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Review

New opportunities and perspectives of high pressure treatment to improve health and safety attributes of foods. A review

Francisco J. Barba [a,d,*], Netsanet Shiferaw Terefe [b], Roman Buckow [b], Dietrich Knorr [c], Vibeke Orlien [a]

[a] Department of Food Science, Faculty of Science, University of Copenhagen, Rolighedsvej 30, 1958 Frederiksberg C, Denmark
[b] CSIRO Food and Nutrition Flagship, Private Bag 16, Werribee, Victoria 3030, Australia
[c] Department of Food Biotechnology and Food Process Engineering, Berlin University of Technology, Königin-Luise-Straße 22, 14195 Berlin, Germany
[d] Nutrition and Food Science Area, Faculty of Pharmacy, Universitat de València, Avda. Vicent Andrés Estellés, s/n. 46100 Burjassot, Spain

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ABSTRACT

High pressure (HP) treatment has emerged as a novel, additive-free food preservation technology. It has been scientifically and commercially proven that HP can produce microbially safe and stable products with improved quality characteristics such as enhanced flavor and color. Recent studies have focused on the effects of HP on health attributes and allergenic potential of foodstuff to develop the next generation of convenience foods. This review provides an overview on the current knowledge of HP treatment to improve the extraction and bioavailability of bioactive compounds, to reduce allergenicity, to retain essential fatty acids, to reduce the salt content, and to reduce formation of processing contaminants. HP has shown encouraging potential to manipulate the functionality, extractability, allergenicity and bioavailability of micronutrients and components in a diverse variety of foods. However, the underlying principles and mechanisms are not yet fully understood and warrant further investigation. More studies are needed to optimize HP treatment conditions and develop a mechanistic understanding of the impacts of HP on different bioactive compounds in food products with health benefits. This can open the doors to new HP applications in the food industry.

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* Corresponding author at: Department of Food Science, Faculty of Science, University of Copenhagen, Rolighedsvej 30, 1958 Frederiksberg C, Denmark.
E-mail addresses: francisco.barba@food.ku.dk, francisco.barba@uv.es (F.J. Barba).

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1. General introduction

The efficacy of high pressure (HP) treatment is governed by Le Chatelier's principle, which implies that reactions or phase transitions associated with a decrease in volume are favored, while those accompanied with a volume increase are inhibited. Low molecular weight molecules like aroma compounds, vitamins, and minerals are rarely affected as such by HP because of the very low compressibility of covalent bonds. On the other hand, macromolecules, such as proteins and starch, can change their native structure during HP in a manner similar to thermal treatments (Gross & Jaenicke, 1994; Heinz & Buckow, 2010).

HP treatment is characterized by three processing parameters: temperature *T*, pressure *P*, and exposure time *t*. The three processing parameters allow great flexibility in the design of the process (Heinz & Buckow, 2010). Generally, the pressure is transmitted instantaneously and uniformly throughout the food system independent of the size and geometry of the food product, unlike heat processing, where heat is gradually transferred through the food system. The momentary pressure transmission can reduce processing time, processing energy and the risk of over-processing of some parts of voluminous products.

It is frequently claimed that HP can be used to produce healthy and fresh-like foods due its minimal effects on nutritional and aroma compounds (Rastogi, Raghavarao, Balasubramaniam, Niranjan, & Knorr, 2007). For the last two decades, HP treatment has been mainly applied to increase food safety and/or extend the shelf-life of refrigerated foods of high value (Barba, Criado, Belda-Galbis, Esteve, & Rodrigo, 2014; Barba, Esteve, & Frígola, 2012a). Some of the current and potential applications of HP treatment are shown in Fig. 1.

This review is intended to highlight several opportunities of HP treatment of foodstuffs beyond the current commercial applications for food safety and shelf-life extension. The great potential of HP treatment to a) recover health-related compounds, b) improve health attributes of foods through increased bioavailability of micronutrients and phytochemicals, c) reduce allergenic potential, d) preserve healthy lipids, e) reduce salt intake by increased saltiness perception, and f) reduce formation of processing contaminants is presented.

