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Issue 4

Design for Sustainability with Plastics

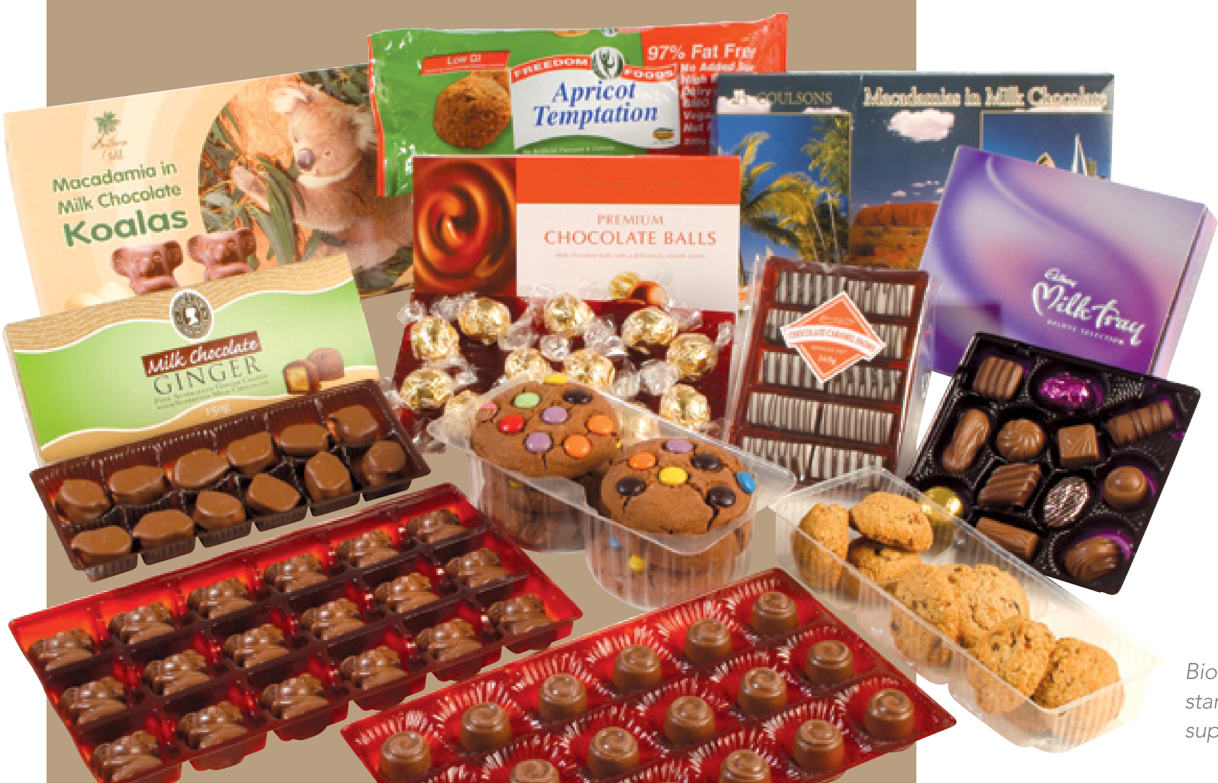
Quickstart

Degradable polymers in product design

This is the fourth in a series of Quickstarts on Design for Sustainability (D4S) with Plastics. It provides an introduction to the effective use of degradable polymers in product design.

The aim of the Quickstart series is to promote the design of products and services that are sustainable - that is, products and services that contribute to social progress and economic growth, as well as providing ecological benefit, throughout their life cycle. The sustainability of a product is largely locked in at the design phase, which is why D4S is so important.

The Quickstarts are written for practitioners at every stage of the plastics product chain, including designers, polymer suppliers, product manufacturers, brand owners and specifiers. The series also supports the implementation of PACIA's Sustainability Leadership Framework (2008), which promotes a whole-of-life approach to product innovation and stewardship and the need for step-change 'transformations' in material and resource use.



