Food Processing

- Drying (Dehydration)
- Frying
- Baking and roasting
- Extrusion
- Evaporation
- Blanching
- Pasteurization
- Sterilization
- Microwave heating
- Infrared radiation

- Chilling
- Freezing
- Freeze drying
- Sorting
- Peeling
- Size deduction
- Mixing and forming
Why food processing?

- Toxin removal
- Preservation
- Improving flavor
- Easing marketing and distribution tasks
- Increasing food consistency
- Seasonal availability of many foods
  - Transportation
- Food safety by removing the microorganisms
- Extra nutrients

**Thermal processing**
- Use large amount of energy that is random in effect – may cause many other reactions in a food, while some are desirable, some are unwanted.

**Non-thermal Processing**
- Foods are processed at reduced temps (may use a combination of slightly elevated temps plus this additional treatment)
**Strategy**

- Hurdle concept - Use a combination of less intensive treatments (compared to heating) to produce a safe, stable higher quality product.

- This mandates the combination of treatments
  - Process plus refrigeration, pH reduction, controlled atmosphere storage, water activity, or preservatives

Intermediate moisture fruit product

High moisture fruit product

Minimally processed refrigerated fruit product
What consumers want

- Convenience: 15 min meal
- Safety
- Quality
  - Restaurant or home quality flavor
  - Fresh
  - Technology balance
    - Green
    - GMO free
    - Organic
    - Minimal additives
- Wellness and Health benefits
  - Nutraceuticals
  - Functional foods

Food safety objective

To impart sufficient heat to the product to inactivate the desired number of bacterial (vegetative and spores) pathogens and ensure a safe shelf life.
To kill or not to kill, That is the question

- Safety vs. quality

Pasteurization

- 1920’s Deaths from Brucellosis & tuberculosis linked to raw milk
- Mass. Public health officials suggest need to heat treat in 1930
  - 140°F for 30 min or more
  - Significant flavor changes
- Consumer resistance
- Eventually all states (exceptions)
  - 20 years
- Now FDA requirement
• **LTLT**
  - Low-temperature-long-time (LTLT) processing is only used to pasteurize dairy products. Temperatures of 145-160°F (62.8-71.0°C) are used with holding times of typically 30 minutes.

• **HTST**
  - High-temperature-short-time (HTST) processing encompasses a range of different heat treatments (Temp. 280°F, 138°C). Some HTST processes can reach 260-275°F (127-135°C) for 15-180 seconds to produce commercially sterile food. At the other extreme, pasteurization is performed at 161-230°F (71.7-110°C) for 1-5 seconds to produce short shelf life refrigerated foods.

• **UHT**
  - A process is described as UHT (Ultra high temperature) when the product reaches a minimum temperature of 280°F (137.8°C) for a minimum of 2 seconds. Typically 5-15 seconds at 285°F (140°C) is sufficient to obtain commercial sterility. These conditions compensate for possible occurrence of laminar flow through the sterilizer where product at the center of the tubes can travel at twice the average velocity of product.

---

### Table 10.1 — Purpose of pasteurisation for different foods

<table>
<thead>
<tr>
<th>Food</th>
<th>Main purpose</th>
<th>Subsidiary purpose</th>
<th>Minimum processing conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH &lt; 4.5</td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>Dairy</td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>Beer</td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>pH &gt; 4.5</td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>Milk</td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>Liquid egg</td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
<td><img src="image_url" alt="Image" /></td>
</tr>
</tbody>
</table>

- Followed by spore growth at 5-7°C
- *Bacteriostatic* organism: which growth is slower
- Pasteurized in the shell eggs (57°C (~135°F) for 40 min)
- 7D salmonellae
- Quality problems
  - Loss of protein functionality
  - Gels if over heat treat
Thermal technologies

- Infrared Radiation (0.76 - 350 µm)
- Microwave Radiation (915 MHz or 2450 MHz; 12.3 or 32.8 cm)
- Radio Frequency Radiation (13.56, 27.12 or 40.68 MHz; 7.4 - 22.1 m)
- Ohmic Heating

http://www.cfsan.fda.gov/~comm/ift-toc.html

Infrared radiation
Infrared radiation

- Herschel (1800): Placed thermometer in solar spectrum resolved by Prism – heating effect
- Infrared cooker: 650 - 900°C
- Absorbed by organic materials at discrete freq.
- Transitions -- Rotational, Vibrational (Stretching) Movements
- Infrared absorption bands of different Food constituents are different
  - O-H -- Water (2.7 - 3.3 µm), C = O -- Fats (5.71 - 5.76 µm)
- Instantaneous heating unlike convection ovens
  - Don’t need Hot Air to Convey the Heat
- Ground beef patties; pest control of seeds, peas
- Effect on humans -- mainly skin and eyes

Microwave radiation

- Effect on humans -- mainly skin and eyes
Microwave radiation

- Magnetron (Tube with Magnetic and Electric Field Perpendicular), waveguide, cavity
- Turntable or Wave-Stirrer for Uniformity
- 915 MHz, 2450 MHz
- Ice is transparent to microwave
  - Thawing problem (runaway effect)
- Volumetric Heating
- Non-Uniform Temperature Distribution

Radio frequency (RF) radiation
Radio frequency (RF) radiation

- Reverse polarity of electrodes at RF
- 13.56 MHz, 27.12 MHz or 40.68 MHz
- Uniform heating within a high moisture product
- Drying of heat sensitive products
  - Timber Industry (Glued Joints), Textile Industry (Fabrics)
- Post-bake drying of cookies
- Preheating of dough and cake mixes
- Application to particulate foods

Ohmic heating

Joule heating, electrical resistance heating, direct electrical resistance heating, electroheating, and electroconductive heating

[Diagram showing electrical analogue and Ohmic heating]
Heating materials by passage of electrical current through them

Ohmic heating
Heat problems?

