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Abstract

In order to test the applicability of certified compostable bio-waste bags, eight composting trials have been performed in different German composting plants. The bags made of BASF's newest generation of biodegradable plastic ecovio FS are 20–25 µm thick and consist of more than 50 % renewable resources. The trials have been performed at Herhof-Boxes, Biodegma-, Horstmann WTT-, rotting drum-, Dynacomp-, cutting screw-, table stacks and Gore Cover plants. During the trials it was shown that the degradation of the ecovio FS bags is in accordance with the requirements of the code of practice, under consideration of the technical dwell time in the different types of plants. The degree of degradation as stipulated by the certification DIN EN 13432 has been reached after a significantly shorter time than stipulated and was even exceeded. Prerequisite for the degradation level to be reached are the rules of proper manufacturing practice in the composting process: good mixing of the source material, maintaining the usual C/N ration and sufficient humidity. As has been shown in previous Pilot projects with participation of communities, the citizens are willing to collect separately more bio waste if this is possible in a hygienic way. By using stable, water-resistant compostable bags, the citizens' acceptance for separate bio waste collection may be increased until the new closed loop recovery regulation comes into effect in Germany in 2015. The quality of the compost is not affected by the bags.

1. Introduction

For composting operations, organic waste is money wasted. In fact, an estimated five million tons slip through the net every year in operations in Germany, because only approximately 8.7 million tons a year are currently composted, although approximately 13.6 million tons of organic waste are produced in the Federal Republic [1]. What happens to this 35 % of organic waste that does not go to compost? It ends up in residual waste. Although 65 million residents today would have the opportunity to dispose of their kitchen waste and food waste by means of an organic waste bin, only 42 million people actually use it [2]. Disposing of organic waste via residual waste, however, is highly inefficient for local authorities from an economic and ecological point of view.

For one thing, compost containing valuable nutrients as a natural fertilizer can be produced from organic waste. One of these is phosphorus which is very important for plant growth and therefore for agricultural food production. Phosphorus cannot be manufactured synthetically; it has to be imported from sites overseas [3]. Domestic compost, on the other hand, would be a (virtually) inexhaustible alternative based on its cycle. However, according to figures from the Witzenhausen Institute, wet kitchen waste in the thermal recovery of waste incineration has such a low calorific value that it does not represent a useful feedstock, yet for local authorities and residents it means costs incurred in disposing of residual waste.

Composting organic waste is therefore a type of recovery that produces not just valuable compost, but in doing so also represents a cost-efficient means of disposal for local authorities.

2. Positive experience in resident surveys

Using organic waste bags can increase the percentage of organic waste collected separately. BASF was able to demonstrate this in two German composting projects using bags made of their own compostable plastic ecovio.

The partners in the mid-2011 Bad Dürkheim pilot project enlisted 65,000 households and had the compost tested by IBK Solutions [4,5]. High compost quality and a positive attitude by residents led to these bags being approved across all areas of the Bad Dürkheim district for collecting organic waste. In particular, the fact that organic waste can be collected and disposed of far more hygienically with water- and tear-resistant bags was a convincing argument for residents following a survey. In the second pilot project that BASF together with Berliner Stadtreinigung conducted at the end of 2011 in over 20,000 households, the amount of organic waste collected separately rose by at least 10 %. In addition, the level of impurities was also observed in this project; it fell by 30 to almost 70 %, depending on the area of the city. Here again, the compost quality remained uncompromised [6].

These positive results give reason to assume that it is possible not only to introduce the organic waste bin in all areas across Germany ahead of the coming into force of the 2015 amended Kreislaufwirtschaftsgesetz (German Waste Management Act), but also to make separating organic waste more attractive to residents, because only then will the bin make sense. Clean disposal in the kitchen would not only lead to more organic waste, more compost and less residual waste; the health hazards [7,8] are also reduced if the organic waste can be collected in plastic bags that are watertight yet permeable to air and odor-free. There is therefore still great potential to be tapped into here – even before 2015.

