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Ultra High Pressure Technology: Principle, Its Application and Microbiological Aspects of Food.

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Abstract
In order to nullify the effect of high temperature processing and to retain the nutritional value of food the various non-thermal method of food preservation were invented. The High Pressure Processing (HPP) is also one of the popular technique which has successfully used in various commercial processing practices since last 25 years. It is effective for microbial destruction in food.The limited effect of HPP on covalent bonds represents a unique characteristic of this technology because HPP has a minimal effect on food chemistry.The typical industrial high pressure system consist of a high pressure vessel, a pressure generation means, a temperature control device (optional), and a material handling system. High-pressure processing provides a unique opportunity for food processors to develop a new generation of value-added food products having superior quality and shelf-life to those produced conventionally,Provided lots of research needs to be done to advancement of technology and lowering the cost of technology.(27)

Key words: High Pressure Processing (HPP),microbial inactivation,covalent bonds,, nutritional composition,kind of microorganisms,pressure vessel.

1. Introduction

High pressure processing (HPP) which is also known as ultra-high pressure (UHP) or high hydrostatic pressure(HHP) is a non-thermal food processing technology applied when the food is subjected to high hydrostatic pressure commonly at or above 100 Mpa.(9-11)

The heating and cooling of foods may contribute to the degradation of various food quality attributes. The color, flavor and texture of foods processed solely by heating may be irreversibly altered. To ameliorate the undesirable thermal effects on foods, considerable efforts has been made in commercial and academic circles to develop non-thermal technologies other than heating or cooling operation. Investigated technologies are ionization radiation (gamma irradiation), high hydrostatic pressure (HHP), pulsed electrical fields, high pressure homogenization, UV decontamination, pulsed high intensity light, high intensity laser, pulsed white light,manothermosonication (combined ultrasonic, heat and pressure), oscillating magnetic fields, high voltage arc discharge and streamer plasma. Among these emerging technologies, the most promising ones for food application are high-pressure processing. (25)

High pressure processing (HPP) is an interesting non-thermal technology that involves the sterilization of food by the mean of ultrahigh pressures, which lead to extending the shelf life of processed food, as well as maintaining nutritional value and quality of food products.(26)

High pressure processing (HPP) which is also known as ultra high pressure (UHP) or high hydrostatic pressure (HPP) is a non-thermal food processing technology applied when the food is subjected to high hydrostatic pressure commonly at or above 100 MPa.(29) This technology has been established to inactivate microorganisms and denature several enzymes, without flavor and nutrient degradation related to usual thermal processing treatments and other processing methods. HPP has now been increasingly applied in the food production industry to produce high quality food.This is the technology of applying high hydrostatic pressure to materials by compressing the surrounding water and transmitting pressure throughout the product uniformly and rapidly (1)(4)

2. History

It was Certes in 1883 who was the first in history to relate the effects of high pressure on organisms.The effect of high hydrostatic pressures on foods was first revealed at the end of 19th century (1914)by Bert Hite and coworkers in agricultural experiments station at west Virginia University 1899.(6)He used this technology to preserve the milk and later on vegetables and fruits.Its commercial use started at1980s(7)

In 1992 Japan reseased first HHP processed Jam into market, then after with three years other six companies tried the technology.Effects of pressure on physical properties of foods were reported soon after, by others such as Bridgman (1914) (on the coagulation of egg albumin); Payens and Hermens (1969) (effects of the pressure on the beta-casein from milk) and Macfarle (1973) (on pressure–tenderization of meat).Use of HHP is also common in the manufacturing of ceramics, diamonds, super-alloys, simulators and sheet metal forming. Similarly, in the manufacturing of polymeric compounds, such as for the synthesis of low-density polyethylene and in chemical reactors for the manufacturing of quartz crystals.(1)(2)

3.Principle

Pressure processing is a lethal to microorganisms but at relatively low temperatures(0-40^{o}C) covalent bonds are almost unaffected. The limited effect of HPP (at moderate temperature) on covalent bonds represents a unique characteristic of this technology because HPP has a minimal effect on food chemistry.

The basic principles that determine the behavior of foods under pressure are:

Le Chatelier's principle: Any reaction, conformational change, phase transition, accompanied by a decrease in volume is enhanced by pressure.