Biodegradable and water-soluble starch-based packaging (image supplied by Plantic Technologies)

Biodegradable starch-based packaging (image supplied by Sainsbury's)

The Quickstart series is based on three principles of sustainable design: triple bottom line sustainability, life cycle thinking and step-change transformations. Some of the implications of these for degradable polymers are listed in Figure 1.

Principles

Figure 1: Sustainable design principles and degradable polymers

Sustainable design principle	Implications for design with degradable polymers
Triple bottom line sustainability – considering the long term benefits and impacts on human health and quality of life, commercial feasibility, and the natural environment	• A degradable polymer (like any other material) needs to be 'fit for purpose', i.e. it must achieve functional requirements and only degrade after disposal. • Some degradable polymers are more expensive than conventional polymers. The additional expense may be justified where they offer enhanced value. • The environmental benefits of degradable polymers need to be evaluated on a case-by-case basis, depending on the polymer, the application and the disposal environment. • Plant-based raw materials may be contributing to global demand and increasing prices for some food crops.
Life cycle approach – considering the benefits and impacts of a product within the context of its total life cycle	• The environmental impacts of degradable polymers need to be considered over the entire life cycle, not just at end-of-life. • Plant-based raw materials generate impacts associated with agriculture, e.g. land clearing, fertiliser and pesticide use. • Degradable polymers generate methane if they break down anaerobically in landfill. • A compostable polymer which meets relevant Standards will break down into compost, which is beneficial in many agricultural and horticultural applications.
Step-change transformations – developing new and innovative ways to deliver product value with significantly less environmental impact	• Degradable polymers have unique properties which provide opportunities for innovation.

Biodegradable starch-based packaging (image supplied by Garden Express)

Degradable polymers fall into several broad categories according to the triggers that are required for degradation, such as the presence of microorganisms, heat and water. The availability of these triggers will depend on where the product is disposed of, i.e. the end-of-life environment (see Figure 2).

Degradation pathways and impacts

Composting

If a product is intended to be disposed of in a commercial or home composting system, then it needs to be both biodegradable and compostable.

Biodegradable polymers are those capable of being broken down by microorganisms in the presence of oxygen (aerobic) to carbon dioxide (CO_2), water, biomass and mineral salts or any other elements that are present; or in the absence of oxygen (anaerobic) to CO_2, methane, water and biomass[2].

Biodegradable polymers that are suitable for composting need to meet specific requirements, which are established in Australian and International Standards, to ensure that the break-down products and the speed of degradation are compatible with the composting process. For example, in a commercial composting facility, a product needs to degrade at least 90% by weight within a 12 week period, with minimal eco-toxicity impacts[3].

Commercial composting is still in its infancy in Australia. However, between 30% and 50% of households compost their kitchen scraps at home[4].

If a product is likely to end up in an anaerobic digester—which is designed to generate renewable energy from biogas and compost as a residual product—then it only needs to degrade by 50% within a 2 month period[5].

Disposal on soil

If a product is likely to be disposed of on soil, then a biodegradable or oxodegradable polymer might be appropriate.

Oxodegradable polymers are conventional polymers that undergo controlled degradation through the addition of a catalyst which can trigger and accelerate the degradation process. These polymers start to break down through exposure to natural daylight, heat and/or mechanical stress.

Littering is a complex problem created by a mix of consumer behaviour and inadequate infrastructure including bin type, location and recovery services. Products made from degradable polymers can take a long time to degrade, particularly if they do not come into contact with necessary triggers such as water and microorganisms. Litter groups are concerned that these products may encourage some consumers to litter in the belief that the products will break down[6].

Degradable polymers are unlikely to break down in a dry landfill environment, or will degrade extremely slowly, because there is limited exposure to sunlight, heat and water. They degrade more completely in wet 'bioreactor' landfills[7].