3. Wide-ranging field trials at various German composting plants

In order to investigate the wide applicability of these bags, IBK Solutions conducted trials on the degradability of organic waste bags made of compostable plastic at eight very different German composting plants between May and October 2012 (Table 1). In contrast to other investigations conducted within the last two years [9,10], it was possible here to for the first time examine a bag which was based on more than 50 % renewable raw materials. It is therefore the only one of the plastic bags examined in a broad range of composting field trials up to now to meet the requirements of the 2012 amended Bioabfallverordnung (Biowaste Ordinance). In the trials, 20 ecovio® FS organic waste

bags were each introduced into the process of the various types of composting systems. These were the same commercially available bags made of 20 to 25 micrometer thick film used in the pilot projects in Bad Dürkheim and Berlin. In selecting the composting systems, emphasis was placed on the fact that they cover as wide a cross-section as possible of the processes used today in Germany and thus give a comprehensive insight into the bags' degradation process. This allowed very valid comments to be made, with a case-by-case examination of other systems being useful. The sample type test process was used when allocating the composting plants as is the procedure at the Bundesgütegemeinschaft Kompost e. V. (Federal Compost Quality Association) in Cologne. All the important conditions for fulfilling the type model were met. Deviations in the technical set-up and in operation are possible.

Type of systems	*HBPS* [1]	*Capacity*	*Dwell time intensive rotting*[2]	*Dwell time post-rotting*[3] *(not used here)*
Herhof boxes	1.1	9.950 Mg/a	12 days	min. 15 days
Biodegma	1.2	15.000 Mg/a	14 to 21 days	min. 14 to 21 days
Horstmann WTT	3.6	10.000 Mg/a	10 days	min. 28 days
Rotting drum[4] (similar to Envital)	(4.1)	15.000 Mg/a	14 days	min. 42 days
Dynacomp (with wheel loaders)	5.4	40.000 Mg/a	27 days	according to demand
Auger[4] (similar to Dynacomp)	(5.4)	15.000 Mg/a	29 days	according to demand
Windrow, unventilated, covered over	6.8	6.000 Mg/a	14 + 14 days[5]	70 days
Gore Cover	7.1	18.000 Mg/a	28 + 14 days	14 days

1) Description of the type of composting system according to the hygiene type test system of the Bundesgütegemeinschaft Kompost e. V., Cologne
2) Dwell time of the samples corresponds to the normal minimum dwell time of the organic waste
3) Samples were not subjected to post-rotting
4) Direct process test
5) 1x turning after 14 days

Table 1
Types of system with capacity and dwell time in intensive rotting. There was no post-rotting of the samples.

Procedure for the trials

The trials were incorporated in the daily work routines at the composting plants. After the bags were filled on site with organic waste, 50 % of them were left open and 50 % tied with a knot, placed in a rough net in the compost clamps and covered with more organic waste. The net enables the samples to be recovered more easily at a later date. During the trial period, the temperatures in the compost clamps were monitored and the organic waste, where technically possible, analyzed for composition and for moisture content before and after the degradation process. After the trial period which in all cases was adjusted to the normal dwell time in the respective system, the samples were removed and analyzed using a visual and sensory assessment. It should be mentioned for the actual usability of the bags that their stability during sorting and collection in the household had already been checked several times. Even after a storage period extended by four weeks for the bags filled with organic waste, they were still sufficiently strong that they had not split either at the sides or at the bottom.

Description of the process

Only the rotting area and the part of the process in the individual systems to which the samples were exposed when the trial was conducted are described here. Since the bags had already degraded sufficiently in intensive rotting, post-rotting was not applied in any of the cases dealt with here.

Herhof box composting

The intensive rotting boxes have forced ventilation; a process computer continuously calculates and adjusts the volumetric flow rate of air needed for each box based on temperature and CO_2 measurements. The incoming air is taken from the volume of outlet air in the production hall and variably passed in the rotting box as circulating air. This accelerates and intensifies the rotting process. Within around 10 to 12 days, a large part of the readily degradable substances is degraded to organic and green waste and the material is sanitized at temperatures of over 60 °C over a minimum of a week.

Biodegma process

In this process, the organic waste is placed in intensive rotting boxes closed with tarpaulins which are locked in the system examined using a rolling door. The boxes are equipped with pressurized ventilation. The outgoing air is extracted from the boxes and passed over a biofilter. The dwell time in intensive rotting is 2–3 weeks.

Horstmann WTT system

In this system, a wheel loader is used to place the materials supplied on a conveyor belt where fine material is sieved out and any iron parts can be removed using a magnetic separator. The coarse materials are sifted for foreign matter at a sorting station and then crushed. According to the operator, biodegradable organic waste bags would not be sorted out based on size and appearance. Using a wheel loader, the treated raw material is fed into the completely enclosed rotting tunnels where they are subjected to intensive rotting for around three weeks. The compost material is optimally microbially rotted by means of a computer-controlled moisture supply, forced ventilation and fully automatic conversion.