Principle of microscopic ordering: At constant temperature, an increase in pressure increases the degrees of ordering of molecules of a given substance. Therefore pressure and temperature exert antagonistic forces on molecular structure and chemical reactions.

Isostatic principle: The principle of isostatic processing is presented in **Fig. 1**. The food products are compressed by uniform pressure from every direction and then returned to

their original shape when the pressure is released. The products are compressed independently of the product size and geometry because transmission of pressure to the core is not mass/time dependent thus the process is minimized (2)

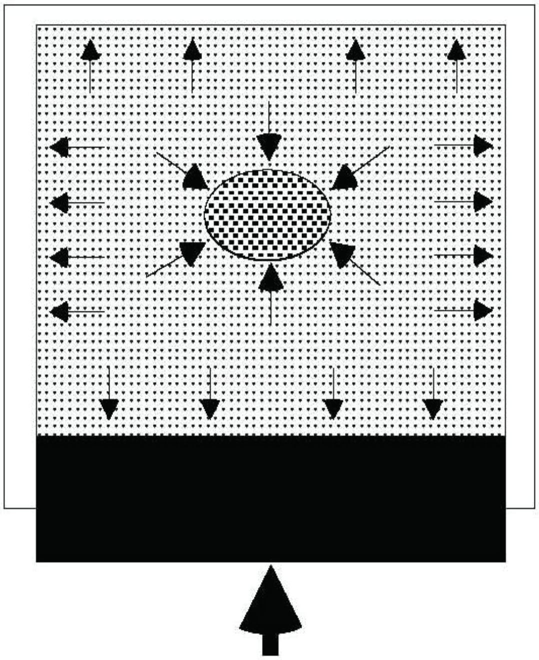
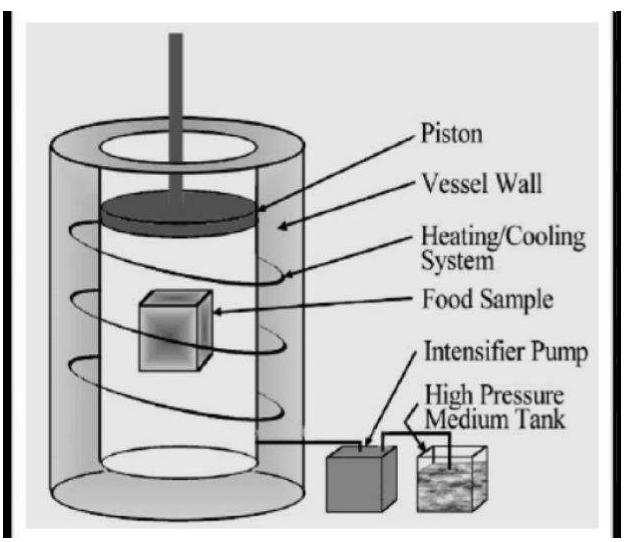
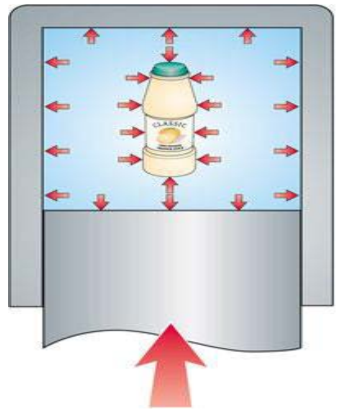


Fig.1The principle of isostatic processing.

4.Components of High Pressure Processing System:

Key components of a high pressure system are: a pressure vessel, pressurizing system, and supporting units such asheating or cooling components.(28) (30)





Fig,2 Components of HHP

1) In HHP process the product is packaged in a flexible container

2)Then loaded into a high pressure chamber filled with a pressure-transmitting (hydraulic) fluid

3)Air is removed and the hydraulic fluid in the chamber is pressurized with a pump, and this pressure is transmitted through the package into the food itself.

4)Pressure is applied for a specific time, usually 3 to 5 min.

5)The processed product is then removed and stored/distributed as in the conventional manner.

6) Applied pressure results in phase transition and chemical changes are accompanied by decrease in volume.

7)Pressure is instantaneously and uniformly transmitted independent of size and geometry of the food.