Disposal in water

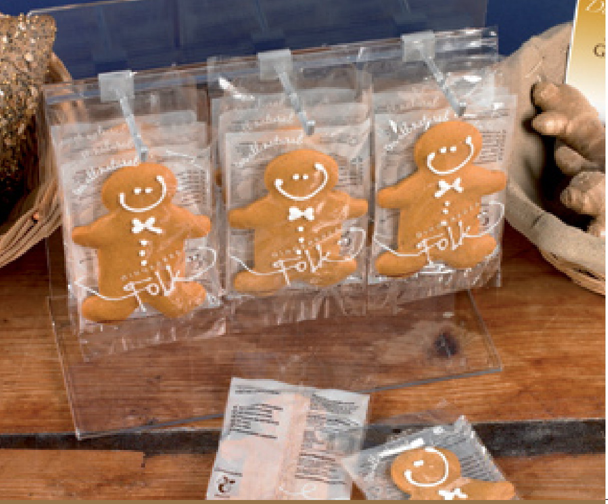
Water soluble polymers—those which are capable of dissolving in water—will break down in marine and freshwater environments. They are also used in industrial applications for environmental, economic, and occupational health and safety reasons[8].

Biodegradable polymers are also used in applications which may end up in water as litter, such as bait bags. However, there are still some concerns about the impact of these on marine animals because they take some time to break down[9].

Figure 2: Types of degradable polymers by end-of-life environment[1]

End-of-life environment	Category	Degradation triggers	Performance standards
Commercial compost	Compostable	Bacteria, heat, water	AS 4736, EN 13432
Home compost	Compostable	Bacteria, heat, water	AS to be developed
On soil (e.g. mulch)		Sunlight, UV, heat, water	AS to be developed
Marine water		Sunlight, UV, water	AS to be developed
Fresh water		Sunlight, UV, water	AS to be developed

Abbreviations: AS = Australian Standard. EN = European Standard.



Biodegradable cellulose-based packaging (image supplied by Gingerbread Folk)

Design strategies

Selection of a degradable polymer

A degradable polymer is only appropriate for a particular application if it adds social, economic or commercial value during use and/or disposal; and the functional and mechanical properties of the product are not compromised.

However, it is critical that at end-of-life, products made from degradable polymers degrade in the right place and at the right time. The potential for the product to contaminate an existing recycling stream should also be considered. If a collection system already exists for similar products (e.g. plastic bags or bottles), plastic recyclers will need to be consulted to minimise any cross-contamination.

Raw material suppliers and product manufacturers can guide the decision on the most appropriate degradable polymer to use, based on a good understanding of commercial requirements and the likely end-environment, i.e. commercial or home compost, soil, marine water or fresh water.

Product design

The product should be designed in such a way that it will not compromise the degradation of the polymer. For example, coatings, pigments, blends with conventional polymers, and thicker walls may interfere with degradability and compost certification. Heavy metals in pigments and printing inks, e.g. lead, cadmium, mercury or chromium, could also have eco-toxicity impacts. Potential risks should be assessed to minimise any ecological or health effects during manufacture, use or disposal.

Labelling

Any environmental claims on the product should be clear, accurate and verifiable and in accordance with AS/NZS ISO 14021:2000 *Environmental labels and declarations – self-declared environmental claims.*

Figure 3: Key steps for good design with degradable polymers[10]

Consider how degradable plastics can add value against the triple bottom line	• Commercial viability • Social responsibility	• Environmental quality
Consider the environments where degradable plastics are expected to end up	• Terrestrial environment – eg. composting, in soil, above the ground, litter • Aquatic environment – eg. freshwater, marine environment, seawater • Will it float or sink?	• Wastewater – domestic, commercial and trade waste • Will it contaminate any recycling streams? • Discuss any concerns with recyclers and consider product labelling
Select a shortlist of materials, for example:	• Compostable to AS 4736 or EN 13432 • Oxodegradable	• Hydrosoluble
Determine the functional product requirements	• What end-of-life environment is it likely to break down in?	• How fast or slow does it need to break down? • How will the material be processed?
Select the best degradable plastic for the application	• Design the product to meet degradability standards	• Avoid dispersion of toxic substances into the environment
Consider issues that may reduce degradability	• Wall thickness • Multiple materials	• Pigments and coatings (particularly heavy overprinting or lacquers)
Consider issues that may increase environmental impact	• Heavy metals in pigments, eg. lead, cadmium, mercury, chromium	• Heavy metals in printing inks • Degradable residues
Proceed with product development		
Design, labelling and information	• Comply with Trade Practices Act and AS/NZS ISO 14021 for environmental claims • Claims should be accurate and not misleading	• Consumers should be advised on preferred end-of-life environments for disposal

