ITP330
TEKNOLOGI BARU
PENGOLAHAN PANGAN

Purwiyatno Hariyadi
hariyadi@seafast.org
History of Food Process Engineering


World's Population (billions)

Hunter-Gatherer Agricultural Industrial

4 million Years ago 10 000 Years ago 1800 1900 2000

1850 Introduction of Food technology

1930

1960

1976

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History of Food Process Engineering

- Fiber crates
- Cellulose packaging
- Gable-top, waxed milk cartons
- Sliced bread
- Jell-O
- Regulations e.g. Food, Drug, and Cosmetic Act

World's Population (billions)

Hunter-Gatherer Agricultural Industrial

4 million Years ago 10,000 Years ago 1800 1900 2000

1850 1930 1960 1976

Introduction of Food technology

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History of Food Process Engineering

- Automation
- Mass production
- Frozen foods
- Vending machines

World's Population (billions)

- 1850: Introduction of Food technology
- 1930
- 1960
- 1976

Timeline:
- 4 million Years ago: Hunter-Gatherer
- 10,000 Years ago: Agricultural
- 1800-2000: Industrial
History of Food Process Engineering

- Frozen dinners
- Foreign foods
- Food for bomb shelters
- Frozen, ready-to-eat bakery goods
- Targeted markets
- Controlled-atmosphere packaging

World's Population (billions)

World Population Timeline:
- 4 million Years ago
- 10,000 Years ago
- 1850
- 1930
- 1960
- 1976

Timeline:
- Hunter-Gatherer
- Agricultural
- Industrial

- Introduction of Food technology

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History of Food Process Engineering

- Diet foods
- Process control computers
- Clean-in-place
- Aseptic canning
- Drying improvements

World's Population (billions)

Hunter-Gatherer

Agricultural

Industrial

4 million Years ago

10,000 Years ago

1850

1900

1800

1930

1960

1976

Introduction of Food technology

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History of Food Process Engineering

- Energy efficiency
- Water/waste utilization
- Membrane processing
- Health/organic foods
- Environmentally robust computers

- Hunter-Gatherer
- Agricultural
- Industrial

World’s Population (billions)

4 million Years ago
10 000 Years ago
1800 1900 2000

Introduction of Food technology

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History of Food Process Engineering

- Dechemicalization
- Automation
- Aseptic processing
- Irradiation
- Packaging

World's Population (billions)

- 1850
- 1930
- 1960
- 1976

Introduction of Food technology

Timeline:
- 4 million Years ago
- 10,000 Years ago
- 1800
- 1900
- 2000

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History of Food Process Engineering

- Intelligent Packaging
- Low Carb
- Sachet Packaging
- Functional Foods

World's Population (billions)

- Hunter-Gatherer
- Agricultural
- Industrial

4 million Years ago
10,000 Years ago
1800
1900
2000

1930
1960
1976

Introduction of Food technology

Purwiyatno Hariyadi - Emerging New Processing Technology in Foods – ITP330
Driving Force of Food Science/Food Technology

- Safe
- Wholesome
- Nutritious
- “Functional”
- “Green”

World’s Population (billions)

- Cheap
- Abundant
- Available

4 million Years ago
10,000 Years ago
1800
1900
2000

Introduction of Food technology

Hunter-Gatherer
Agricultural
Industrial
Driving Force of Food Science/Food Technology

- Safe
- Wholesome
- Nutritious
- “Functional”
- Green

Emerging New Processing Technologies

- Cheap
- Abundant
- Available
Driving Force of Food Science/Food Technology

• Alternatives
Food Processing Technology

Emerging New Processing Technologies

Food Technology

→ Providing better value of foods

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Emerging Processing Technologies

- Microwave and Radio Frequency
- Ohmic and Inductive Heating
- High Pressure Processing
- Pulsed Electric Field
- High Voltage Arc Discharge
- Pulsed Light
- Ultraviolet Light
- Ultrasound
- X-Rays
### Status of the Report on Technologies (1)

