Paper No. 02

Paper: ***Principles of the Food processing and Preservation***

Module No. 25

Module: ***High Hydrostatic Pressure Technology***

25.1 Introduction:

Food preservation using high hydrostatic pressure (HHP) technology is a promising technique in the food industry, as it offers numerous opportunities for developing foods with extended shelf-life, high nutritional value and excellent organoleptic characteristics. This topic covers the components and working principles, brief mechanism of processing, and its impact on physico-chemical and sensory properties of food are elucidated, advantages and disadvantages, packaging requirements, legal and safety concerns are also covered.

25.2 What is High Hydrostatic Pressure Technology?

HHP technology is a novel food processing technique, wherein the food is subjected to very high pressure (with or without the addition of heat), to achieve microbial inactivation or to alter the food attributes in order to achieve consumer-desired qualities and to render safe food. HHP is an alternate, non-thermal food processing method, in which food products are exposed to very high pressure range from 100-800 MPa (1MPa = 145.03 Psi or 10 Bar). HHP is also called as high pressure processing (HPP) or ultra high pressure processing (UHPP) or isostatic processing, and it is also considered as a type of cold processing technique, since temperature employed in most of the HHP is at ambient temperature.

The concept of food processing using HHP was proposed by Royer in 1895 to kill bacteria and later by Hite in 1899 explored HHP effects on milk, meat, fruits and vegetables processing. In early 1990s commercial HHP processed food products; fruit juices, jams, fruit topping and tenderized meats were introduced for the first time in Japanese industry, in Tokyo.

25.3 Principles of High Hydrostatic Pressure Technology

The fundamental operational principles underlying HHP are described below:

a. **Le Chatelier's principle:** Whenever pressure is applied to a system in equilibrium, bio-molecules obey the Le-Chatelier principle. The system will react so as to counteract the applied pressure, reactions that result in reduced volume will be promoted under high pressure, and such reactions may result in inactivation of microorganisms or enzymes.

b. **Isostatic rule:** According to the isostatic principle; when food products are compressed by uniform pressure from every direction and then returned to their original stage and the pressure is released. Food products are compressed independently of the product size and geometry, because transmission of pressure to the core is not mass/time dependant, hence HHP is also called as isostatic processing technique.

c. **Electrostriction:** Pressure leads to increased ionization, because water molecules arrange more compact around electric charges. This result in more or less pronounced negative and reversible pH shifts dependant on the chemical nature of the buffer and the bio-chemical reaction are controlled.

d. **Compression of energy and heat:** Energy input during the pressure process is very small compared to thermal processes. Therefore no chemical reactions involving covalent bonds are observed. Usually HHP is accompanied by a moderate increase in temperature, by the adiabatic heating, which depends on the composition of the food product being processed (Each food component has specific heat of compression values). Hydrostatic pressure is generated by increase in the free energy in the system; this can be achieved by physical compression during pressure treatment in closed system by mechanical volume reduction.

25.4 Components and Working of HHP

The basic key components of a high pressure system are: a pressure vessel, pressurizing system, and supporting units such as heating or cooling components etc. as shown in Figure 1.

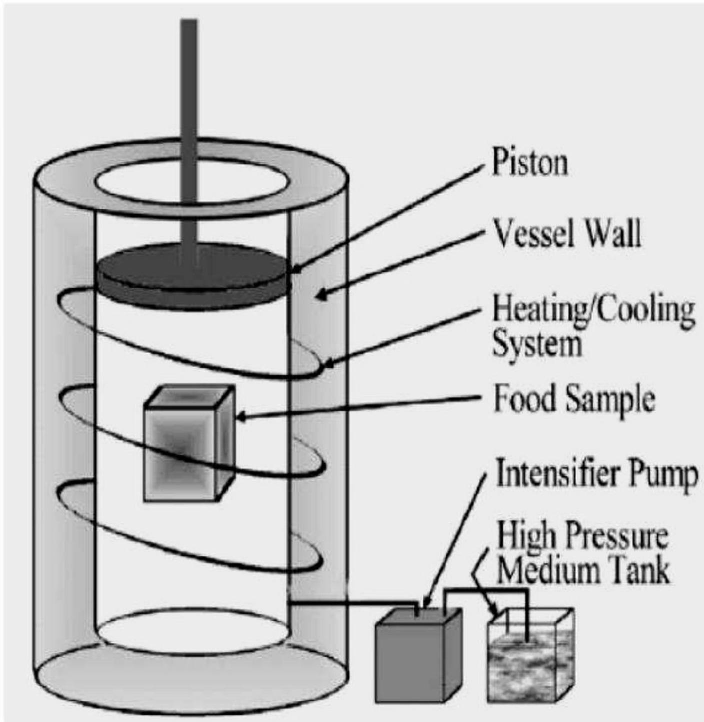


Fig. 1: Diagram showing components of High hydrostatic pressure processing.

