Food Quality and Shelf Life
(Shelf Life, Deterioration, & Packaging)

• Definitions
• Mechanisms of deterioration
• Current role of packaging
• Examples of future concepts

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Objective

• Describe the problems and needs related to food quality and shelf life.
Food Quality

- Degree to which a food meets expectations
- “High” exceeds expectations
- “Low” does not meet expectations
Expectations for Food

• “Taste” (appropriate sensory factors)
  – Appearance, texture, taste, odor, auditory
• Nutrition/Healthful profile
• Convenience & preparation
• Storage shelf life
• Intangible needs & benefits
• Physical structure
• Safety & environmental costs
What is the Shelf Life of Milk?

- Stored at room temperature.
- Aseptically processed and packaged.

The shelf life of a food depends on
- How it is processed
- How it is stored
- How it is packaged
Shelf Life

• The **time** it takes a food product to **deteriorate** to an **unacceptable degree** under **specific storage, processing, and packaging conditions**.
Time to Deteriorate is Relative

- Product composition
- Storage conditions
  - temperature
  - atmosphere
- Processing conditions
- Distribution conditions
- Initial quality
- Packaging
Shelf Life Plots

ESL Package

ESL Provides higher quality at any time

Conventional Package

Quality Parameter(s)

Time (hrs, days, wks, months)

SL1

SL2

MAQ

ESL Provides higher quality at any time
Selected Measurable Food Quality Factors

- Microbial counts and types
- Nutrient content
- Color & appearance
- Moisture content
- Physical shape/size
- Mechanical properties
- Flavor panel score
- Toxicant level (chemical risk)
- DAL (e.g. insect fragments)
Setting Minimum Acceptable Quality

• Regulatory limits (e.g. 20,000 cfu/ml)
• Just noticeable difference (JND)
  – Sensory
  – Expert vs. consumer
• Customer complaints
• Detected by >50th percentile of consumers
• MAQ IS A MANAGEMENT DECISION
Modes of Food Deterioration

• Biological
  – Microorganisms
    • spoilage
    • pathogenic
  – Vermin
    • insects
    • rodents
Modes of Food Deterioration

• Chemical
  – Oxidation
  – Flavor deterioration
  – Color change or loss
  – Vitamin loss
  – Chemical contamination
  – Enzymatic
Modes of Food Deterioration

• Physical
  – Moisture gain or loss
  – Breakage or clumping
  – Textural changes
  – Contamination (objects)
Motivations for Extending Shelf Life

- Reduce distribution costs
- Enter new markets
- Non-traditional distribution channels
- Improve quality
- Reduce restocking costs
- Provide longer code dates
Peanut Snack Shelf Life

- Packed in air
- Packed in 80% N₂
- Packed in 95% N₂

Peroxide Value

Time (wks)
Major Goal of Packaging

• Reduce the rate of quality loss
• Increase the shelf life of the product
Recent Packaging Technologies to Extend Shelf Life

- Higher barrier packaging
- Modified atmosphere packaging (MAP)
- Direct addition of CO$_2$ to products
- Broader use of irradiation
- New processes (e.g. high pressure, ohmic, pulsed light, etc.)
Question: In what ways could packaging improve food quality and shelf life beyond current technologies?

What new packaging materials or methods could be developed which would improve quality and shelf life?

What research is needed to affect these improvements?
Examples of Emerging Packaging Technologies Which May Extend Shelf Life

- Antimicrobial Materials
- Bio-Active Materials
- Selective & Adjusting Barriers
- Indicating & Sensing Materials
- Flavor Maintenance & Enhancing Materials
Example:
Antimicrobial Packaging
Fig. 2. Growth inhibition of *Lactococcus lactis* HP by Nisaplin® immobilised on cellulose-based packaging material prepared with lacticin 3147 (A1) and nisin (A2) and plastic prepared with nisin (B). Controls prepared without bacteriocins are shown on the left of each picture.

