Advantages and applications of LLDPE Quaterpolymer Technology

Antônio Xavier
Head of Product Development
Agenda

- Braskem introduction
- Pluris® a new generation of LLDPE
  - Production background
  - Properties
- Applications
  - Automatic Packaging
  - Shrink Film
  - Heavy Duty Bags
  - Pet Food
  - Agricultural silage
  - Adhesion agent for PP / PE
- Questions and Answers
Braskem introduction

- Braskem is the leader in the Latin America thermoplastics resins market
- Integrated operations

Diagram:
- Refining
  - Raw Material
- 1st generation
  - Basic Petrochemicals
- 2nd generation
  - Thermoplastic Resins
- 3rd generation
  - Plastic Products

Integration
Braskem introduction

14 industrial units in Brazil

Polyolefins technologies

- HDPE / LLDPE
- HDPE / UTEC
- HDPE / LLDPE
- LDPE / EVA

- Unipol
- Mitsubishi
- Sclairtech
- Sumitomo

- LDPE
- LLDPE
- PP

- Equistar
- Spherilene
- Spheripol
Center of Technology and Innovation

- Focus on value creation for customers
  - Product customization
  - New applications
  - Client services

- 200 researchers
- 8 pilot plants
- US$ 100 MM in technology assets
- Partnerships with customers, suppliers, universities and research centers
- Development of products, technologies, catalysts and applications
- 159 patents filled until 2007
<table>
<thead>
<tr>
<th>Development of new product families</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UTEC</strong></td>
</tr>
<tr>
<td>Internally developed technology for the production of UHMWPE</td>
</tr>
<tr>
<td><strong>Braskem Prisma</strong></td>
</tr>
<tr>
<td>High clarity PP grades for rigid packaging</td>
</tr>
<tr>
<td><strong>Braskem Symbios</strong></td>
</tr>
<tr>
<td>BOPP sealant layer</td>
</tr>
<tr>
<td><strong>Braskem Flexus</strong></td>
</tr>
<tr>
<td>Pioneer on the production of metallocene PE in Latin America</td>
</tr>
<tr>
<td><strong>Braskem Idealis</strong></td>
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<tr>
<td>Ideal product for kitchen cutting boards and playground toys</td>
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Quaterpolymer LLDPE

Ethylene – Propylene - Butene - Hexene

Produced exclusively at Spherilene® technology plant in a four reactors line
Braskem Pluris® main advantages:

- Unique mechanical properties balance
  - Higher stiffness
  - Excellent impact strength
- Better bubble stability compared to other LLDPE’s
- Low blocking force
- High sealing strength
<table>
<thead>
<tr>
<th>Property</th>
<th>ASTM Method</th>
<th>Units</th>
<th>Braskem Pluris®</th>
<th>LLDPE C4</th>
<th>Metalloocene LLDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt Flow Index (190°C/2,160kg)</td>
<td>D-1238</td>
<td>g/10 min</td>
<td>0.55</td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Density</td>
<td>D-1505</td>
<td>g/cm³</td>
<td>0.920</td>
<td>0.921</td>
<td>0.917</td>
</tr>
<tr>
<td>Haze</td>
<td>D-1003</td>
<td>%</td>
<td>16.0</td>
<td>8.6</td>
<td>6.7</td>
</tr>
<tr>
<td>Gloss - 60°</td>
<td>D-2457</td>
<td>%</td>
<td>7.5</td>
<td>11.5</td>
<td>12.0</td>
</tr>
<tr>
<td>Tensile at break (DM/DT)</td>
<td>D-882</td>
<td>MPa</td>
<td>56/39</td>
<td>40/31</td>
<td>72/63</td>
</tr>
<tr>
<td>Elongation at break (DM/DT)</td>
<td>D-882</td>
<td>%</td>
<td>863/1197</td>
<td>973/1228</td>
<td>1007/1207</td>
</tr>
<tr>
<td>1% Secant Modulus (DM/DT)</td>
<td>D-882</td>
<td>MPa</td>
<td>261/291</td>
<td>196/223</td>
<td>132/151</td>
</tr>
<tr>
<td>Dart Drop Impact Strength</td>
<td>D-1709</td>
<td>g</td>
<td>146</td>
<td>127</td>
<td>&gt;850</td>
</tr>
<tr>
<td>Elmendorff Tear Strength (DM/DT)</td>
<td>D-1922</td>
<td>kgf/cm</td>
<td>109/238</td>
<td>69/155</td>
<td>97/153</td>
</tr>
</tbody>
</table>
Braskem Pluris®
Sealing strength

