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DO THE DEGRADABLE/BIODEGRADABLE PLASTIC MATERIALS DECOMPOSE IN DOMESTIC COMPOST BIN?

CZY DEGRADOWALNE/BIODEGRADOWALNE TWORZYWA SZTUCZNE ROZKŁADAJĄ SIĘ W DOMOWYM KOMPOSTOWNIKU?

Abstract: Biodegradation of plastic materials advertised as degradable/biodegradable or certified as compostable was tested in composting conditions (domestic compost bin). This study was carried out in order to assess the biodegradability of the samples under real conditions of home composting, and to find out whether there were any physical changes in terms of their thickness when exposed to natural composting environment. The samples were obtained from retail chains in the Czech Republic, Poland, Slovakia and the UK. The experimental samples were placed in home compost bins and were checked and visually assessed during the experiment, which lasted 14 weeks. From the results it can be concluded that the polyethylene samples with the additive (samples A, B and E) have not decomposed, their colour has not changed and that no degradation neither physical changes has occurred. Samples C, F have not decomposed. Samples certified as compostable G, H and I have not decomposed. Sample D exhibited the highest decomposition rate. The main conclusion from this study is that degradable/biodegradable plastics or plastics certified as compostable are not suitable for home composting.

Keywords: biodegradable waste, biodegradability, compostability, degradation, home composting, plastic

Introduction

The management of the organic fraction of municipal solid wastes (OFMSW) is a growing problem due to the rapid collapse of landfills, the "not in my backyard" practice and the potential contamination and loss of organic resources derived from landfilling [1]. Furthermore, in 1999, the European Union Landfill Directive [2] required the Member States to reduce the amount of biodegradable waste being dumped, promoting the adoption of measures to increase and improve sorting activities at the origin, such as recovery and recycling. Composting is one of the most frequently used alternatives to landfill [3, 4]. Compost can be applied as a fertilizer, organic amendment or growing medium, improving soil physical properties and increasing both water retention and the supply of essential nutrients [1, 5-8].

Composting of OFMSW has been considerably developed and studied at industrial level and it is widely reported in literature [4, 9-14]. However, at a smaller scale, composting can be developed at home, a process that has been scarcely studied from a technical and scientific point of view [11, 15, 16]. Home composting, or backyard composting [3], presents some potential benefits in comparison to industrial composting. Home composting avoids the collection of an important part of municipal solid wastes, thus reducing the economic, material and energetic investments in infrastructures [15, 17, 18]. It implies less land use and, finally, it allows a more specific control of the composting process and the organic materials treated [1].

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Although these benefits are evident, home composting can present some concerns. In recent years, biowaste 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 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.

Experimental procedures

The aim of the experiment was to expose samples labelled as degradable or biodegradable to the process of composting at home compost bins and to prove whether the information stated on the wrappers is true and testifies the features of the particular materials. The evaluation of the disintegration of the samples was carried out according to ČSN EN 14806 a ČSN EN ISO 20 200. In the course of the experiment photographic documentation was realized and the experiment diary into which data were regularly recorded was created.

Description of the samples

As research samples were selected carrier bags, which are commonly available in retail chains in the Czech Republic, Poland, the Slovak Republic and the UK, while they state that they are biodegradable, degradable or other designation. In addition, 2 bags certified for composting were chosen. One of them was a carrier bag from a Czech manufacturer and the other sample came from the UK. In total, the experiment contained 9 samples of carrier bags. Types and descriptions of the samples are listed in Table 1. The examined samples were labelled with letters A - I. At the beginning of the experiment, all 9 samples were photographically documented.

Table 1

Types and descriptions of the samples

Sample	Type	Descriptions
A	PE HD + TDPA ADDITIVE	100% degradable
B	PE-HD + ADDITIVE	100% degradable, after certain period of time degrades itself
C	PE-HD	Degrades into CO_2 and H_2O within 3 years
D	N/A	-
E	PE-HD	100% degradable
F	N/A	Biodegradable
G	Starch	Compostable
H	Starch	Compostable
I	Bioflex-219F	In compost biodegrades within 90 days

Preparation of the samples

Samples were weighed on a scale model AND HF 200V in laboratory at the Department of Applied and Landscape Ecology, Mendel University in Brno. Weights of all

9 samples were recorded in the experiment diary. Measured values are stated in Table 2. Subsequently, the samples were inserted into a mesh pocket with meshes of dimension 1 x 1 mm. These mesh pockets were then secured with metal frames at all sides. The samples in mesh cases were weighed. The obtained values were recorded in the experiment diary. Samples were provided with descriptions in order to secure their identification during and after the termination of the experiment.

