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Commercialization of high pressure processed foods: A consumer choice for quality and safety products

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ABSTRACT

Emerging food processing technologies are growing to meet consumer demands for safer and more natural products with fewer additives and preservatives. High pressure processing (HPP), a non-thermal technology, offers benefit of sensory and nutritional qualities of fresh-like food products. Consumer demands for HPP products have increased, resulting in a fast growing of global HPP food markets. Mostly, HPP applications are used for preserving food on niche market such as fresh fruit juices, dairy, meat and seafood. The market price for HPP products are inevitably higher than thermal processing products about 5 times for milk and cold-pressed juice. However, consumers are willing to pay more for a better quality. This review gives the information about the HPP as an alternative to thermal treatments for consumers and selling price comparison between HPP and thermal processing products in food markets.

Keywords: High pressure processing; Conventional thermal processing; Non-thermal processing; Food processing; Preservation technique

1. INTRODUCTION

The food industry is rapidly changing as consumers develop an appetite for healthier and more eco-friendly options. Recently, growing consumers demand for low-impact processing and emphasize on product quality, healthy food, natural flavor, texture and nutrient, those are required developments in minimal processing of food preservation which HPP reduces the heat exposure of the food during processing to extend nutritional quality and sensory attributes (Ohlsson, 1994). From this point of view non-thermal new techniques have emerged. High pressure processing (HPP) is described as a non-thermal treatment with the key challenges of ensuring high performances of microbial while keeping original organoleptic characteristics of the products such as flavor, taste and texture (Yamamoto, 2017). HPP treatment is suitable for a variety of products preservation, from juices and beverages to vegetables and meat industry. In meat products, the food additives would be replaced with HPP process which spoilage microbes were inactivated and extended shelf life resulting in wider product distribution (Chotyakul and Boonnoon, 2016). The use of HPP for food processing is finding increased application within the food industry, therefore the demand of HPP machine is increasing due to the wide range of commercial application of pressure-treated food products. HPP market was broadly segmented into meat, seafood, fruits, vegetables, juice and beverages that a market value earns about $2.5 billion in various

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products (Balasubramaniam et al., 2015). High-pressure technology is used in several countries, including the United States, Mexico, South Korea, Spain, and Japan. The rapid sales growth in HPP market volume has been increasing every year from 1990 to 2010 by US $10 billion and used mostly in America (Wang et al., 2016). HPP machine had increased five times in 2014 more than that produced ten years ago in 2004 (Elamin et al., 2015). Also, commercial HPP equipment have been operating between 1990 and 2015 more than 300 sets for mass production worldwide mainly in North America (54%), Europe (25%), and Asia (12%) (Huang et al., 2017). HPP has been considered as one of the best novel processing technologies during the past 50 years and up until recently.

An alternative non-thermal food processing technologies such as microwave (MW) heating, high pressure processing (HPP), ohmic heating, ultrasounds (US), dielectric heating, radio frequency (RF), pulsed electric fields (PEF) offer on improving sustainability of production and requires lower energy input or fewer resources than conventional thermal processing which heat has a negative influence on the taste, texture, and nutrient integrity of food products (Toepfl et al., 2006). Non-thermal technologies are able to inactivate microorganisms at ambient or sublethal temperatures with benefits preserving the sensory and nutritional quality of the fresh-like food products (Pereira and Vicente, 2010). The main advantage of HPP is to extend product shelf life and guarantee for food safety without affecting taste, appearance and nutritional properties whereas food exposed to high temperatures can alter taste, texture and nutritional value. Therefore, when any novel technological method is employed in the processing of food, it is important that key micronutrients such as vitamins are not adversely affected. The limitation of HPP application for food industry is carried out using a batch or semi-continuous process and it has been widely demonstrated that HPP is more costly than conventional thermal processing, especially high cost of initial investment, cost intensive maintenance, and service (Muntean et al., 2016). HPP low temperature processing technology costs are considerably higher than those of conventional thermal processing for manufacturing. In future, HPP products are more widely spread out to local supermarkets due to a high acceptance of consumer demand of these products which is leading to the reducing their cost considerably. However, cost estimation for HPP-treated products is depended on the region, energy source, labor, and food product (Sampedro et al., 2014).

