

# **Global review of biodegradable plastics testing and standards**

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## **Introduction**

Besides DIN V 54900, various other standards on the testing of the compostability of materials, or of products made from them, have been developed in recent years. One of them, for example, is the European Standard EN 13432. This standard is part of a whole series of standards prepared under a mandate from the EU to support the implementation of the Directive on Packaging and Packaging Waste (94/62/EC). In addition, ASTM standards have been developed in the United States, ISO standards at international level, and in Japan, too, specifications on compostability have been drawn up, though no generally accepted Japanese Standard (JIS) has been adopted there, as yet. Accordingly, to permit the proposed comparison between the various standards used world-wide, reference will be made below to the GreenPla certification scheme instead of to a Japanese standard.

Each of these standards is now being applied by a number of certification organisations in the testing and assessment of compostable products and materials. By way of a comparison of the individual standards or certification schemes, it is to be shown here in what respects they differ and where they are in agreement, before a perspective on future developments in the harmonisation of standards and certification procedures of compostable material is offered.

## **Comparison of standards for assessing compostability**

In addition to the German standard DIN V 54900, the European standard EN 13432 and the American standard ASTM D 6400 are also used as the basis for assessment purposes. These standards are very similar in all essential respects, but differ in certain details. The certification scheme of GreenPla (Japan) differs more significantly in a number of points from the other standards referred to.

As a rule, the assessment of compostable materials and products comprises five different parts:

- characterisation
- determination of ultimate biodegradability
- determination of compostability (disintegration)
- analysis of the quality of the compost

- determination of ultimate anaerobic biodegradability (not obligatory)

### **Characterisation**

All three standards require comparable chemical tests (cf. Table 1). They differ i.a. in respect to the limit values for hazardous substances (cf. Table 2). Both EN 13432 and ASTM D 6400 dispense with an analysis of the nutrients (N, P, K, Mg, Ca). Assessment as specified in the certification scheme of GreenPla includes ecotoxicity testing from the initial material stage on. Such tests are not provided for in the other standards until the quality of the composts is to be analysed.

**Table 1** Overview of characterisation specifications

<b>Standard</b>	<b>DIN V 54900</b>	<b>EN 13432</b>	<b>ASTM D 6400</b>	<b>GreenPla</b>
Detailed specifications	DIN V 54900-1 Clauses 5,6 and 7	EN 13432, Subclause 4.2.2 and Annex A.1	ASTM D 6400, Subclause 6.4.1  40 CFR 503.13	-
Information and identification of constituents	Organic constituents not less than 50 %	Volatile solids content not less than 50 %	-	Organic constituents not less than 50 %
General characterisation	TOC TC Volatile solids Ash content Elemental analysis (C, H, O, S, N)	TOC Total dry solids Volatile solids	-	-
Nutrients	N, P, K, Mg, Ca	-	-	
Hazardous substances - inorganic	Zn, Cu, Ni, Cd, Pb, Hg, Cr	Zn, Cu, Ni, Cd, Pb, Hg, Cr, Mo, Se, As, F	Zn, Cu, Ni, Cd, Pb, Hg, Se, As	Zn, Cu, Ni, Cd, Pb, Hg, Cr, Mo, Se, As, F
Hazardous substances – organic	PCB, PCDD/F	-	-	-
Ecotoxicity test	-	-	-	OECD Guidel. 201 OECD Guidel. 202 OECD Guidel. 203 Oral Acute Toxicity Tests (Rats)

Specification of the limit values in all three standards follows the same basic approach. The respective legal limit values for soil, e.g. as specified in the German bio-waste regulation or in US law in the "Codes of Federal Regulation" (40 CFR 503.13) are taken as the basis and then increased by a certain percentage value, in the case of ASTM D 6400 by 50 %.

The limit values in EN 13432 are all less stringent than those in DIN V 54900-1. For PCB and PCDD/F there are no limit values at all in EN 13432, though these are not defined in DIN V 54900, either. On the other hand, other hazardous substances have been included in the scope of testing (cf. Table 2). ASTM D 6400 permits the highest concentrations of hazardous substances.