Rotting drum process

In the rotting drum process with special equipment by the owner and operator, the organic waste was placed in the rotting drum without further pretreatment. The main rotting took place in the six rotting drums. The outgoing air temperature from the rotting drum is measured to monitor the sanitizing effect of composting. Temperatures of minimum 60 °C are maintained over two weeks. The dwell time in the drum is approximately 2–3 weeks.

Dynacomp process

In the Dynacomp process (using wheel loaders), the organic waste is stacked by wheel loaders in the intensive rotting hall to form windrows. The compost is completely sanitized here, the rotting time being on average 27 days.

Auger (similar to Dynacomp)

In the intensive rotting boxes in the system with an auger (similar to Dynacomp), the organic waste is stacked

by wheel loaders in the ventilated boxes to form windrows. The compost is then completely sanitized. In a two week-cycle, the rotting clamps are loosened with a screw operating on a coordinate system (Figure 1) and turned virtually upside down on the spot. This allows moisture to be introduced by adding industrial or fresh water. The organic waste remains in the boxes for a minimum of four weeks, being turned after two weeks. There was no turning in the area of the inserted samples.

Windrow, unventilated, covered over

In the process using unventilated, covered-over windrows, wheel loaders are used to place the organic waste on triangular clamps under cover without processing.

During the main rotting, temperatures of minimum 60 °C are maintained over two weeks.

In post-rotting, the organic waste is matured and stabilized over a minimum of six weeks with turning using a self-propelled turner in a storage hall with a side opening. Turning was not used for the trial and instead the rotting period in the static clamp was set at 28 days.

Gore Cover process

The series of trials also looked at green material composting using the Gore Cover process. The coarse organic waste is picked up by wheel loaders and shredded for further treatment. The green fraction shredded in this way is then mixed and homogenized with the residual organic waste and irrigated if required.

The first intensive rotting takes place over four weeks, the organic waste being placed on a concrete plate with ventilation pipes. The concrete plate is bounded on three sides by a concrete wall which is opened from the front to allow access for the wheel loader. If the rotting clamp is ready built to a height of approximately 2.8 to 3 m, it is covered with a semi-permeable tarpaulin and moved downwards until practically compact. The rotting clamp is then subjected to forced ventilation, with a process computer continuously calculating and adjusting the volumetric flow of air needed for each clamp on the basis of temperature and CO_2 measurements. In the first intensive rotting, a large part of the readily degradable substances in the green waste is biologically converted within four weeks and the material sanitized at temperatures of over 60 °C.

Figure 1
Rotating screw

Selection of the types of system and conducting of trials

The types of system described and summarized in Table 1 cover a wide range of the processes used in Germany. In only one of the systems was there any manual sorting of contaminants. In two of the systems, the organic waste was screened before composting. In the Horstmann WTT system, only the undersized material is separated out. The organic waste bags are passed here into composting. In the system with an auger, the material is screened using a screen size of 120 to 150 mm. Trials have shown that the bags tear in the collection vehicles (compression plate and rotary drum vehicles). It can therefore be assumed that a large part passes into composting. Treatment of the organic waste by crushing would ensure virtually 100 % collection for composting. In the trial using a Bühler-Wendelin system with pre-fractionation by screening (evaluation of this is ongoing and has not yet therefore been included in the present table), it has not been possible to test the effect of tearing of the organic waste bags in the collection vehicles.

With the exception of the system for shredding the green waste using the Gore Cover system, the organic waste was not mechanically shredded. There were no negative effects of the plastic waste bags on the composting processes. The important parameters for composting - moisture and temperature - remained in the non-critical range. The temperature rose to 60 to 70 °C as is typical in the systems in the first two days and as the increase plateaued they achieved a maximum of 75 °C (the exception being the Gore Cover system at up to 85 °C) (Figures 2–4). Determining the moisture of organic waste is difficult, as is known. The moisture content is dependent not only on the season and rainfall, but sampling and treatment also lead to significant fluctuations in the readings.

An examination of the moisture content of the organic waste before and after the trial showed a difference of 1 to 5 % in the majority of systems. Exceptions were the Horstmann WTT and auger systems with a moisture loss of around 8 % and the Biodegma system with 13 %. The final moisture here was just under 43 %. The initial values varied in all systems between 62 and 51 % (Table 2). It is important that there is sufficient moisture for the microorganisms over the active turning process. In processes where compost clamps are highly force-ventilated and work with a high air extraction rate, there is a danger that the biomass will dry out and the process will not run at optimum level. This can lead to lower conversions and lower degradation rates.

Tests and results

After the rotting period for each of the composting systems, the organic waste was removed from the system using a wheel loader. The recovery rate in percent, and thus assessment of the biodegradation, is obtained from the ratio of the recovered surface to the surface of the bags used.

