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High Pressure Processing Technology in Fruits & Vegetables Processing Industry – A Review

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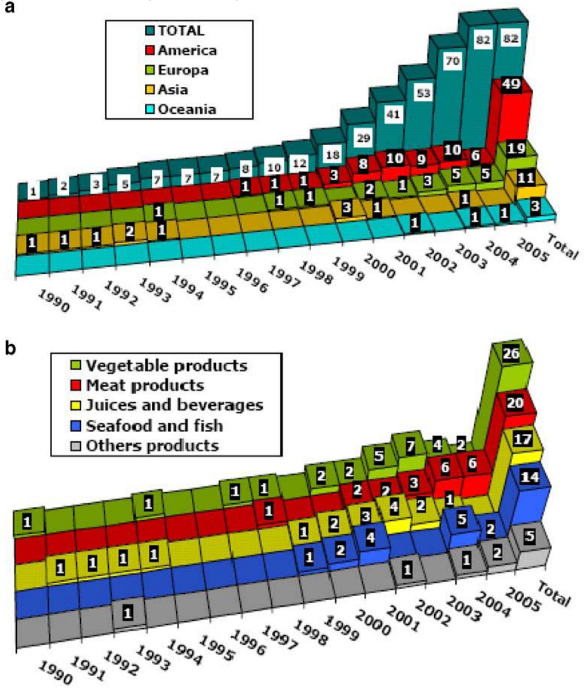
Abstract: **- High pressure processing is a technology that potentially addresses many, if not all, of the most recent challenges faced by the food industry. It can facilitate the production of food products that have the quality of fresh foods but the convenience and profitability associated with shelf life extension (McClements et al. 2001). HPP has already become a commercially implemented technology, spreading from its origins in Japan, followed by USA and now in Europe, with worldwide take-up increasing almost exponentially since 2000 (Fig. 1a); although as of yet, this has not been homogenous throughout the food industry. HPP can be applied to a range of different foods, including juices and beverages, fruits and vegetables, meat-based products (cooked and dry ham, etc.), fish and pre-cooked dishes, with meat and vegetables being the most popular applications(Fig. 1b). European companies presently employing. This technology include orange juice by UltiFruit®; the Pernod Ricard Company, France; and sliced ham by Españа, Spain; fruit jams by Solo fruita, Italy (Urrutia- Benet 2005).A wide variety of companies provide HPP technology to the food industry.**

- **It is Non-thermal processing technology**
- **First reported use of HHP was in 1899 in USA.**
- **First commercialized in Japan in the early 1990s for pasteurization of acid foods for chilled storage.**
- **HPP is an all natural, clean, environmentally friendly technology.**
- **HPP machines only require electricity and water, which is recycled.**

Key words: HPP, Fruits , Vegetables, Meat products

DEFINETION OF HHP

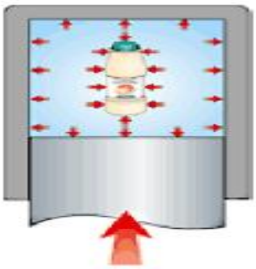
High Pressure Processing (HPP) is a method of food processing where food is subjected to elevated pressures (up to 87,000 pounds per square inch or approximately 6,000 atmospheres), with or without the addition of heat, to achieve microbial inactivation or to alter the food attributes in order to achieve consumer-desired qualities. Pressure inactivates most vegetative bacteria at pressures above 60,000 pounds per square inch. HPP retains food quality, maintains natural freshness, and extends microbiological shelf life. The process is also known as high hydrostatic pressure processing (HHP) and ultra high-pressure processing (UHP).



PRINCIPLE INVOLVED IN HHP

There are two principle involved in High Pressure Processing

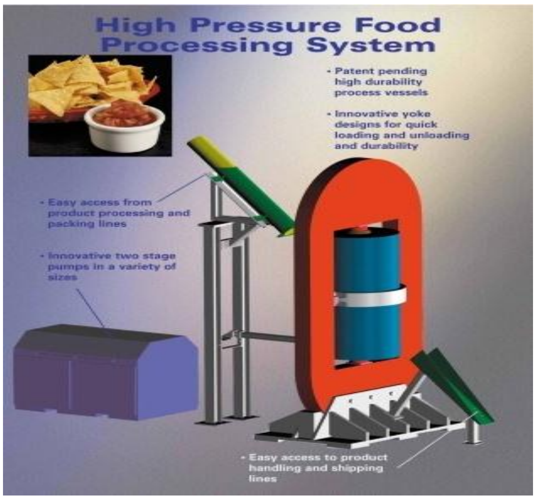
1. Le-Chatelier-Braun principle. It state that “under equilibrium condition any event that is accompanied by a decrease in volume is reinforced by an increase in applied pressure, while an event accompanied by an increased in volume is suppressed by a pressure increase.”
   - High pressure affects the non-covalent bonds substantially as such bonds are usually very sensitive to pressure, it follows that low molecular weight food components are not affected by pressure.
2. Pascal’s law or iso-static rule
   “It state that transmittance of pressure is uniform and instantaneous”
   - This makes the HHP independent of size and geometry of the sample and shortens the processing time