8)Resultant pressure regulates most of the biochemical reactions occurring in food system, consequentially food retains its shape, even at extreme pressures.

9)Heat is not needed for processing, hence, the sensory characteristics of the food are retained without compromising microbial safety.(22) (23)

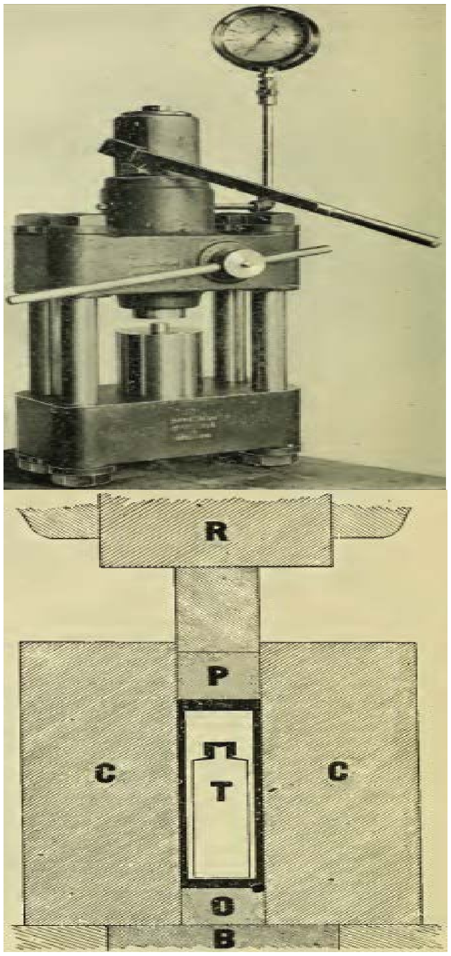


Fig. 3 First High Pressure Food Processing Equipment (4)

5.Microbial inactivation

It has excellent potential for use in processing crab, shrimp, crawfish, lobsters, and hot and cold-smoked products to produce a safer product free from some vegetative pathogens. of special concern is the elimination of various *Salmonella* microorganisms and *Listeria monocytogenes*, both of which have a zero defect action level in ready-to-eat products. *Listeria monocytogenes* has had a significant legal and economic impact on the fish and shell-fish processing industry.

5.1 Factors affecting on microbial inactivation

1)The effect is more lethal to bacteria growing in log phase while spores are more resistant.

2)The various factors like time temperature (15-30^{o}C) activity is maximum and decreases at lower or higher temperature. (13) (24)

3)type of microorganisms species and strain. Generally Gram-positive bacteria are more resistant to pressure than Gram-negative bacteria, moulds and yeasts. (bacterial spores are more resistant).

4)Rich nutrient media such as meat reinforce the resistance of the microorganisms to HPP Carbohydrates, proteins and lipids also have a protective effect .

5) A low water activity protects microorganisms against pressure and tends to inhibit pressure inactivation with noticeable retardation as water activity falls below 0.95 extent of pressure as pressure increases the inactivation increases.(2)

6) More susceptible to pressure at low PH. (12)

7) Redox potential and medium composition also affect indirectly on microbial inactivation.

5.2Bacteria

High pressure processing can effectively inactivate the spoilage microorganisms of several foods, and important foodborne pathogens such as *Campylobacter jejuni*, *Escherichiacoli* O157:H7, *Listeria monocytogenes*, and *Salmonella spp*. (31)(32)Foods can be pasteurized at low or moderate temperatures under pressure. Pressurization at high temperature can sterilize foods. Pressure treatment is of special interest for products or meals containing ingredients that are extensively modified by heat. (2)

HPP has potential as a phytosanitary treatment to control quarantine insect pests in fresh or minimal processed fruits and vegetables to extend their shelf-life. Pressure inactivation of yeast and moulds has been reported in citrus juices. Juices pressurized at 400 MPa for 10 min at 40°C did not spoil during 2-3 months of storage. The high pressure treatment effectively reduced the bacterial flora of fresh goat milk cheese and significantly extended the refrigeration storage life No surviving *E. coli* was detected in cheese after 60 days of storage (2-4°C) in inoculation studies after treatments at 400-500 MPa for 5-10 min.Gallot-lavallee(1998) studied the efficiency of HHP treatment for *L.monocytogenes* destruction in goat cheese from raw milk finding that 450Mpa for 10 min or 500Mpa for 5 min treatments achieve more than 5.6 log units of reduction of this microorganisms without significantly affecting sensory characteristics of cheese.(15)Another study of Presamo et al(2000)reported that the microbial population microbial load of tofu decreased from 5.54*104 cfu/g to 0.31,1.58 or 2.38log units at 400Mpa for 5,30,and 45 min respectively if treated at 5 °C.(16)