**Table 2** Differences in limit values between EN 13432, DIN V 54900-1, and ASTM D 6400

	<b>DIN V 54900-1</b>	<b>EN 13432</b>	<b>ASTM D 6400</b>	<b>GreenPla</b>
	Limit values [mg/kg]	Limit values [mg/kg]	Limit values [mg/kg]	Limit values [mg/kg]
Zn	100	150	1400	150
Cu	23	50	750	37,5
Ni	15	25	210	25
Cd	0,3	0,5	17	0,5
Pb	30	50	150	50
Hg	0,3	0,5	8,5	0,5
Cr	30	50	-	50
Mo	-	1	-	1
Se	-	0,75	50	0,75
As	-	5	20,5	3,5
F	-	100	-	100
PCB	Not defined	-	-	-
PCDD/F	Not defined	-	-	-

### ***Determination of ultimate biodegradability***

The criteria for biodegradability under laboratory conditions as specified in EN 13432, DIN V 54900-2 and ASTM D 6400 are similar, as Table 3 shows. DIN V 54900-2 specifies that homopolymers must have achieved a level of degradation of 60 % after six months, and copolymers, a level of degradation of 90 %. The same values are specified for homopolymers and copolymers in ASTM D 6400, but this level of degradation need only be achieved in comparison to a known reference material and not absolutely. EN 13432 specifies in all cases that the percentage of biodegradation shall be 90 % in respect to a

reference substance. The test duration is not to exceed 6 months. ASTM D 6400 permits the test duration to be extended to one year if radiolabelled test substances are used.

DIN V 54900 and EN 13432 agree in that the biodegradability must be determined for each significant organic constituent (> 1%) and that the total organic content must amount to not less than 50 %. An equivalent specification is not made in ASTM D 6400.

An exemption is made in EN 13432 for chemically unmodified materials and constituents of natural origin (wood, wood fibre, cotton, starch, paper pulp or jute). These are accepted as being biodegradable without further testing. They must, however, be chemically characterised and meet the criteria for disintegration and compost quality.

In the GreenPla certification scheme, as in EN 13432, reference is made in respect to testing to various ISO Standards and to the OECD Guideline 301. No specification is made, however, with regard to a time limit for the compostability test, and the minimum level of degradation is only 60 % instead of 90 %.

**Table 3** Overview of criteria for assessing biodegradability

Standard	DIN V 54900	EN 13432	ASTM D 6400	GreenPla
Test method	DIN V 54900-2  Method 1: Determination of the biochemical oxygen demand in a closed respirometer	ISO 14851	-	JIS K 6950 (ISO 14851)
	DIN V 54900-2  Method 2: Determination of the evolved carbon dioxide in an aqueous medium	ISO 14852	-	JIS K 6951 (ISO 14852)

	DIN V 54900-2  Method 3: Determination of the evolved carbon dioxide in compost	ISO 14855	ASTM D 6002 ASTM D 5338	JIS K 6953 (ISO 14855)
Test object	Constituents present in a concentration of more than 1 % (No more than 3 % without determined biodegradability)	Constituents present in a concentration of more than 1 % (No more than 5 % without determined biodegradability)	Constituents present in a concentration of more than 1 %	Constituents present in a concentration of more than 1 % (No more than 5 % without determined biodegradability)
Maximum duration	6 months	6 months	6 months (1 year for radiolabelled materials)	(Not specified in the GreenPla certification scheme)
Required level of degradation	60 % (homopolymers) or 90 % (copolymers)	90 % of the value of a suitable reference material	60 % (homopolymers) or 90 % (copolymers) of the value of a suitable reference material	60 % of the value of a suitable reference material

### ***Determination of compostability (disintegration)***

DIN V 54900-3 specifies both pilot-scale and full-scale testing, whereas EN 13432 specifies only the pilot-scale test as obligatory. The standard EN 13432 indicates the criteria of a successful test under item A.3, but does not prescribe a specific method for the practical performance of the test. ASTM D 6400 does not specify a particular method, either. DIN V 54900-3 further specifies the performance of a compostability test with a considerably higher concentration of compostable materials (ecotoxicity test) that is not prescribed in the other standards. The GreenPla certification scheme makes no provision for compostability testing.

**Table 4** Overview of disintegration tests

<b>Standard</b>	<b>DIN V 54900</b>	<b>EN 13432</b>	<b>ASTM D 6400</b>
Test method	DIN V 54900-3  Pilot-scale testing under optimised process conditions	No method specified. Testing obligatory	ASTM D 6400, Subclause 6.2  ASTM D 6002-96, Subclause 7.2.1
	DIN V 54900-3  Full-scale testing under real conditions	No method specified. Testing voluntary	-
Maximum duration	12 weeks (pilot-scale) 10-15 weeks (full-scale)	12 weeks	5 weeks (may be extended)
Specified level of degradation	90 % of the sieve fraction > 2 mm	90 % of the sieve fraction > 2 mm	90 % of the sieve fraction > 2 mm

### ***Analysis of quality of composts***

For the analysis of the quality of the composts, various ecotoxicity tests are referenced. DIN V 54900 further comprises a visual inspection (content of unwanted residues). In the case of EN 13432 a more precise chemical characterisation of the compost is also to be conducted to determine, among other things, the nutrient content, which in DIN V 54900 is incorporated in the chemical characterisation of the material.

