Journal of Ecological Engineering
Volume 15, No. 4, Oct. 2014, pages 82–89
DOI: 10.12911/22998993.1125461

Research Article

HOW DO DEGRADABLE/BIODEGRADABLE PLASTIC MATERIALS DECOMPOSE IN HOME COMPOSTING ENVIRONMENT?

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Received: 2014.06.23
Accepted: 2014.08.05
Published: 2014.10.07

ABSTRACT
This paper provides information about biodegradability of polymeric (biodegradable/degradable) materials advertised as 100%-degradable or certified as compostable, which may be a part of biodegradable waste, in home composting conditions. It describes an experiment that took place in home wooden compost bins and contained 9 samples that are commonly available in retail chains in the Czech Republic and Poland. The experiment lasted for the period of 12 weeks. Based on the results thereof it can be concluded that polyethylene samples with additive (samples 2, 4, 7) have not decomposed, their color has not changed and that no degradation or physical changes have occurred. Samples 1, 3 and 5 certified as compostable have not decomposed. Sample 6 exhibited the highest decomposition rate. Samples 8, 9 (tableware) exhibited high degree of decomposition. The main conclusion from this study is that degradable/biodegradable plastics or plastics certified as compostable are not suitable for home composting.

Keywords: biodegradation, degradability, degradable/biodegradable plastics, home composting, waste treatment.

INTRODUCTION

At present, waste management is becoming a global problem in developed countries due to the rapid collapse of landfills and the high impacts related to biowaste dumping. One of the major tasks of municipal waste management in European Union countries is the systematic reduction of waste that is removed and transported to landfills. This refers particularly to biodegradable waste [Suchowska-Kisielewicz et al. 2012]. The presence of such waste influences the amount of pollution emitted with leachate and biogas to the natural environment [Suchowska-Kisielewicz et al. 2012]. In view of these problems European Union (EU) published the Landfill Directive in 1999 [Directive 1999/31/63]. The Directive imposes on the member states the necessity of developing a three phase program to reduce the landfilling of organic waste, and explicitly defines the required degree of reduction in the volume of biodegradable waste going to landfills and the timetable for its implementation [Myszograj 2013]. However, The Directive does not specify how to achieve the necessary degree of reduction in the biodegradable fraction of waste [Myszograj 2013].

The overall annual food and garden waste included in mixed municipal solid waste in the European Union is within 76.5–102 Mt that represents 30–40% of the total annual municipal waste generation [Green Paper 2009, Martínez-Blanco et al. 2010]. The organic fraction of municipal solid waste (OFMSW), or biowaste, is mainly composed of food rejects of vegetable or animal origin and green waste, in an amount that depends on the region considered [Waste Statistics 2013, Puyuelo et al. 2013]. According to European recommendations and environmental considerations, these wastes need to be separately collected at home to be biologically treated through composting or anaerobic digestion to ensure the production of high quality compost, in accordance to new European regulations [Puyuelo et al. 2013].

Composting, which can be defined as aerobic biological degradation and stabilization of organic substrates under controlled, thermophilic and aerobic conditions [Martínez-Blanco et al. 2010, Haug 1993], has been presented as an environmental friendly and sustainable alternative to manage and recycle organic solid wastes, with the aim of producing a quality product known as compost, to be used as organic amendment in agriculture [Green Paper 2009, Martínez-Blanco et al. 2010]. Composting may considerably reduce the amounts of municipal waste that are presently directed to incineration facilities and landfills [Vasarevičius et al. 2011]. Composting is the keystone of sustainable development but, unfortunately, it is often not applied in a system of municipal waste [Vasarevičius et al. 2011]. For these reasons, exhaustive and systematic evaluations about its environmental performance are necessary. Potential environmental impacts, positive and negative, of municipal waste treatments should be considered including their potential pollution and their contributions to climate change, among other environmental impacts [Martínez-Blanco et al. 2010].