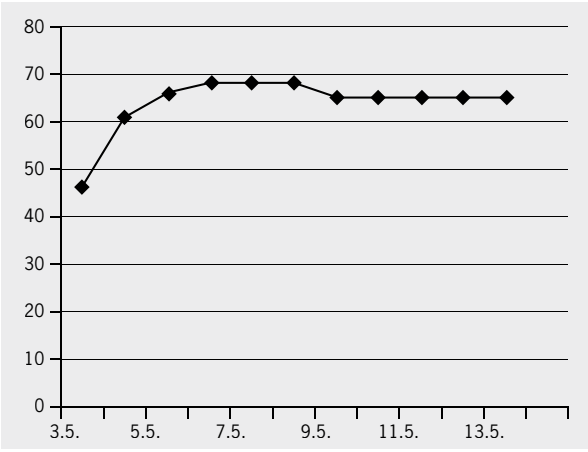

Figure 2
Temperature profile of the Herhof boxes system

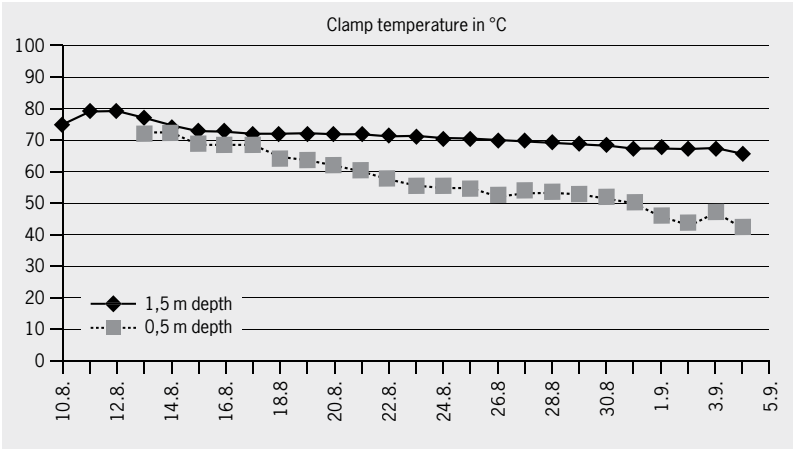

Figure 3
Temperature profile of the Dynacomp (similar) system

This examination in principle produces a worse degradation rate than a weight-based comparison, because the structure degradation is not factored in here. Within the meaning of the quality and test provisions of the Bundesgütegemeinschaft Kompost e. V., however, an assessment of the surface area appears to be useful (Table 3). The mechanical and physical behavior were analyzed using a sensory evaluation by assessing the extensibility and notched tear strength. As shown in Table 3, it was possible to prove within the context of this series of trials that the degradation of the ecovio FS bags meets the practical requirement, taking into consideration the technical dwell time in the individual types of system. The degree of degradation defined according to the procedure for the certification of biodegradable and compostable materials and packaging according to DIN EN 13432 and/or DIN EN 14995, has been achieved and even exceeded in a significantly shorter time than required. The prerequisite for achieving the degradation rates is the rules on good composting practice – good mixing of the starting materials, compliance with the normal C/N ratios and sufficient (moisture) supply. In one of the cases described in Table 3, the C/N ratio was unfavorable and the loss of moisture high, so that the degradation rate there was only 50 %.

In addition, the newly developed ecovio FS plastic meets the requirements that the 2012 amended Biowaste Ordinance places on organic waste bags in the organic waste bin. They must consist predominantly (i.e. more than 50 %) of renewable raw materials. According to the manufacturer, the plastic and bags meet this requirement, and the ecovio FS bags which with a wall thickness of 40 micrometers are considerably more stable and which were subjected to the examinations described here, also degraded correctly within the normal rotting process of each system examined.

Conclusion

Germany is very well advanced in terms of the separation and recovery of waste in an international comparison, but there is still a lot to do before the amended Waste Management Act, under which organic waste will be separated across all of Germany from 2015, comes into force. Not all residents are yet convinced about the benefit of the industrial composting of organic waste and hygienic collection options, too, are not yet available in all areas. At the same time, the capacities of the currently existing composting plants in Germany are not fully utilized, and yet communities are paying for the costly incineration of biological waste in residual waste. With hygienic, stable and compostable organic waste bags, a lot can be done in this respect – hygienic collection for residents, more valuable compost for the composter, increased plant utilization, improvement of soil by more nutrient-rich compost and