**Table 5** Methods of determining compost quality

<b>Standard</b>	<b>DIN V 54900</b>	<b>EN 13432</b>	<b>ASTM D 6400</b>
Test method	Ecotoxicity test with summer barley to subclause 5.1 of E DIN 54900-4 (or in accordance with LAGA-Merkblatt M10 E 2.6.1)	Ecotoxicity test with not less than two types of plants. In accordance with OECD Guideline 208.	Ecotoxicity test with cress and at least two other types of plant is to be conducted in accordance with OECD Guideline 208
	No obviously distinguishable unwanted residues	-	-
	No loss of quality in comparison with blank compost (of same maturity)	-	-
	-	Chemical characterisation of the compost: Volumetric weight, total dry solids, volatile solids, salt content, pH-value Nutrient content (N, NH <sub>4</sub> -N, P, Mg, Ca)	-

***Determination of ultimate anaerobic biodegradability***

Testing of ultimate anaerobic biodegradability is an option in testing to EN 13432. If performed, tests may be undertaken in accordance with ISO/DIS 15985, ISO 11734 or ISO/DIS 14853. Within 2 months, a percentage of biodegradation of not less than 50 % shall then be achieved.

## Use of the compostability standards in various certification systems for compostable materials and products

### *Status quo*

The standards referred to in the previous section are used by various organisations offering world-wide certification schemes for compostable materials. Table 6 gives an overview of these. This table, which makes no claim to be complete, clearly indicates the large number of standards and procedures currently applied. In addition, all organisations implement various special arrangements which are not described here.

**Table 6** Certification bodies and schemes for compostable materials

Organisation (location)	DIN CERTCO IBAW (Germany)	AIB Vinçotte (Belgium)	Biodegradable Products Institute / US Composting Council (USA)	Jätelaito- syhdistys (Finland)	Biodegradable Plastics Society (Japan)
Logo					
Chemical characteri- sation	DIN V 54900 or EN 13432 or ASTM D 6400	EN 13432	ASTM D 6400	EN 13432	GreenPla certification scheme
Determination of ultimate biodegrada- bility	DIN V 54900 or EN 13432 or ASTM D 6400	EN 13432  ISO 14851  ISO 14852	ASTM D 6400	EN 13432  ISO 14851  ISO 14852	OECD 301C  JIS K 6950 (ISO 14851)  JIS K 6951

		ISO 14855		ISO 14855	(ISO 14852) JIS K 6953 (ISO 14855)
Determination of compostability (disintegration)	DIN V 54900 or EN 13432 or ASTM D 6400	EN 13432	ASTM D 6400	EN 13432	-
Compost quality	DIN V 54900 or EN 13432 or ASTM D 6400	EN 13432	ASTM D 6400	EN 13432	-
Additional tests	-	Mechanical stability of bio-waste bags	-	-	-

### ***Relevance of EN 13432***

Especially important for the European market is the adoption of the European standard EN 13432 by the European Commission. Products legally manufactured or marketed in one country of the European Union should in principle move freely throughout the community, if such products meet equivalent levels of safety. To achieve this aim a new regulatory technique and strategy was laid down by the Council Resolution of 1985 on the New Approach to technical harmonisation and standardisation, which established the following principles:

- Legislative harmonisation is limited to essential requirements that products placed on the Community market must meet, if they are to benefit from free movement within the Community.
- The technical specifications of products meeting the essential requirements set out in the directives are laid down in harmonised European standards.
- Application of harmonised European standards or other standards remains voluntary, and the manufacturer may always apply other technical specifications to meet the requirements.

- Products manufactured in compliance with harmonised European standards benefit from a presumption of conformity with the corresponding essential requirements

For compostable materials and products this means that it is assumed that any product that fulfils the requirements of EN 13432 also fulfils the basic requirements for compostable packaging as they are laid down in the Directive on Packaging and Packaging Waste (94/62/EC). However this does not mean that EN 13432 is the only standard that would guarantee the fulfilment of the basic requirements for compostable packaging as they are laid down in the Directive on Packaging and Packaging Waste. Other standards may be applicable as well but the legal assumption that other standards would fulfil the basic requirements for compostable packaging as they are laid down in the Directive on Packaging and Packaging Waste is not made. The manufacturer has to prove that other standards are equally applicable.

### ***Outlook on future developments***

The various test and certification requirements that the compostable material sector must meet are increasing. In order to avoid unnecessary expense and to strengthen the confidence of consumers in the new technology of compostable materials, common standards and certification schemes should be developed.