Home composting or backyard composting, which means self-composting of the biowaste as well as the use of the compost in a garden belonging to a private household [Green Paper 2009], presents some potential benefits when compared to the industrial process: it avoids the collection of the OFMSW; it considerably reduces the economic, material and energetic investments; and finally, it allows a direct control of the process and the organic materials input by avoiding or reducing the inclusion of impurities [McGovern 1997, Ligon and Garland 1998, Jasmin and Smith 2003, Martínez-Blanco et al. 2009]. However, home composting also presents some problems: compost obtained often is not homogeneous; odors and other pollutants such as methane, ammonia or nitrous oxide are emitted directly to the atmosphere during the decomposition process [Martínez-Blanco et al. 2010, Amlinger et al. 2008, Ansorena 2008], etc. The suitability of raw materials for biological treatment, as well as the efficiency of the processes of degradation depends on their chemical composition and structure. Besides organic compounds, the raw materials must also contain the appropriate proportions of other nutrients, and be characterized by adequate hydration and pH level [Myszograj 2013]. Moreover, in recent years, this kind of waste has been collected in single-use plastic bags. Manufacturers claim that these bags can be composted (inserted into compost pile). However, not all of these materials are truly biodegradable and therefore may pose problems within home composting.

The work reported within this paper documents observation and results obtained from monitoring home composting of biowaste from households. The aim of this paper is to provide information about biodegradability of polymeric (biodegradable/degradable) materials advertised as 100%-degradable or certified as compostable, which may be a part of biodegradable waste, in home composting conditions.

AIMS AND OBJECTIVES

In order to realize recovery and recycling via backyard composting, it must be clarified whether and how these different types of biodegradable/degradable materials or certified as compostable degrade under special conditions of domestic composting systems. In fact, the existing investigations concern almost exclusively aerobic degradation of biodegradable/degradable polymers under laboratory conditions or in technical composting facilities as certain standards are fixed for this way of recycling. Since the input material of backyard composting can differ considerably from that of a large plant, i.e. composition, amount, moisture etc., it must be examined how the composting process is influenced by inserting biodegradable/degradable polymers into the input material. Furthermore, the conditions of domestic composting can differ considerably from those in an industrial system. In home composting processes high temperature levels are partly not achieved, the material does not have optimum moisture contents and very wet biosolids with a bad structure can provoke anaerobic conditions. The objective of this work is to examine the degradability of biodegradable/degradable materials advertised as 100%-degradable or certified as compostable in two home or backyard composting systems thus providing data about the materials` degradation and to give recommendations concerning their treatment, or rather recycling in these systems under their special conditions.

MATERIAL AND METHODS

The research was aimed at verifying the degradation of biodegradable and compostable plastic materials at home composting conditions and in the environment of uncontrolled conditions – the soil conditions. The objective of the research was to find out how biodegradable or compostable plastics behave in conditions other than laboratory or real composting conditions (controlled conditions).

Description of the area

The site where the research was conducted is located in the Czech Republic, in a village called Borač that is situated in a valley on the border of the Vysočina Region and the South Moravian Region, with an altitude of 279 m. Location of the site is shown in Figure 1.

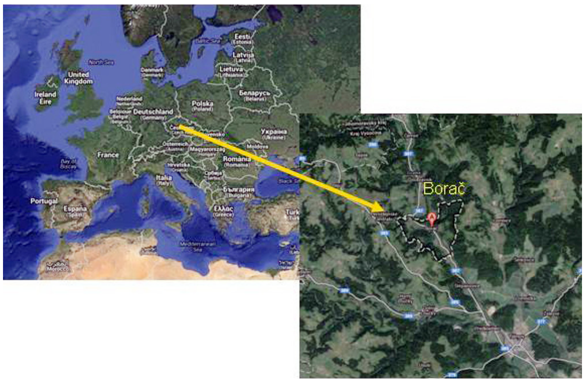

Figure 1. Location of the research

The experiment took place in home wooden compost bins (Figure 2). The bins were placed in an apple orchard under southern slope in the distance of about 10 m from a brick wall of a building. Direct sunlight was falling on the compost bins throughout the whole morning and after 2 pm the bins got into shade.