WORKING PRINCIPLE

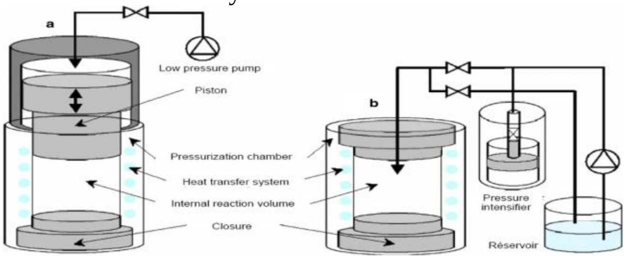
In a typical HPP process, the product is packaged in a flexible container (usually a pouch or plastic bottle) and is loaded into a high pressure chamber filled with a pressure-transmitting (hydraulic) fluid. The hydraulic fluid (normally water) in the chamber is pressurized with a pump, and this pressure 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. Because the pressure is transmitted uniformly (in all directions simultaneously), food retains its shape, even at extreme pressures. And because no heat is needed, the sensory characteristics of the food are retained without compromising microbial safety

The governing principles of HPP are based on the assumption that foods which experience HP in a vessel follow the iso static rule regardless of the size or shape of the food. The iso static rule states that pressure is instantaneously and uniformly transmitted throughout a sample whether the sample is in direct contact with the pressure medium or hermetically sealed in a flexible package. Therefore, in contrast to thermal processing, the time necessary for HPP should be independent of the sample size (Rastogi et al. 2007).



The effect of HP on food chemistry and microbiology is governed by Le Chatelier’s principle. This principle states that “when a system at equilibrium is disturbed, the system then responds in a way that tends to minimise the disturbance (Pauling 1964). In other words, HP stimulates some phenomena (e.g. phase transition, chemical reactivity, change in molecular configuration, chemical reaction) that are accompanied by a decrease in volume, but opposes reactions that involve an increase in volume. The effects of pressure on protein stabilisation are also governed by this principle, i.e. the negative changes in volume with an increase in pressure cause an equilibrium shift towards bond formation. Alongside this, the breaking of ions is also enhanced by HP, as this leads to a volume decrease due to the electrostriction of water. Moreover, as hydrogen bonds are stabilised by high pressure, as their formation involves a volume decrease, pressure does not generally affect covalent bonds. Consequently, HP can disrupt large molecules of or microbial cell structures, such as enzymes, proteins, lipids and cell membranes, and leave small molecules such as vitamins and flavour components unaffected (Linton and Patterson 2000). Due to the work of compression, HPP causes temperatures to rise inside the HP vessel. This is known as adiabatic heating and should be given due consideration during the preservation process. The value of the temperature increments in the food and pressure transmitting medium will be different, as they depend on food composition as well as processing temperature and pressure and the rate of pressurisation (Otero et al. 2007a). In food sterilisation, adiabatic heating can be used advantageously to provide heating without the presence of sharp thermal gradients at the process boundaries (Toepfl et al. 2006).

Knowledge of the engineering concepts of HPP has been broadened extensively in recent times.



Examples **a** direct system **b** an indirect systems (Urrutia-Benet 2005)

The main components of high pressure systems are

- a pressure vessel & its closure
- a pressure generation system
- a temperature control device
- a materials handling system

Most of the vessels are made from high tensile steel alloy which can withstand the pressure of 400-600MPa. Vessels are sealed by a threaded steel closure, a closure having interpreted thread, which can be removed more quickly or by a sealed frame that is positioned over the vessel. In operation, after all air is removed, a pressure transmitting medium is pumped from a reservoir into the pressure vessel using a pressure intensifier until the desired pressure is reached. This is termed indirect compression and requires static pressure seals. Another method, termed as direct compression uses a piston to compress the vessel, but this requires dynamic pressure seals between the piston and internal vessel surface, which are subjected to wear and are not used in commercial application.