<table>
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<td>Critical Factors and Quantification</td>
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<td></td>
<td>Hard to predict cold zone</td>
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<tr>
<td>Process deviations</td>
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<td>Organisms of concern</td>
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<td>Indicator organisms</td>
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<td>Main research need</td>
<td>Prediction of cold zone</td>
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## Status of the Report on Technologies (2)

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<tr>
<td>Main research need</td>
<td>Multiple combination with other technologies</td>
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<sup>1</sup> Lack of critical process factors quantification does not permit suggested responses to process deviations

<sup>2</sup> Must identify pathogen of concern before indicators are finalized

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# Status of the Report on Technologies (3)

<table>
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<th>PROCESSING</th>
<th>TECHNOLOGIES</th>
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<td>HIGH VOLTAGE ARC DISCHARGE</td>
<td>PEF</td>
<td>PULSED LIGHT</td>
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<tr>
<td>PROCESS DESCRIPTION</td>
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<td>Well described</td>
<td>Well described</td>
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<td>MECHANISM OF INACTIVATION</td>
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<td>CRITICAL PROCESS FACTORS AND QUANTIFICATION</td>
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<td>Kinetic models proposed, need validation</td>
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<td>PROCESS DEVIATIONS</td>
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<td>MAIN RESEARCH NEED</td>
<td>Independently conducted research</td>
<td>Treatment measurement and kinetic models validation</td>
<td>Independently conducted research</td>
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<sup>1</sup> Lack of critical process factors quantification does not permit suggested responses to process deviations.

<sup>2</sup> Must identify pathogens of concern before indicators are finalized.
PENGUNAAN GEL MIKRO (MICROWAVE/MW) UNTUK KEPERLUAN INDUSTRI:

PEMANASAN DIELEKTRIK (& GEL MIKRO)

- dipantulkan oleh metal
- diserap (diubah menjadi panas) oleh dielektrik: *internal heating* (Molecular friction).

```
δ-
d/H
δ+
```

```
Oδ-
δ+
H
δ+
```

```
Hδ+
```

```
δ-
```

```
δ+
```

```
δ+
```

```
δ-
```

```
`Perub. Orientasi polarisasi`
```

```
Ionic displacement
```

Generator (Oscillator)

Bahan pangan

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\[ P = 2\pi(\varepsilon_o)(\varepsilon') \tan \delta E^2 f \]
\[ P = 5.56 \times 10^{-13} (\varepsilon') \tan \delta E^2 f \]

\( P \) = jumlah panas yang diproduksi per satuan volume \([=] \) W/m\(^3\)

\( \varepsilon_o = \text{permittivity of free space} \)

\( \varepsilon' = \text{konstanta dielektrik} \)

(sifat fisik bahan yang berhubungan dengan polaritas atau \( \Sigma \) dipole)

\( \delta = \text{loss angle} \)

\( E = \text{kekuatan medan listrik } [=] \) volts/m

\( f = \text{frekuensi (hz, s}^{-1})\)

\( \varepsilon' \tan \delta = \varepsilon'' = \text{loss factor} \)
LOSS FACTOR

$\varepsilon'' = f (SUHU, FREKUENSI)$
DAYA PENETRASI GEL MIKRO = \( d \)

\[
d = \frac{\lambda_o}{2\pi \sqrt{\varepsilon'} \tan \delta}
\]

\( \lambda_o = \) panjang gelombang

<table>
<thead>
<tr>
<th>Kadar air</th>
<th>(\varepsilon')</th>
<th>915 MHz</th>
<th>2450 MHz</th>
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<tr>
<td>tinggi</td>
<td>15</td>
<td>8,4</td>
<td>3,1</td>
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<tr>
<td>sedang</td>
<td>4</td>
<td>11,7</td>
<td>4,4</td>
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<tr>
<td>rendah</td>
<td>1,5</td>
<td>22,1</td>
<td>8,2</td>
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PENINGKATAN SUHU DALAM PRODUK

Jumlah panas yang diperlukan untuk meningkatkan suhu produk sebesar $\Delta T$

$$Q = mc \Delta T$$
$$Q = \rho Vc \Delta T \quad atau$$
$$\Delta T = \frac{Q}{\rho Vc}$$
dimana $V = volume$