In a typical HHP process, the product is packaged in a flexible container (usually a pouch or plastic bottle) and is then loaded into a high pressure chamber filled with a pressure-transmitting (hydraulic) fluid. Air is removed from the vessel with an automatic deaeration valve by means of a low-pressure fast fill-and-drain pump. The hydraulic fluid (normally water) in the chamber is pressurized with a pump, and this pressure is transmitted through the package into the food itself. Pressure is applied for a specific time, usually 3 to 5 minutes. The processed product is then removed and stored/distributed in the conventional manner.

Processing by HHP is carried out usually in a low compressibility liquid such as water. According to the above mentioned principles; the phenomenon of phase transition and chemical changes are accompanied by decrease in volume; favored by pressure. Pressure is instantaneously and uniformly transmitted independent of size and geometry of the food. Resultant pressure regulates most of the biochemical reactions occurring in food system. Consequentially food retains its shape, even at extreme pressures. And because no heat is needed for processing, hence, the sensory characteristics of the food are retained without compromising microbial safety.

In biological systems most important changes that are brought about by HHP are volume-decrease reactions, also includes denaturation of proteins, gelation, hydrophobic reactions, phase- changes in lipids and increases in the ionization of dissociable molecules due to œelectro-restrictionö. This technique improves food safety by destroying the bacteria that can cause food borne illness and spoilage and hence the food remains fresh.

25.5 Comparison of HHP with other Processing Method

In a qualitative approach, process efficiency is assessed in terms of the lethality of the treatment and its structural impact on the food matrix. Evidently, those treatments which are powerful in killing microbes have usually a strong destructive effect on the integrity of the food matrix with severe consequences on quality and consumer acceptance. The HHP is characterized by three parameters; temperature (T), pressure (p) and exposure time (t). This three parametric HHP offers broad variability for process design and enhancing the shelf life as explained in below table.

Table 20.1 Characteristic feature of different preservation treatments

Process	Parameter	Intensity	Lethality	Structure Impact	Cost (€/kg)
Drying	T, t	+	Ъ Ъ	++	5
Smoking	c, T, t	+	+	++	2
Salting	c, t		+	++	1
Fermentation	b, T, t		+	+	2
Heat	T, t	+++	+++	+++	0.05
Irradiation	Úw	++	+++	++	0.3
High Pressure	p, T, t	+	++	+	0.3
Pulsed Electric Field	E, Úw	++	++	+	0.1
Super critical gas	c, p, T, t	+	+	+	1

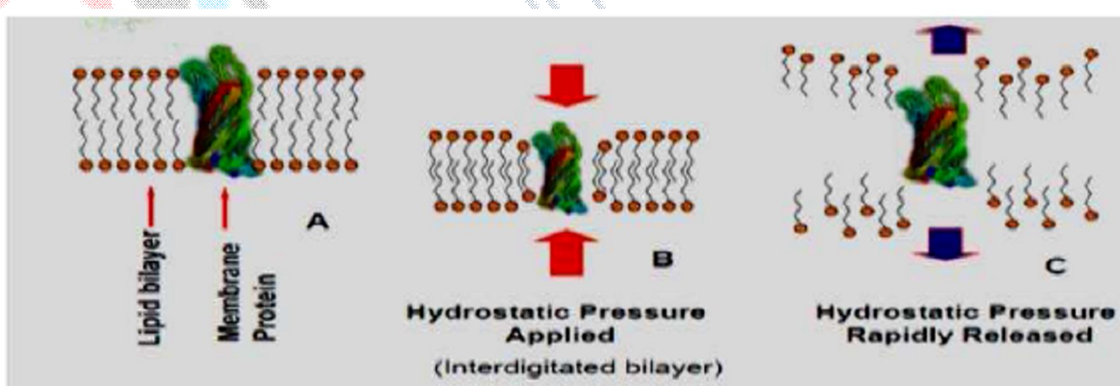
Note: b microbial growth parameter; c chemical efficiency parameter; E electric field strength; Úw specific total energy input; p pressure; T temperature and t exposure time (Source: Heinz and Buckow 2009).