Temperature control in commercial can be achieved by pumping heating/cooling medium through a jacket surrounded by pressure vessel. If any temperature changes occur an internal heat exchangers are fitted

There are two methods of processing of foods in high pressure vessel 1) in-container processing and 2) bulk processing. Because of foods reduce in volume at the very high pressure used in processing (for example water reduce in volume by approximately 15% at 600MPa), there is considerable stress and distortions to the package and the seal when in-container processing method is used. Bulk handling is simpler, requirement only pumps, pipes and valves.

FOOD ITEM	PROCESSING PRESSURE(MPa)
Fruit juices	
orange juice	100-800
apple juice	151-620
peach juice	600
jam/ jelly	100-400
apple cubes	400
strawberry coullies	200-500
banana puree	500-700

HHP treatment

All pressure experiments were performed in a laboratory-scale vessel high-pressure processor (model 2L, Autoclave Systems Inc., USA) (Table). The pressure medium was de-ionized water. A thermo stated mantel, which surrounded the vessel, was connected to a cryostat keeping the vessel wall temperature constant during the experiment. Temperature was recorded by a thermocouple placed inside the vessel. The samples were filled in 2mL eppendorf tubes and were enclosed in the pressure vessel already equilibrated at an initial temperature. The vessel was then pressurized and after a preset hold time, decompressed. After pressure release the samples were immediately cooled in ice-water.

HHP process conditions (2 L model)

Description	Operating conditions
Pressure range (MPa)	450–650
Come-up time (min)	2
Holding time (min)	15
Initial temperature (°C)	30-50
Final temperature after pressurization at highest pressure (°C)	44.7a±2.5b 68.0±1.9
Final temperature after holding time at highest pressure (°C)	34.9±1.3 55.3±1.7
Final temperature after decompression at highest pressure (°C)	18.3±1.2 39.9±2.1

a Value based on mean of three replicates.
b Standard deviation.

PRESSURE RANGE FOR FRUITS
PRESSURE RANGE FOR VEGETABLES

FOOD ITEM	PROCESSING PRESSURE(MPa)
vegetables	200-400
Fresh raw vegetables	200-400
Lettuce	200-400
Tomato	200-400
Asparagus	200-400
Onion	200-400
Cauliflower	200-400
Green beans	400-900
Crushed/Liquid extract of vegetables	200-400
Carrot	600
Tomato	335-600

ADVANTAGES OF HHP

- It does **not break covalent bonds**; therefore the development of flavors alien to the products is prevented , maintaining the natural qualities of products.
- It can be applied **at room temperature** there by reducing the amount of thermal energy needed for products during the conventional processing.
- Because HHP is **iso-static ,** the food is preserved evenly throughout its mass without any particles escaping treatment.
- High pressure is **not time or mass dependent**; it reduces processing time by acting instantaneously.
- HHP is independent of the **size and geometry** of the food
- The process is **environment friendly** since it requires only electrical energy and there are no waste products.
- HPP can extend the shelf life by **two to three fold** over a non-pasteurized counterpart, and improve food safety.
- HPP impart to **functional properties of food** products; high pressure has very little effect on low molecular weight compounds such as flavor compounds vitamins, and pigments compared to thermal processes.
- HPP equipment is **safe to operate**; With a little training, food plant personnel can learn to safely operate the equipment

LIMITATIONS OF HHP

- Food enzymes and bacterial spores are very resistant to pressure and very high pressure is required to their inactivation.
- Residual enzyme activity and the presence of dissolved oxygen result in enzymatic and oxidative degradation of certain food components. Most pressure-processed foods need low temperature storage and distribution to retain their sensory qualities.

