an additive to facilitate

degradation. These polymers break down into small fragments over time but are not considered biodegradable since they do not meet the ASTM D6400 standards. Bioerodable polymers, photodegradable polymers, and water-soluble polymers break down in environments different from the biodegradable and compostable polymers and as such are outside the scope of the research.

The Biodegradable Products Institute (BPI) provides important criteria for valid full-scale testing of compostable plastics.[5] The BPI Logo Program is designed to certify and identify plastic products that will biodegrade and compost satisfactorily in actively managed compost facilities. [6] The Biodegradable Products Institute and US Composting Council (USCC) use ASTM D6400 standards to approve products for their compostable logo. The ASTM standards are the result of eight years of intensive work to identify plastic and paper products, which disintegrate and biodegrade completely and safely when composted in a municipal or commercial facility. The approved products with a compostable logo include compostable bags and film, food service items, and resins.

The composting environment for the degradable materials is a commercial production composting operation in Mariposa County, California. The composting facility is located at the Mariposa landfill. The 50,000 $ft^2$ facility can accept approximately 40 tons of municipal solid waste (MSW) per day. The in-vessel composting process utilizes the Engineered Compost System (ECS).[7] The SV Composter™ features excellent control of temperature and moisture in an enclosed room made from concrete and stainless steel. The MSW is placed in the room and air is evenly distributed to the composting materials through perforated floor covers. Moisture and water runoff is collected in the floor and drained to a sump. The water removal helps reduce anaerobic conditions. The ECS in-vessel composting process has excellent PC-based system control, wherein, the temperature, pressure, and positions are measured in several locations of the compost pile and room. The MSW materials are sent through a temperature regime that destroys pathogens in the first three days and then maximizes composting over the next 3 weeks with proper aeration, drainage, and temperature control. The in-vessel compost is typically heated to 60°C for 3 days and then maintained at 58°C for 14 to 21 days. The composting process typically reduces the volume of the MSW by 30 to 60%.

## Materials and Procedures

Biodegradable, compostable, controls, and oxodegradable samples were placed in burlap sacks along with municipal solid waste (MSW) from the compost site and then buried in the in-vessel compost. Approximately, 80 g of full-sized samples were mixed with approximately, 1 kg of MSW. As with the Vacaville compost experiment, the samples included, corn starch based biobag, Mirel bag, BioTuf Ecoflex bag, Husky Eco-Guard plastic bag Eco-Guard plastic bag, PLA lids, sugar cane lids, and Kraft paper. Also buried were polyethylene shrink-wrap, UV degradable plastic bag, and oxodegradable plastic bag. Debris included plastic water bottles, plastic cups, paper cups, plastic straws, newspaper, glass bottles, metal lids, miscellaneous paper products, and plastic bags.

The compostable and degradable plastics were buried. After 14 days the experiment had to be restarted due to problems with the compost that resulted in low temperatures. Green yard waste and manure were added to the vessel and the process was restarted. The temperature and moisture of the compost were recorded by the process control unit. After 28 days the materials were removed from the ECS vessel and placed on a concrete pad to cool and aerate. Biofilters remove noxious gases from the compost. Typically, the compost pile is screened for recyclable materials, e.g., glass, metal, and plastic, and for debris. The recyclable materials are recovered and the debris waste is sent to the landfill. The screened compost is used as cover for the landfill. In our experiment, the compostable and biodegradable samples were removed from the burlap sacks and placed in perforated plastic bags. Some of the burlap sacks had holes in them. The samples and bags were relocated to the Vacaville compost site and placed in the static pile for further composting for an additional 120 days.

## Results

After 180 days, the materials that completely degraded included PLA lids, Mirel bags, Ecoflex bags, Husky Eco-Guard plastic bag bags, and corn starch trash bags. Small fragments of sugar cane lids and Kraft paper were visible. Similar to the Vacaville compost results, the sugar cane and Kraft paper fragments were very moist and would disintegrate when picked up. The Kraft paper and sugar cane fragments did not completely biodegrade due to the segregation in the plastic sacks. If the materials were placed in the compost soil, higher degradation would occur due to better interaction with the compost soil. The oxo-biodegradable plastic bags, LDPE plastic bags and UV-degradable plastic bag did not appear to experience any degradation. During the experiment, the average top temperature was 56.4°C, the average bottom temperature was 56.3°C, the supply pressure was 1.5 in $H_2O$, the air supply temperature was 28.2°C, and the exhaust temperature was 34.7°C. Pictures of the plastic fragments during the experiment at the Mariposa compost site are provided in Appendix F.

## Conclusions and Recommendations

Compostable plastics biodegrade very well in commercial compost operations in 180 days. Oxodegradable and UV-degradable plastics do not degrade or disintegrate for in-vessel composting operations in 180 days. The materials that completely degraded in 180 days while in the in-vessel aerobic compost systems at Mariposa included PLA lids, Mirel bags, Ecoflex bags, Husky Eco-Guard plastic bag bags, and corn starch trash bags. Small fragments of sugar cane lids and Kraft paper were visible. The oxo-biodegradable plastic bags, LDPE plastic bags and UV-degradable plastic bag did not appear to experience any

degradation under in-vessel and windrow compost conditions.

The research work can help increase the use of compostable plastic materials for selected applications. The compostable materials should be certified as compostable by BPI and included in procurement standards. A procurement officer or recycling coordinator can use the BPI certification as a minimum requirement for purchased compostable products. The compostable plastic materials should perform well in simple applications, e.g., food service ware, lawn and leaf refuse bags that have dry contents, grocery bags, department store bags, and pet bag products.

Compostable plastic materials could be very economical for organizations and institutions that service a controlled population, e.g., hospitals, correctional facilities, schools, and cruise lines. The cost of disposal of waste at these locations can be offset by the use of compostable plastics, which have a compost nutrient value. Compostable plastics can be a boon to compost operators by having an organic nutrient source that does not have the bacteria problems of food waste.

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## Appendix

Figure 1. ECS in-vessel compost vessel.

Figure 2. Inside chamber with samples and MSW

Figure 3. Kraft paper and sugar cane 180 days

Figure 4. Oxodegradable plastic bag 180 days

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