Sustainable polymer from sugar cane
- BIOCYCLE® -

2012

Workshop for Sustainable Production of Biopolymers and other Bio-based Products
July 25th - FAPESP - São Paulo
Company Overview

- The development of PHB in Brazil

1991
Research grant establishes the “Production of Biodegradable Plastics from Sugar via Biotechnological Route”
COPERSUCAR - IPT

1994
Implementation of the Pilot Plant to produce PHB / PHB-HV at Usina da Pedra, Serrana -SP

1994

2000
PHB Industrial S/A was created along with the BIOCYCLE® brand.

2004
PHB production process proves to be economically viable
Focus on Material Engineering – Market Applications – “1st generation”

2008
Consolidation of productive process
Applications, New Solvent, New Patents – “2nd generation”
ORGANIZATIONAL STRUCTURE

- **Pedra Agroindustrial S.A. / The Balbo Group**
  - More than 80 years of experience in the sugar and alcohol industry
  - Industrial assets comprised of six mills in the state of São Paulo and one in the state of Minas Gerais
  - Total annual production (1):
    - 20 Million tons of crushed Sugar Cane
    - 650 Million kilograms of sugar
    - 900 million liters of alcohol
    - More than 10,000 employees
  - Culture area of more than 180,000 hectares of sugarcane (1)
  - Energy generation capacity of approximately 800,000 MWh (1)
  - Commercialization of CERs through Kyoto Protocol
  - Major worldwide organic sugar producer

- **PHB Industrial S.A.**
  - Leverages the collective experience and relationships of Pedra Agroindustrial S.A. and the Balbo Group

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(1) 2010 / 2011 crop
Company Overview

- PHBISA’s technology has been developing and refining over 16 years of research
PHB INDUSTRIAL S.A. – Overview

- PHBISA utilizes a **completely renewable concept** to produce PHB, its blends and composites (brand - Biocycle®)

- 100% Brazilian Technology to produce biopolymer based in vegetable glucose supported by know-how and **patents (17)**, embodying from the bacteria selection to the applications;

- Production process filled **without GMO**.

- Biopolymer completely **biodegradable, compostable and sustainable** – PP contra type.

- Product with **high performance** and functionality

- “**New technology frontier**”
Sugar Cane
Competitive advantage over other biomass

Fossil-fuel energy used to make the fuel (input) compared with the energy in the fuel (output)

Sugar Cane presents the **highest energetic productivity** compared to other biomass.
Biopolymers - Productivity comparison & Demanded Area

**Biopolymer Production**

(ton/hectare)

<table>
<thead>
<tr>
<th>Biopolymer Source</th>
<th>Production (ton/hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHB from Sugar Cane</td>
<td>4.39</td>
</tr>
<tr>
<td>PE from Ethanol**</td>
<td>3.09</td>
</tr>
<tr>
<td>PHB from Corn</td>
<td>2.20</td>
</tr>
</tbody>
</table>

**Necessary area to produce 100.000 tpy of PHB**

(thousand hectares)

<table>
<thead>
<tr>
<th>Biopolymer Source</th>
<th>Necessary Area (thousand hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHB from Sugar Cane</td>
<td>32</td>
</tr>
<tr>
<td>PE from Ethanol**</td>
<td>45</td>
</tr>
<tr>
<td>PHB from Corn</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: PHBISA's Analysis /
** Braskem's Green Polymers: A Partnership Beyond Renewable Raw Materials** – European Bioplastics Conference – Nov09
Biocycle is a net CO₂ consumer / cleaner, when considered the entire lifecycle

1 kg of PHB rescue around ~4.4 kg CO₂

**Lifecycle CO₂ - Rescue Comparison**

<table>
<thead>
<tr>
<th>Product</th>
<th>CO₂ (kg) / Ton of Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHB – Biocycle (Sugar Cane)</td>
<td>4.400</td>
</tr>
<tr>
<td>PE Green</td>
<td>2.500</td>
</tr>
<tr>
<td>PHB (corn)</td>
<td>2.200</td>
</tr>
<tr>
<td>PLA (corn)</td>
<td>1.700</td>
</tr>
<tr>
<td>PP</td>
<td>(1.900)</td>
</tr>
<tr>
<td>PET</td>
<td>(3.200)</td>
</tr>
</tbody>
</table>

