An introduction to Biopolymers and their applications in packaging

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Background on Centre

• Established for 25 years
• Focussed on applied research related to biomass
• Funding from competitive bids and commercial
• 22 full time members of staff
Distribution of companies interacting with BEACON based on their SIC codes

- Biotechnology R&D: 23%
- Environmental consulting: 11%
- Educational: 5%
- Forestry: 4%
- Agriculture: 6%
- Food & feeds: 10%
- Food & beverage processing: 13%
- Wood products: 5%
- Pharmaceuticals & chemicals: 6%
- Scientific consulting: 3%
- Knowledge transfer: 3%
- Warehousing & storage: 1%
- Wholesale products: 5%
- Waste management: 5%
BioRefining Technology Transfer Centre

- BC has invested £2M through Welsh Assembly funding to set up a pilot scale facility

Recent investments
- Wet fractionation
- Pulp moulding
Pilot Scale Refiner
Twin screw extruder for formulations
PLASTICS AND BIOPLASTICS
Plastics converter demand main market sectors

Distribution of European (EU28+NO/CH) plastics converter demand by segment in 2016.

Source: PlasticsEurope Market Research Group (PEMRG) and Conversio Market & Strategy GmbH

Total converter demand 49.9 m t

- **39.9%** Packaging
- **19.7%** Building & Construction
- **10%** Automotive
- **6.2%** Electrical & Electronic
- **4.2%** Household, Leisure & Sports
- **3.3%** Agriculture
- **16.7%** Others

(*PlasticsEurope 2017*
Glossary

**PP**
Polypropylene – a recyclable polyolefin that is commonly used for margarine tubs, microwaveable meal trays, also produced as fibres and filaments for carpets, wall coverings and vehicle upholstery (WRAP 2018).

**PET**
Polyethylene terephthalate is a type of polyester that differs from the common one polyethylene terephthalate (PET) as it contains one more methylene group in the aliphatic chain that links the terephthalic moiety (European Commission Joint Research Centre 2013).

**PA**
Polyamides (Nylon) comprise the largest family of engineering plastics with a very wide range of applications. Polyamides are one of the major engineering and high performance plastics because of their good balance of properties. Polyamides are very resistant to wear and abrasion, have good mechanical properties even at elevated temperatures, have low permeability to gases and have good chemical resistance, good dimensional stability, good toughness, high strength, high impact resistance, good flow.

**Starch blends**
The majority of bio-based plastics are currently manufactured using starch as a feedstock (ca. 80% of current bio-based plastics). The current major sources of this starch are maize, potatoes and cassava. Other potential sources include arrowroot, barley, some varieties of flax, millet, oats, rice, sago, sorghum, sweet potato, taro and wheat (BPF 2018).

**PLC**
Polycaprolactone is a biodegradable polymer that is suitable for applications requiring years of stability. In recent years it is becoming of increased interest to manufacturers of medical devices and drug delivery particles (polysciences.com 2018).
**Plastics Pact**

**BY 2025**

100% of plastic packaging to be reusable, recyclable or compostable

**BY 2025**

70% of plastic packaging effectively recycled or composted

**BY 2025**

Eliminate single-use packaging

Take actions to eliminate problematic or unnecessary single-use packaging items through redesign, innovation or alternative (reuse) delivery models.

**BY 2025**

30% average recycled content across all plastic packaging
1.0 Wales Plastic Facts

Wales has achieved great success in recycling and has come a long way in improving the recycling of plastics from households, achieving a 75% recycling rate for plastic bottles. It was also the first nation in the UK to introduce a single use carrier bag charge. However, there’s still work to do.

Key Statistics:
- 400,000 tonnes per annum total plastic waste arising
- Re-processing capacity circa 55,000 tonnes per annum
- 10% recycled plastic used in manufacturing (primarily packaging)
- Around 51% of collected plastic waste is recycled outside of Wales.

How much household plastic is recycled?