The fundamental achievement for the thermal food processing is to reduce or inhibit microbial activity, enzyme activity, and to produce physical or chemical changes to meet certain requirements with regard to food quality and food safety. Food industry widely used conventional thermal technologies of preserving and extending the shelf life of foods which several nutrients, minerals, and vitamins were changed by heat, especially for processed fruits and vegetables (Petruzzi et al., 2017). Food manufacturers ultimate goal was designed an innovative approaches for process to protect nutrients due to sensitivity of physical and chemical factors in food processing, storage, and improved human health through more effective nutrition. HPP has required less processing time and processing could be completed in final packaging which avoids post-processing tempering and contamination (Jan et al., 2017). For purpose of this paper, we reviewed the literature on applying mild preservation techniques such as high pressure processing in global food markets as an alternative choice for consumers.

2. HPP APPLICATION IN FOOD PROCESSING

Pressure processing technologies were being investigated as an alternative preservation technique to achieve the bactericidal effects of pasteurization and sterilization at lower process temperatures and/or shorter treatment times than thermal processing (e.g.,

Mújica-Paz et al., 2011; Norton and Sun, 2008; Verbeyst et al., 2013; Verbeyst et al., 2012). HPP was known as cold pasteurization that utilized extremely high levels of pressure (100-1,000 MPa) from several seconds to minutes by compression of water to inactivate microbes and enzymes, to extend quality such as color and flavor (e.g., Fellows, 2009; Yaldagard et al., 2008). The pressure was transmitted into product uniformly and simultaneously in all directions during the process called isostatic pressure. Therefore, HPP application was independent of sample geometry and mass (Yaldagard et al., 2008). This was the main effectiveness of HPP when compared to thermal preservation process that resulted from slowly increase in temperature to transfer the heat from hot surfaces to the product without treated food uniformly (Balasubramaniam and Farkas, 2008). The product was generally pre-packed in flexible pouch or plastic container, then was placed in HPP vessel. The vessel was sealed and completely filled with water serving as the medium to transfer the pressure to the product, and then introduced to high levels of pressure. The product in the pressure chamber has normally increased by 3-6°C for every 100 MPa depending on product compositions (Rastogi et al., 2007). Current industrial HPP operating treatments are described for three major types; a batch, continuous, and semi-continuous (Farkas and Hoover, 2000). One of the most important components of high pressure machine is high pressure vessel in operating of vertical or horizontal mode. The Batch operating mode has the advantage for both liquid and solid food products which products are usually pre-packed first. Whereas continuous and semi-continuous systems are used to apply with liquids, slurries and other pumpable products (Elamin et al., 2015).

General fruit juice manufacture, HPP treatment was used to enhance the overall quality of thermally sensitive juice products. For example in white grape juice, HPP used in maintaining the overall quality attributes such as organoleptic properties and nutritional value. Meanwhile, the inactivation of spoilage and pathogenic microorganisms was pressure treated at 600 MPa. HPP treatment was not only provided safety grape juice to drink for few weeks after being packed, but high amounts of essential nutrients were preserved in juice as well. Therefore, HPP-treated grape juice was effectively extending the shelf-life during refrigerated storage which was important for its wider distribution and commercialization (Chang et al., 2017). A research paper studied by Chen et al. (2015) found an effectiveness of HPP (550 MPa/5 min) and high temperature short time (HTST, 110°C/8.6 s) on papaya beverage allowed completely microbial inactivation. However, the original color of papaya beverage was changed after HTST treatment but color, total phenols and antioxidant capacity were retained after HPP during storage at 4°C for 40 days. HPP was a promising method for food processing to have a good prospect for use as an alternative method. Many new studies on HPP products have been performed and advertised to consumers. It was not surprisingly if HPP application in food industry has been cited as one of the best innovation for commercial food processing in next 50 years (Balasubramaniam et al., 2008). Some of commercial applications of HPP by product category are demonstrated in Table 1.