25.6 High Hydrostatic Pressure and Food Safety

Microbial destruction is the main objective of food processing; beneficial effects of HHP in food are evident only when applied pressures exceed 400 MPa. HHP inactivates most of spoilage and pathogenic bacteria present in food. Resistance of microorganisms to pressure varies considerably depending on the applied pressure, temperature, duration of treatment and type of microorganism associated with food system. Nature of the food is also important, as it may contain substances which protect the microorganism from high pressure.

Generally, gram positive bacteria are more resistant to pressure than gram-negative bacteria and yeasts and moulds, due to presence of teichoic acid (a bacterial polysaccharide). On the other side, spores are more resistant than vegetative cells because it contains calcium rich dipicolinic acid, as it protects from excessive ionization. Heat resistant groups of microorganisms are usually pressure resistant, exponential-phase cells are more pressure sensitive than stationary-phase cells. The number of yeasts, moulds, psychrotrophs and coliforms gets inactivates more rapidly than that of acidic and heat-resistant bacteria and proteolytic microorganisms.

Vegetative bacterial cells are inactivated by pressures between 400 and 600 MPa. The inactivation of virus is supposed to depend on the denaturation of capsid proteins essential for host cell attachment. Figure 2 depicts the damage of cell membranes at high-pressure cycle; compression of cell membrane material as and when pressure is applied and sudden expansion of lipid bi-layer after pressure release, leading to destruction and looses of cell membrane integrity and they therefore cannot reproduce. Once damaged, the cells are unable to control the transport of water and ions across the membranes, leading to collapse of the cells.



25.7 Effect on Food Components

Water content of the food gets compressed to about 4% at 100 MPa and 15% at 600 MPa. Depression in freezing point of water is observed at high pressure to -4°C to -8°C or -22°C at 50, 100 or 210 MPa, respectively. Thus, this technique enables sub-zero food processing without ice crystal formation.

Distribution of minerals between colloidal and diffusible phase as well as on the ionization state is observed in HHP. In case of milk, the increase in the content of diffusible calcium has been reported following HPP. When milk is pre-heated, HHP treatment solubilizes both native and heat precipitated colloidal calcium phosphate which leads to slight increase in pH. In general pH of milk increases following high pressure treatment and this change in pH is reversible.

HHP reduces the time period required to induce fat crystallization and this is due the fact that solid/liquid transition temperature of milk fat shifts to high value at high pressure.

Proteins, in native state are stabilized by covalent bonds (peptide and disulphide bonds), electrostatic interactions, hydrophobic interactions and hydrogen bridges. Covalent bonds are almost unaffected by HHP and hence primary structure of proteins remains intact during high pressure treatment. Sensitivity of different bonds to HHP is in the order of Hydrobhobic > Electrostatic bonds > Hydrogen bonds > Covalent bonds.

Enzymes, being proteins, will at sufficiently high pressure undergo conformational changes and thus lose activity. Most enzymes of importance in food deterioration are relatively resistant to pressure and complete inactivation is difficult to achieve. Thus polyphenoloxidases, the enzymes responsible for browning in fruits and vegetables, require pressures of 800 MPa, at room temperature, or more to bring about complete inactivation.

At sufficiently high concentrations and at the appropriate pH many proteins, especially if they have potential disulphide bond forming abilities, will gel or precipitate, but the texture of the gels formed will be markedly different to their heat-set counterparts. Such pressure-set gels will normally contain a relatively high concentration of hydrogen-bonded structure(s) and thus will melt or partially melt on heating. In addition, they will be less able to hold water, i.e. they will synerese and be much softer in texture and óglossierô in appearance.

Since covalent bonds are unaffected by pressure, many of the small molecules that contribute to the colour, flavour and nutritional quality of a food are unchanged by pressure.

