Biodegradable plastics in the UK – past, present and future

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The UK plastic heritage (BPF, 2012)

- 1832 - Charles Macintosh
  - The invention of ‘Mac’: mixture of India-rubber, naphta and cloth.
- 1850 - Gutta-Percha
  - Type of latex extracted from trees.
- 1862
- Parkesine, first man-made plastic from cellulose
  - Alexander Parkes
- In 19th century it was the UK created the commercial plastic industry
- 1933 : Discovery of polyethylene.
- 1980 - ICI Biopol
The UK plastic industry – KEY FACTS
(British Plastic Federation, 2012)

- the UK plastic manufacturing is big
- ~ 7% of total UK manufacturing activity
- 2.5 million tonnes of plastic materials in produced in the UK
- 7,500 companies
- 180,000 people employed
- £ 13.1 billion sales turnover
Introduction

- Plastics derived from petrochemicals have earned for themselves a dominant position.

- Plastics have many attractive features such as:
  - flexibility and versatility
  - strength and excellent barrier properties

- They also enjoy a significant cost advantage when compared to any number of their competitors.
A modern world enabled by plastics
Problems with plastic

- Plastic litter affects the oceans and the coastlines.

- Plastics use valuable resources of oil
  - ~ 4% of the world’s oil production

- 40% ends up as non-biodegradable waste in the environment.

- Some can leach small amounts of pollutants, toxic to animals and humans.
Plastic problem in the UK

- The final disposal of such materials continues to pose a growing problem for authorities at both the local and national level.

- UK government is committed to a greenhouse gas (GHG) reduction target of 80% from 1995 levels by 2050 (http://www.bpf.co.uk)
Tax for each plastic bag?

- England plastic bag tax plan?

- Liberal Democrat sources say the tax in Wales led to a drop of roughly 75%, and in N. Ireland by 80%. Retailers in Scotland will start charging for bags in October 2014

(source BBC News 14 Sept 2013)
Plastic consumption in the UK by application

http://www.bpf.co.uk/Industry
What are bioplastics?

- Bioplastics are partly or wholly made from biological materials.

Definition of the European Plastics association:

- Biodegradable and compostable polymers according to standards (EN 13432 a.o.)
- Bio-based polymers: use of renewable raw materials
Bioplastics can be:

Biodegradable / compostable but NOT bio-based e.g.:
- Synthetic Polyesters

Biodegradable / compostable AND bio-based e.g.:
- **Natural bio-based polymers** – synthesised by living organisms
  - Starch/Cellulose
  - Polysaccharides
  - Proteins
    - Polyhydroxyalkanoates (PHA)
- **Synthetic bio-based polymers** – monomers derive from renewable resources but a chemical transformation is needed for conversion to a polymer.
  - poly(lactic acid) PLA

Bio-based but non-biodegradable e.g.:
- PE from Bioethanol
- PVC from Bioethanol
- PP from Bioethanol
- Polyamides

http://www.bpf.co.uk/Topics/Biobased_and_Degradable.aspx
Bio-based & biodegradable plastics

- Used in a variety of applications to replace petroleum-based plastics
- Most bio-based plastics used in Europe today are starch-based.
- Starch bio-based bioplastics in the UK are used to manufacture:
  - refuse and carrier bags
  - food and consumer goods packaging

Source: [http://www.bpf.co.uk/Plastipedia/Polymers/Biobased_plastics_Feedstocks_Production_and_the_UK_Market.aspx](http://www.bpf.co.uk/Plastipedia/Polymers/Biobased_plastics_Feedstocks_Production_and_the_UK_Market.aspx)
Bioplastic market

- Bioplastics have experienced fast growth in the past decade due to:
  - public concerns over the environment,
  - climate change,
  - and the rising cost of fossil fuels.

- Global bioplastics production is set to grow by 500% by 2016.

Biodegradable plastic market

**Bioplastic market** remains small compared to that of fossil-based polymeric materials
- currently accounting for less than 0.5% of all plastics manufacture

**BUT** the significance of bioplastics in the European bio-economy is not controversial.

**Consumers** – people are becoming progressively more ecologically aware.

**Industry** – plastics manufacturers within the UK are introducing biodegradable materials into their product portfolios supporting the move towards green packaging.
ICI and Biopol

- In the 1980s, the British chemical company, Imperial Chemical Industries (ICI) developed and created PHA co-polyester under the trade name Biopol.