- Destroys texture of tissue foods
- Some cooked flavor
- Does not inactivate all enzymes
- Hot and cold spots: still some microbes left
  - pathogen problem

**Paradigm Shift**

- Oh wow! Paradigm shift!
Non-thermal techniques
Novel cold preservation techniques

1) High pressure (studied as early as 1899 – found pressures ca. 6,800 atmospheres stopped grape fermentation)
2) Irradiation (been around many years – timing. Problem FDA considers irradiation a "food additive" which means it must be labeled as being irradiated)
3) High intensity pulsed electric fields (milk pasteurized with electricity in 1935)
4) Pulsed light (relatively new concept)
5) Oscillating magnetic fields (studies on the growth of yeasts and bacteria in 1938)
6) Hurdle technology – combining several approaches (processing or storage conditions, water activity, pH, redox potential, and preservatives)

High Pressure Processing (HPP)

• Find pressures of 4,000-9,000 atmospheres to inactivate some enzymes and bacteria
  – Damage to microbial cell walls, enzymes

• First commercial products – 1990 Japan
  – Preserves and fruit juices
  – Cost 3-4x thermal processed – must be made up in quality offered
Hite, B.H. 1899. The effect of pressure in the preservation of milk. *West Virginia Agricultural Experiment Station Bulletins* 58: 15-35
Destruction of micro-organisms

Benefits/Strengths

- No evidence for toxicity
- Good retention of sensory properties and nutritional value
- May get some desirable textural changes
- Positive consumer perception
- Foods can be processed in packages

Weaknesses

- Equipment is expensive: $2MM
- Enzymes activity may remain
- Some microbes survive
- Kinetics not totally developed
- Regulatory issues
Irradiation

- First patented in 1905 by British workers
- Used on pork in the US in 1921 to eliminate trichina.
- US – early research - military for the sterilization of foods.
- Today:
  - Interest in pasteurization, disinfestations (e.g. spices), delay of fruit ripening or to stop sprouting.
  - Milder treatments have minimized some of problems.
Radiation Sources

- Gamma irradiation - radioactive source such as Cobalt 60 (max energy of 1.25 MeV)
- Electrons - electron accelerator (do not penetrate well; max energy of 10 MeV)
- X rays - electron accelerator focused on metal target to give X-rays (max energy of 5 MeV) (better penetration but large loss of energy)
- Energy maximums to minimize creation of radioactivity during process.
Effects on Food

• Cellulose - shorter chain carbohydrates (change in texture – softening)
• Fats - fatty acids, free radicals promoting oxidation and hydrocarbons (possible off flavors)
• Proteins - peptides and amino acid fragmentation (off flavors – burnt feathers)
• Potential losses of some vitamins (e.g. A, B, C and E ) but less than equivalent heat treatment.

Benefits/Strengths

• Reliably kills insects
• Little change in food quality (depends upon treatment)
• Works on low or dry materials
• Low energy costs (reduced processing costs) $0.01$/lb
• Can be used in large scale production
Weaknesses

- Politics
- Possible changes in flavor
- "Nuclear" image/regulation
- Large capital costs
- Radioactive risks
- Difficult to detect (labeling)
- Probably not eliminate enzyme activity

Pulsed Electric Field

- Early use was just to produce heating – ohmic heating
- Recent - static or oscillating electric fields (5-30 kV/cm)
  - Short pulses – 1-100 μsec
  - Kills vegetative cells, molds, yeast
    - Spores: Resistant due to tough protective coats and dehydrated cells
- How
  - Formation of pores in cell membranes – cells swell and rupture
Benefits

- Energy efficient
- Little effect on color, flavor, nutrients
- No evidence of negative health effects
- Very rapid treatment
- Liquid whole eggs, apple juice, milk, soup
- *E. coli, Staphylococcus, Pseudomonas*

Weaknesses

- No effect on enzymes or spores
- Difficult to use on very conductive materials – salt content
- Electrolysis products?
- Concerns over safety in food processing environment
- Regulatory issues - validation
- High initial costs
Major barriers include:

1) Lack of knowledge (what are most stable organisms under new technology? How does process work?)
2) Legal approval
3) Safety of operators and consumers must be proven (e.g. working around irradiation, magnetic fields)
4) Consumer approval
5) Processing hurdles (cost, scale, etc.)

Is non-thermal product ‘fresh’?
- The term “fresh,” when used on the label or in labeling of a food in a manner that suggests or implies that the food is unprocessed, means that the food is in its raw state and has not been frozen or subjected to any form of thermal processing or any other form of preservation (except waxing, washing, post harvesting pesticides, irradiation at low levels)
- Consumer expectations
  - Purity and highest quality
  - High pressure rates highly with consumers in terms of acceptance
- Fresh or pasteurized?
- FDA has not changed the definition of ‘fresh’, yet.
- Consumers want to know more about how their foods are produced.
Future needs

- What is best apparent model for both pressure and electric field predictions of log N vs. time?
- Resistant spores and enzymes
- Statistically reliable protocol for model testing
- How do you verify process (dosimetry)?
- Research needs
  - [http://vm.cfsan.fda.gov/~comm/ift-need.html](http://vm.cfsan.fda.gov/~comm/ift-need.html)
- Summary of current data available
  - [http://vm.cfsan.fda.gov/~comm/ift-over.html](http://vm.cfsan.fda.gov/~comm/ift-over.html)
  - [http://www.cfsan.fda.gov/~comm/ift-toc.html](http://www.cfsan.fda.gov/~comm/ift-toc.html)