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Review

Current status and future trends of high-pressure processing in food industry

Hsiao-Wen Huang [a], Sz-Jie Wu [a], Jen-Kai Lu [b], Yuan-Tay Shyu [a], Chung-Yi Wang [c, *]

[a] Department of Horticulture, National Taiwan University, Taipei, 10617, Taiwan
[b] Department of Agricultural Economics, National Taiwan University, 10617, Taiwan
[c] The Experimental Forest, National Taiwan University, Nantou, 55750, Taiwan

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ABSTRACT

The increased consumers' interest in high quality foods with fresh-like sensory and additive free attributes led to the development of non-thermal food processing technologies as alterative to conventionally heat treatments. This review describes the current application status and market trends of high-pressure processing (HPP) technology in food industry. As the most successfully commercialized non-thermal processing technology, HPP eliminates food pathogens at room temperature and extends the shelf life of foods circulated through the cold chain. These processes maintain the organoleptic properties and nutritional value of the foods, which is not possible using traditional thermal pasteurization. The U.S. Food and Drug Administration has officially approved HPP as a non-thermal pasteurization technology that can replace traditional pasteurization in the food industry. Clearly defined regulations and specifications will facilitate the development of the application market to improve product quality and consumer trust. The widespread application of HPP technology has boosted the development and market demand for HPP equipment. HPP has been widely used in the production of packaged vegetables, fruits, meat, seafood, and dairy products. By the end of 2015, more than 300 units of HPP equipment were operating globally. Despite the high price and high barriers to investment, the specialized original equipment manufacturer service sector has been gradually increasing, and the annual output value of global HPP market has approached $10 billion. HPP technology also can be combined with existing food trends, as organic food, health food or clean label to boost the development in the food market.

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* Corresponding author. No. 12, Sec. 1, ChienShan Rd., Nantou, 55750, Taiwan.
Tel.: +886 49 2642183; fax: +886 49 2659927.
E-mail address: wangcy@ntu.edu.tw (C.-Y. Wang).

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1. Introduction

Increasingly health-conscious consumers are demanding better food quality, such as improved food safety, nutritional value, freshness, and flavors. Clean label foods, which claim to be natural and fresh as well as free from chemical additives, have gradually gained attention among consumers (Zemser, 2015). Processors in the food industry must use processing technologies capable of reducing additives while maintaining natural flavors and food quality, which has increased the development of emerging non-thermal processing technologies. Traditional thermal pasteurization technology negatively affects sensory characteristics, flavors, and nutritional contents of food. Non-thermal processing technology has attracted widespread attention from food industry practitioners. Each year, numerous symposiums regarding non-thermal processing technologies are conducted worldwide to discuss high pressure, pulsed electric field, pulsed light, electron beam, plasma, and modified atmosphere packaging; however, high pressure processing (HPP) is the most successfully commercialized non-thermal processing technology (Farkas, 2016). Application of HPP technology as follows: food is hermetically sealed in a flexible container under an high pressure of 100–600 MPa applied at room temperature, using a liquid (typically water) as the pressure transfer medium, subjecting the interior and surface of the food to even pressure to achieve pasteurization (Balasubramaniam, Martínez-Monteagudo, & Gupta, 2015). The pasteurization effect of HPP is not affected by the packaging form and volume of the food, and thus foods of different volumes can be processed in the same batch. In addition, this technology ensures the microbial safety of food without the addition of preservatives and allows the processed food to maintain the natural flavors and nutritional value of the original food material. Therefore, HPP technology is recognized as a minimal processing technology that ensures both food safety and flavor (Daryaei & Balasubramanian, 2012). Compared with traditional thermal processing technology, HPP is performed at room temperature, reducing energy consumption associated with heating and subsequent cooling. In addition, the food is in packaged form and does not directly contact the processing devices, preventing the secondary contamination of food after pasteurization. Additionally, the pressure transfer medium can be recycled after processing. With the advantages of low energy consumption and low contamination risk, HPP technology is an environmentally friendly processing technology (Rastogi, Raghavarao, Balasubramaniam, Niranjan, & Knorr, 2007).

The earliest HPP study was conducted in the United States in 1885, in which it was reported that high pressurization eliminated bacteria. Subsequently, researchers found that HPP extended the storage life of milk. These studies revealed the potential application of high pressure in the food industry. A number of universities, governmental departments, and research institutions actively conduct studies on high pressure pasteurization technologies using laboratory high pressure equipment with the goal of helping the food sector establish a common technical standard for the pasteurization of foods. Since HPP technology is a new pasteurization technology for the food industry, its health and safety aspects, economic value, and product forms should be assessed in detail before commercialized application. Additionally, the scientific theories and processing parameters for practical application should be further established. Basic pasteurization data should be established based on HPP research achievements to meet the actual needs of food practitioners in product development. Such pasteurization data can also serve as the criteria for hygienic safety assessment of HPP products (Huang, Lung, Yang, & Wang, 2014). Equipment manufacturers, such as Avure, Stansted Fluid Power, Baotou, Kobelco, and Toyo Koatsu, produce laboratory HPP equipment with different specifications and capacities of 0.3–10 L to meet different experimental needs. The earliest commercial product was the widely available HPP jam in Japan. Subsequently, various HPP food products were launched in Europe and North America. In recent years, the gradual widespread adoption of HPP equipment has become a key factor driving the development of HPP technology. An increasing number of machinery manufacturers worldwide have engaged in the research, development, and manufacture of HPP equipment, leading to better equipment manufacturing technology, continuously improved production performance, and long-term, stable production operation. Avure and Hiperbaric, which have gained most of the market share, developed HPP devices with a volume of 525 L and an annual production capacity of approximately 60 million tons (Balasubramaniam, Farkas, & Turek, 2008). This review introduces HPP equipment, the current application status of HPP equipment in various types of foods, and the technical bottlenecks for future applications.

2. Current status

With the gradual maturation of HPP equipment technology in recent years, various manufacturers in U.S.A, Spain, U.K, Japan, and China have developed the capacity to produce HPP equipment. Major global manufactures include Avure (Middletown, OH, USA), Hiperbaric (Burgos, Spain), and Multivac (Germany, formerly Uhde High Pressure Technologies, merged with Multivac in 2011); the largest manufacturer in China is Baotou Kefa High Pressure Technology Co., Ltd. (Baotou, China). There are more than 10 HPP equipment suppliers; the world's largest supplier is Hiperbaric, with a market share of more than 50%. HPP devices are divided into two types, the horizontal and vertical types. Most devices used in commercial applications are the horizontal type to facilitate the loading and unloading of containers in the production line (Marketsandmarkets, 2013). More than 300 sets of HPP equipment have been operating for mass production worldwide (Fig. 1), mainly in North America (54%), Europe (25%), and Asia (12%). Fig. 3 show a horizontal type HPP system from Multivac Inc., German. A set of HPP equipment costs approximately $0.5–2.5 million depending on the capacity and operating parameter range of the equipment. HPP technology has been widely used in the production of meat products, dairy products, aquatic products, vegetable and fruit products, and various beverage products. The global market for HPP foods reached approximately $9.8 billion in 2015 and will is expected to culminate in a market value of $ 54.77 billion in 2025 (Fig. 2) (Visiongain, 2015). Manufacturers in Europe, North America, and Japan have been actively developing commercial applications, and the production output of HPP products has increased each year. Every year, approximately 500,000 tons of HPP products are