- Force (N)
- Temperature (°C)

- Conventional LLDPE
- Braskem Pluris®
Braskem Pluris® - applications

High Performance Automatic Packaging Films (Form Fill Seal)
High Performance Automatic Packaging Films

Advanced solution for food packaging

- High gloss and clarity
- Very good stiffness/toughness balance
- Excellent sealing properties

- Braskem proposes a combination of Pluris®, Flexus®, conventional LLDPE and LDPE
High Performance Automatic Packaging Films

“Braskem Solution” 3 layer coex structure

70-80% C4 LLDPE + 20-30% LDPE

80% Pluris® 9310 + 20% LDPE

80-90% Braskem Flexus® 9211 + 10-20% LDPE
High Performance Automatic Packaging Films

Stiffness vs. Impact Strength

Film samples: 3 coex layer, 80 micra thickness, 20% LDPE
High Performance Automatic Packaging Films

Puncture Strength (J/mm)

Film samples: 3 coex layer, 80 micra thickness, 20% LDPE
Film samples: 3 coex layer, 80 micra thickness, 20% LDPE
High Performance Automatic Packaging Films

Hot Tack

Film samples: 3 coex layer, 80 micra thickness, 20% LDPE
Shrink Films
Shrink Film

- Secondary package for handling, storage and transportation
- High Stiffness/Tear strength
- Competitive to LDPE shrinkage levels
- Lower failures in handling, storage and transportation
- Integrity of the package
- **Braskem**: 70% Pluris® 9300 + 30% blown molding HDPE
- **Standard**: 60% LDPE + 30% HDPE + 10% LLDPE

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Braskem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (μm)</td>
<td>58</td>
<td>54</td>
</tr>
<tr>
<td>Shrinkage (%) MD/TD</td>
<td>70/11</td>
<td>70/10</td>
</tr>
<tr>
<td>Internal COF</td>
<td>0.23</td>
<td>0.23</td>
</tr>
<tr>
<td>External COF</td>
<td>0.26</td>
<td>0.25</td>
</tr>
</tbody>
</table>

MD: machine direction / TD: transverse direction
Shrink Film

1% Secant Modulus (MPa) MD
1% Secant Modulus (MPa) TD

MD: machine direction / TD: transverse direction
Shrink Film

Elmendorf Tear (Kgf/cm) MD
Elmendorf Tear (Kgf/cm) TD

MD: machine direction / TD: transverse direction
Shrink Film

Dart Drop Impact Strength (Joule)

- Standard: 0.22
- Braskem: 0.29
Braskem Pluris® - applications

Heavy Duty Bags
Heavy Duty Bags

- Chemicals, Agricultural Products, Fertilizers
- Higher Stiffness
- Very good Impact Strength
- Superior Sealing strength
- High Coefficient of Friction (COF)
- Low bag deformation
- Better stack stability
- Package storage handling & shelf life integrity
Heavy Duty Bags

“Braskem Solution” 3 layer coex structure

- 70-80% Pluris® 9300 + 20-30% LDPE
- 80-90% Pluris® 9300 + 10-20% LDPE
- 80-90% Braskem Flexus® 9200 + 10-20% LDPE
Heavy Duty Bags