The treatment of microbial cell and spores with high pressure results in many changes in the morphology, cell membranes, biochemical aspects and genetic mechanisms and all these Processes are related to the inactivation of microorganisms. The lethal effect of high pressure on vegetative microorganisms is thought to be the result of a number of possible changes that take place simultaneously in the microbial cell. The membrane is the most probable site of disruption .High-hydrostatic pressure treatments can alter membrane functionalities such as active transport or passive permeability and therefore perturb the physicochemical balance of the cell. There is a considerably evidence that pressure tends to loosen the contact between attached enzymes and membrane surface as a consequence of the changes in the physical state of lipids that control enzyme activity. The leakage of intracellular constituent through the permeabilized cell membrane is the most direct reason for cell death after high pressure treatment.Inactivation of key enzymes, including those involved in DNA replication and transcription is also mentioned as apossible inactivating mechanism.(2)(1)

5.3Fungi

Most yeast are inactivated by exposure to300-400 MPa at 25°C within a few minutes, however, yeast ascospores may require treatment at higher pressure. Pressure inactivation of moulds follows a model similar to yeast.(2)

5.4 Bacterial spores

Bacterial spores represent a challenge for high pressuretechnology and more information about their resistance is required. Microbial spores suspended in foods or laboratory model system could be inactivated by high pressure treatment but compared to vegetative cells the treatment conditions must be extreme: higher pressure and long exposure time at elevated temperature. When pressure-temperature is combined at 690 MPa and 80°C for 20 minutes, the treatments was effective with a significant reduction in the *Clostridium sporogenes* spore count. Successful treatment of *Bacillus stearothermophilus* is observed were pressure treatments is combined with moderate temperature (70°C).There are no published reports on the high-pressure resistance of*Clostridium botulinum* spores, and their ability to withstand high pressure at low or high temperatures is unknown.

Bacterial spores have demonstrated pressure resistance and the mechanisms through which they are inactivated are different from these for the vegetative cells.(17)(18)(19)(20)(21) It has been suggested that the spore proteins are protected against solvation and ionization. Microbial spores could be inactivated by chosen suitable conditions for high pressure treatment: higher pressure and long exposure time at elevated temperature .It was assumed that pressure caused inactivation of spores by first initiating germination and then inactivating germinatedforms. The spore germination could be induced by hydrostatic pressure of 100-300 Mpa can induce sopre germination and resultant vegetative cells are sensitive to environmental conditions. Usually for pasteurization purpose the considered treatment is generally in the range of 300-600 MPa for a short period of time, from seconds to minutes, inactivating vegetative pathogenic and spoilage microorganisms. For sterilization the range is over 600 MPa and combination with high temperature is needed because some spores are resistant even to pressure over than 1000 Mpa.(8)To explain the response of microorganisms to different pressure, high-pressure effects on several biological molecules have been studied. Protein denaturation, lipid phase change and enzyme inactivation can perturb the cell morphology, genetic mechanisms, and biochemical reactions. However, the mechanisms that damage the cells are still not fully understood (2)

6 Applications

The leading Japanese companies that were manufacturing the vessels at that time besides Mitsubishi Heavy Industries Ltd. were Kobe Steel Ltd. and Nippon Steel Ltd. Later, high pressure processed products were gradually introduced in other countries and subsequently other manufacturers of high pressure equipment began to appear in the market of HPP treated foods. They include Engineered Pressure Systems, ABB Autoclave Systems Inc., ACB, NICK Corp., and Autoclave Engineers.The technique of HPP is currently successfully used in Japan, the United States and Europe for pasteurization of food products. The industrial application of HPP has been on an increasing trend for the last decade.High pressure machine in 2014 had increased five times more than that produced ten years ago in 2004.. At present days, HPP vegetable products, meat products, seafood, fresh fruits, and beverages are regularly sold in some markets throughout the developed world. Even so, HPP condiments, dressings, soups and sauces are already in the markets. (1)

7. Advantages

1.Inactivation of microorganisms and enzymes

2. Modification of biopolymers

3. Quality retention, such as color and flavor

4. Changes in product functionality.

5. High pressure is not dependent of size and shape of the food.

6. High pressure is independent of time/mass, that is, it acts instantaneously thus reducing the processing time.

7. It does not break covalent bonds, therefore the development of flavors alien to the products is prevented maintaining the natural flavor of the products.