Jumlah panas yang diproduksi oleh pemanasan gel mikro:

$$Q = PV\Delta t$$
$$Q = (5.56 \times 10^{-13} \varepsilon'' E^2 f) V \Delta t$$

Jadi,

$$\Delta T = 5.56 \times 10^{-13} \frac{\varepsilon''}{\rho c} E^2 f \Delta t$$

untuk pemanasan gel mikro yang sama,

$$\Delta T = \approx \frac{\varepsilon''}{\rho c} = f \ (Komponen \ bahan \ pangan)$$

homogenitas pemanasan = homogenitas bahan pangan
APLIKASI PEMANASAN GEL. MIKRO (UMUM):

• Rumah tangga : microwave oven

• Komersial
  ▶ Pemanasan tanpa merubah sifat-sifat dasar produk : *thawing & defrosing (tempering)*

  ▶ Pemanasan dengan merubah sifat-sifat dasar produk :
    Pengembangan adonan & pemanggangan
    Pemblansiran buah/sayuran : inativasi enzim
    Pemasakan (*cooking*)
    *Roasting* (untuk kacang-kacangan)

  ▶ Pengeringan : Dehidrasi pada tekanan normal
    Dehidrasi pada tekanan vakum

  ▶ Inaktivasi Mikroba :
    Sterilisasi & Pasteurisasi (kurang sukses ! : masih dalam penelitian!)
Utama: membantu proses pengeringan lanjut

Proses pemanggangan dimulai dengan oven tradisional (mengg. udara panas):

- Efektif untuk produk dengan kadar air tinggi
- Dengan semakin menurunnya kadar air: efektifitas oven menurun case hardening?!
- Pengeringan/pemanggangan selanjutnya: oven gel. Mikro mengeringkan bag dalam (tanpa “overcooked” di permukaan)
APLIKASI PEMANASAN GEL. MIKRO PADA PROSES THAWING:

😊 Konduktivitas panas air < konduktivitas panas es
   Proses pencairan: menurunkan proses pindah panas

😊 Loss factor air > loss factor es
   Proses pencairan: menaikan kadar air dan loss factor
   >> mempercepat proses pemanasan

😊 Problem: Pada bahan baku yang ukuran besar
   - proses pencairan tidak seragam
   - mengakibatkan overcooked pada bagian ttt
APLIKASI PEMANASAN GEL. MIKRO PADA PROSES DEFROSTING:

→ Menaikan suhu produk beku: -20°C menjadi -3°C
→ Untuk daging dan mentega mempermudah penanganan (*slicing*)
→ Minimum overcooked
→ Cepat: daging dapat didefrost selama 10 menit
  (tradisional: beberapa hari pada *cold room*)
→ Minimum perubahan phase
→ Minimum *drip loss* (kehilangan karena penetesan)
→ Mutu meningkat: lebih higienik, lebih cepat, dapat dilakukan di dalam box (pengemas)
→ Ruang yang diperlukan sedikit
→ Ekonomis
APLIKASI PEMANASAN GEL. MIKRO PADA PROSES DEHIDRASI:

VS. PEMANASAN TRADISIONAL/UDARA PANAS:

- Pindah panas turun: 
  *thermal conductivity* turun pada bahan pangan kering
- Semakin lama waktu pengeringan mutu sensori dan mutu gizi turun
- Oksidasi tinggi: mengakibatkan warna dan vitamin menurun.
  Untuk produk dengan kadar pufa tinggi, terjadi ketengikan
- *Case hardening*: perubahan karakteristik permukaan
  >> keras, susah ditembus oleh panas/uap air (kualitas produk menurun)
APLIKASI PEMANASAN GEL. MIKRO PADA PROSES DEHIDRASI:

VS. PEMANASAN GELOMBANG MIKRO:

- Memanaskan bahan dari dalam:
  - Tidak ada masalah ttg konduktivitas panas
  - Tidak memanaskan udara: mrengurangi ksidasi rendah
  - Tidak terjadi case hardening
    (pindah massa/uap air .......> lancar)

- Umumnya dipakai untuk mengeringkan semi/partly dried foods, dimana gel. Mikro akan tetap memanaskan daerah yang masih basah, tanpa mempengaruhi daerah/bagian yang sudah kering.