Table 2

Weights of the samples

Sample	m_i [g]
A	5.1
B	7.6
C	5.1
D	8.1
E	7.5
F	8.6
G	9.6
H	14.8
I	12.0

m_i - initial weight of the samples

For the purpose of the experiment two plastic garden compost bins (bins A and B) were used, with capacity: 270l, height: 70 cm, base: 63 x 63 cm. The composition of the compost pile was chosen to resemble the most favourable materials that normally people use for composting. The compost pile consisted of horse manure, soil and grass, mixed with sawdust at a ratio of 1:3.

The initiation of the experiment

Compost bins were placed next to a wall of a house, on southeast side, in order to be protected from weather conditions and to prevent excessive drying out of the compost pile. Each compost bin was layered with the same amount of material. The bottom layer of the compost pile in the bin consisted of 20 dm^3 of horse manure mixed with garden soil. Horse manure, a mixture of manure and bedding, in this case consisted of horse manure together with a combination of sawdust and shavings. On the top of it were subsequently placed layers consisting of a mixture of grass and sawdust. The samples were put among single layers. After filling the compost bins, each was sealed by 20 dm^3 of rainwater.

The experiment took place from 07.2012 until 10.2012. Temperatures in compost bins were measured and recorded at regular intervals. The first 4 weeks the temperature was measured daily, afterwards every second day. When the temperature dropped to 20°C, temperatures were measured once a week. The compost pile was periodically dug over and dampened when necessary in order to achieve and maintain optimal humidity. During the experiment three visual inspections of the samples took place. Samples were taken out of the compost, their condition was visually checked and photographs were taken. Table 3 shows time schedule of the experiment.

The graph (see Fig. 1) shows the development of ambient air temperatures within monitored period of time.

Table 3

Time schedule of the experiment

Day of the experiment	Date	Operation
0	20.07.2012	Initiation of the experiment
29	18.08.2012	Sample checking
58	16.09.2012	Sample checking
66	23.09.2012	Sample checking
101	28.10.2012	Termination of the experiment

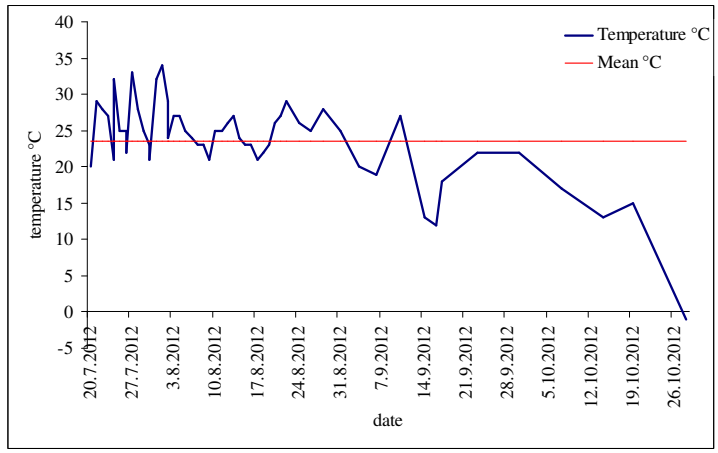

Fig. 1. The development of ambient air temperatures within monitored period of time

The following graph shows the development of temperatures in compost bins (see Fig. 2).