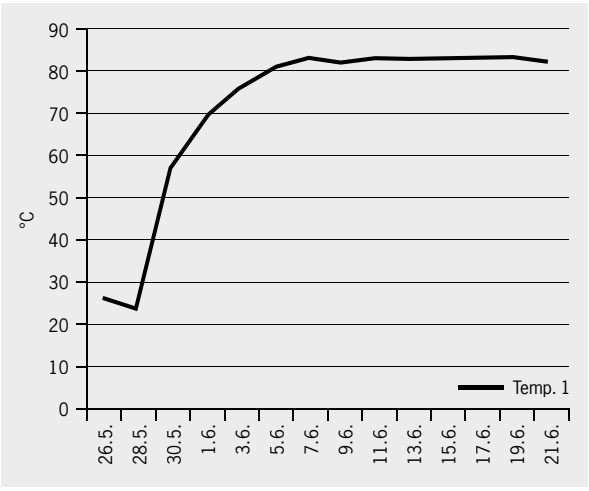

Figure 4
Temperature profile of the Gore Cover system

Table 2
Moisture content of the organic waste before and after the trial

Type of system	*HBPS*	*Moisture content in % of the weighed fresh matter*		
		Before the process	*After the process*	*Difference*
Herhof boxes	1.1	59,9	56,1	3,8
Biodegma	1.2	55,7	42,7	13,0
Horstmann WTT	3.6	62,4	54,4	8,0
Rotting drum	(4.1)	56,0	52,0	4,0
Dynacomp (with wheel loaders)	5.4	51,0	46,0	5,0
Auger	(5.4)	52,0	43,8	8,2
Windrow unventilated, covered over	6.8	51,0	49,5	1,5
Gore Cover	7.1	55,9	54,7	1,2

It is known that the greatest deviations in moisture analyses are largely caused by sampling. In the heterogeneous material of the untreated organic waste in particular, it is important, despite the attempt to produce good mixed samples, to consider the readings more as guide data.

Anlagentyp	*HBPS[1)]*	*Dwell time in the trial*	*Degradation rate in % according to area[1)]*	*Comments*
Herhof boxes	1.1	12 days	100 %	Ventilation with circulating air, good distribution of moisture
Biodegma	1.2	21 days	50 %	C/N ratio unfavorable, high moisture loss
Horstmann WTT	3.6	10 days	100 %	Suction ventilation, low volume of air, high moisture contents
Rotting drum[4)] (similar to Envital)	(4.1)	15 days	> 90 %	Intensive mechanical effects, high moisture contents
Dynacomp (with wheel loaders)	5.4	27 days	100 %	Low ventilation rate (depending on the oxygen demand of the clamp)
Auger[4)] (similar to Dynacomp)	(5.4)	29 days	> 90 %	Pressure ventilation and addition of moisture as required
Windrow unventilated, covered over	6.8	28 days	100 %	Good ventilation due to appropriate (2.8 m) clamp height
Gore Cover	7.1	28 days	100 %	Ventilation according to temperature and CO_2 measurement, moisture high under Gore Cover

1) According to inspection

Table 3
Abbauraten nach Verfahren und Rottedauer

lower disposal costs for local authorities due to a reduction in the amount of residual waste. The composting trials in the different plants show that the biodegradable waste bags keep their promise and also the quality of the compost is not compromised by them.

The new plastic ecovio FS – performance properties and compostability

BASF has been supplying the compostable plastic ecovio® certified to DIN EN 13432 and/or DIN EN 14995 since 2006. The company has for some years been working closely along the value chain with its direct clients, end clients and with many disposal companies such as composters to optimize and review the properties of ecovio. As a result of these cooperation arrangements together with research work, BASF can with ecovio FS supply an enhanced material for biodegradable organic waste bags that is completely compostable according to the current international standards. At the same time, it is predominantly composed of renewable raw materials and yet sufficiently stable for the production of tear-resistant and water-resistant films and bags. As verified by the certification and numerous trials under standardized laboratory conditions, the degree of degradation demanded in the standards can be safely met. Extensive practical tests have been conducted since the technical dwell times of various types of composting, however, differ considerably from one to another and also from the standard conditions and the microbial conversion process is affected by the plant technology. The result is that there are now verifiable results for the use of these organic waste bags for decision-makers such as local authorities and operators.

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Explanation

HBPS
As defined in Hygiene Baumuster Prüfsystem; Bundesgütegemeinschaft Kompost e.V., March 2010: http://www.kompost.de/fileadmin/docs/shop/Grundlagen_GS/HBPS__Auflage_4_mit_Deckblatt.doc.pdf

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