8. It can be applied at room temperature thus reducing the amount of thermal energy needed for food products during conventional processing.

9. Since high pressure processing is isostatic (uniform throughout the food); the food is preserved evenly throughout without any particles escaping the treatment.

10. The process is environment friendly since it requires only electric energy and there are no waste products.(1)

8.Disadvantages

1. It is more expensive than conventional methods such as, high temperature sterilization. For this reason, high pressure processing is mainly used for niche products such as fresh fruit juices, sea foods and guacamole. Food enzymes and bacterial spores are very resistant to pressure and require very high pressure for their inactivation.
2. The residual enzyme activity and dissolved oxygen results in enzymatic and oxidative degradation of certain food components.
3. Most of the pressure-processed foods need low temperature storage and distribution to retain their sensory and nutritional qualities.(1)

9.Future perspectives

The number of installed HPP equipment is increasingly rising since the mid-90s However, this number of HPP units is still small in comparison to the global demand, and this may be attributed to the high cost of investment in the technology.As the research of next step, we can carry on the work as follows. Some enhancement methods of Ultra-high-pressure processing, such as magnetization and ultrasonic wave, are carried on fruit juice. Research of dynamics model about Sterilization and enzyme inactivity of Ultra high pressure processing on fruit juice are also needed.(1)

10.Conclusion

The current equipment advances, successful commercialization of HPP products and a consumer demand for minimally processed safe and high quality foods resulted in a significant research attention on HPP technology.High-pressure processing provides a unique opportunity for food processors to develop a new generation of value-added food products having superior nutritional quality and extended shelf-life to those produced conventionally.

8. References:

1) The principles of ultra high pressure technology and itsapplication in food processing/preservation: A review of microbiological and quality aspects.
Maryam Yaldagard1*, Seyed Ali Mortazavi2 and Farideh Tabatabaie2

2) High Pressure Processing For Foods PreservingD.G. Yordanov1, G.V. Angelova2

3) Mertens B (1995). Hydrostatic pressure treatment of food: equipment and processing.

4)Commercial Fish & Shellfish Technology:High Hydrostatic Pressure Processing Has Potential
originally appearing in Global Aquaculture Advocate, Volume 6, Issue 1 (February 2003)

5) Journal of Engineering Science and Technology Review 8 (5) (2015) 75- 83 High Pressure Processing Technology and Equipment Evolution: A Review
Wael M. Elamin*1,2, Johari B. Endan1, Yus A. Yosuf1, Rosnah Shamsudin1 and Anvarjon Ahmedov1

6) Hite BH (1899). The effect of pressure in the preservation of milk. WestVirginia Agric. Exp. Station Bull. 58: 15-35.

7)Mertens B (1995). Hydrostatic pressure treatment of food: equipmentand processing. In: Gould GW (Ed.), New Methods of Food Preservation. Glasgow: Blackie, Academic and Professional.Chapman & Hall, London. pp. 135-158.

8) Patterson MF, Quinn M, Simpson R, Gilmour A (1995). Effects of highpressure on vegetative pathogens. In: Ledward DA, Johnston DE,Earnshaw RG, Hasting APM. (Eds.), High Pressure Processing ofFoods. Nottingham University Press, Nottingham, pp. 47-64.

9). R. Banerjee and A. Verma, "Minimally Processed Meat and FishProducts," in Minimally Processed Foods, M. W. Siddiqui and M.S. Rahman, Eds., ed New York: Springer International Publishing,2015, pp. 193-250.

10). D. F. Farkas and D. G. Hoover, "High pressure processing," Journalof Food Science, vol. 65, pp. 47-64, 2000.