The following table (Table 1) shows data of annual precipitation [mm] and temperatures [°C] in the research area in 2012 according to the Czech Hydro-meteorological Institute (CHMI).

Table 1. Annual precipitation and temperatures at the site

Year 2012	Territorial annual precipitation [mm]	Territorial annual temperature [°C]
South Moravian Region	501	9.5
Vysočina Region	646	8

Characteristics of the samples and description of the compost bins

The experiment contained 9 samples that are commonly available in retail chains in the Czech Republic and Poland. These were plastic bags, single-use plastic bags and single-use compostable tableware (namely cups and trays). The manufacturers declared all samples biodegradable in nature or compostable. Photographic documentation of the samples at the beginning of the experiment is shown in Figure 3. The descriptions of the materials as well as the observed samples are listed in Table 2.

Following labeling (samples 1-9) and photographing of the samples, they were placed into compost pile of the home composting bins. The bins were made of wood, placed directly on the ground surface without any modification thereof. The first compost bin (compost bin 1) had a rectangular shape with dimensions of 160×130×100 cm,

Table 2. Description of the samples

Sample	Type	Description
1	N/A	Compostable 7P0202
2	N/A	BIO-D plastic material
3	Natural material	Compostable 7P0073
4	HDPE	Epi – 100% degradable
5	Starch and PCL	OK Compost AIB VINCOTTE
6	Starch	Compostable 7P0147
7	N/A	Degradable plastic material – d_2w
8	–	N/A
9	–	N/A

Figure 2. Home compost bins

Figure 3. Photographs of the observed samples

the other bin (compost bin 2) had dimensions of 105×100×80 cm (see Figure 2).

Prior to the start of the experiment the compost pile had been already set up, the degradation process within the pile was thus in progress. The compost pile was dug over and refilled with new biowaste once during the monitored period of time. The compost pile consisted of rabbit manure, cut grass, biodegradable kitchen waste (tea bags, fruit rinds, coffee, etc.), as well as parts of plants, feathers or fur from farming animals and wood ashes. An elemental analysis of the compost pile wherein the investigated samples were put was carried out in laboratories of Mendel University in Brno. Parameters of the compost pile sample (incinerable substances, pH, lead, cadmium) are listed in Table 3.

Simultaneously, a test of degradation of the studied materials was performed outside the compost pile. All 9 samples were placed into soil in the orchard. The grassy area (the research site) was delineated with dimensions of 210×150 cm. Soil features based on the Estimated Pedologic-Ecological Units are stated in Table 4.

Table 3. Parameters of the compost pile sample

Parameters	Compost pile
Incinerable substances [%]	44.6
pH	8.74
Pb [mg/kg]	0.852
Cd [mg/kg]	0.186

The course of the experiment

The experiment was initiated on 1 September 2012 and continued for the period of 12 weeks. 7 samples containing plastic bags and single-use plastic bags made of degradable or compostable material were loosely placed into compost bin 1. The remaining 2 samples - disposable tableware (cup and tray) made of biodegradable plastic material were inserted into compost bin 2. The samples were placed into newly excavated spaces on the surface of the compost pile and subsequently covered with 20 cm layer of compost pile. Pictures documenting the initiation of the experiment are displayed in Figure 4.

The same samples that were put in home compost bins were evenly placed in grassy area of the size of 210×150 cm, which was located in the orchard. The samples were inserted into hollowed spaces with dimensions of 20×20×15 cm situated on the surface, then covered with the original layer of soil, see Figure 5. For the purpose of future visual comparison, the samples were photographically documented prior to their placement into the soil.

The compost pile was not dug over or otherwise interfered during the course of the research. The samples were not manipulated anyhow. After 12 weeks, in early December 2012, the samples were removed from the bins.

