



P-ISSN: 2349-8528

E-ISSN: 2321-4902

www.chemijournal.com

IJCS 2020; 8(2): 2964-2967

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Received: 07-01-2020

Accepted: 09-02-2020

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Review on principles, effects, advantages and disadvantages of high pressure processing of food

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DOI: <https://doi.org/10.22271/chemi.2020.v8.i2at.9202>

Abstract

High Pressure Processing (HPP) is an emerging process technique which makes food safer and extends its shelf life. Unlike most conventional heat treatments, it is a non-thermal preservation and pasteurization technique that causes little or no change in the organoleptic and nutritional attributes of the product being processed. High-Pressure Processing (HPP) using 100 MPa to >1,000 MPa for short period and has been shown to enhance safety and extending shelf-life, free from additives with minimal influence on the sensory, physical and nutritional properties of the food and minimizes the microorganisms to the safe level. It meets consumer demand for freshness without the negativity often associated with other methods such as irradiation. This paper reviews the literature on high pressure application in food industry, principles of High-Pressure Processing, types of HPP, advantages and limitations of HPP.

Keywords: High pressure processing, pasteurization technique, organoleptic attributes, nutritional properties, irradiation

Introduction

High Pressure processing (HPP) which is also known as ultra-high pressure (UHP) or high hydrostatic pressure (HHP) is essentially a non-thermal decontamination process, in which the food is typically subjected to pressures of 400 to 600 MPa at ambient or cooled temperature for 1 to 15 minutes. This method causes no damage or distorts to the foods as long as the treated product is neither hollow nor having an empty space inside. Patterson MF^[13] observed that these conditions inactivate vegetative microorganisms, providing safety and prolonged shelf life to chill or high-acid foods like fruit juices, guacamole etc. Toshiaki Ohshima *et al*^[16], carried out the study on high pressure processing of fish and fish products. Wilson *et al.*^[18], stated that during the last decades, this technology has emerged as an industrially adopted method for food pasteurization of rare and cooked meat, fish and seafood, dairy and vegetable products, and ready-to-eat meals.

HPP is the application of uniform and even ultra-high pressures to the product from all sides within a few minutes. Black *et al.*^[13], observed that bacterial spores are extremely resistant to commercially attainable pressure levels, and therefore low-acid shelf-stable products cannot be achieved by elevated pressure only. To reach commercial sterility, an additional inactivating factor is necessary. High hydrostatic pressure results in protein denaturation, resulting in inhibition of some inherent enzymatic activities and of the biogenic activity of some microorganisms.

D. Knorr^[5] stated that Certes was the first in history to relate the effects of high pressure on organisms in 1883. However, at the end of 19th century at West Virginia University, in agricultural experiment station, Bert Hite^[2] and co-workers first revealed the effect of high hydrostatic pressures on foods in the year 1899. B. H. Hite in their research used high hydrostatic pressure up to 600 MPa as a tool to preserve milk, and fruits and vegetables. M. F. Patterson *et al.*^[12], observed that only a few works have been done to these prime studies and no sustained research were published about high pressure processing until 1980's. The interest was resumed in mid-80 due to the successful growth of commercial HPP treatment as an alternative preservation method to traditional thermal processing of foods. D. Knorr^[6] summarized that in 1992, a Major revolution in HPP came in Japan by releasing the first high pressure processed product into market.

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Many studies have been performed to understand significant advances of HPP technology, which produced food products that are safe, fresh, nutritious, and innovative.

Principles of HPP

According to Yordanov and Angelova ^[7] a number of physical and chemical changes result from the use of pressure. Physically applied pressure brings about a volume decrease and an increment in temperature and energy. Le Chatelier, Isostatic pressing and microscopic-ordering are the principles that explain the behaviour of foods under effects of high pressure.

Le Chatelier's principle

This principle addresses changes to equilibrium as a result of pressure application. According to H.L. Le Chatelier ^[10], a chemical system under equilibrium condition would experience a reaction change, accompanied by a decrease in volume when enhanced by pressure and vice versa. If pressure changes, the equilibrium shifts in a direction that tends to reduce the change in the corresponding intensive variable (Volume). Thus pressure shifts the system to that of the lowest volume.

Isostatic principle

D. Yordanov and G. Angelova ^[7] stated that the first consideration involving the application of high pressure is the Isostatic Pressing (Pascal's Principle) in which the pressure is transmitted in a uniform manner in all directions. Following the decompression, the material returns to its initial shape.

Microscopic ordering principle

G. U. Benet ^[9] stated that according to Microscopic Ordering Principle, at a constant temperature, increasing the pressure mutually increases the degree of ordering of the molecules of a substance. As a result, pressure, as well as temperature, exerts antagonistic forces on molecular structure.

Effects of high pressure processing on foods

High-pressure processing (HPP) is a method of food processing where food is subjected to elevated pressures (up to 87,000 pounds per square inch or approximately 600 MPa), with or without the addition of heat, to achieve microbial inactivation or to alter the food attributes in order to achieve consumer-desired qualities. Unlike high-pressure homogenization where the food is exposed to high velocity, turbulence and shear forces, during HPP the food is subjected to isostatic pressure treatment. The extent of bacterial inactivation also depends on the type of microorganism, food composition, pH, and water activity. Knorr *et al.*, studied that HP treated foods are generally claimed to have superior quality compared to their thermally treated counterparts, including a better retention of nutritional value, flavor, texture and colour. Several studies have evaluated the beneficial effects of pressure treatment over conventional treatment on preserving quality attributes of foods. However, high capital expenditure and limited throughput are some current limitations of this technology for fluid-food processing.