Current HPP product manufacturers consist of Suja Life, Motivatit, Universal Pasteurization, Avure Technologies, Echigo Seika, Hain Celestial, Espuna, Cargill, Safe Pac Pasteurization, Hormel food, and Campofrio Alimentacio (Cruz, 2018). A commercial application for food products was represented in pasteurization of meats and vegetables, pasteurization and sterilization of fruits, sauces, yoghurts and salad dressings, high value heat sensitive ingredients including flavorings and vitamins and decontamination of high risk products (Muntean et al., 2016). Numerous companies have invested in HPP systems for juices expanded for 20 companies globally in 2010 and has increased to more than 100 HPP juice brands in 2015

(Huang et al., 2017). Moreover, HPP application (Table 1) was already in the market of condiments, dressings, soups and sauces (Elamin et al., 2015).

Table 1 Application of high pressure processing (HPP) to the food industry

Product	Range of Pressure	Purpose
Fruits and vegetables, meat, milk, dairy products, seafood	200–800 MPa	Microbial inactivation in raw products
Orange juice	200 MPa	Microbial quality and pectin methylesterase activity of pressure-treated juice was similar to thermally pasteurized
Deli meats and ready-to-eat foods	400 MPa	Microbial reduction in processed and packaged foods
Meat	200 MPa	Meat texture modification
Milk, cheese, yogurt	200 MPa	Reduction of fat globule size
Mainly fruit- and vegetable-based products	200–600 MPa	Enzyme inactivation
Low-acid foods	Over 600 MPa plus about 60°C or higher)	Sterilization
Salad dressing (ranch)	600 MPa	Prevented microbial spoilage throughout the storage period (26 week at 4 and 26°C)
Vegetable soup (gazpacho)	150 to 350 MPa	Preserved the carotenoid content in vegetable soups and retained the antioxidant activity during storage
Sauces (guacamole)	600 MPa	Maintain nutritional and nutraceutical values, particularly carotenoid profiles

Adapted from Bermúdez-Aguirre and Barbosa-Cánovas, 2011; Plaza et al., 2006; Waite et al., 2009; Wang et al., 2016

3. HPP FOODS IN GLOBAL MARKET AND CONSUMER CHOICE

New food processing technology has developed to achieve consumer demands for fresher products with microbiological safe and improved flavor (e.g., Deliza et al., 2005; Rosenthal and Silva, 1997). A global demands for food and nutrition security were creating opportunities and challenges for HPP development which introduced to commercial applications in the 1990s for fruit products (Yamamoto, 2017). Later on, it has been successfully implemented in all type of food industries worldwide due to the commercial pressurized products success of jams in Japan, also other products have been marketed such as jellies and sauces produced by Meidi-ya Food Co. From the year 1990s in the United States, first commercially available HPP-treated avocado products were guacamole which is a traditional Mexican sauce and has been successfully introduced in the southern US market by Avomex Company in US (Texas/Mexico) (e.g., Paloua et al., 2000; Yaldagard et al., 2008). HPP guacamole has minimal changes in the fresh characteristics such as taste and appearance compared to fresh (non-processed) guacamole. Pressurized guacamole currently

obtained 4 to 8 weeks shelf life and safety, also natural green color preserving due to the inactivation of polyphenoloxidase under pressure (Jung and Tonello-Samson, 2018). Other HPP-treated products were marketed in 2000 for shucking oyster, fruit juices, and poultry products. In addition, Mainland Europe started producing and marketing fresh citrus fruit juices and delicatessen-style cooked meats in the same year. HPP products in the UK has historically been the initial development for fruit pieces and fruit juices which launched in 2001 (e.g., Bermúdez-Aguirre and Barbosa-Cánovas, 2011; Patterson et al., 2006).

