Biopolymer Films and Potential Applications to Meat and Poultry Products

Paul Dawson, James Acton, & Amod Ogale
Clemson University
Potential Advantages

- Reduced dependence on petroleum sources
- Use of U.S. agricultural raw materials
- As a food contact layer to carry adjuncts
- Biodegradability
- Cost??
Definition of Biopolymer Packaging

• Packaging produced from renewable, biological material
# Biopolymers for Packaging

<table>
<thead>
<tr>
<th>from biomass</th>
<th>Polysaccharides</th>
<th>Proteins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cellulose</td>
<td>Casein</td>
</tr>
<tr>
<td></td>
<td>Starch</td>
<td>Whey</td>
</tr>
<tr>
<td></td>
<td>Gums</td>
<td>Gluten</td>
</tr>
<tr>
<td></td>
<td>Chitosan/Chitin</td>
<td>Soy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Egg/meat</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>synthesized</th>
<th>Polylactate (PLA)</th>
<th>Other polyesters</th>
</tr>
</thead>
</table>

| microbial     | Polyhydroxy-alcanoates (PHA) – butyrate (PHB) |

Ref: Vibeke K Haugaard and Grete Bertelsen, Centre for Advanced Food Studies (LMC) The Royal Veterinary and Agricultural University, Copenhagen, Denmark
### Biopolymer films-commercial materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Supplier</th>
<th>Trade name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA</td>
<td>Cargill Dow</td>
<td>NatureWorks PLA</td>
</tr>
<tr>
<td></td>
<td>Hycaill</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mitsui</td>
<td>LACEA</td>
</tr>
<tr>
<td>Starch</td>
<td>Novamont</td>
<td>Mater Bi</td>
</tr>
<tr>
<td></td>
<td>Biotec</td>
<td>Bioplast</td>
</tr>
<tr>
<td></td>
<td>Earth Shell</td>
<td>Earth Shell</td>
</tr>
<tr>
<td>PHB</td>
<td>Biomer</td>
<td>Biomer</td>
</tr>
</tbody>
</table>

Ref: Vibeke K Haugaard and Grete Bertelsen, Centre for Advanced Food Studies (LMC) The Royal Veterinary and Agricultural University, Copenhagen, Denmark
Biodegradation

• Microbial
  – Aerobic ➔ compost or sludge
  – Anaerobic ➔ methane + hydrogen

• Animal feed

• Chemical
### Optimal Packaging Requirements

<table>
<thead>
<tr>
<th>Product</th>
<th>Shelf life</th>
<th>Barrier Needs</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>O₂</td>
<td>CO₂</td>
<td>H₂O</td>
<td>light</td>
<td></td>
</tr>
<tr>
<td>MAP raw meat</td>
<td>1-2 wk</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Raw meat</td>
<td>1-2 wk</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooked meat</td>
<td>1-4 wk</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Cured Meat</td>
<td>1-6 mo</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Biopolymer films-meat research

- 1949 – Pearce & Lavers – carrageenan
- 1952 – Klose et al – gelatin
- 1963 – Allen et al – alginates
- 1967 – Bauer et al – cellulose
- 1971 – Mullen – wheat gluten
- 1972 – Turbak – corn zein
- 1972 – Turbak – soy protein
- 1972 – Baker at al – albumen/soy/wheat protein
- 1980’s and 1990’s – numerous (mostly cast films)
Biopolymer films - applications

• Moisture/oxygen barrier
• Physical protection
• Oil barrier
• Breading adhesion
• Texture modifier
• Antimicrobial/Antioxidant carrier
Coating vs. Film

- Coating applied as a fluid
- Coating adheres to the food surface
- Coating is often consumed with the food
Meat coating applications

- Coatings reduce moisture loss in raw and cooked meat
- Antioxidants added to coatings to preserve cooked meat flavor
- Coatings used to reduce moisture loss/oxidation in frozen meat and fish
Nisin-coated cellulosic films applied to frankfurters

Research by Dr. Kay Cooksey, Clemson University
Biopolymer films- flexible films

• Crosslinking required to form flexible film
• Proteins and carbohydrates have the ability to crosslink and form a film matrix

