“BIOPLASTICS for food packaging: better biobased or biodegradable?"
Packlab is the only laboratory in the University of Milan exclusively devoted to food packaging science.

We are engaged in research, teaching and testing in the specialistic field of Food Packaging.
UN World Environment Day 2018: «Beating plastic pollution»

Overview

A Platform for Action World Environment Day is the UN’s most important day for encouraging worldwide awareness and action for the protection of our environment. Since it began in 1974, it has grown to become a global platform for public outreach that is widely celebrated in over 100 countries.

The People’s Day Above all, World Environment Day is the “people’s day” for doing something to take care of the Earth. That “something” can be focused locally, nationally or globally; it can be a solo action or involve a crowd. Everyone is free to choose.

The Theme Each World Environment Day is organized around a theme that focuses attention on a particularly pressing environmental concern. The theme for 2018 is beating plastic pollution.

The Host Every World Environment Day has a different global host country, where the official celebrations take place. The focus on the host country helps highlight the environmental challenges it faces, and supports the effort to address them. This year’s host is India.
World Plastics Production

World plastics production (Mtons)

Source: Statista, PlasticsEurope
World Plastics Production

Plastic, steel, cement and oil world production (Mtons)

- Plastics: 311
- Steel: 1600
- Cement: 4500
- Oil: 4400
The packaging materials in Europe

- Wood: 16%
- Plastic: 19%
- Glass: 19%
- Metal: 8%
- Paper and cardboard: 41%

What are the petroleum products people consume most?

- Gasoline, HGL, Kerosene, aviation gasoline: 68.5%
- Heating oil, asphalt: 21.5%
- All the rest: 10.1%


Note: estimates for Romania (2012 data); and Ireland, Greece and Cyprus (2013 data)

Source: CONAI
http://www.conai.org/en/
World Plastics Production

[Graph showing the estimated world plastics production (in Mtons) from 1930 to 2070.]
It seems reasonable to think that problems posed by materials that originate from fossil resources and are obtained through chemical processes can be solved through a *reversal of the conventional paradigm, a change in the model of reference*. Therefore, looking for "BIO" solutions.
Bio-plastics are not a single kind of polymer but rather a family of materials that can vary considerably from one another. The term bio-plastics refers to materials which are **bio-based, biodegradable, or both**.

http://en.european-bioplastics.org
**PCL**: Polycaprolactone is a biodegradable polyester with a low melting point of around 60 °C. The most common use of PCL is in the manufacture of special polyurethanes, even adhesives. It is oil-based but completely bio-degradable.
Biodegradation is the process in which materials are metabolised to CO2, water, and biomass with the help of microorganisms, enzymes, living organisms. The process depends on the conditions (e.g. location, temperature, humidity, presence of microorganisms, etc.) of the specific environment (industrial composting plant, garden compost, soil, water, etc.) and on the material or application itself.

**Biodegradability** is a feature of the material and the process of biodegradation can vary considerably, according to the media.

Compostability is a characteristic of a product that **allows it to biodegrade under specific conditions** (e.g. a certain temperature, timeframe, etc). These specific conditions are described in standards, such as the European standard on industrial composting EN 13432 (for packaging) or EN 14995 (for plastic materials in general).
PVOH: Poly(vinyl alcohol) (PVOH, PVA, or PVAl) is a water-soluble synthetic polymer. It is used in papermaking, textiles, and a variety of coatings. It offers a very high oxygen barrier if maintained dry. It is oil-based but completely bio-degradable.
PBS: Polybutylene succinate is a thermoplastic polymer with properties that are comparable to polypropylene. It is oil-based but completely bio-degradable. Nowadays, new technologies are available to obtain PBS from biomasses.
Bio-plastics are not a single kind of polymer but rather a family of materials that can vary considerably from one another. The term bio-plastics refers to materials which are **bio-based, biodegradable, or both**.