Fruits and vegetables

High pressure technology does not depreciate the nutritional and sensory characteristics of food, and yet it maintains the shelf life. As compared the effect of HPT with water blanching on the microbial safety, quality and functionality (poly phenol oxidase (PPO) activity, leaching of potassium,

and loss of ascorbic acid) of potato cubes. Total inactivation of microbes and PPO activity occurred at 20 °C (using dilute citric acid solution at 0.5 at 1.0 per cent as immersion medium). Water-balanced and high pressure-treated potato cubes had similar softness but potassium leaching was reduced by 20 per cent in addition, ascorbic acid was better retained (90 per cent at 5 °C to 35 per cent at 50 °C) in high pressure treated vacuum packaged samples. Daniel *et al* ^[4], concluded that HP processed avocado paste is commercially available and is stable to the action of spoilage microorganisms during refrigerated storage. However, there are no prior reports on the effects of HP processing and storage time on the stability of health bioactive compounds present in avocados, particularly carotenoid profiles.

Dairy and egg industry

High pressure technology have many applications in the dairy and egg industries due to changes induced in the functional properties of whey protein as well as in other milk components and native constituents. The pressure was applied to the protein before homogenization or to the emulsion prepared with native whey protein concentrate. Functional properties of WPC were examined along with the relationship between stability of WPC emulsions and degree of adsorption of the protein emulsifier. They found that oil-in water emulsions (0.4 wt per cent protein, 20 volume per cent n-Tetradecane, pH 7) prepared with pressure treated WPC solutions gave a broader droplet size distribution than emulsions made with native untreated protein. HPP had little effect on the stability of WPC emulsions made with native protein. The high pressure slightly improved the microbiological quality of milk without modifying lacto peroxidase activity (a native milk enzyme). The increase in cheese yield was found (at 300 and 400 MPa) in conjunction with additional lacto globulin and moisture retention. They concluded that HPP can improve the coagulation properties of milk and can increase moisture retention of fresh cheese.

Types of High Pressure Processing of Foods

A. Batch type

P. S. Rao *et al* ^[14], stated that equipment using batch high pressure treatment of foods usually consist of a cylindrical pressure vessel; end closure; a mean to fasten the end closure/s (e.g. yoke, threads); an intensifier pump which uses a low-pressure pump to supply the pressurizing fluid and essential system controls. Due to its cleanliness, flexibility and technical reasons, Batch processing is mostly preferred for high pressure food treatments. This process is necessary for packaged foods. The food is prepared and aseptically sealed in plastic containers, then placed in a pressure chamber for pressurizing, using pure water as the transmitting fluid. The cycle time depends on the food type and the processing temperature. The chamber is then decompressed, and the cycle begins again. Batch processing eliminates any risks that the food may be contaminated by lubricants or wear particles from machinery. The equipment doesn't need cleaning between product changes, thus eliminating any danger of cross contamination by food particles. More ever, handling, drying and storage of packages lengthens the overall processing cycle and hence increases the overall cost.

B. Semi continuous type

G. A. Cavender ^[8] stated that Semi-continuous process systems typically consists of two or more pressure vessels, low-pressure pump to fill the vessels, high pressure transfer

pump, holding and sterilized tanks and controlling valves. Compared to Batch processing direct introduction of food into the high pressure chamber is a promising alternative process. So far, this is achieved industrially only in a semi-continuous mode, which means that the food is introduced periodically into the high pressure processing chamber. The overall processing cycle includes a number of discrete steps like filling, pressurising, holding, decompression and expulsion. The combination of multiple vessels, which sequentially fed by a central high pressure compressor, can be used to make continuity in the process.

C. Continuous Processing Equipment

V. M. Balasubramaniam *et al* ^[17], stated that Continuous processing is a subset of high pressure processing in which the liquid foods are the only products that can be processed. In this the products flow through an open-end tube system that pressurizes them at 100 MPa or more by means of high-pressure intensifiers. After that, a mean to depressurize the product is applied in such way that avoids extreme shear and heating. R. W. Vanden Berg ^[15] observed that following the decompression, the processed liquid then goes to a sterile tank for final clean filling. G. A. Cavender ^[8] observed that thermal effects during depressurizing have often been difficult to separate from the anti-microbial contribution made by pressure. Due to high shear forces, frictional heating, and other flow phenomena, this method had been replaced by Semi-continuous operations.

Advantages of High Pressure Processing

1. High pressure used in this process is independent of size and shape of the food.
2. High pressure is not dependent of time/mass, that it acts instantaneously thus reducing the processing time.
3. It does not break covalent bonds; therefore, the development of flavours alien to the products is prevented, maintaining the natural flavour of the products.
4. It can be applied at room temperature thus reducing the amount of thermal energy needed for food products during conventional processing.
5. This process has Potential for reduction or elimination of chemical preservatives.
6. Since high pressure processing is Isostatic (uniform throughout the food), the food is preserved evenly throughout without any particles escaping the treatment.
7. In-package processing is possible in this technology.
8. The process is environment friendly since it requires only electric energy and there are no waste products.

Disadvantages of High Pressure Processing

1. 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.
4. Foods should have approximately 40% free water for anti-microbial effect.

Conclusion

High pressure processing has the potential to develop into a preservation technique that is applied on a large scale in the

food industry, in particular for products where retention of flavours and nutrients is desired. HPP not only improves safety of foods but also extends its shelf life, while maintaining the food attributes normally associated with "minimally processed" foods. Although, HPP technology has extremely many strong points in food processing since the 1990s, there are still some gaps regarding the investment in this sector. Commercial benefits of HPP technology require more research to fill the gaps and to fully understand the process, to reduce the cost of production.

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