• Two principal methods of forming
  – Casting
  – Thermal compression

• Extrusion methods
Crosslinking Agents

- Formaldehyde
- Glutaraldehyde
- Cysteine
- Transglutaminase
- UV radiation
- Glyoxal
Batch Processing - Compression

BEFORE

AFTER
Biopolymer films - flexible films

CAST

COMPRESSED
Continuous Processing
### Physical properties of films

<table>
<thead>
<tr>
<th>Film type</th>
<th>Thickness (mil)</th>
<th>Tensile Strength (MPa)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat-press soy protein</td>
<td>11.8</td>
<td>5.0</td>
<td>123</td>
</tr>
<tr>
<td>Cast wheat gluten</td>
<td>3.98</td>
<td>2.6</td>
<td>276</td>
</tr>
<tr>
<td>Cast whey protein/glycerol</td>
<td>4.33</td>
<td>13.9</td>
<td>31</td>
</tr>
<tr>
<td>Cast soy protein/glycerol</td>
<td>NA</td>
<td>37</td>
<td>4.0</td>
</tr>
<tr>
<td>Cast corn zein</td>
<td>3.5</td>
<td>0.4</td>
<td>&lt;1.9</td>
</tr>
<tr>
<td>cellophane</td>
<td>14.17</td>
<td>114</td>
<td>20</td>
</tr>
<tr>
<td>High density PE</td>
<td>0.98</td>
<td>17.3-34.6</td>
<td>300</td>
</tr>
<tr>
<td>Low density PE</td>
<td>0.98</td>
<td>8.6-17.3</td>
<td>500</td>
</tr>
<tr>
<td>0.75% chitosan/LDPE</td>
<td>4.48</td>
<td>9.2</td>
<td>60</td>
</tr>
</tbody>
</table>
THERMALLY COMPACTED SOY PROTEIN FILM

Listeria monocytogenes (CFU/ml) vs. Time of Exposure to Film (Hours)

- CONTROL
- NISIN
- LAURIC ACID
- NISIN + LAURIC

Graph showing the decrease in Listeria monocytogenes (CFU/ml) over time for different treatments.
Protein Films

C-CZ

HP-CZ

C-WG

HP-WG
Comparison of nisin diffusivity

- **C-CZ**: 5.5E-11
- **C-WG**: 2.3E-10
- **HP-CZ**: 2.1E-10
- **HP-WG**: 1.8E-10

**Film Type**: C-CZ, C-WG, HP-CZ, HP-WG

**Nisin Diffusivity (cm²/s)**
Application on bologna
L. monocytogenes-inoculated turkey bologna exposed to biocide-impregnated soy films
Turkey bologna inoculated with L. monocytogenes and packaged with nisin in wheat gluten film
CIE a-value Results for Steaks Allowed to Bloom Prior to Packaging with Antioxidant Films

- Film Control
- BHA
- BHT
- Rosemary Extract
- d-tocopherol

Days
0 1 2 3 4 5 6 7 8 9 10

a-value
0 4 8 12 16 20 24 28 32 36 40
Color Differences - Antioxidant Discs within Packaged Steaks
Chitosan tested as a coating and film

Cellulose: $R = \text{OH}$
Chitin : $R = \text{NHCOCH}_3$
Chitosan : $R = \text{NH}_2$
Chitosan coated onto drumsticks

P < 0.05
SEM = 0.7
n = 6
Chitosan coated onto drumsticks

Log CFU/ml

control 91% DE 91% DE + nisin 93% DE 93% DE + nisin

P < 0.05
SEM = 0.4
n = 6
8% chitosan within LDPE films - steak surface

delta a* value

0  1  2  3  4  5  6  7  8  9  10

0% chitosan
4% chitosan
8% chitosan

days
8% chitosan within LDPE films - steak surface

![Bar chart showing total plate count over days for different chitosan concentrations](chart.png)
Future

• Coatings will still be developed for specific applications
• Biopolymer films will eventually enter the market as cost and functionality get near that of synthetic polymers
• Requirements for meat packaging make this one of the most difficult areas for biopolymers to meet