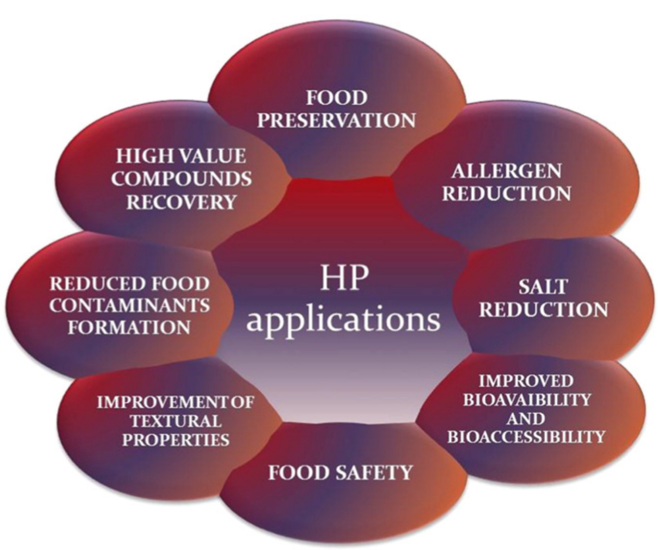

Fig. 1. Current and potential applications of high pressure (HP) treatment in food, wastes and by-products.

2. Effect of HP on bioactive compounds recovery

Bioactive compounds from plant food materials are interesting due to their health and nutraceutical benefits (Barba, Esteve, & Frigola, 2014). Polyphenols have been related to reduction in risk of coronary heart diseases and degenerative human diseases because of their antioxidant and free radical scavenging properties (Barba, Esteve, & Frigola, 2013; Wang, Melnyk, Tsao & Marcone, 2011; Wootton-Beard & Ryan, 2011). Carotenoids are known to be functional components of a healthy diet, some of them with vitamin A function (β-carotene, α-carotene, and β-cryptoxanthin) (Melendez-Martinez, Vicario, & Heredia, 2003). In addition, glucosinolates and the derived isothiocyanates have attracted much interest from both food and pharmaceutical industries due to their potential health benefits (Deng et al., 2014; Dinkova-Kostova & Kostov, 2012).

In general, cellular tissue must be denatured to become permeable for the intracellular compounds targeted by extraction. In industry, such tissue permeabilization is most often achieved through a thermal process (e.g., using steam or hot water) and consumes a high amount of energy. The heating process may degrade the thermo-sensitive compounds of plant tissue affecting the quality of the products (loss of vitamins, colors, flavors, etc.) and complicating the purification of the extracts. Alternative physical, chemical, or enzymatic treatments can also be used to denature the cellular structure of plants and biological suspensions (yeast, seaweeds), and make the extraction of cellular compounds easier. Some physical treatments (microwaves, ohmic heating, sub- and supercritical water) allow shortening of product exposure to heat. Some other alternative treatments (e.g., supercritical carbon dioxide, pulsed electric fields, shockwaves, ultrasound, high-pressure homogenization) are considered as “non-thermal” even if the temperature elevation of products by these treatments is far from negligible (sometimes tens of degrees) (Deng et al., 2014; Parniakov, Barba, Grimi, Lebovka, & Vorobiev, 2014; Rosello-Soto et al., 2015). The classical treatments (grinding, heating), and the different alternative treatments currently used in industry to make extractions easier, degrade and disrupt the tissue structure (membranes and cellular walls) in an uncontrollable way. Unfortunately, the entirely disrupted tissue loses its selectivity (capacity to sieve) and becomes permeable not just for the target cell compounds, but also for undesirable compounds (impurities) passing into the extract. As a result, the extract is contaminated by auxiliary compounds (cell debris, pectins, etc.), which are difficult to separate (Barba, Grimi, & Vorobiev, 2015). Organic solvents such as dichloromethane, dichloroethane, acetone, hexane, and alcohol are widely used for the extraction of different molecules of agricultural origin (carbohydrates or polysaccharides, proteins, bioactive compounds, aromas, flavors, etc.). Extraction is often linked with the use of environmentally polluting chemical or biological agents. Among solvents considered to be “green”, water should be primarily noted, with supercritical fluids (such as carbon dioxide), renewable solvents (bio-solvents such as ethanol or isopropanol) and ionic liquids also considered ‘green’. Unfortunately, the “green” solvents, and particularly water at room temperature, are often inadequate for an efficient extraction from food plants (Kerton, 2009).