http://en.european-bioplastics.org
PLA: polylactic acid or polylactide is a biodegradable thermoplastic polyester derived from corn starch, cassava roots, or sugarcane. The most common route to PLA is the ring-opening polymerization of lactide with various metal catalysts in solution, in the melt, or as a suspension.
**PHA:** Polyhydroxyalkanoates are polyesters produced through bacterial fermentation of sugar or lipids. More than 150 different monomers are known with extremely different properties, but always biodegradable.
**TPS:** Thermo-plastic starch. The characteristics of TPS bioplastics can be tailored to specific needs by adjusting the amounts of plasticiser such as sorbitol and glycerine. Starch-based bioplastics are often blended with PLA or PHA.
Bio-plastics are not a single kind of polymer but rather a family of materials that can vary considerably from one another. The term bio-plastics refers to materials which are **bio-based, biodegradable, or both**.
Bio-PE: Ethylene is obtained by the catalytic dehydration of bio-ethanol, followed by normal polymerizations.

Bio-PP: the ethylene obtained from bio-ethanol is dimerized to produce n-butene. The n-butene is then reacted with the ethylene to produce bio-PP. A similar production route is possible using butanol from sugar fermentation.
Bio-PET: Bio-ethylene glycol is already produced from bio-ethanol; Bio-para xylene (precursor of therephtalic acid) might be produced, by pre-commercial technologies, converting biomasses into para xylene or muconic acids to obtain bio-therephtalic acid

![Bio-PET chemical structure]

Bio-PEF: a new bio-based not biodegradable polyester (polyethylene furanoate) can be obtained converting fructose into 2,5-furan dicarboxylic acid that can be polymerized to PEF, by reaction with bio ethylene glycol

![Bio-PEF chemical structure]
Bio-plastics are not a single kind of polymer but rather a family of materials that can vary considerably from one another. The term bio-plastics refers to materials which are **bio-based, biodegradable, or both**.

http://en.european-bioplastics.org
Global production capacities of bioplastics 2017
(by material type)

- **PET**: 26.3%
- **PA**: 11.9%
- **PEF**: 0.0%
- **PE**: 9.7%
- **PP**: 0.0%
- Other (bio-based/non-biodegradable): 9.2%
- PBAT: 5.0%
- PBS: 4.9%
- PLA: 10.3%
- PHA: 2.4%
- Starch blends: 18.8%
- Other (biodegradable): 1.5%

Total: 2.05 million tonnes

**Source:** European Bioplastics - nova institute
http://www.european-bioplastics.org/market/

---

**Biodegradable vs Bio-based**

Bio-based/non-biodegradable: 57.1%

Biodegradable: 42.9%
Biodegradable vs Bio-based

Bioplastics, actual and forecasted capacity

<table>
<thead>
<tr>
<th>Year</th>
<th>Bio-based non Biodegradable</th>
<th>Biodegradable</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>1174</td>
<td>880</td>
</tr>
<tr>
<td>2018</td>
<td>1182</td>
<td>911</td>
</tr>
<tr>
<td>2019</td>
<td>1192</td>
<td>946</td>
</tr>
<tr>
<td>2020</td>
<td>1202</td>
<td>987</td>
</tr>
<tr>
<td>2021</td>
<td>1215</td>
<td>1033</td>
</tr>
<tr>
<td>2022</td>
<td>1354</td>
<td>1086</td>
</tr>
</tbody>
</table>
Biodegradable vs Bio-based

Bioplastics capacities by market segment (2017)

- Others
- Electrics & electronics
- Agriculture
- Textiles
- Building
- Automotive & transport
- Consumer goods
- Packaging

(%)
About 690 tons (mainly of Bio-PE and Bio-PET) over 1200 tons of Bioplastics for flexible and rigid packaging. Around 58%
It seems that the Packaging sector is already addressed toward Bio-based non biodegradable bioplastics, instead of biodegradable materials.

Why?

• Biodegradable bioplastics are more expensive and less performing.
Biodegradable vs Bio-based

Why?

• Biodegradability is not always the best choice for food products....
• Disposable problems, doubts about the landfill capacity...
• Converting a solid material to a gas via composting is considered not really sustainable, being much better to recycle or recover the feedstock energy...
• Bio-based non biodegradable bioplastics can make energy recovery more attractive because of their almost complete carbon neutrality; a zero carbon footprint, refers to achieving net zero carbon emissions by balancing amount of carbon released with an equivalent amount sequestered or offset.
Bio-based instead of food?