Source: Rescue CO₂
1. PHBISA: “Estudo LCA” CETEA/ITAL & Estudos CTC / Unicamp
3. PHB Milho:Metabolix
4. PE / PET / PLA: Cargill Dow LLC
Production Technology

Chemical Formula
Linear chain of poly (3-hydroxybutyric) acid (PHB)

\[
\begin{align*}
\text{CH}_3 & \quad \text{O} \\
\text{CH} & \quad \text{CH}_2 \\
\end{align*}
\]

Laboratory Propagation → Prefermentation → Sterilization

Sugar → Nutrients → Water

Fermentation

Nutrient Broth → Syrup

Microorganism Settling

PHB Extraction

Cristallization

Purification

Drying

PHB

Land Field → Water
Production Technology

- **Sterilization**
  - At this point, inputs are introduced into a fermenter:
  - The streams are mixed in the fermenter, along with the bacteria, to begin the process of converting the feedstock to PHBs

- **Fermentation Process**
  - Bacteria act as biofactories with the ability to turn a feedstock into PHB in an aerobic environment
  - PHBISA has achieved up to 90% content in the biomass in this process
Production Technology

- Microorganism Settling
  - Material is in liquid form with bacteria fully suspended
  - The cells are separated from the solution
  - Cells are then separated and passed on to the PHB extraction phase
Production Technology

- **PHB Extraction**
  - The solvent, a non-toxic ethanol production by-product, is mixed
  - The cells react to the solvent by bursting, leaving the PHB absorbed in the solvent
  - The rest of the cell particles remain undissolved, suspended in the solvent
  - The bulk of the solvent plus dissolved PHB is then filtered from the cell debris
  - At this point, the mixture of solvent and dissolved PHB moves on to the crystallization / purification steps while the debris by-product is removed from the batch
Production Technology

- Crystallization / Purification
  - After the filter stage, the PHB and separated it from the remaining solvent
  - In the purification stage, the separated solvent is removed and recycled
  - Once the PHB is at this high purity level, it is steam dried and packaged for delivery to converters and other end customers
Production – “New Technology Frontier”

**PHB Production**

1. **Laboratory Propagation**
2. **Pre-fermentation**
3. **Fermentation**
4. **Microorganism Settling**
5. **PHB Extraction**
6. **Crystallization**
7. **Purification**
8. **Drying**
9. **Sterilization**

**Compound with…**

- Copolyester
- PCL
- PLA
- Wood Powder
- Starch
- Bagasse
- Sisal Fiber
- Other

**BIOCYCLE**
Technical characteristics of the base polymer that can be improved through polymer blends and alloys with PHB

- Processing Technology – viscosity, crystallization and reactive extrusion
- Mechanical Properties – tensile strength and impact resistance
- Thermal Properties – heat deflection, melting point, glass transition and decomposition
- Biodegradability – velocity and rate
- Cost
Such products have been obtained through joint efforts with potential clients and partners. Applications developed by PHBISA include:

- **Traditional Polymer Replaced**
  - **Polypropylene**
    - Extrusion
    - Thermoforming
  - **Polystyrene**
    - Thermoforming
  - **Polyurethane**
    - Injection
    - Extrusion
    - Elastomers and foams
      - Isolation (construction)
      - Shoes
      - Automotive parts
  - **ABS**
    - Extrusion
    - Thermoforming

These materials are used in various applications such as:

- **Recipients for nursery crops**
- **Automotive parts**
- **Parts to crop monitored growth**
- **Toys**
- **Packaging parts**
  - Caps
- **Banking cards**
Major Players from Europe, America and Asia are investing in different biobased technology streams, showing the market trends…