Tackling Standardisation:
What are biodegradable plastics ?

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Moving towards a universal definition

Universal definitions of technical properties are a valuable item for international trade. Imagine the following situation. A producer in Country A wants to purchase screws. He needs them to build his product. With a universal definition for screws asking a supplier if he can deliver an M6 screw is a fairly easy task. Without this definition, the process to procure screws easily becomes awkward. International standards are such universal definitions that enhance international trade.

Economic benefits of standardisation

The economic benefits of standardisation in general have been subject of a research project of the German Institute for Standardisation (DIN).
"Company standards have the greatest positive effect on businesses, for they help improve processes. When it comes to the relationship with suppliers and customers, however, industry-wide standards are the main instruments used to lower transaction costs and assert market power over suppliers and customers. In fact, industry-wide standards play a vital role in our increasingly globalised world. 84% of the companies surveyed use European and International Standards as part of their export strategy, in order to conform to foreign standards" (p. 4, DIN 2001).
"From a macroeconomic perspective, it is significant that standards make a greater contribution to economic growth than patents or licences, that export-oriented sectors of industry make use of standards as a strategy in opening up new markets, and that standards help technological change" (p. 4, DIN 2001).

Macroeconomic benefits include for example:

- Reduced costs to comply with foreign standards
- Reduction of transaction costs
- Easier contract development
- Reduction to barriers of trade

- Diffusion of innovations

As a whole these economic benefits of standardisation sum up to 16 billion € per year for Germany. Standardisation creates approximately one third of the economic growth (DIN 2000).
Of course standardisation is not for free. Costs for standardisation within the system of the German Institute for Standardisation are app. 770 Million € (DIN 2000). Companies have to contribute with money and experts to the standardisation process. But the individual costs for companies active in standardisation also translate into specific benefits:

- Influence on the content of a standard
- Competitive edge in the implementation of standards (timing and knowledge)
- Substitution for state regulation
- Use of economic power on the market (towards suppliers or customers)
- Reduction of R&D risks
- More security (product liability)

A universal definition for compostable materials

Nearly everybody knows the standard definitions of screws or papers (DIN-A-4) but standards for compostable materials are not so well known in the general public although such standards exist. Precise definitions can be found in the international standard ISO 14021:

- Degradable: “A characteristic of a product that, with respect to specific conditions, allows to break down to a specific extent within a given time.”
- Compostable: “A characteristic of a product that allows it to biodegrade, generating a relatively homogeneous and stable humus-like substance.”

Additional standards elaborate these definitions e.g. for compostable materials. Currently DIN V 54900, EN 13432 and ASTM D 6400 are the relevant standards for the determination of compostability. Each of these standards is being applied by a number of certification organisations in the testing and assessment of compostable products and materials. The above-mentioned standards are very similar in their general construction, the applicable tests and the necessary pass levels.

Comparison of standards for assessing compostability

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. They differ i.a. in respect to the limit values for hazardous substances (cf. Table 1). 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 1). ASTM D 6400 permits the highest concentrations of hazardous substances.

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

	DIN V 54900-1	**EN 13432**	**ASTM D 6400**	**GreenPla**
	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 2 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 2 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.

Table 3 Overview of disintegration tests

Standard	**DIN V 54900**	**EN 13432**	**ASTM D 6400**
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 4 Methods of determining compost quality

Standard	**DIN V 54900**	**EN 13432**	**ASTM D 6400**
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_4-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.

Promoting clarity in standards and regulations

Experience has however shown that because of the relatively limited knowledge about these standards, end users or buyers of compostable materials where confronted with lots of other standards. Among these were for example the following ones:

- BS 6642 “Specification for disposable plastics refuse sacks made from polyethylene”
- ASTM D 1238 “Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer (Melt Index)"
- BS 6085 “Methods for determination of the resistance of textiles to microbiological deterioration”

However, none of these standards allows an assessment of the compostability of these products. It is therefore needed that e.g. experts, leading manufacturers and also certification bodies take the necessary steps to make the existing standards on compostability like DIN V 54900, EN 13432 or ASTM D 6400 known.