<table>
<thead>
<tr>
<th>Plastic Bottle Recycling Rates</th>
<th>UK Average</th>
<th>Wales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic Bottles</td>
<td>57%</td>
<td>75%</td>
</tr>
<tr>
<td>Food Packaging</td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>Bottles</td>
<td>73%</td>
<td></td>
</tr>
<tr>
<td>Other Plastics</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>Films</td>
<td>33%</td>
<td>18%</td>
</tr>
<tr>
<td>Total</td>
<td>33%</td>
<td></td>
</tr>
</tbody>
</table>

Where does Wales’ Plastic Waste Go?

Figure 1 Plastic facts for Wales
Taxes

California city approves 25-cent fee on disposable cups
By OLGA R. RODRIGUEZ  January 24, 2019
Global production capacities of bioplastics 2019 (by material type)

- PLA: 5.6%
- Biodegradable polyesters: 6.6%
- Biodegradable starch blends: 2.4%
- PHA: 1.3%
- Other: 0.5%
- Bio-PA: 1.2%
- PTT: 2.2%
- Bio-PE: 2.5%
- Bio-PET: 76.5%
- Other\(^1\) (biobased/non-biodegradable): 1.2%

Total: 7.85 million tonnes

Biobased/non-biodegradable: 83.6%
Biodegradable: 16.4%

\(^1\)Contains durable starch blends, Bio-PC, Bio-TPE, Bio-PUR (except thermosets), PEF; \(^2\)Biobased content amounts to 30%, increase in volume subject to realisation of planned production facilities; \(^3\)Contains fossil-based PBAT, PBS, PCL; \(^4\)Blend components incl. in main materials; \(^5\)Incl. Newlight Technologies (CO\(_2\)-based); \(^6\)Contains regenerated cellulose (compostable hydrated cellulose foils) and biodegradable cellulose ester

More information: [www.bio-based.eu/markets](http://www.bio-based.eu/markets) and [www.downloads.ifbb-hannover.de](http://www.downloads.ifbb-hannover.de)
**Land use for bioplastics 2014 and 2019**

- **Global land area**: 13.4 billion ha = 100%
- **Global agricultural area**: 5 billion ha = 37%

**Global Agricultural Area**
- **Pasture**: 3.5 billion ha = 70%*
- **Arable land**: 1.4 billion ha = 30%*
- **Food & Feed**: 1.24 billion ha = 26%*
- **Material use including Biofuels**: 106 million ha = 2%*
- **Biofuels**: 53 million ha = 1%*

**Bioplastics**
- **2014**: 0.68 million ha ≈ 0.01%*
- **2019**: 1.4 million ha ≈ 0.02%*

* In relation to global agricultural area
** Also includes approx. 1% fallow land

More information: [www.bio-based.eu/markets](http://www.bio-based.eu/markets) and [www.downloads.ifbb-hannover.de](http://www.downloads.ifbb-hannover.de)
Market Demand

Brands are informed about bio-based materials. 59% said they felt informed about bio-based materials.

Brands are looking for information on how bio-based materials meet performance and availability demands at a competitive price.

To evaluate whether to adopt bio-based materials, 63% said they need more information from suppliers on pricing, 61% on availability and 57% on performance.

Brands are vocal about their use of bio-based materials. 71% said their brand communicated externally on its use of bio-based materials.

Moderate to strong growth expected for bio-based materials. 96% of the brands surveyed expect the bio-based materials market to experience moderate to strong growth by 2025.
Biopolymers- some definitions

• Based on renewable raw materials
  – Agricultural resources: sugar, starch, vegetable oils, cellulose
  – Food residues

• Degradable polymers according to standards
  – Synthetic oil-based polymers with
  – Certain degrees of inherent biodegradability
  – Or chemically modified plastics
Bioplastics (2.05 million tonnes in 2017) represent less than one per cent of the approx 320 million tonnes of plastic produced annually on a global basis.
Anaerobic Bacteria, no fungi