An overview of degradable polymers

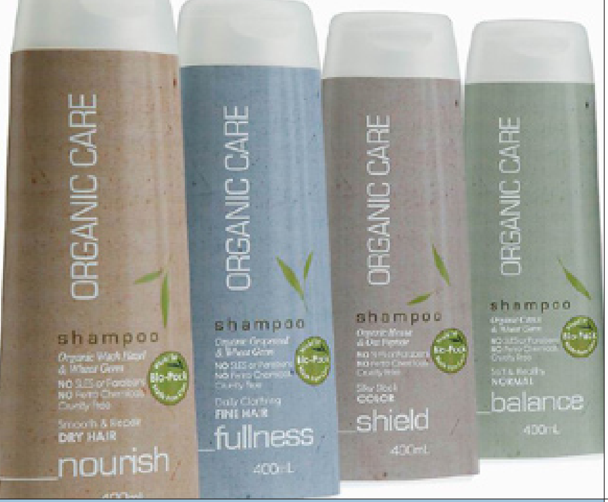
Figure 4 provides a brief overview of some of the degradable polymers that are currently used in Australia. Most manufacturers provide a range of polymer grades which are suitable for different applications – designers and manufacturers should discuss their specific requirements and expectations with suppliers.

Figure 4: Characteristics of degradable polymers

Type of polymer	Trade names	Characteristics	Typical applications	Raw materials	Degradation triggers
Biodegradable starch-based polymers	Mater-Bi™ (Novomont, Italy)	Suitable for most manufacturing processes, anti-static, can be sterilised using gamma rays, permeable to water vapour, certified to EN 13432, meets the requirements of AS 4736	Bags, food service cutlery, mulch film, nappies, paper coating	Starch from corn, potato or wheat, combined with biodegradable polyesters through a reactive compounding process	Micro-organisms, heat, water
	Biograde™ (Biograde, China)	Different grades available for blowing film and injection-moulding, good mechanical strength, certified to AS 4736, EN 13432 and ASTM D6400	Blown film and bags, cutlery, golf tees, caps and closures	Thermoplastic starch from corn, blended with biodegradable polyesters and natural plasticisers	Micro-organisms, heat, water
Biodegradable and water soluble starch-based polymers	Plantic (Plantic Technologies, Australia)	Can be thermoformed and injection-moulded, oil resistant, heat sealable, good gas and odour barrier, certified to EN 13432	Thermoformed biscuit and chocolate trays; injection moulded products for various applications; film grade resin being developed	Primarily consists of thermoplastic starch from corn; all products are of highest renewable content in comparison to competitive products in the class	Micro-organisms, heat, water
Biodegradable cellulose-based polymers	NatureFlex™ (Innovia Films)	Clear, very good dead-fold, transparency and gloss, heat sealable, good gas barrier, can be re-heated in a microwave or oven, certified to EN 13432	Film wrap for bakery products, confectionary and fresh produce	Wood pulp from managed plantations	Micro-organisms, heat, water
Biodegradable polyesters	Polylactic acid (PLA) - Ingeo® (Nature Works LLC, United States)	Suitable for most manufacturing processes, clear or opaque, stiff or flexible, tough, good stiffness, oil resistant, good odour barrier, heat sealable, certified to EN 13432	Food service containers, drink cups, water bottles, paper coating	Lactic acid, produced by fermenting dextrose from corn	Micro-organisms, heat, water
	Aliphatic aromatic copolyester (AAC) – Ecoflex (BASF, Europe)	Suitable for film and bag applications, oil resistant, moisture resistant, high tensile strength, heat sealable, certified to EN 13432	Compost bags, garbage bags, general packaging films, agricultural mulch films, coating for food service packaging made from corn starch, paper or PLA	Crude oil or natural gas	Micro-organisms, heat, water
Oxo-biodegradable additives	d2w® (Symphony Environmental)	A small percentage (typically 1%) added to PE, PP or PS during extrusion to facilitate controlled degradation	Flexible and semi-rigid products, e.g. shopping bags, landfill cover, mulch film, bubble wrap, news wrap	Carrier resins (PE, PP or PS) from crude oil or natural gas; prodegradant additive from a transition metal salt	Oxidation triggered by sunlight, heat, mechanical stress; followed by micro-organism activity
	TDPA (EPI, Canada, China)	As above	Blown film and bags, injection-moulded products	As above	As above