EFFECT OF HHP TREATMENT ON FOOD

HHP can help to maintain the quality attributes of fresh food, rendering products microbiologically safe with an extended shelf life (Hogan, Kelly, & Sun, 2005; Patterson, 2005). However HHP can sometimes affect the food yield, sensory qualities such as color and texture, and produce biochemical changes affecting negatively to the food properties, but these effects are less severe than those experienced using thermal processing techniques (Buckow & Heinz, 2008; Hogan et al., 2005). In addition, those side effects on food properties can be attenuated by a suitable selection of the processing parameters: temperature, time and pressure (Buckow & Heinz, 2008). HHP, in contrast to heat, does not disrupt covalent bonds thus maintaining the

primary structure of proteins, but does alter the conformation of proteins by causing irreversible changes to the secondary, tertiary, quaternary, and supramolecular structure (Murchie et al., 2005; Palou, Lopez-Malo, Barbosa-Canovas, & Swanson, 1999). The secondary structure of proteins is disrupted only at very high pressures, leading to irreversible denaturation, and finally proteins can aggregate in gel (Cheftel, 1995; Hendrickx, Ludikhuyze,
Van den Broeck, & Weemaes, 1998; Knorr, 1999; Palou et al., 1999). HHP can also inactivate protease inhibitors such as phytate and increase in vitro protein digestibility (IVPD) of legumes (Han, Swanson, & Baik, 2007). The secondary structure and function of complex polysaccharides and lipids is also modified by HHP (Ledward, 1995). The application of HHP can affect smaller molecules such as vitamin C and b-carotene or inactivate some enzymes (Butz et al, 2002; Bull et al., 2004; Cheftel, 1995).HHP can also alter the food rheological properties (Patterson et al., 2007). Whereas the physical structure of most high-moisture foods remains unchanged, colour and texture may change after HPP treatment in gas-containing products due to gas displacement and liquid infiltration, leading shape distortion and physical shrinkage, and finally irreversible compression of whole foods (Hogan et al.,
2005). However, those modifications can vary in different products; whereas minimal changes in colour, shape and overall appearance can be observed in different fruits such as grapes and blueberries, especially in segments of fruits, similar pressure treatments affected the aspect of green onions and strawberries (Kingsley et al., 2005; O'Reilly et al, 2002). Moreover, changes in colour are minimal in white or cured meats (Cheftel & Culioli, 1997), but colour can be affected in fresh meat and poultry due to modifications in myoglobin, heme displacement/release or ferrous atom oxidation (Hugas, Garriga, & Monfirt, 2002; Cheftel & Culioli, 1997).

Effect of treatment on PME activity in the orange juice–milk based beverage

Fig. 2 represents the combined thermal and HHP inactivation of PME in the OJMB at 30 and 50 °C for 15 min. At 25 °C and low pressures (450 MPa) no inactivation effect was observed, revealing the pressure tolerance of the orange PME. By increasing the temperature to 50 °C (final temperature 65 °C) and pressure to 650 MPa the inactivation increased and reached a maximum of 90.5%. Several authors have observed this resistance to pressure treatment. Nienaber and Shellhammer (2001) andTruong, Boff, Min, and Shellhammer (2002) found that PME was stable under pressure below400 MPa and combination of high temperature and high pressure (40–50 °C and 600–700 MPa) were necessary to inactivate it. From an industrial point of view, a higher pressure and/ or temperature would be needed to shorten the holding time.

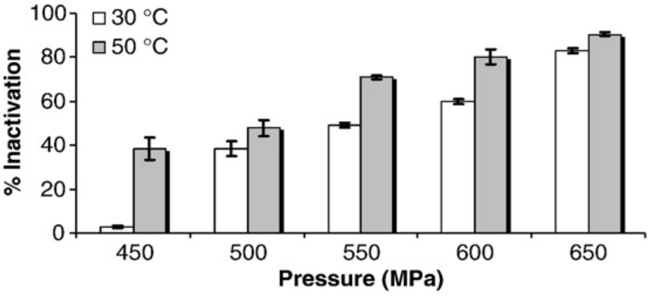


Fig. 2. Combined thermal and HHP inactivation of PME in orange juice–milk based beverage at two initial temperatures.

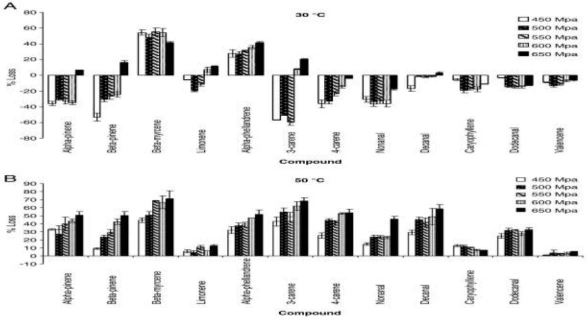


Fig.3 Effect of combined thermal and HHP treatment (A—30 and B—50 °C) on volatile compounds content in orange juice–milk based beverages

Effect of HPP on bioactive compounds and antioxidant activities of some vegetables