Stiffness

- C8 LLDPE
- Braskem Solution
Braskem Pluris® - applications

Pet Food Packaging
Pet Food Packaging

- High stiffness and toughness
- Excellent sealing properties
- Good fat barrier

- Braskem developed a structure combining Pluris®, Flexus®, HDPE and LDPE that leads to superior films
Three layer coex film + Lamination

LLDPE/LDPE

Adhesive

80% Pluris 9300 + 20% LDPE

Pluris 9300® + HE 150 (80/20 to 20/80%)

80-90% Flexus® 9211 + 10-20% LDPE
Three layer coex film + Lamination

- LLDPE/LDPE
- Adhesive
- 80% LLDPE C₃ + 20% LDPE
- 80% LLDPE C₈ + 20% PP
- 80% LLDPE C₈ + 20% LDPE
## Pet Food Packaging
Better Properties Combination

<table>
<thead>
<tr>
<th>Property</th>
<th>Braskem Solution</th>
<th>C8 LLDPE/PP based Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% Secant Modulus MD/TD (MPa)</td>
<td>195/223</td>
<td>190/200</td>
</tr>
<tr>
<td>Tensile at Break MD/TD (MPa)</td>
<td>40,0/36,8</td>
<td>34,9/33,5</td>
</tr>
<tr>
<td>Elongation at Break MD/TD (%)</td>
<td>1115/1112</td>
<td>1098/1213</td>
</tr>
<tr>
<td>Elmendorf Tear Strength MD/TD (kgf/cm)</td>
<td>99/267</td>
<td>118/207</td>
</tr>
<tr>
<td>Dart Drop - energy at Max Load (J)</td>
<td>1,52</td>
<td>1,44</td>
</tr>
<tr>
<td>Fat barrier – time to failure (h)</td>
<td><strong>48</strong></td>
<td><strong>43,2</strong></td>
</tr>
</tbody>
</table>

Remarks: 130 µm thickness film  % of HDPE and PP = 20%
Hot Tack STL 869/2004

Força (N)

Temperatura (°C)

Braskem Solution
C8/PP Based

Pet Food Packaging
Excellent Sealing Performance
Ultimate Strength STL 869/2004

Força (N) vs Temperatura (ºC)

- C8/PP Based
- Braskem Solution
Braskem Pluris® - applications

Silos for agricultural application
Braskem Solution for agricultural silage – expected benefits with Pluris and LDPE in the formulation:

- Higher stiffness
- Better mechanical properties
- Higher gloss
- To increase grain protection
- To increase silo capacity
Silos for agricultural application

Tear strength

Puncture test

Better mechanical properties increase protection of the grains
Higher stiffness / tensile at break and lower elongation increase silo capacity
Higher gloss improves sunlight reflection and implies in a low temperature inside the silo and better protection of the grains.
Pluris: adhesion agent for PE/PP
Adhesion Agent between PE/PP

3 layer coex structure
With or without Slip agent, depending on the application

Polypropylene
Pluris®
Polyethylene
Adhesion Agent between PE/PP

Films before sealing test

<table>
<thead>
<tr>
<th>External layer - PP</th>
<th>Core layer</th>
<th>Sealing layer - PE</th>
</tr>
</thead>
</table>

Sealed Films

<table>
<thead>
<tr>
<th>External layer - PP</th>
<th>Core layer</th>
<th>Sealed Layer - PE</th>
</tr>
</thead>
</table>

Core Layer

External Layer - PP

Core Layer

Pluris or C4 LLDPE

Tensile test after sealing

<table>
<thead>
<tr>
<th>External layer - PP</th>
<th>Core layer</th>
</tr>
</thead>
</table>

Forced Delamination

Sealed Layer - PE

Core Layer

External Layer - PP
Adhesion Agent between PE/PP
Summary of benefits of Pluris® technology

- Improved quality of packaging
- Optimal pallet and stack stability
- Excellent compatibility within PE/PP coex layers
- Important opportunities of film downgauging
- Higher stiffness than conventional LLDPE’s
- Mechanical resistance like C6 LLDPE
- Good sealability
Questions and answers