- Mahal
APLIKASI PEMANASAN GEL. MIKRO : LAIN-LAIN

Masih dalam taraf penelitian:
  Blansir, Pasteurisasi, Sterilisasi

PENGARUH GELOMBANG MIKRO TERHADAP BAHAN PANGAN :

- tidak ada pengaruh langsung pada mikroorganisme
- waktu proses menurun
- retensi gizi lebih baik (prinsip HTST)
PEMANASAN OHMIC

P = I^2R
P = I^2k_e^{-1}
I = k_eEL^{-1}

- kecepatan pemanasan tergantung pada nilai k_e bahan pangan
- k_e bahan pangan = f(kadar air, garam ionik dan asam)
- k_e bahan pangan cair >> k_e bahan padat
- minyak dan lemak mempunyai nilai k_e sangat rendah

P : laju jumlah panas yang diproduksi per satuan volume (W.m^{-3})
E : kekuatan medan listrik (Volt cm^{-1})
k_e : konduktivitas listrik (ohm^{-1}/m· S/m)
I : densitas arus listrik (amps/m^2)
R : tahanan listrik (ohm^{-1})
Arah perambatan panas, $Q$

$$Q(r) = \frac{Pr}{2}$$

$$T - T_0 = \frac{Pr^2}{4k} \left[ 1 - \left( \frac{r}{R} \right)^2 \right]$$

$k = \text{konduktivitas panas}$

**Kenaikan suhu maksimum**

$$T_{\text{max}} - T_0 = \frac{PR^2}{4k}$$

**Kenaikan suhu rata-rata**

$$\bar{T} - T_0 = \frac{PR^2}{8k}$$
Contoh:
Sebuah bahan berbentuk silinder dengan diameter 2R dan panjang L. Berapa $\Delta$ voltase (E) yang perlu diberikan supaya terjadi peningkatan suhu di pusat bahan sebesar $(T_{\text{max}} - T_0)^\circ\text{C}$, dimana suhu awal = $T_0$.

Jawab:
Gunakan persamaan peningkatan suhu

$$T_{\text{max}} - T_0 = \frac{PR^2}{4k}$$

$$T_{\text{max}} - T_0 = \frac{l^2R^2}{4k_e k}, \quad I = \frac{k_e E}{L}$$

$$T_{\text{max}} - T_0 = \left(\frac{k_e E}{L}\right)^2 R^2 = \left(\frac{E^2R^2}{4L^2}\right) \left(\frac{k_e}{k}\right)$$

Jadi,

$$E = 2\left(\frac{L}{R}\right)\sqrt{\frac{k}{k_e T_0}} \sqrt{T_0 (T_{\text{max}} - T_0)}$$
PERBANDINGAN ANTARA PEMANASAN GEL MIKRO DAN OHMIC

<table>
<thead>
<tr>
<th>Kriteria</th>
<th>Pemanasan Gel Mikro</th>
<th>Pemanasan Ohmic</th>
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<tr>
<td>Konduktivitas listrik (siemen/m)</td>
<td>0.25-4</td>
<td>0.005-1.2</td>
</tr>
<tr>
<td>Generasi Panas untuk medan listrik 20 V/m (W/cm³)</td>
<td>1-16</td>
<td>0.02-5</td>
</tr>
<tr>
<td>Kenaikan suhu (°C/sec)</td>
<td>0.25-4*</td>
<td>0.004-1.2*</td>
</tr>
</tbody>
</table>

* kenaikan suhu di permukaan kaleng pada proses pemanasan retort adalah sekitar 0.2°C/sec
PEMANASAN OHMIC VS GELOMBANG MIKRO

- Mirip dengan pemanasan gel. Mikro:
  - Konversi energi listrik menjadi energi panas
- Penetrasi panas/daya penetrasi: tidak terbatas
- Suhu dalam bahan pangan merata ($\nabla T \approx 0$)
- Tidak perlu “pengadukan”
- Cocok untuk memanaskan bahan pangan cair dgn partikulat:
  - sop dll.

