SCHRIFTENREIHE

des Lehrstuhls Abfallwirtschaft und
des Lehrstuhls Siedlungswasserwirtschaft

11

Herausgeber:

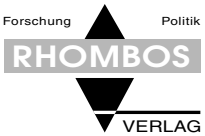
Bauhaus-Universität Weimar
Fakultät Bauingenieurwesen
Lehrstuhl Abfallwirtschaft
Lehrstuhl Siedlungswasserwirtschaft

99423 Weimar, Coudraystraße 7

RHOMBOS-VERLAG • BERLIN

Bibliografische Information Der Deutschen Bibliothek

Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.ddb.de abrufbar



Printed in Germany

Umschlag: RHOMBOS-VERLAG, Berlin

VK-Nr. 65 859
www.rhombos.de

Druck: dbusiness GmbH, Berlin, Eberswalde

ISBN 3-937231-26-9

Matthias Klauß

Degradation of Biologically Degradable Packaging Items in Home or Backyard Composting Systems

With a Special Focus on the Pilot Scale Field Test for Compostable Packing in Kassel, Germany

Bauhaus-Universität Weimar, 2004

RHOMBOS-VERLAG

PhD Thesis

Date of the examination: 23/02/2004

Head of the Grading Board:
Prof. Dr.-Ing. habil. Anette Müller, Weimar, Germany

Assessors:
Prof. Dr.-Ing. habil. Werner Bidlingmaier, Weimar, Germany
Prof. Edward I. Stentiford, Leeds, U.K.
Dr. Luis F. Diaz, Concord, U.S.A.

Bauhaus-Universität Weimar, 2004

Particular emphasis of waste disposal in Germany within the scope of the new legal framework is being placed on the recovery of organic residues (native-organic materials as well as plastics). This means enforcing the exploitation of organic residues, e.g. in composting plants. Biodegradable materials should be decomposed in reasonable and for waste management acceptable time periods.

Closing the lifecycle of materials will be important for waste management in the near future. To be mentioned are:

- completed industrial cycles of material by recycling measures and
- completed cycles of material in the biosphere. Terms like *regenerative raw materials, biodegradable materials* and *composting* are to be considered.

Systems involving the separate collection and subsequent composting of exclusively organic waste are gaining acceptance. The separate collection of organic residues allows the production of compost that meet both consumer's quality requirements and the needs of the environment. Therefore many mixed-refuse compost production plants are now being retrofitted, if possible, for the processing of separately collected organic waste.

About 80 biowaste composting facilities were operated in Germany in 1993, with a total treatment capacity of about 800.000 tons per year. This capacity was sufficient to treat the organic residues earned by a organic waste collection system available to 10% of the population.

The corresponding figures of the year 2003 show differences:

- the organic waste collection system availability increased, up to 60% of the households joined the organic waste collection and
- about 9 million tons of residual organics were treated per year.

That means a compost production of around 4 million tons per year. 1.7 million tons of organic waste are additionally processed by home composting. These amounts were not considered in waste management and are absconded from current standards, e.g. the proof of compostability for biodegradable materials.

Every organic substance, whether of fossil or of natural origin, is generally decomposable. It is just a question of time and the process conditions. This does not mean that all these organic materials can be decomposed in reasonable and for waste management acceptable time periods. Therefore it is necessary to draw up guidelines which control if and when such waste can be supplied to a composting plant. The main goals are:

- the definition of the requirements for the composting of biodegradable materials and
- the development of a standard method or a check list to test the suitability of biodegradable materials intended for composting.

Preface

The standards to test biodegradability of materials were developed and are available. The special conditions of home composting are actually not considered in current standards.

This work deals with the question if it is necessary to account for the specific cirumstances of a composting process in backyard composting facilities. The author not only dwells on the specific conditions of home or backyard composting but also verifies which biodegradable materials could be treated in such systems and which not. The results show that an assessment of the compostability according to the current DIN V 54 900 may lead to a misinterpretation in some cases.

This work is a substantial basis for all persons responsible for the decision if biodegradable products are allowed for biological waste treatment.

Weimar, April 2004 Werner Bidlingmaier

I would like to express my sincere thanks to Prof. Dr.-Ing. habil W. Bidlingmaier, who encouraged me to carry out this investigation beside my daily work and who supported me in my numerous scientific inquiries. Many thanks to my colleagues, esp. Jun.-Prof. Dr.-Ing. E. Kraft and J. Liebetrau, with whom I had many thought provoking discussions and who gave me so much advice.