25.8 Shelf life and regulatory requirements on HHP processed product

In general, HHP can extend the shelf life by two to three folds over a non-pasteurized counterpart, and improve food safety. HHP can provide shelf lives similar to thermal pasteurization. Pressure pasteurization kills vegetative bacteria and, unless the product is acidic, it requires refrigerated storage. For foods where thermal pasteurization is not an option (due to flavor, texture or color changes) HHP is the best option. As commercial products are developed, shelf life can be established based on microbiological and sensory testing.

HHP does not present any unique issues for food processors concerning regulatory matters or labeling. The requirements are similar to traditional thermal pasteurization or sterilization

25.9 Packaging Requirements of HHP Technology

Packaging requirements for HHP have different considerations, based on whether a product is processed in-container or packaged after processing. For batch in-container process flexible or partially rigid packaging is best suited. On the other hand, fluid products require continuous or semi-continuous systems, which are aseptically packaged after pressure treatment. The effectiveness of HHP is greatly influenced by the physical and mechanical properties of the packaging material. The packaging material must be able to withstand the operating pressures, encompass good sealing properties and the ability to prevent quality deterioration during the application of pressure. At least one interface of the package should be flexible enough to transmit the pressure. Thus, rigid metal, glass or plastic containers cannot be used for packaging materials.

Most commonly used packaging materials for HHP food are polypropylene (PP), polyester tubes, polyethylene (PE) pouches, and nylon cast polypropylene pouches. Plastic packaging materials are the best suited for HHP packaging application, because of reversible response to compression, flexibility and resiliency. The headspace must be also minimized while sealing the package in order to ensure efficient utilization of the package as well as space within the pressure vessel. Packaging materials for HHP must be flexible to withstand a 15% increase in volume followed by a return to original size, without losing physical integrity, sealing or barrier properties.

25.10 Which Type of foods can be processed using HHP

Any food with sufficient moisture can be subjected to HHP. Like any other processing method, HHP cannot be universally applied to all type of foods. This technique can be used to process both the liquid as well as solid foods, expect for those food material which contains large quantity of air pockets, (e.g. watermelon). Foods with a high acid content are particularly good candidates for HHP technology.

25.11 Advantages of HHP

Some of the advantages of HHP are listed below:

a. Significant reduction of heating, this will minimize thermal degradation of food components.
b. Retains natural antimicrobial systems without changing the sensory and nutritional quality of foods and extend shelf life up to 2-3 folds.
c. Inactivation of microorganisms, spores and enzymes.
d. Higher rate of retention of flavor, colour and nutritional value.
e. Pressure is transmitted uniformly and instant so that food product retains its shape.
f. Potential for the design of new products due to the creation of new textures, tastes and functional properties.
g. Clean technology, flexible system for number of products and operation.
h. Process time is less dependence of product shape and size.
i. Reduced requirement of chemical additives, and
j. Increased bioavailability

HHP processed foods can be kept for a longer period under better condition. Small molecules, which are the characteristics of flavouring and nutritional components, typically remain unchanged by pressure. HHP causes minimal changes in the ófreshô characteristics of food by eliminating thermal degradation. When compared to thermal processing, HHP results in foods with fresher taste, better appearance, texture and nutrition. HHP can be conducted at ambient or refrigerated temperatures, thereby eliminating thermally induced cooked off-flavors. The technology is especially beneficial for heat sensitive products.

Main benefits of HPP in food processing include inactivation of microorganisms, structural modification of proteins and depression of freezing point of water. These could be used advantageously in several segments of food industry including sea food, meat and dairy industry.

25.12 Disadvantages of HHP

a. Food must contain water, as the whole phenomenon is based on compression.
b. Some enzymes are very pressure resistant.
c. May not inactivate spores.
d. Structurally fragile foods needs special attention, and
e. High installation cost.

25.13 Conclusion

In recent years there has been a consumer-driven trend towards better tasting and additive-free foods. Hence, emergences of the non-thermal processing technologies are gaining importance. One of the promising technology which could serve as an alternative method for food preservation is the application of high pressure processing. This method helps in food product by retaining their natural color, flavor and texture without loss of vitamins and nutrients, total inhibition of microorganism, keeping the granules structure of pasteurized swelled starch & improving enzyme digestibility and gelatinized structure (without retrogation) and total inactivation of poly phenol oxidase activity. Hence, food preservation using HHP is emerging as a promising technique in food industry.