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<table>
<thead>
<tr>
<th>Bahan</th>
<th>nilai $k_e$ (s/m)</th>
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<tbody>
<tr>
<td>Air murni (25°C)</td>
<td>$5,7 \times 10^{-6}$</td>
</tr>
<tr>
<td>Asam sulfat (25°C)</td>
<td>1</td>
</tr>
<tr>
<td>kentang (19°C)</td>
<td>0.037</td>
</tr>
<tr>
<td>wortel (19°C)</td>
<td>0.041</td>
</tr>
<tr>
<td>kacang kapri (19°C)</td>
<td>0.17</td>
</tr>
<tr>
<td>daging sapi (19°C)</td>
<td>0.42</td>
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<tr>
<td>Larutan pati (5.5%, 19°C)</td>
<td></td>
</tr>
<tr>
<td>+ garam 0.2%</td>
<td>0.34</td>
</tr>
<tr>
<td>+ garam 0.55%</td>
<td>1.3</td>
</tr>
<tr>
<td>+ garam 2%</td>
<td>4.3</td>
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</table>
Figure 10.3 Schematic flowsheet for the APV Baker ohmic heater, after [10].
High hydrostatic pressure

Juga disebut

(Ultra) high pressure processing
High hydrostatic pressure

**Historical Timeline**

- **1895** H. Royer uses high pressure to kill bacteria.
- **1899** Bert H. Hite at the West Virginia Agricultural Experimental Station examined pressure effects on milk, meat, fruits and vegetables.
- **1914** P. W. Bridgman coagulated egg albumen under high pressure.
- **1990** First commercial products like fruit juices, jams, fruit toppings and tenderized meats introduced in Japan.
- **1995** Orange juice commercialized in France.
- **1997** Market introduction of guacamole in the US and sliced cooked ham in Spain.
- **1999** Oysters introduced in the US.
- **2000** Range of salsas launched in the US market.
High hydrostatic pressure

How High??

Two elephants balanced on a piston with a cross section of a dime will create a pressure of 400 Mega Pascal (Mpa). This is approximately 60,000 pounds per square inch.
High hydrostatic pressure

- High Pressure can kill microorganisms by interrupting with their cellular function without the use of heat that can damage the taste, texture, and nutritional value of the food.
The "mechanism" of high-pressure based bacteria kill is low energy and does not promote the formation of new chemical compounds, "radiolytic" by-products, or free-radicals.

- Vitamins, texture and flavor are basically unchanged.
- For example, enzymes can remain active in high pressure produced orange juice.
High hydrostatic pressure

............ the system
High hydrostatic pressure

Applications for High Pressure Processing are found in the areas of...

**Preservation**

Elimination or substantial reduction of spoilage microorganisms and enzymes for *shelf life extension* of refrigerated food products with *superior sensory quality*, e.g. juices, jams, guacamole, salsa, meat & dairy products, seafood (*commercialized*)

Acidified and low-acid shelf-stable products (under development)
High hydrostatic pressure

Applications for High Pressure Processing are found in the areas of...

**Food safety**

*Elimination of pathogens*: e.g. *Listeria* in meat products, *Salmonella* in eggs and poultry, *Vibrio* in oysters

*Hypotheses for vegetative cell inactivation...*
- denaturation of proteins and enzymes
- damage of DNA replication & transcription
- solidification of membrane (phospho)lipids
- breakage of bio-membranes (cell leakage)

*Spores* are very resistant to pressure, but can be destroyed by combining pressure with elevated temperatures

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High hydrostatic pressure

Applications for High Pressure Processing are found in the areas of...

Fruit Juice treated with HHP

- Juice tests have shown that food pathogens such as *salmonella* and *E.coli* 0157:H7 can be effectively destroyed without changing the fruit juice's fresh, natural characteristics.
- A pressure exposure of 80,000 psi for 30 seconds can achieve a 3-5 log reduction of all of the pathogens of concern in fresh juice.
High hydrostatic pressure

Applications for High Pressure Processing are found in the areas of...