Vegetable	Treatment condition	Major findings	References
carrot, tomato, broccoli	500-800 MPa, 25 or 75c	beta-carotene and antioxidative activities in tomato and carrot, chlorophyll a and b in broccoli	Butz et al (2002)
Green peas	900 MPa 20 c for 5-10 min	vitamin C retention 82%	Qiu et al (2006)
Green peas	500 MPa 25 c for 1 min	vitamin C retention 92% soon after HHP processing	Qiu et al (1996)
tomato puree	700 MPa 20 c	lycopen content was unaffected by HHP	Krebbers et al (2002)
tomato juice	200 MPa 4 and 25c	maintains the extractable total carotenoids and lycopenn and radical scavenger capacity	Hsu et al (2008)

HHP APPLICATION

- HPP has been applied in various areas of the food industry such as food preservation, starch gelatinization, enzyme inactivation(blanching), osmotic dehydration enhancement , pressure-shift freezing and thawing enhancement.
- Strawberry jams prepared by high pressurization at pressures from 4000- 6000kg/cm2 helps to not only maintain their original fresh fruit color, and flavor, but also retain up to 95% of the vitamin C originally present in the fruit.
- Pressure treated vegetables that were subjected to freezing had higher drying and dehydration rates.
- for example cabbages are subjected to pressure-shift freezing using the pressure of 100-700MPa and temperature of -20 °C , found that there was an

increase in both textural and histological attributes of cabbage.

- Smith and collin investigated the effect of HHP on the texture of fruits (pear, apple, pineapple and orange)and vegetables (carrots, celery , green and red pepper).
- Robertson found that water and solute of pressure-pretreated pineapple had a significantly higher diffusion rate than in control during the osmotic dehydration.
- Syderhelm and others showed that application of pressure as high as 900 Mpa for 2 minute at 45 °C was sufficient for inactivate the commercial pectin methyl esterase(PME).
- Bask investigate the pressure induced inactivation kinetics of the PME at ph levels of 3.2 & 3.7 in both single strength & concentrated orange juices.

1. Ready-to eat cooked vegetable meals
2. Juices and smoothies
3. Chunks and slices
4. Functional / Organic foods and beverages

RECENT APPLICATIONS OF HPP

Fruit and Vegetables and Derived Products

The texture of fruit and vegetable products are largely determined by the structure of the cell wall and middle lamella. Under pressure, the composition of these can change, as certain cell wall enzymes are inactivated and/or structural changes occur in the polysaccharide, lipid and protein fraction. On a physical level, HP can disrupt the tissues morphology, cell organelles and cell membranes (Hartmann et al. 2004). Pressure has been shown to have a softening influence on texture of fruits and vegetables, and tissue firmness may be lost due to cell wall breakdown and loss of turgidity (De Belie 2002). Trejo-Ayara et al. (2007) have found that textural changes in raw carrots are primarily caused by loss of turgidity induced by rapid compression and decompression. They noted that texture loss may be reduced by turgidity manipulation of the cells or reduced by pectin methylesterase (PME) activation during high pressure processing given optimal conditions. In addition, they observed loss in texture when carrots were treated with pressures of above 300 MPa. Turgidity loss has also been found in the cell structures of spinach, which were exposed to a pressure level of 400 MPa for 30 min, owing to the soft and elastic structures which characterise the cell walls; the same was not found for tougher plant tissues such as cauliflower (Préstamo and Arroyo 1998).

In many fruit and vegetable products, HPP has either no or minor influence on flavour. Lambadarios and Zabetakis (2002) found that HP had very little effect on strawberry flavor compounds. Highest flavour stability was observed when samples were treated with pressures of 200–400 MPa, and the best flavour retention was observed at 400 MPa. Fruit juices, jams and purees all show excellent retention of fresh like flavours for a far greater time period than that exhibited by conventional thermal treatment under optimal storage conditions (Ludikhuyze and Hendrickx 2001). In fact, quite recently Baxter et al. (2005) found that HPP of orange juice could produce a product acceptable to most consumers even after storage for 12 weeks at temperatures up to 10 °C. On the other hand, storage at 30 °C causes 900% increase in the rate of flavour deterioration (Polydera et al. 2004).