Consumer demands for HPP products have increased, resulting in a fast growing of global HPP food market focuses on product sales, value, market share and growth opportunity in many regions covering Canada, USA, Mexico, Columbia, Chile, Brazil, Ireland, United Kingdom, Norway, Finland, Poland, Germany, France, Italy, Spain, Portugal, India, Korea, Japan, Australia, and New Zealand (Bermúdez-Aguirre and Barbosa-Cánovas, 2011). HPP investment pays approximately $0.5-$2.5 million per installed equipment depending on operation capacity and parameter. The global HPP food market in 2015 has reached approximately $9.8 billion with more than 300 units of HPP equipment in operating and marketing and in 2025 are expected to result in value of $54.77 billion (Huang et al., 2017). A trend in HPP global food production estimated exceeding 500 million kilogram in 2014. Vegetables and meat products owned 27% each of the total, followed by 14% of juices and beverages. Seafood products industry showed up the third place with 12%, and 20% completed with other products (Elamin et al., 2015). By the reason of HPP was considered as an expensive processing method compared to conventional thermal processing, an increasing HPP capacity with highly productive equipment was a key driving force in the implementation of HPP in the food industry which higher production helped reducing the unit costs. Commercially available as the largest machine options for HPP equipment maximum had working pressure of 600 MPa consisted of a vessel 215 L and 525 L volume in 2011 and 2014, respectively (Balasubramaniam et al., 2016). Recently, the world's biggest productivity from Hiperbaric USA, Miami, Fla., is designed for Hiperbaric 1050 Bulk (10,000 L/h) to process beverage in bulk and allow the use of any kind of bottling or packaging after HPP (Lingle, 2017).

The high costs of HPP in comparison with traditional methods such as chemicals, heat, and preservatives are important factors influencing consumer payment choices. The actual investment and processing costs depended on a variety of factors such as equipment, installation, labor, utilities, and packaging (Bermúdez-Aguirre and Barbosa-Cánovas, 2011). The attitudes survey of 1,204 U.S. consumers indicated that 39% consumers were willing to pay an additional cost of $0.25 to $0.50 for HPP products when an explanation of HPP and its food safety benefits were given to consumers (Hicks et al., 2009). Although, HPP is a promising technique for shelf life extension but the cost of HPP process ranging from $0.1- $0.2 per litter was higher than conventional thermal process ranging from $0.2- $0.4 per litter. Thus, mostly HPP application was used for gentle preservation of delicate food products to retain its original sensorial appearance and nutritional value and specific section on niche market such as fresh fruit juices, seafood and guacamole (Yaldagard et al., 2008).

Describe on the different costs of pasteurizing 1 liter of orange juice among three types of processing technologies were calculated for capital and operating costs. The calculated values per 1 liter were $0.015, $0.037, and $0.107 for thermal processes, PEF, and HPP, respectively. The non-thermal processing of orange juice market was estimated to be valued of 2.5- and 7-fold for PEF and HPP, respectively, higher than thermal pasteurization (Sampedro et al., 2014). Low levels of output bring in relatively high-cost products.

Therefore, contribute to maintain a commercial option of low production volume, HPP is suitable for only high-value products. In commercial market products (Table 2), cold-pressed juice that refers to juice made using a hydraulic press to extract the juice from fruits and vegetables, then undergo the additional step of HPP to kill potentially harmful microorganisms and sell in the market for a month. The cost is up to $10 for a 16-ounce (approx. 480 ml) bottle or as high as $12 for 12 ounces (approx. 350 ml) (Hiperbaric, 2014). Whereas the cost of conventional thermal fruit juices are varied from $1.5 to $2.75 for 16-ounce bottle and $2.52 to $3.50 for 12-ounce (www.amazon.com) which prices show ten times cheaper per bottle than HPP fruit juice. Cold-pressed watermelon juice is $4.17 for 12-ounce which selling price is two times higher than $2.99 of pasteurized one per 12-ounce (e.g., www.drinkmaple.com; www.bevnet.com). While some companies such as Starbucks have established a market segment for HPP fruit juice that sells at highest average price for $7.99/480 ml to differentiate between HPP fruit juice and conventional fruit juice products. Starbucks remains confident in this non-thermal process which keeps original fruit taste and color, allowing the creation of the highest quality premium range of products and plans to apply its successful marketing strategy previously used in the coffee industry to HPP fruit (Huang et al., 2017).