- However, the interest in the future development of PHA polymers faded when it became clear that the cost of this material was too high, and its properties could not match those of synthetic plastics.

- ICI patents were sold in 1996. In 2005 Metabolix in the US developed novel methods for production of PHAs, including PHB.
Microbial polyhydroxyalkanoates (PHA)

- Are produced by Gram positive and Gram negative bacteria as a carbon and energy storage material
- Synthesized as intracellular granules
- Accumulated as a result of nutrient limitation in the presence of excess supply of carbon source

Bacterial synthesis of biodegradable polyhydroxyalkanoates

Energy, Oxygen, Water → Fermentation
Carbon sources (sugars, lipids) → Plants
Sunlight → Carbon dioxide

Extraction, Purification → PHAs (polyhydroxyalkanoates)
Moulding → Bioplastic products (packaging, implants, etc.)
Recycling → Composting

Journal of Applied Microbiology
Volume 102, Issue 6, pages 1437-1449, 10 APR 2007 DOI: 10.1111/j.1365-2672.2007.03335.x
Bacterial PHB

- White crystalline powder
- High molecular weight and melting point (~180 °C)
- Biodegradable and non-toxic
- **BUT** rather brittle

Solution: Copolymerization

PHBV Biopol

Adapted from:
Copolymers


Different monomers

\[
\begin{align*}
\text{CH}_2\text{CH}_3 & \quad \text{3-hydroxyvalerate} & \text{PHBV} \\
\text{CH}_2\text{CH}_2\text{CH}_3 & \quad \text{3-hydroxyhexanoate} & \text{PHBHx}
\end{align*}
\]

Mixed carbon sources needed
Better properties so commercially more attractive

Adapted from:
Future

- To investigate new cheap organic sources for production of biodegradable plastics to significantly reduce production costs and improve their performance.

- To investigate microbes for production of biodegradable plastics
  - can poly-γ-glutamic acid – bacterial biopolymer be of commercial interest?
  - what about bacterial cellulose?

- To produce decomposable and recyclable bioplastic from the thin wrappers found in eggshells.
Bacterial bioplastics from vegetable frying oil

Work by a research team at the University of Wolverhampton, UK suggests that using waste cooking oil as a starting material for the production of bioplastic can reduce production costs significantly.
Bioplastic from eggs?

University of Leicester in the UK developed bioplastic from extracted eggshell proteins called glycosaminoglycans.

- Material natural, fully biodegradable and recyclable
- Can also be used for agricultural compost
- Eggshell is a waste product
  - disposal poses a significant economic problem for food companies

Application is in the packaging sector.

Bacterial cellulose

Produced by:
- Acetobacter sp,
- Pseudomonas sp.
- Rhizobium sp.

Properties:
- unique properties
- high water holding capacity
- high crystallinity
- ultrafine fibre network
- high tensile strength
- bacterial polysaccharide is secreted free of lignin, pectin, hemicelluloses.

Bacterial cellulose pellicle produced by ATCC 10245 G. xylinus strain in static culture

Andrade et al. 2010
UK companies are now:

- Increasingly employ industrial biotechnology to produce biodegradable food packaging from biological materials rather than petroleum.
  - Flying the (potato) flag for UK biotechnology at Westminster 2013
  - Biome Bioplastics (UK) Ltd. has focused on using potato starch for the production of bioplastics.
    - Biome Bioplast TPS made of greater than 85% starch
  - Biome Bioplastics Ltd. also investigate the possibility of using lignin, a waste product of the pulp and paper industry, as an alternative source of chemicals for the manufacture of bioplastics.

http://www.packagingeurope.com/Packaging-Europe-News 2013
Future

- The utilization of biological systems for the production of biodegradable materials.
- The research and development of:
  - new methodologies
  - new technological solutions to recycle
- We need to create the necessary conditions to address the urgent threat of pollution to the environment.
Microbes can and will do anything, microbes are smarter, wiser and more energetic than microbiologists, chemists, engineers, and others.

(Perlmon, 1980)

Thank you
References


- http://www.nnfcc.co.uk/bio-based-products/working-groups


- http://www.nnfcc.co.uk/publications/nnfcc-renewable-polymers-factsheet-bioplastics