Information provided by third parties and no endorsement implied.

Abbreviations: PE = polyethylene. PP = polypropylene. PS = polystyrene.
AS = Australian Standard. EN = European Standard.
ASTM = American Society for Testing and Materials



Biodegradable Polylactic acid bottles (image supplied by Nature Works)

The Quickstart series is part of the 'Design for Sustainability with Plastics' program managed by a collaborative partnership between Sustainability Victoria and PACIA. The Quickstart series can be downloaded from www.pacia.org.au.

Standards and certification

There are a number of Standards for biodegradable and compostable polymers, which are listed on the D4S page of PACIA's web site at www.pacia.org.au.

Materials that have been independently verified by third parties as conforming to Australian or international Standards are listed on the degradable polymers page of the PACIA web site.

Further information

Reports

ExcelPlas, RMIT and Nolan-ITU 2003, *The impacts of degradable plastic bags in Australia*, Report to Department of Environment and Heritage, www.environment.gov.au/settlements/publications/waste/degradables/impact/pubs/degradables.pdf

PACIA 2007, *Using degradable plastics in Australia: a product stewardship guide and commitment*

Organisations and web sites

Australian Bioplastics Association (information on membership and their Code of Conduct): www.bioplastics.org.au

Biopolymer.net (information on degradable polymers and links to other resources): www.biopolymer.net

PACIA (to download the product stewardship guide for degradable polymers, to access a list of certified degradable polymers and for the D4S toolbox): www.pacia.org.au

Sustainability Victoria (to download a range of D4S resources): www.sustainability.vic.gov.au

Publication details

Quickstart: Design for Sustainability with Plastics was prepared by Helen Lewis Research for Sustainability Victoria and the Plastics and Chemicals Industries Association (PACIA) with input and advice from practitioners and others involved in the sector.

Footnotes

1 Based on PACIA (2007), *Using degradable plastics in Australia: a product stewardship guide and commitment*, p. 14.

2 Standards Australia (2006), AS 4736-2006: *Biodegradable plastics—biodegradable plastics suitable for composting and other microbial treatment*, p. 5.

3 Standards Australia, *Ibid.*

4 Ipsos (2005), *2004 Waste disposal and recycling community survey*, report to EcoRecycle Victoria, p. 31; ABS (2003), *Cat. 4602-Environmental issues: people's views and practices*, p.14.

5 Standards Australia, *Ibid*, p. 8.

6 ExcelPlas, RMIT and Nolan-ITU, 2003, *The impacts of degradable plastic bags in Australia*, Department of Environment and Heritage, Canberra, pp. 61-63.

7 These are increasingly used as an alternative waste technology. For example, Veolia has built two bioreactor landfills, one at Woodlawn in NSW and one near Ipswich in Queensland. They are designed to accelerate degradation and maximise the capture of methane for green energy. (www.veoliaes.com.au/recycling-services/resource-recovery-facilities/bioreactor-landfills.asp).

8 For example, polyvinyl alcohol (PVOH) is used for laundry bags in hospitals and nursing homes. The bags are sealed and put directly into a washing machine, where they dissolve completely. This avoids the need for further handling of infected or soiled linen. They replace conventional cotton laundry bags, which require washing after use, or plastic bags, which require safe disposal with other contaminated waste.

9 ExcelPlas *et al, Ibid*, pp. 61-63.

10 PACIA, *Ibid*, p. 12