Scanell et al 2000
Scheme 3  Schematic diagram showing the quaterization of chitosans and their immobilization on PET-A.
Antimicrobial Peptides
Immobilization on PS Beads

- Peptide
- Spacer Molecule
- Polymer Bead
Concentration (mg/ml) of SMPS required to give a 3 log reduction in counts in buffer in 10, 30, or 60 min at 25°C

<table>
<thead>
<tr>
<th>ORGANISM</th>
<th>10 MIN</th>
<th>30 MIN</th>
<th>60 MIN</th>
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<tbody>
<tr>
<td>E. coli 0157:H7</td>
<td>8</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>S. typhimurium</td>
<td>18</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>S. liquefasciens</td>
<td>8</td>
<td>5</td>
<td>ND</td>
</tr>
<tr>
<td>P. fluorescens</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>B. subtltis</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>L. monocytogenes</td>
<td>12</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>S. aureus</td>
<td>&gt;60</td>
<td>57</td>
<td>50</td>
</tr>
<tr>
<td>K. marxiamus</td>
<td>16</td>
<td>9</td>
<td>8</td>
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</table>
Example: Selective/Adjusting Barrier Films
Effect of Atmosphere on Cut Apple Respiration

Gurbuz & Hotchkiss, 2001
Optimizing Film Permeation for Cut Fruits and Vegetables

• Senescence and decay are closely related to
  – temperature
  – ethylene exposure
  – composition of the surrounding atmosphere

• Atmosphere composition relates to
  – respiration rate
  – package permeability & Permselectivity
  – film permeability & area/product mass ratio
Permselectivity

Permselectivity ($\beta$) = ratio of CO$_2$ permeability coefficient ($P_{CO_2}$) to O$_2$ permeability coefficient ($P_{O_2}$), $\beta = \frac{P_{CO_2}}{P_{O_2}}$
Perm Selectivity & Cut Apples
Under optimum atmosphere of 30% CO₂, 0.5% O₂;
R_{CO₂} = 2.1 Kg/hr, and RQ = 1.9 (Gunez & Hotchkiss, 2001).

Assume: Package A = 1320 cm²; x = 1 mil; mass apples = 2.27 Kg;
bulk apple volume = 3818 cm³; package volume = 5090 cm³; and
headspace = 1272 cm³; optimum CO₂; y_{oCO₂} = 0.30; O₂; y_{oO₂} = 0.005;
external CO₂ and O₂ concentrations; y_{eCO₂} = 0; and y_{eO₂} = 0.21.
Calculated (Exama et al, 1993) required permeability for fresh-cut apples is:

\[
P^{R}_{CO₂} = \frac{W_{RCO₂}L}{Ap(y_{oCO₂}-y_{eCO₂})} = 1.2 \times 10^{-2} \text{ mL mil/cm}^2 \text{ hr atm}
\]

\[
P^{R}_{O₂} = \frac{W_{RO₂}L}{Ap(y_{eO₂}-y_{oO₂})} = 9.23 \times 10^{-3} \text{ mL mil/cm}^2 \text{ hr atm}
\]

\[
P^{R}_{CO₂}/ P^{R}_{O₂} = 1.3
\]
## Permselectivities of Some Common Films

<table>
<thead>
<tr>
<th>Material</th>
<th>Perm Coeff.</th>
<th>Permselectivity</th>
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<tbody>
<tr>
<td></td>
<td>CO₂</td>
<td>O₂</td>
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<tr>
<td>LDPE</td>
<td>99</td>
<td>27</td>
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<tr>
<td>PP</td>
<td>58</td>
<td>9</td>
</tr>
<tr>
<td>PVC</td>
<td>0.65</td>
<td>0.19</td>
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<tr>
<td>Cell. Acetate</td>
<td>348</td>
<td>10</td>
</tr>
<tr>
<td>PET</td>
<td>53</td>
<td>6.1</td>
</tr>
<tr>
<td>Ionomer</td>
<td>—</td>
<td>--</td>
</tr>
<tr>
<td>Nylon 6</td>
<td>1.6</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Al-Ati & Hotchkiss, 2001
Recommended Gas Composition for Fruits and Permselectivity of Plastic Films

- A = LDPE (6.7)
- B = HDPE (4.8)
- C = PET (3.4)
- D = Saran (10)
- E = PVC (6)
- F = PA (5)

Al-Ati & Hotchkiss, 2001
Example: Microbial Condition
THE END
Conclusions

• Packaging plays a central role in reducing the rate of quality loss in foods.
• There is a need for technologies that reduce the rate of food deterioration and/or provide information about the quality/safety of foods.
• Research & development will be necessary to affect these desirable changes.