Table 4. Features of the soil at the research site based on Pedologic-Ecological Units

Pedologic-Ecological Units			
Climatic region	The main pedologic unit		
	Soil type	Soil substrate	Remark
Mildly dry and humid	Light to lighter medium heavy	Various substrates	Extreme inclination (up to 12 °C)
Inclination	Exposure	Skeletality	Depth of the soil
Considerable slope (12–17 °C)	South (SW-SE)	Medium to very skeletal	Shallow, medium deep and deep

Figure 4. Initiation of the experiment in compost bins

Figure 5. Initiation of the experiment in the orchard

RESULTS AND DISCUSSION

After 12 weeks the samples were removed and photographically documented. Visual evaluation of the decomposition of each sample material was conducted. The samples that were examined in compost bin 1 showed no visual modification, except for sample 6 (plastic bag, according to manufacturer made of starch, country of origin – Poland), see Figure 6. The sample exhibited partial degradation, separation into smaller fragments and colour changes. Samples 1–5 and 7 experienced no modifications compared to their original state (at the start of the experiment), see Figure 7. The following picture (Figure 7) shows photographs of samples 1–5 and 7 after the termination of the experiment.

The samples that were examined in compost bin 2, the disposable tableware made of degradable plastic material (samples 8 and 9) entirely degraded; no visible fragments were left, see Figure 8.

Figure 6. Sample 6 before and after the experiment – the compost pile

Sample 1

Sample 2

Sample 3

Sample 4

Sample 5

Sample 7

Figure 7. Samples 1-5, 7 before and after the experiment – the compost pile

The samples of plastic bags and single-use plastic bags (samples 2–7) stored in the soil of the grassy area of the orchard experienced no visual changes. Photographs of the samples before and after the experiment are shown in Figure 9.

Figure 8. Sample 8 and 9 before and after the experiment – the compost pile

Only sample 1 that was placed in the soil of the grassy area of the orchard showed signs of partial degradation into smaller pieces, see Figure 10.

The samples 8 and 9 (disposable tableware made of biologically degradable plastic material) placed in the grassy area of the orchard exhibited a high degree of decomposition. There were only several visible fragments left, see Figure 11.

Bio-based polymers have increasingly attracted attention from industry and consumers as one of the ways of reducing municipal solid waste and reducing the dependence on producing polymers from petroleum-based resources. These new polymers have the inherent advantage of being produced from renewable resources such as cellulose and starch, and if their end-of-life scenario is properly designed by using recycling or composting, their environmental footprint can be reduced. Most of them are blends, containing a certain percentage of mineral oil based biodegradable polymers. Marketable packing products are bags, trays and dishes for fruits, vegetables, bread, cakes, pastries and meat products as well as containers for dairy products, bin liners and compostable food ware/catering articles.

Unfortunately, there are now many plastic materials in the market claiming to be "biodegradable" or environmentally preferable in other ways. Often claims cannot be verified or are misleading. The companies selling those products are taking advantage of markets that are unaware of the difference between certifiable compostable and biodegradable products and those that are not. Oxo-degradable plastics for instance, do not meet any standards in place for biodegradability and should not be considered biodegradable or compostable.

While many bioplastics are certifiable as compostable in commercial compost facilities, not all can be home composted and not all are bio-