In the standardisation committees of ISO activities are going on to develop international standards on the test procedures for compostable materials and products and the definition of pass-levels that would have an international consensus. The development of harmonised test procedures is relatively easy and many test methods are already published as ISO standards. To find a consensus on the pass-levels for compostable materials and products will probably take more time.

In order to facilitate trade and to promote the use of compostable materials and products, several leading certification organisations are currently discussing possibilities for intensifying their co-operation. Representatives from test institutes and certification bodies in Belgium, Japan, Germany, the USA, France, Sweden and Finland agreed on a step by step approach. The separate stages would be the mutual recognition of testing laboratories and test reports, efforts to harmonise the standards and procedures, mutual recognition of certificates, and even a uniform logo for products made of compostable materials. Memorandums of Understandings have been signed between DIN CERTCO (Germany), BPI (USA), and BPS (Japan). Currently intense negotiations on the mutual recognition of testing laboratories and test reports are going on.

## Summary

Now that many test standards have been developed, it will be necessary in future to place these standards on a recognised international basis and to create generally accepted certification schemes. That will require close co-operation with a view to implementing an efficient and generally accepted testing and certification system for the compostable materials sector that precludes the need for having to repeat tests for separate national markets. The benefits to consumers of global standards and products that can be trusted are obvious.

## Literature

### *EU directives, laws and regulations*

Directive 94/62/EEC on packaging and packaging waste, OJ No. L 365 of 31.12.1994

Regulation on the use of bio-waste on soils used for agriculture, forestry and horticulture,

Bio-waste regulation (BioAbfV) of 21.9.1998, Federal Legal Gazette Part I No. 65, 1998

### *Standards*

**ASTM D 5338**, Standard Test Method for Determining Aerobic Biodegradation of Plastics Materials Under Controlled Composting Conditions, September 1998

**ASTM D 6002**, Standard Guide for Assessing the Compostability of Environmentally Degradable Plastics, October 1996

**ASTM D 6400**, Standard Specification for Compostable Plastics, May 1999

**EN 13432** Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging - December 2000

**EN ISO 11734**, Water quality - Evaluation of the "ultimate" anaerobic biodegradability of organic compounds in digested sludge - Method by measurement of the biogas production, November 1998

**DIN V 54900-1** Testing of compostability of plastics - Part 1: Chemical testing, October 1998

**DIN V 54900-2**, Testing of the compostability of plastics - Part 2: Testing of the complete biodegradability of plastics in laboratory tests, September 1998

**DIN V 54900-3**, Testing of the compostability of plastics - Part 3: Testing under practice-relevant conditions and a method of testing the quality of the composts, September 1998

**E DIN 54900-4** Testing of the compostability of polymeric materials – Part 4: Testing of ecotoxicity of composts, January 1997

- ISO 14851**, Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium – Method by measuring the oxygen demand in a closed respirometer, May 1999
- ISO 14852**, Determination of the ultimate aerobic biodegradability of plastics materials in an aqueous medium – Method by analysis of evolved carbon dioxide, May 1999
- ISO 14855**, Determination of the ultimate aerobic biodegradability and disintegration of plastic materials under controlled composting conditions – Method by analysis of evolved carbon dioxide, May 1999
- ISO/DIS 14853**, Plastics-Determination of the ultimate anaerobic biodegradability in an aqueous system – Method by measurement of biogas production, April 1999
- ISO/DIS 15985**, Plastics-Determination of the ultimate anaerobic biodegradability and disintegration under high-solids anaerobic-digestion conditions - Method by analysis of released biogas, April 1999

### ***OECD Guidelines***

- OECD Guidelines for the Testing of Chemicals 201, Algae Growth Inhibitor Test, June 1984
- OECD Guidelines for the Testing of Chemicals 202, *Daphnia* sp. Reproduction Test, April 1984
- OECD Guidelines for the Testing of Chemicals 203, Fish Acute Toxicity Test, July 1992
- OECD Guidelines for the Testing of Chemicals 208, Terrestrial Plants, Growth Test, April 1984
- OECD Guidelines for the Testing of Chemicals 301, Ready Biodegradability, July 1992

### ***Certification schemes***

- AIB Vinçotte, Initial acceptance test with regard to OK Compost conformity mark, January 1999
- AIB Vinçotte, Initial acceptance test with regard to the VGS conformity mark, May 1999
- Biodegradable Plastics Society, GreenPla Identification and Labeling System, April 2000
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- Biodegradable Plastics Society, Rules for Positive List, April 2000
- Biodegradable Plastics Society, Test Methods Necessary for PL Listing, April 2000
- DIN CERTCO, Certification scheme – Products made of compostable materials (3rd revision), July 2001
- International Biodegradable Products Institute / United States Composting Council, Certification Program for Products Made of Compostable Plastics - Program Rules, September 1999