Summary of some food quality characteristics after HPP

Product type	Treatment (MPa/°C/min)	Comparison to experimental control	Reference
Orange juice	500/35/5	Improved shelf-life, better consistency, lower acid loss	Polydera et al. (2003)
Sausages	500/65/5	Better texture, improved taste, more juicy, less firm, no loss in colour	Mor-Mor and Yuste (2003
Green Beans	500 /room temp./1	Retention of colour, good firmness and extended shelf-life, showed residual peroxidase activity	Krebbers et al. (2002)

HPP is the ideal alternative to heat processing for fruit & vegetable products. The main advantage is achieving a significant shelf life extension while keeping fresh and home-made taste, because the temperature will stay ambient or chilled during High Pressure Processing.

Products maintain higher sensorial, functional and nutritional values while improving food safety. HPP is a good tool to produce high value added products: premium, exportation, RTE, natural and/or organic.

- Wet salads, purees, coulis, sauces, smoothies, chunks, slices, ready-to-eat products, these are only some examples of a wide range of fruit and vegetable products that can be processed by HPP. Shelf life is extended while keeping taste and nutritional properties of fresh fruits and vegetables. Shelf life can be multiplied by 2 to 8 times, depending on the product, while sensorial and nutritional properties remain intact.
- New product development possibilities. Functional molecules that are destroyed by heat, can be preserved using HPP. Ie: HPP keeps the antimutagenic components of carrot, cauliflower, kohlrabi, leek, spinach, beet, tomatoes, broccoli and many others. New functional products made of fruit or vegetables with antioxidant properties can be launched.
- Protects the brand/Safe products. Pathogenic and spoiling microorganisms are eliminated and cross-contamination is not possible due to the post packaging nature of the process.
- Local products can be exported to the highest quality demanding countries like USA, Japan, etc. Due to high sensorial, nutritional and microbiological quality,

along with enhanced shelf life, products will distinguish themselves because of quality.Ref: Vefruco. Video

- HPP is a great option for keeping fresh flavor of juices and smoothies. This non-thermal process keeps original fruit/vegetable taste and color, allowing the creation of the highest quality premium range of products. The real taste of a freshly squeezed juice.
- Juice products where flavor and nutritional values are seriously compromised by heat treatment, can now be High Pressure Processed. Ie: Pomegranate, apple, carrot, broccoli, beetroot, etc.
- Nutritional and functional properties of the product remain intact. One of the main trends that is making HPP successful is the development of natural, organic, preservative free, and functional products. HPP as a non-thermal and delicate post-packaging lethality intervention, allows development of healthier food: rich in vitamins, anti-oxidants and thermosensitive antimutagenic components, bringing a higher level of functionality to new products.

CONCLUSION

High pressure processing is an industrially tested technology that offers a natural alternative for the processing of a wide range of different food products. It is a technology that can achieve thefood safety of heat pasteurisation whilst meeting consumer demand for fresher tasting minimally processed foods. Application of HP can inactivate microorganisms and enzymes and modify structures whilst having little or no effects on nutritional and sensory quality aspects of foods. The key advantages of HP applications to food systems are the independence of size and geometry of the sample during processing, possibilities for low temperature treatment and the availability of a waste-free environmentally friendly technology.

REFERENCE

[1] P. Fellows, 2000, Food Processing and Technology principles & practice,2nd edition, Woodhead Publishing Limited.

[2] S.C. Bhatia, 2008, Hand book of Food Processing Technology Volume-1 Basic Concepts & Processing Aspects, Atlantic publication & distribution (P) LTD, Delhi

[3] Fernando Sampedro , David J. Geveke , Xuetong Fan , Howard Q. Zhang,2009,Effect of PEF, HHP and thermal treatment on PME inactivation and volatile compounds concentration of an orange juice–milk based beverage, Innovative Food Science and Emerging Technologies, Institute of Agro-Chemistry and Food Technology, CSIC, P.O. Box 73, 46100 Burjassot, Valencia, Spain

[4] Jordan, S.L.; Pascual, C.; Bracey, E. & Mackey, B.M. Inactivation and injury of pressure-resistant strains of Escherichia coli O157 and Listeria monocytogenes in fruit juices. Journal of Applied Microbiology 2001, 91(3), 463–469.

[5] Bull, M. K.; Zerdin, K.; Howe, E.; Goicoechea, D.; Paramanandhan, P.; Stockman, R.; Sellahewa, Jay.; Szabo, E.A.; Johnson, R.L.; Stewart, C.M. The effect of high pressure processing on the microbial, physical and chemical properties of Valencia and Navel orange juice. Innovative Food Science and Emerging Technologies 5, 2004, 135–149.