Oyster treated by HHP

- Another example of food safety is the destruction of *Vibrio* bacteria in raw oysters without destroying the raw feel and taste of the oyster.
- A pressure of 200 to 300 MPa for 5 to 15 minutes at 25°C inactivated:
  - *Vibrio parahaemolyticus* ATCC 17803,
  - *Vibrio vulnificus* ATCC 27562,
  - *Vibrio choleare* ATCC 14035,
  - *Vibrio choleare* non-O:1 ATCC 14547,
  - *Vibrio hollisae* ATCC 33564
  - *Vibrio mimicus* ATCC 33653

(from: “D. Berlin, D. Herson, D. Hicks, and D. Hoover; Applied and Environmental Microbiology, June 1999”)
High hydrostatic pressure

Applications for High Pressure Processing are found in the areas of...

Oyster treated by HHP

Pressure shucked raw clams. Pressure not only destroys the vibrio family of bacteria that can be found in shellfish, but also detaches the meat from the shell, saving labor and increasing production efficiency.
High hydrostatic pressure

Applications for High Pressure Processing are found in the areas of...

Styrofoam cup subjected to 40,000 psi, sliced ham, and fruit pack (with juice) subjected to 80,000 psi.

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High hydrostatic pressure

Applications for High Pressure Processing are found in the areas of...

Texturization

As an alternative to heat processing texturization can be accomplished by exposing protein (e.g. egg, whey, soy) and hydrocolloid (e.g. pectin, starch) solutions to hydrostatic pressure. The resulting gels are characterized by uniquely different textures.
High hydrostatic pressure

Applications for High Pressure Processing are found in the areas of...

Heat-sensitive compounds

HPP offers the unique potential to stabilize products with heat-sensitive components (e.g. flavors, nutrients, biologically active compounds).

Biotechnology

Specific enzymes can be activated under pressure leading to enhanced reaction rates and shorter process times.
High hydrostatic pressure

Jams & Fruit Toppings (Japan)
High hydrostatic pressure

Examples of products commercialised in Europe and treated on HYPERBAR installations supplied by ACB

ULTI / PAMPRYL (Groupe PERNOD-RICARD) - France freshly squeezed fruit juice Fresh pressed

ESPUNA - Spain – sliced cooked ham

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High hydrostatic pressure

Examples of Food products in the USA
High hydrostatic pressure

Effect of pressure is very similar to the effect of temperature in thermal processes.

**Figure.** Change in inactivation of *Zygosaccharomyces bailii* with pressure.

Note that 345 MPa = 50,000 psi. (Enrique Palou, GRA, BSysE Dept., WSU)
High hydrostatic pressure

Thermally-assisted high-pressure lifts quality of shelf-stable foods

Process Variables for Optimum Quality

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Pressure</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>90°C</td>
<td>700 MPa</td>
<td>Main meal entrees, meats, pasta dishes, most vegetables, sauces, cheese, soups, stews, flavored milk drinks</td>
</tr>
<tr>
<td>80°C</td>
<td>830 MPa</td>
<td>Whole potatoes, most vegetables</td>
</tr>
<tr>
<td>70°C</td>
<td>1,000 MPa</td>
<td>All potato products, all vegetables, seafood</td>
</tr>
<tr>
<td>60°C</td>
<td>1,240 MPa</td>
<td>Eggs, milk</td>
</tr>
</tbody>
</table>

Source: Richard S. Meyer, PhD, Washington Farms, Inc.
High hydrostatic pressure

Thermally-assisted high-pressure lifts quality of shelf-stable foods

What's needed to commercialize UHP for sterilizing shelf-stable products?

Two things must be done.

1. First, develop the kinetic information necessary to file a petition with the FDA and USDA. To do that, we have to select the most heat and pressure-resistant strain of *Clostridium botulinum*.

2. Second, we need commercial-size, inexpensive high-pressure vessels.