11). D. Yordanov and G. Angelova, "High pressure processing for foodspreserving," Biotechnology & Biotechnological Equipment, vol.24, pp. 1940-1945, 2010.

12)Linton M, McClements JMJ, Patterson MF (1999). Inactivation ofEscherichia coli O157:H7 in orange juice using a combination of high pressure and mild heat. J. Food Prot. 62(3): 277-279

13)Knorr D , Heinz V(1999). Recent advances in high pressure processingof foods. New Food, 2(3): 15-19.

14)Knorr D (1993). Effects of high-hydrostatic-pressure processes on foodsafety and quality. Food Technol. pp. 156-161.

15) Gallot-Lavalle´e T (1998). Effectiveness of high pressure treatment fordestruction of Listeria monocytogenes in raw milk goat cheese.Sciences des Aliments. 18(6):647–655.

16) Pre´stamo, G, Lesmes M, Otero L, Arroyo G (2000). Soybean vegetableprotein (tofu) preserved with high pressure. J.Agric.Food Chem. 48: 2943-2947.

17) Murrell WG , Wills PA (1977). Initiation of Bacillus spore germination byhydrostatic pressure: effect of temperature. J. Bacteriol. 129: 1272-1280

18) Kimugasa H, Takao T, Fukumoto K, Ishihara M (1992). Changes in teacomponents during processing and preservation of tea extracts byhydrostatic pressure sterilization. Nippon Nogeiku Kaichi 66: 707-712.

19) Kowalski E, Ludwig H, Tausche B (1992). Hydrostatic pressure tosterilize foods 1. Application to pepper (Piper nigrum L). DeutscheLebensmittel Rundschau 88: 74-75.

20) Seyerderholm I, Knorr D (1992). Reduction of *Bacillus stearothermophilus* spores by combined high pressure and temperature treatments. J. Food Ind. 43: 17-20.

21) Hayakawa I, Kanno T, Tomita M , Figio Y (1994). Application of highpressure for spore inactivation and protein denaturation. J. Food Sci.59: 159-163.

22)T. Koutchma, "Design for High-Pressure Processing," in Handbookof Food Process Design, J. Ahmed and M. Shafiur Rahman, Eds.,ed Oxford: Wiley-Blackwell, 2012, pp. 998-1030.

23). J. Cheftel, "High Pressure and Biotechnology," in High Pressureand Biotechnology, C. Balny, R. Hayashi, K. Heremans, and P.Masson, Eds., ed Paris: INSERIM/Libbey Eurotext Ltd,Montrouge, 1992, pp. 195-209.

24) E. Ting and V. Balasubramaniam, "Determining thermal effects inhigh-pressure processing," Food Technology, vol. 56, pp. 31-35,2002.

25) E. Hogan, A. L. Kelly, and D.-W. Sun, "High Pressure Processingof Foods: An Overview," in Emerging Technologies for FoodProcessing, D.-W. Sun, Ed., ed London, UK: Elsevier Academic,2014, pp. 3-24.

26). T. Norton and D.-W. Sun, "Recent advances in the use of highpressure as an effective processing technique in the food industry,"Food and Bioprocess Technology, vol. 1, pp. 2-34, 2008.

27). D. F. Farkas and D. G. Hoover, "High pressure processing," Journal of Food Science, vol. 65, pp. 47-64, 2000.

28). D. Yordanov and G. Angelova, "High pressure processing for foods preserving," Biotechnology & Biotechnological Equipment, vol.29), pp. 1940-1945, 2010.

29). N. Rastogi, "Introduction," in Recent Developments in High Pressure Processing of Foods, ed: Springer US, 2013, pp. 1-7.

30) T. Koutchma, "Design for High-Pressure Processing," in Handbook of Food Process Design, J. Ahmed and M. Shafiur Rahman, Eds.,ed Oxford: Wiley-Blackwell, 2012, pp. 998-1030.

31) Pre´stamo G, Sanz PD, Fonberg-Broczek M, Arroyo G (1999). Highpressure response of fruit jams contaminated with *Listeria monocytogenes*. Lett. Appl. Microbiol. 28(4): 313-316.

32) Styles MF, Hoover DG, Farkas DF (1991). Response of Listeriamonocytogenesand Vibrio parahaemolyticus to high hydrostatic pressure.J. Food Sci. 56: 1404-1407.

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