Next steps for a truly universal definition

Of course the standards for the evaluation of compostable materials (DIN V 54900, DIN EN 13432, and ASTM D 6400) however similar are not a truly universal definition. DIN V 54900 is a German standards, EN 13432 is a European standard and ASTM D 6400 is an U.S. standard. An international standard should be developed for a truly universal definition.
This must not be a long road. Most of the used test methods are already harmonised at an international level, like 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", ISO 14852 "Determination of the ultimate aerobic biodegradability of plastics materials in an aqueous medium – Method by analysis of evolved carbon dioxide" or ISO 14855 "Determination of the ultimate aerobic biodegradability and disintegration of plastic materials under controlled composting conditions – Method by analysis of evolved carbon dioxide"
The harmonisation of the pass-levels may be the only obstacle on the way towards a universal definition for compostable materials and products.

Assessing the need for a multi-disciplinary approach

For the testing of compostable materials a multidisciplinary approach is already used. Some factors that influence the standard development are listed in Table 5. This table shows in a certain way also how much know-how was already put into the standard development.

Table 5 Overview on disciplines involved in standard development

Area of testing	Detailed analysis	Needed qualification
Characterisation	Heavy metal testing	Chemical Analysis
	Setting of heavy metals limits Evaluation of results	Toxicity Environmental Sciences
Determination of ultimate biodegradability	Testing for complete biodegradation	Microbiology
Determination of compostability (disintegration)	Testing for disintegration	Microbiology Process Engineering
Analysis of the quality of the compost	Testing for the quality of compost	Toxicity Agricultural Sciences
Determination of ultimate anaerobic biodegradability (not obligatory)	Testing for ultimate anaerobic biodegradation	Microbiology Process Engineering
Control tests	Measurement and Assessment of IR-Transmission-Spectra	Chemical Analysis

This multidisciplinary approach was needed and will be needed in order to continue the development of standards for the testing of compostable materials. Especially a look at the potential future development will show the evidence for the continuation of this multidisciplinary approach. At the moment the development of specific standards for specific environments in which biodegradable materials shall disintegrate is being discussed. These environments could include:

- Composting Environment
- Sea Water
- Fresh Water
- Soil
- (Human tissue)

This simple punctuation makes it clear that experts for other fields will have to be included in the future standard development, like e.g. marine scientist. The standardisation process as used by DIN is trying to gain the benefits from a multidisciplinary approach by the participation of all interested parties.

Harmonising the labelling process with the standards in place

For compostable materials having a universal definition that will be continuously refined in a multidisciplinary approach is a valuable asset. For screws having this universal definition is already enough to achieve the benefits outlined in the first chapter. For compostable materials and products however having a universal definition might not be enough. The difference between screws and compostable products is that the inherent characteristic of compostable materials is invisible to the normal eye. A potential buyer cannot see easily if a product is really compostable whereas a user of a screw can easily check if it fits or not. This example should make it clear that something more than just a universal definition may be needed for compostable products. These needed additional benefits can be obtained through certification:

- Easy recognition of products
- Trust into the new products
- More security in product liability
- Use of a known and recognised mark

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)
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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 ISO 14855	ASTM D 6400	EN 13432 ISO 14851 ISO 14852 ISO 14855	OECD 301C JIS K 6950 (ISO 14851) JIS K 6951 (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	GreenPla certification scheme
Compost quality	DIN V 54900 or EN 13432 or ASTM D 6400	EN 13432	ASTM D 6400	EN 13432	GreenPla certification scheme
Additional tests	-	Mechanical stability of bio-waste bags	-	-	-

DIN CERTCO (Germany), BPI (USA), and BPS (Japan) have already signed a co-operation agreement on the mutual recognition of testing laboratories and test reports. This means that the goal for one stop testing is within reach. However, the full harmonisation of the certification systems may still take a while i.a. because of different legal systems.

Activities for the creation of certification systems for compostable materials are currently reported from the Netherlands, Spain (Catalunia), Korea, and Taiwan. Negotiations are under way to link the newly created or about to be created certification systems to the ones that are already existing.

Summary

The standardisation process within DIN, CEN and ISO for compostable materials was already successful in creating widely accepted standards for compostable materials. The principle to involve all interested parties in the standardisation work ensured a multidisciplinary approach. The benefits of this standardisation can already be reaped even if future improvements are still needed. And the benefits that cannot be created by a standard or a universal definition alone can be provided by independent third party certification systems, which are converging in terms of used standards and the sharing of results already, which is in turn creating a cost efficient and reliable mechanism to build trust in the new technology of compostable products.

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