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Review

A review on recent development in non-conventional food sterilization technologies

Xiang Li, Mohammed Farid*

Department of Chemical & Materials Engineering, The University of Auckland, Private Bag 92019, Auckland, New Zealand

A R T I C L E I N F O

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A B S T R A C T

Sterilization is one of the most effective food preservation methods. Thermal sterilization technologies have been widely employed in food industry since they are well developed and require low investment cost. Demands of consumers for higher quality and fresh tasting products are growing rapidly. Recently, non-conventional sterilization technologies have gained significant attention, since they have the potential to provide products with a better quality, fresh-like taste, and may require lower energy to operate. However, none of these technologies have been commercialized yet. This review addresses the efforts, which have been made in the literature to lower sterilization temperature using combination of thermal and one of the non-thermal processing technologies, such as high pressure, UV, pulsed light, ultrasonic, pulsed electric field, irradiation, and cold plasma.

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* Corresponding author.
E-mail address: m.farid@auckland.ac.nz (M. Farid).

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1. Introduction

Sterilization is one the most effective food preservation methods and has been widely used in almost all food manufacturing areas. Sterilization is defined as the process which can provide near complete inactivation of microorganisms (including spores). Sterilization is achieved by applying high intensity heat (normally between 121 °C and 140 °C) to food products (Deak, 2014; Lin, 1976). It should be highlighted that 'sterilization' in food industry refers to 'commercial sterilization' status instead of being sterile in the medical sense of the word (Teixeira, 2015). Sterilization is used to eliminate all bacteria and heat-resistance spores but usually lead to serious quality losses of the products (Featherstone, 2015). Commercial sterilization is achieved through a combination of relatively mild thermal treatment and other processing parameters and storage conditions (Teixeira, 2015). The criterion to evaluate commercial sterilization process is the inhibition of the growth of microorganisms and not their presence or absence (Heinz and Hautzinger, 2007).

Nowadays, conventional sterilization technology (i.e. thermal sterilization) is still holding a dominating position in food industry. Normally, it is achieved by using high pressure endurance equipment like retorts which allows food products to be heated to higher than 100 °C. However, sterilization is also limited by the condition of packaging process which could lead to recontamination of products (Berk, 2013; Wani et al., 2014). The efficacy of sterilization processing is evaluated by the reductions of most heat resistance spore-forming spoilage microbes in food products (Deak, 2014). In the food industry, thermal sterilization is usually achieved through two well-known methods; in container processing (retorting) and ultra-high-temperature (UHT) processing (with aseptic filling) (Busta, 1967, 1970; Clark, 1967; Fellows, 2009). One of the advantages of thermal sterilization is its ability to produce food with extraordinary long shelf life. The limitations of thermal sterilization are the losses of food nutritional value and the changes it induces in color, flavor, and texture of final products (Berk, 2013; Deak, 2014; Fellows, 2009; Lin, 1976; Teixeira, 2015). Significant research has been done on microbial inactivation mechanism and on product quality change during the process of sterilization (Busta, 1967; Berk, 2013; Bown, 2003; Carlson, 1996; Clark, 1967; David, 1996; Deak, 2014; Featherstone, 2015; Franklin, 1970; Fellows, 2009; Goullieux and Pain, 2014; Guerrero-Legarreta, 2014; Holdsworth, 2004; Icier, 2012; Ito et al, 2014; Noh et al., 1986; Oliveira, 2004; Ramesh, 1999; Rosenberg, 2011; Sandeep et al., 2004; Teixeira, 2015; Wani et al., 2014). In order to overcome the limitations of thermal sterilization, recent works have been focused on developing new sterilization technologies. It is the objective of this article to review and critically discuss the works done up to date on non-conventional sterilization technologies, which combine thermal treatment with one or more of the well-known non-thermal treatment such as high pressure (HPP), UV, pulsed light, ultrasonic, pulsed electric field (PEF), irradiation, and cold plasma.

2. Non-conventional sterilization technologies

Recently, the number of studies conducted on non-conventional sterilization technologies has increased rapidly. These novel technologies can be categorized into two major groups. The first group refers to the use of high pressure processing, UV, pulsed light, ultrasonic, and pulsed electric field processing in combination with heat. The other group refers to technologies which maybe considered as purely non-thermal, which include cold plasma and irradiation. The following section will discuss the efficacy and mechanism of these technologies. It must be noted that none of the above mentioned sterilization technologies have been commercialized.

2.1. High pressure processing

High pressure processing (HPP), also known as high hydrostatic pressure (HHP) processing is a novel non-thermal food treatment. HPP is achieved by pressurizing food products contained in flexible pouches, placed in a vessel and subjected to an extreme high pressure (usually at over 600 MPa), which is transmitted by pressure medium (normally water). HPP is capable of inactivating foodborne spoilage and pathogenic microorganisms without causing significant loss of sensory and nutritional values of food products (Tao et al., 2014; Wilson et al., 2008). The first application of HPP was reported by Hite (1899) to pasteurize milk and other food products and extend their shelf life (Rivalain et al., 2010).

HPP alone has very little effect on spores, but it can sterilize food products only when combined with other treatments (Daryaei and Balasubramaniam, 2012; Kimura et al., 1996; Tao et al., 2014; Wilson et al., 2008). In 2006, Farid developed a novel process treatment called *mild pressure assisted thermal sterilization* (Farid, 2006). The concept of 'generating pressure by thermal expansion' was the key issue; which has been proven effective on spore inactivation (Wimalaratne and Farid, 2008). However, pressure assisted thermal sterilization (PATS) which is studied more in the literature (Wilson et al., 2008) is based on using combination of HPP and heat. In the process, the food is heated prior to compression to an elevated temperature but below 100 °C and when compressed its temperature rises to 110–120 °C inducing sterilization in a short time (Wilson et al., 2008). Uniform compression heating and rapid cooling on decompression can avoid the side effect of thermal processing (Ahn et al., 2007). It has been reported (Meyer et al., 2000) that combined heat and pressure can lead to complete inactivation of vegetative micro-organisms and spores, with a minimal impact on sensory properties.

2.1.1. Mechanism of microorganism inactivation

In HPP, the high pressure induced membrane damage, denaturation of protein and decrease of intracellular pH are responsible for the inactivation of vegetative microorganisms (Smelt, 1998). However, the mechanism of inactivation of spores has not been elucidated. The resistances of spores are different even among the same species (Wilson et al., 2008). The mechanism of inactivation of *Bacillus subtilis* has been well studied. It is believed that the inactivation can be achieved by combining HPP with subsequent heat treatment (Paidhungat et al., 2002; Wuytack et al., 2000). It is assumed that, spores will germinate under moderate pressure condition (the germination pressure depends on the types of spores), then the germinated spores will be thermally inactivated (Vercammen et al., 2012; Wilson et al., 2008; Wimalaratne and