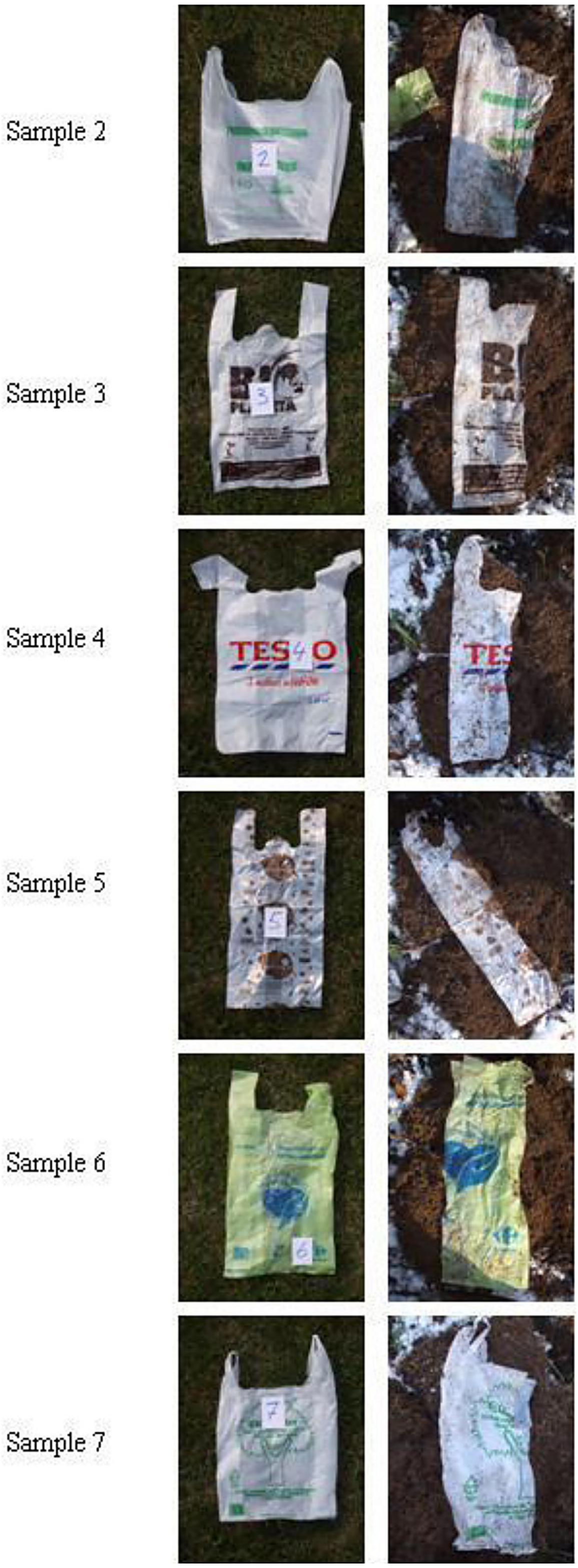

Figure 9. Samples 2-7 before and after the experiment – the orchard

degradable in the marine environment. Furthermore, a number of petrochemical-based polymers are certified biodegradable and compostable. Biodegradability is directly linked to the chemical structure, not to the origin of the raw materials.

Figure 10. Sample 1 before and after the experiment – the orchard

Figure 11. Sample 8 and 9 before and after the experiment – the orchard

Products that can compost in a variety of backyard/home system greatly increase the opportunities for waste diversion, given that many regions of Czech Republic lack commercial composting facilities.

In real conditions of the Central Composting Plant in Brno, similar research was conducted in 2011 and 2012. It focused on verifying the degree of degradation of plastic bags labelled as compostable, degradable or 100% biodegradable in controlled composting conditions of the composting plant. The authors of that research discovered that the (observed) samples that carry a compostability certification, showed high degree of decomposition and some disintegrated completely. In contrast, samples made of PE with additives did not decompose, alike in the experiment in home composting conditions [Adamcová et al. 2013, Vaverková et al. 2013]. The results show that biodegradable plastic materials are not entirely suitable for domestic composting. The reason why the samples did not degrade may be the failure to achieve the required temperature inside the compost pile. Another aspect that may play a significant role in the decomposition and disintegration of the examined materials is the rain factor. In home composting conditions compost humidity depends on the amount of rainfall.

CONCLUSION

The monitoring undertaken has demonstrated that although PE with additive sacks are suitable for the collection of organic wastes, they are not compostable under home composting conditions as a determining feature of a compostable polymer is its ability to undergo biological degradation at a rate consistent with other known compostable materials, in addition to leaving no visually distinguishable residues within the final compost product. The plastics certified as compostable are not suitable for home composting and that in home compost bin they do not degrade.

Actually, the product may be backyard or home compostable if they are certified by Vinçotte OK Compost HOME. OK Compost HOME is the only certification that assesses compostability in typical backyard compost settings, which do not reach or maintain high temperatures of industrial compost facilities. Systematic research to investigate the effects of composting conditions on the degradability biodegradable/biodegradable plastics should be performed in the future.

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