Table 2 Commercial price comparison in US dollar between HPP-treated products and conventional thermal processing

Product	Unit of measure	HPP	Thermal	References
Fruit juice	16 ounce bottle	$7.99 - 10	$1.50 - 2.75	Huang et al., 2017 and Hiperbaric (2014) and www.amazon.com
	12 ounce bottle	$12	$2.52 - 3.50	
Watermelon juice	12 ounce bottle	$4.17	$2.99	www.drinkmaple.com and www.bevnet.com
Milk	750 ml bottle	A$5 ($3.78*)	A$2.95 ($2.24*)	Sullivan (2016) and www.4realmilk.com.au
	1000 ml bottle	A$6.65 ($5.02*)	A$1.29 - 1.31 ($0.97 - 0.99*)	Sampson (2016) and www.harrisfarm.com.au
Sliced Canadian Style Bacon	lb	$10.48	$8.67	www.store.wellshirefarms.com and www.jonesdairyfarm.com

*A$ 1 = $ 0.76

As a selling price, low volume production has linked to a share-price increase. Moreover, a trend boosts battling dairy industry in Australia, cold-pressed milk 750 ml and 1000 ml bottles at priced A$5 ($3.78) and A$6.65 ($5.02), respectively (Table 2) are allowed to sell in retail stores following food regulatory approval (Sullivan, 2016). The average retail pasteurized milk price is A$1.29 ($0.97) per liter in NSW and A$1.31 ($0.99) per liter in Australia (e.g., Sampson, 2016; www.harrisfarm.com.au) whereas, in the AU pasteurized milk for 750 ml bottle price is about A$2.95 ($2.24) (www.4realmilk.com.au). The market price for HPP milk is higher than pasteurized milk for about 5 times. Nevertheless, HPP became more common in the cold-pressed juice and milk, consumers are willing to pay more for a better quality. In meat product market, for example sliced Canadian style bacon is not many differences in price between HPP

treatment and thermal treatment (e.g., www.store. wellshirefarms.com;www. jonesdairyfarm.com). Also, the influence of customers' decision have expressed a higher product intention to buy for HPP pineapple juice when they understood the benefit of the representing technology (Deliza et al., 2005). Moreover, HPP was currently used as an intervention of the processing technologies for oyster postharvest processing. Muth et al. (2013) studied on HPP-trigger treatment to open oysters and estimated costs provided with 4 process sizes for HPP processing based on 2000 h and 4800 h annual operating schedules for half-shell and shucked oysters. The cost values achieved per sack (100 pounds) for 2000 h/4800 h per year, respectively were $12.24/$5.88 for 100 L horizontal equipment; $6.61/$3.49 for 320 L vertical equipment; $6.54/$3.75 for 350 L horizontal equipment; $6.96/$3.48 for 687 L horizontal equipment. In addition to conventional pasteurization process, cost values achieved per sack (100 pounds) were $8.00 and $6.25 for small and large process, respectively (Barba et al., 2016). However, to reduce market price has resulted in the high-volume production which provided many opportunities for cost reduction such as capital equipment costs, energy, materials, and size operation.

4. CONCLUSION

Non-thermal processes are developed as potential alternatives to thermal and chemical operations in food processing. There have been many other innovative products such as fruit juice, milk, processed meats, and oysters introduced through HPP capabilities but the cost was relatively high compared to several traditional food-processing. If the demand for pressurized products have continued as growth in the developed market economies, the cost of these products will be actually declined in absolute terms which reduced capital and operating costs per unit with increase in vessel volume. However, products price are the top factors that impact consumer buying decisions, therefore the manufactures need to consider as a big picture in the future gaining a better trend in food processing and response to the consumer demand.

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