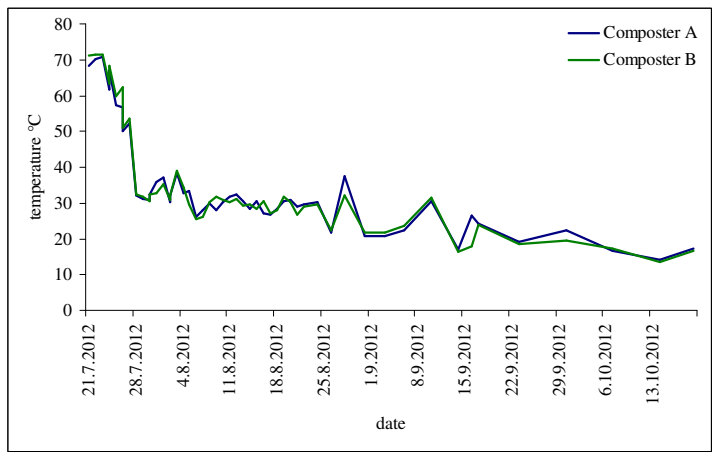

Fig. 2. The development of temperatures in both compost bins

In compost bins the thermofilic phase of the experiment lasted 7 days and the temperature reached and then surpassed 70°C, as shown in Figure 2. The highest temperature in the compost bin A was 71.3°C, in bin B it was 71.4°C. After 7 days, the temperatures in the bins dropped and the compost pile got to the stage of transformation. At the beginning of the phase of transformation the following temperatures were measured in compost bin A: 32.1°C and compost bin B: 32.3°C, in the next days temperatures in the range of 27-39°C were measured. This phase lasted 29 days. During this phase the appearance of the samples was checked and photographs taken. Samples A, E, F, G, H and I showed no visual change by visual observation. Samples B and C showed certain change in colour. The printing on the examined samples changed colour. Sample D showed signs of advanced disintegration, decay in small separate pieces, in some places the original material was entirely absent. In the phase of ripening, the temperature of material in the compost bins approximated to ambient air temperature. Temperatures ranged from 30.3 to 14.3°C in bin A and from 32.1 to 13.6°C in bin B. The compost pile was kept at this stage until the end of the experiment. In this phase, two visual inspections of the samples took place. The first one was conducted after 8 weeks of the experiment. Samples A, E, F, G, H showed no changes when controlled. Samples B and C showed more intense change in colour, but there was no sign of degradation or disintegration. Sample D showed signs of advanced disintegration and signs of occurring disintegration were also observed at sample I.

Within the second inspection, the samples were removed from mesh pockets and photographed. Small fragments occurred only in sample D (these were apparent already at the first inspection). Samples G, H and I also succumbed to disintegration, the sample split into large parts, cracks emerged. Samples A, E and F showed no change in colours or signs of disintegration, their condition at this stage was the same as their initial condition (prior to being placed into the compost pile). Samples B and C show changes in colour printing, some colours disappeared, others changed shades.

Termination of the experiment

The experiment was terminated after 14 weeks, after the expiration of the composting process. Samples were removed from the compost bins and transported to the laboratory of the Department of Applied and Landscape Ecology, Mendel University in Brno, where they were prepared for further research. At the stage of completion and evaluation of the experiment, the samples were treated in accordance with standards of ČSN EN 14806 and ČSN EN ISO 20 200.

The samples were weighed and cleaned in the laboratory. After thorough washing, the samples in mesh pockets were placed in the oven with air circulation and the temperature was set to 58°C. The samples were left for 24 hours at this temperature (set by the Standard ISO 20200). After drying the samples to constant weight, they were removed from mesh pockets. At sample D, all small parts were collected using tweezers. In order to avoid loss of material, this sample was placed into a container for the purpose of weighing and subsequent handling. The same procedure was repeated with samples G and H. The samples were weighed and the weights recorded in the experiment diary.

Results and discussion

Determination of the degree of degradation and samples evaluation

All data recorded in the experiment diary (see Table 4) were used for the calculation determining the degree of degradation of plastics (hereinafter referred to as *D*) according to the norm. In order to calculate *D*, mathematical formula (1) was used:

$$D = \frac{m_i - m_r}{m_i} 100 \quad (1)$$

where: *D* - degree of disintegration [%], m_i - initial weight of dry tested material [g], m_r - weight of tested material after washing and drying to constant weight [g].

Table 4

Weights and degree of degradation

Sample	m_i [g]	m_r [g]	m_x [g]	m_y [g]	*D* [%]
A	5.060	5.090	10.5	17.2	–5.9
B	7.638	7.805	13.5	23.3	–2.1
C	5.327	5.188	-	17.9	2.6
D	8.643	3.115	16.7	23.9	63.9
E	7.462	9.878	16.8	31.1	32.3
F	8.076	7.635	-	23.1	5.4
G	9.595	8.693	-	25.5	9.4
H	14.805	14.818	-	37.9	0.0
I	12.031	12.236	-	32.2	–1.7

m_i - initial weight of dry tested material [g], m_r - weight of tested material after washing and drying to constant weight [g], m_x - weight of tested material in netpockets after drying [g], m_y - weight of tested material after removal from compost pile [g], *D* - degree of disintegration [%]