One more controversial topic, in fact, deals with the use of land to produce bioplastics (and bio-fuels) instead of foods.

Arable land, the 29% of the global agricultural area

<table>
<thead>
<tr>
<th>Material</th>
<th>2017</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioplastics (2017)</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>Bioplastics (2022)</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td>Biofuels</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Material use</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Food and Feed</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>
According to UNEP’s findings, 5 billion tons of waste agricultural biomass is generated every year. Cellulose amount in the agricultural biomass waste ranges from 32% to about 43%:

**ALMOST 2 BILLION TONS OF CELLULOSE ARE AVAILABLE EVERY YEAR FROM AGRICULTURAL WASTE ONLY**
Bio-based products have been properly defined by various Institutions. According to the European Committee for Standardizations (CEN) they are:

“Products that are wholly or partly derived from biomass: material of biological origin, such as from trees, plants or animals. The biomass may have undergone some kind of physical, chemical or biological treatment before being turned into a product. Bio-based products can be either material, intermediate, semi-finished or final products”
Bio-based products for innovative and sustainable food packaging

May 2018

Computational Methods to Assess the Production Potential of Bio-Based Chemicals

**ABSTRACT:** Elevated costs and long implementation times of bio-based processes for producing chemicals represent a bottleneck for moving to a bio-based economy. A prospective analysis able to elucidate economically and technically feasible product targets at early research phases is mandatory. **Computational tools can be implemented to explore the biological and technical spectrum of feasibility,** while constraining the operational space for desired chemicals. In this chapter, **two different computational tools for assessing potential for bio-based production of chemicals from different perspectives** are described in detail.
Adequate fragmentation of native fibers and fibrils of cellulose leads to cellulose nanoparticles (CNs) whose properties may be really interesting for packaging applications; their use as possible mechanical reinforcement and for a gas barrier enhancement has been largely investigated.
Bio-based products for innovative and sustainable food packaging

◊ poly(ethylene terephthalate) PET, 12 ± 0.5 μm
◊ oriented polypropylene OPP, 20 ± 0.5 μm
◊ oriented polyamide OPA, 12 ± 0.5 μm
◊ cellophane 12 ± 0.5 μm
The Potential of NanoCellulose in the Packaging Field: A Review

By Fei Li, Erika Mascheroni and Luciano Piergiovanni*

Cellulose (2013) 20:2491–2504

Multi-functional coating of cellulose nanocrystals for flexible packaging applications

Fei Li · Paolo Biagioni · Monica Bollani · Andrea Maccagnan · Luciano Piergiovanni

Cellulose Nanocrystals from Lignocellulosic Raw Materials, for Oxygen Barrier Coatings on Food Packaging Films

By Riccardo Rampazzo,¹,³† Derya Alkan,¹† Stefano Gazzotti,²,³ Marco A. Ortenzi,²,³* Giulio Piva⁴ and Luciano Piergiovanni¹,³* Š

DOI 10.1007/s10570-015-0853-2

The Effect of Moisture on Cellulose Nanocrystals Intended as a High Gas Barrier Coating on Flexible Packaging Materials

Ghislain Fotie¹, Riccardo Rampazzo²,³, Marco Aldo Ortenzi²,³, Stefano Checchia²,³,⁴, Dimitrios Fessas¹,³ and Luciano Piergiovanni¹,³*

Comparison of cellulose nanocrystals obtained by sulfuric acid hydrolysis and ammonium persulfate, to be used as coating on flexible food-packaging materials

Erika Mascheroni · Riccardo Rampazzo · Marco Aldo Ortenzi · Giulio Piva · Simone Bonetti · Luciano Piergiovanni
“BIOPLASTICS for food packaging: better biobased or biodegradable ??“
Luciano Piergiovanni

Thanks for your attention!

Mon, June 11, 2018 9:00 AM CEST