High pressure processing

Identification

Key words
- high hydrostatic pressure, inactivation, enzyme, virus, spore, pasteurization, sterilization, structure modification, phase equilibrium, simulation, p-T diagram, pressure intensifier

Latest version
2012/07/23
Completed by
DIL

How does it work?

Primary objective
Microbial inactivation, stabilization, structure modification, preservation
**Working principle**

Thermodynamic: Thermodynamic properties and phase equilibrium of any media such as thermal conductivity, viscosity or diffusivity show a functional relationship to pressure and temperature. Hydrostatic pressure may be generated by the addition of free energy, e.g., heating at constant volume or mechanical volume reduction. Under (high) pressure all reactions of low- and macromolecular compounds follow the principle of Le Chatelîer. Reactions with a negative reaction volume indicate an increasing product formation with increasing pressure. For example dissociation reactions often show a negative volume-difference and are enhanced during pressure application. The physicochemical and biological effects of high pressure application include structural changes of macro-molecules by coagulation, swelling, denaturation and auto-oxidation. (1, 2, 3, 10, 11, 12)

**Biological Effects:**

- **Inactivation:** In general, vegetative cells are inactivated at low pressure levels, around 400-600 MPa, while more resistant bacterial spores can survive pressures higher than 1.000 MPa. High pressure affects the permeability of the cellular membrane, which is responsible for the nutrient and respirative transport mechanisms of the cell. The modified permeability of the cellular wall results in a disturbed transport mechanism which may cause a loss of vitality. The extent of inactivation depends on several parameters such as type of micro-organism, pressure level, processing temperature and time, pH and composition of the product or treated media. In general gram- negative bacteria were found to be more sensitive than gram-positive bacteria. A combination of pressure and other inactivation mechanisms or antimicrobial hurdles allows a reduction of processing intensity or enhanced inactivation, e.g. also in inactivation of pressure and thermo-resistant spores. (5, 17, 7, 15, 14, 12)

- **Effects on Proteins:** Pressure levels higher than 300 MPa induce modification of the tertiary structure of proteins, characterized by modification of hydrogen bonds and disruption of hydrophobic bonds, often resulting in modified functionality and reactivity of proteins and enzymes. Some studies also describe an impact of pressure on secondary protein structures. In summary when increasing pressure structural changes such as disintegration of micelles, protein dissolution and structure modification such as unfolding or aggregation can occur. These denaturation process typically increase with increasing pressure, temperature and treatment times. (8, 5, 16, 10)

- **Effects on Lipids:** By pressure phase equilibria of lipids are subject to change, often a higher amount of crystalline-structures is observed. In some studies lipid oxidation by pressure is reported, which may results from enzymatic as well as chemical reactions. These equilibria and the extent of other desired or undesired reactions such as oxidation depend on the media composition (lipid type and structure, saturation, presence of oxygen). (9)

- **Effects on Polymers:** The properties (MW, isostatic index, density, crystallinity...) and the phase equilibria of (bio-)polymers such as starch or cellulose are pressure and temperature dependent. The investigation of melting and crystallization of polymers by pressure is interest due to its potential to induce structure modification. E.g. for starch a potential to achieve a physical structure modification is observed (10)

**Images**

**Additional effects**

- Enzyme inactivation
- Textural changes (polymers)
- Vitamin, flavour and colour retention
- Structure modification
- “Cold cooking”
- Swelling
- Gelation
- Minimisation of thermal energy stress

**Important process parameters**

- Pressure
- temperature
- treatment time
Important product parameters
• pH
• protein, lipid, salt or sugar content
• water activity

What can it be used for?

Products  Liquid, semi-liquid and solid products in a final or processing package. Meat, fish, chicken, shellfish, vegetable and fruit (apple, carrot and celery) products
Operations  Preservation and structure formation, f.e. starch gelation by High Pressure
Can be used for pasteurisation, low temperature process, sterilisation (packaging material for sterilisation) is still under investigation.
Solutions for short comings  Preservation of heat sensitive products, reduction of processing time, “cold cooking”, structure formation in protein and carbohydrate based material.

What can it NOT be used for?

Products  Dry products such as powders. Due to discoloration fresh meat treatment is limited.
Operations  Can be used for pasteurisation, sterilization is still under investigation.
Other limitations  • Often applied as a batch process with limited capacity of 4t/h
• High investment cost and maintenance costs e costs
• Choice and adaptation of appropriate packaging geometry and material required.
• Undesired changes of functional and technological properties of polymers (proteins) are possible
Risks or hazards  Pressure resistance of target strains different from heat resistance, processing uniformity (mainly temperature distribution) is still an issue for sterilization applications.

Implementation

Maturity  Industrially available up to pressure levels of 600 MPa. About 130 industrial equipments have been installed worldwide with vessel volumes ranging up to 420 L and production volume of more than 120,000 tons. Most of these applications (about 31%) are found in the meat industry.
Modularity /Implementation  Inactivation in the final package, scalable by use of multiple machines or pressure vessels. Short processing times allow a simple implementation of the technique, but often high efforts for loading/unloading of products are required.
Consumer aspects  Consumers perceive the technique as environmental friendly and are positive to naturalness of the product. HPP products are seen as positive because the natural texture is retained better, fresher taste and environmental friendliness. The main benefits linked to HPP technologies are the health-related, taste-related (products’ naturalness) and environment-related benefits(20, 21, 22). According to several researches HPP has been judged to be relatively similar to conventional process technologies in terms of overall consumer acceptability. (23)
Legal aspects

HPP foods fall in the scope of Regulation (EC) 258/97 on novel foods and novel food ingredients, article 1, item f. Among other categories, this legislation applies to foods and food ingredients to which a production process not currently used has been applied, and evaluates possible changes in nutritional value, metabolism and level of undesirable substances (19). In January 14th 2008, EU published a proposal for the amendment of Regulation (EC) 258/97 (18). The competent authorities of the member states agreed in 2001 that the national authorities should decide on the legal status of high pressure treated foods, as it was no longer considered to be a novel process. Case-by-case assessment by national authorities must ensure the products’ safety.

Environmental aspects

Energy efficient, waste free technique

Facilities that might be interesting for you

<table>
<thead>
<tr>
<th>Title</th>
<th>Institute/company</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP FRIP unit</td>
<td>FRIP</td>
</tr>
<tr>
<td>HP Industrial scale IRTA</td>
<td>IRTA</td>
</tr>
<tr>
<td>HP Labscale IRTA</td>
<td>IRTA</td>
</tr>
<tr>
<td>HP lab-scale multivessel equipment KU Leuven</td>
<td>KU Leuven LFT</td>
</tr>
<tr>
<td>HP lab-scale single-vessel equipment KU Leuven</td>
<td>KU Leuven LFT</td>
</tr>
<tr>
<td>HPHT lab-scale multivessel equipment KU Leuven</td>
<td>KU Leuven LFT</td>
</tr>
<tr>
<td>HPP Pilot system DIL</td>
<td>DIL</td>
</tr>
<tr>
<td>HPPS Labscale System FBR</td>
<td>Wageningen UR - FBR</td>
</tr>
<tr>
<td>HPPS Pilot System FBR</td>
<td>Wageningen UR - FBR</td>
</tr>
</tbody>
</table>

Further Information

**Institutes**
KU Leuven LFT, DIL, IRTA, TU Berlin, Wageningen UR - FBR

**Companies**
Hiperbaric, Resato, Uhde-HPT, APA Processing
References

21. Nielsen H.B. et al. (2009). Consumer perception of the use of high-pressure processing and pulsed electric field technologies in food production, Appetite 52: 115–126