According to calculations using formula 1, degradation occurred at 4 of the observed samples: Sample C: $D = 2.6\%$. This sample during interim controls exhibited only colour alterations, remained in one piece, and showed no signs of significant damage. Sample D: $D = 63.9\%$. Degree of decomposition was high. Sample F: $D = 5.4\%$. Besides low degree of decomposition this sample showed no other modifications. Sample G: $D = 9.4\%$. There were visual signs of decay, integrity and structure is impaired. Sample H: $D = 0\%$. No degradation occurred. The sample showed changes in structure, the material lost strength and peripheral parts showed signs of decay. Sample I: The sample exhibited negative stage of decomposition, initial signs of degradation occurred. Samples A, B and E showed no signs of degradation neither during the composting process nor at its end, only sample B changed the colour of printing.

Conclusions

This study was carried out in order to assess the biodegradability of the above-described samples under real conditions of home composting, and to find out whether there were any physical changes in terms of their thickness when exposed to a natural composting environment. The experimental samples were placed in the home

compost bin and were checked and visually assessed during the experiment that lasted 14 weeks (standards for the laboratory test required 12 weeks).

From the results obtained during the biodegradability test, it can be concluded that the PE samples with the additive (samples A, B and E) have not decomposed, their colour has not changed (except sample B) and that no degradation neither physical changes (thickness) has occurred. Therefore, the samples made of PE with additives cannot be claimed to be biodegradable. They should have exhibited at least some changes or signs of the occurring decomposition (similarly as common organic waste), which were however not observed. Similar results are described in study carried out by Davis et al [19], where it has been found that shredded PE sacks in an open windrow composting did not degrade, thus resulting in fragments of PE being highly visible within the windrow throughout the composting process. Samples C, F, G, H and I have not decomposed. Sample D exhibited the highest decomposition rate.

In contrast to the laboratory conditions, the real conditions (including home composting) are affected by a number of factors that cannot be influenced such as air temperature, pH of the environment, water content of the compost pile, precipitation etc. It is necessary to emphasize that the nature of the compost's raw material plays an important role in polymers' degradation since different compost systems (*ie*, manure, yard, and food waste) produce different microbiological activity [20]. All these factors can significantly affect the rate and degree of degradation.

The main conclusion from this study is that degradable/biodegradable plastics or plastics certified as compostable are not suitable for home composting and that in home composting bin they do not degrade. However, according to Kale [20], an overall conclusion cannot be exclusively derived, since all the variables in real composting, such as compost raw materials, enzymes, ambient atmosphere, etc., and their interaction with biodegradable plastics, should be considered and explored for better understanding and insight of the biodegradation process.

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CZY DEGRADOWALNE/BIODEGRADOWALNE TWORZYWA SZTUCZNE ROZKŁADAJĄ SIĘ W DOMOWYM KOMPOSTOWNIKU?

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Abstrakt: Biodegradacja materiałów sztucznych reklamowanych jako degradowalne/biodegradowalne oraz certyfikowanych jako kompostowalne była badana w przydomowych warunkach kompostowania (w kompostownikach). Badania zostały przeprowadzone w celu oceny rozkładu próbek w rzeczywistych warunkach kompostowania oraz w celu sprawdzenia, czy badane próbki wykazują jakiekolwiek zmiany fizyczne. Badane materiały pochodziły z sieci sklepów handlowych w Czechach, Polsce, Słowacji i Wielkiej Brytanii. Umieszczone w domowym kompostowniku próbki sprawdzano i oceniano wzrokowo podczas eksperymentu, który trwał 14 tygodni. Na podstawie wyników można stwierdzić, że próbki wykonane z polietylenu z dodatkami (próbki A, B i E) nie uległy rozkładowi, ich barwa nie zmieniła, jak też nie wystąpiła degradacja fizyczna, nie rozłożyły się także próbki C, F. Również próbki certyfikowane jako kompostowalne G, H i I nie uległy rozkładowi. Próbka D wykazywała najwyższy stopień rozkładu. Z przeprowadzonego doświadczenia wynika, że degradowalne/biodegradowalne oraz certyfikowane jako kompostowalne tworzywa sztuczne nie nadają się do przydomowego kompostowania.

Słowa kluczowe: odpady biodegradowalne**,** biodegradacja, kompostowalność, degradacja, przydomowe kompostowanie, tworzywa sztuczne