My wife Antje deserves special thanks for tolerating my caprices and pushing me to complete this work.

Thanks to my family for providing me with all the needed assistance during my life and studies.

Thanks to both of my co-advisors, Prof. E.I. Stentiford and Dr. L.F. Diaz, who gave valuable advice and comments for this work.

Special thanks to René Strempel, Thomas Harrlandt, Christain Springer and Christian Kohout, who supported me by preparing samples and conducting the experiments. This investigation would have been almost interminable without their effective help.

The companies APACK AG., FARDIS B.V., Wentus Kunststoff GmbH, Compopure - Spezialrohstoff und Bioplastikprodukte GmbH, Eastman Chemical B.V., Klöckner Pentaplast GmbH, AUTOBAR Group Ltd., natura Verpackungsmaterial GmbH and the DIN CERTCO GmbH deserve thanks for providing test materials.

Abstract

Biodegradable polymer packing (BDP) can be collected via the municipal organic waste collection and treated by composting. All certified biodegradable products commercialised in Germany were labelled explicitly as “compostable”. The compostability of such products is tested in technical (European, US, Japanese standards). A recovery of biodegradable polymer packing is possible by backyard composting. It must be clarified how these different BDP degrade under the special conditions of a domestic composting. The objective of this work is to examine the aerobic degradability of BDP (starch/copolymer blends, PLA, copolymers) in home composting systems: Investigations included the pilot-scale composting of 1% (w/w) BDP in two different home composting systems under defined environmental and under outdoor conditions, the composting of BDP in windrows in a commercial composting plant and in existing composting systems of volunteers as comparative studies. The duration of all experiments was 12 months.

The results indicate that neither the construction of the compost maker nor the charging regime had significant influence on the degradation behaviour of the tested BDP. Starch-blended films and products degraded almost completely. Up to 100% (w/w) mass loss can be achieved, depending on the thickness of the material. The highest degradation effects were achieved in central zones of the compost makers. PLA showed almost no mass losses during home composting, although they lost their structural stability by becoming brittle and physically unstable. Degradation of fossil based aliphatic aromatic co-polyesters needed more time to start. Degradation rates in outdoor trials showed principally the same results, although absolute degradation was slightly slower due to climatic influences. Windrow composting trials and the experiments in existent home composting sites proved the degradability of the tested biopolymers. Additional trials to investigate possible enhancement measurements for the PLA pre-treatment failed. Neither pre-treatment nor any of the auxiliary additives resulted in a significantly higher degradation. Starch-based biodegradable products or those made of a starch blend, as well as tested and certified (according DIN V 54 900 or equivalent) biodegradable products, can be recommended without restriction for backyard composting. Fossil-based aliphatic aromatic co-polyesters are only partially adequate for home composting, needing apparently more time for a complete degradation. Current PLA based products should be excluded from backyard composting, showing almost no degradation effects in backyard composting systems. Generally, a testing of new BDP products related to their compostability in backyard composting systems should be included in the testing and certification procedure, as it is intended to label these new products as *compostable*.

Biologisch abbaubare Werkstoffe (BAW) können über die Biotonne und die anschließende Kompostierung verwertet werden. Alle in Deutschland zertifizierten Verpackungen aus BAW sind explizit als „kompostierbar“ gekennzeichnet. Die Kompostierbarkeit wird entsprechend den nationalen Regelungen (DIN, ASTM etc.) in technischen Kompostanlagen getestet. Eine Verwertung der BAW über die Eigenkompostierung ist ebenfalls denkbar. Ein mögliches Recycling der BAW auf diesem Wege geklärt werden. Ziel dieser Arbeit war es, den aeroben Abbau von BAW unter den speziellen Bedingungen einer häuslichen Kleinkompostierung zu untersuchen. Dazu wurden verschiedene BAW Produkte (Stärke/Copolymer Blends, PLA, Copolymere) in üblichen Komposten getestet. Der BAW Abbau (1 M-%) wurde in zwei Kompostersystemen im Technikum und unter Freilandbedingungen untersucht. Zusätzlich wurde der BAW Abbau in kleinen Mieten (1m³) in einer technischen Kompostierung und in existierenden Eigenkompostierungen von Freiwilligen untersucht. Die Dauer aller Versuche wurde auf 12 Monate festgelegt.