50-60°C
- Chemical pulp
- Starch & Blends
- PLA
- PHA
- PBS

≤35°C
- Chemical pulp
- Starch & Blends
- PHA
- PBS

Aerobic Bacteria & fungi

Thermophilic digestion
- Chemical pulp
- Mechanical pulp
- Starch & Blends
- PBAT
- PLA
- PHA
- PBS

Industrial composting

Mesophilic digestion

Home composting

PBAT
- PHA
- PBS

Starch & Blends

Chemical pulp
- Mechanical pulp
Test Standards

• EN 13432 on industrial compostability.
• The process of biodegradation under aerobic conditions within a time frame of 6-12 weeks.
• The speed of biodegradation depends on the temperature (50-70°C are typical for a industrial composting process).
BIOPOLYMERS
Polylactic acid (PLA)

- Has the highest modulus of elasticity of all the polymers, similar to PP
- Leading producer: Natureworks (Cargill)
- The company marked 1 billion pounds of Ingeo sold in 2013
- With an average annual sales growth of 20% each year
- In the final stages of planning the location for its second plant – possibly in Thailand
Polyhydroxyalkanoates (PHAs)

- Produced by bacterial fermentation of sugar or lipids
- More than 150 different monomers can be combined within this family
- Leading producer: TianAn Biologic Material, China
- Fully biodegradable, compostable and suitable for food contact

What’s PHBV?
High performance natural polymers
- produced by nature, harvested by TianAn.
Polybutylene succinate (PBS)

- Promising mechanical properties
- Biodegradability
- Melt processability
- Thermal and chemical resistance
- Competitive price
Starch polymers

- Starch polymers are based on gelatinized starch from potato, corn, wheat or tapioca.
- Two natural polymers in starch: amylopectin and amylose.
- Pure starch provides brittle and friable materials.
- Can be improved increasing degree of amorphous regions or by blending with other polymers, nanofillers, plasticisers and fibres.
Characterisation and testing
LCA-KEY ISSUES
LCA capability

- LCA / economic evaluation of new products/processes
- Hotspot identification
- Process optimisation
Greenhouse gas emissions: polymer production

All data is from Ecoinvent v3 based on average European production except for Ingeo PLA which is from Natureworks (Vink & Davies) 2015.
Inter-regional farm variation:

GHGs associated with production 1kg maize, by country

From: Agri-footprint LCI database
Process energy: national grids compared

GHGs associated with consumption of 1 kWh grid electricity, by country (2013)

From: DEFRA Greenhouse Gas Conversion Factor Repository
Projects
Bread4PLA

OBJECTIVES

- To demonstrate the technical viability at pilot plant scale
- To obtain new biodegradable packaging for bakery and pastry products using the new PLA, closing the life cycle.
Scale up of Award winning Project

BioComposites Centre @BCBangor · 31 May 2017
Well done to Slava and Team for #bread4pla winning #environment award for #lifegreenawards with @aimplas

BREAD4PLA
Environment Winner
GREEN AWARDS

EU Green Award
Brussels 30 & 31 March 2017
HDT-Coffee Cup Lids

- Replacement of the disposable coffee cup lid with a biobased compostable alternative.
- Around 3.9 Million of polystyrene (PS) coffee cup lids are used per day.
- Same functional performance as the PS competitor, reduction in cycle times by 40-60%.
SafeBioPack

• Improve the preservation of food
• reduce urban solid waste going to landfill,
• reduce food loss across the supply chain
• improve health and well being
Fibre based packaging for fresh produce
Challenges

• Many biopolymers need to have improved
  – Barrier properties to gases
  – Strength (more flexible)
• Need to develop new processing additives
• Cost
Useful website

- [http://www.defra.gov.uk](http://www.defra.gov.uk)
- [http://www.berr.gov.uk/](http://www.berr.gov.uk/)
- [http://www.nnfcc.co.uk](http://www.nnfcc.co.uk)
- [http://www.innovateuk.org/](http://www.innovateuk.org/)
- [http://www.biopolymer.net/](http://www.biopolymer.net/)
- [http://www.wrap.org.uk/content/the-uk-plastics-pact](http://www.wrap.org.uk/content/the-uk-plastics-pact)