Die Ergebnisse zeigen, dass weder der Kompostertyp noch der Befüllungsmodus signifikanten Einfluss auf das Abbauverhalten von BAW Produkten haben. Stärkebasierte BAW wurden innerhalb von 12 Monaten in der Eigenkompostierung fast komplett abgebaut. BAW auf Stärkebasis erreichten Abbauraten bis zu 100%, abhängig von der Materialstärke. Folien und Becher aus PLA zeigten innerhalb von 12 Monaten fast keinen, als Masseverlust messbaren, Abbau, obwohl sie teilweise ihre Stabilität und Elastizität verloren. Versuche, den PLA Abbau mittels Vorbehandlung und/oder Zugabe abbaufördernder Stoffe zu beschleunigen, zeigten keine eindeutigen Resultate. Fossil basierte aliphatisch-aromatische Copolyester brauchen einen längeren Zeitraum, um komplett abgebaut zu werden. Die Abbauraten in den Freilandversuchen zeigten generell die gleichen Tendenzen, obwohl durch klimatische Einflüsse die Absolutwerte der Masseverluste niedriger ausfielen.

Zusammenfassend kann konstatiert werden, dass getestete und zertifizierte BAW auf der Basis von Stärke bzw. Stärkeblends ohne Einschränkung über die Eigenkompostierung verwert- und kompostierbar sind, speziell Produkte aus relativ dünnen Folien sind problemlos abbaubar. Fossil basierte aromatisch-aliphatische Copolyester sind nur mit Einschränkungen für die Eigenkompostierung geeignet, da sie längere Intervalle für ihren Abbau benötigen, als für die Eigenkompostierung empfohlen werden. PLA Artikel sollten vorerst nicht über die Eigenkompostierung verwertet werden, da sie innerhalb eines Jahres fast überhaupt keine Abbauerscheinungen zeigten. Generell wird empfohlen, bei als *kompostierbar* gekennzeichneten BAW die Kompostierbarkeit in der Eigenkompostierung im Rahmen der technischen Norm ebenfalls zu überprüfen.

AD	Absolute degradation ratio
A-PLA	Cups made of A-Poly Lactic Acid (PLA)
BDP	Biologically Degradable Polymer (packing), biopolymers
BioAbfV	Ordinance on the Utilisation of Biowastes on Land Used for Agricultural, Silvicultural and Horticultural Purposes (Biowaste Ordinance) - Verordnung über die Verwertung von Bioabfällen auf landwirtschaftlich, forstwirtschaftlich und gärtnerisch genutzten Böden (Bioabfallverordnung)
Biowaste	Separately collected organic residues
C-PLA	Cups made of C-Poly Lactic Acid
DD_{VS}	Degree of organic matter degradation [% dm]
dm, DM	Dry mass
Eq.	Equation
FARD	Waste bags made of FARDEM®
HB	Small bag for fruits and vegetables (shirt shaped, Ecoflex®)
IBAW e.V.	Interessengemeinschaft Biologisch Abbaubare Werkstoffe e.V.
kg/(p·d)	kg per person and day
kg/(p·w)	kg per person and week
kg/(p·y)	kg per person and year
KrW/AbfG	Act for Promoting Closed Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal - Kreislaufwirtschafts- und Abfallgesetz
l/p	Litres per person
LR	Wooden, open compost maker
m, M	Mass
Mg	Mega gram (= ton)
MBB	Mater-Bi® cup
MBBe	Mater-Bi® cutlery
MBF	Mater-Bi® film
odm, ODM	Organic dry mass
OM	Organic matter
pH	Acidity/alkalinity

PLAF	Poly Lactic Acid film
PCL	Poly-ε-caprolactone
S	Layer of a compost maker
TPSS	Thermoplastic starch tray
TK	Plastic, insulated compost maker
VerpackV	Ordinance on the Avoidance and Recovery of Packaging Waste (Packaging Ordinance) - Verordnung über die Vermeidung und Verwertung von Verpackungsabfällen (Verpackungsverordnung)
VS	Volatile solids
w.b.	Wet matter basis
WM	Wet mass
w/w	Mass based