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Review

Pulsed electric field technology in the manufacturing processes of wine, beer, and rice wine: A review

Nannan Yang [a,1], Kang Huang [a,b,1], Chenang Lyu [a], Jianping Wang [a,*]

[a] College of Biosystems Engineering and Food Science, Zhejiang University, 866 Yuhangtang Road, Hangzhou, 310058, China
[b] Department of Food Science, University of Massachusetts, 102 Holdsworth Way, Amherst, MA, 01003, USA

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ABSTRACT

Pulsed electric field (PEF) technology is an alternative to traditional food processing because this application can ensure good product quality and energy use efficiency. In PEF applications, the functional compounds extracted from food products can be enhanced, and the microorganisms contaminating the food products during processing can be inactivated. These properties are considered advantageous by alcoholic beverage producers. In this review, studies on the PEF treatment of wine, beer, and rice wine are summarized. The PEF technology is used in the pretreatment in grape wine and control of microbial growth in grape wine, beer, and rice wine. In grape wines, the PEF pretreatment can increase phenolic compound and anthocyanin contents and can enhance color intensity; this pretreatment slightly influences the organoleptic characteristics of samples. The PEF technology is also an effective tool to sterilize grape wine, beer, and rice wine. With this application, the quality of these three alcoholic beverages can be ensured because the PEF technology can be applied in the absence of heat. In addition, the main negative effect of PEF technology is discussed as well.
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Contents

1. Introduction

Non-thermal technologies, which can be applied to maintain both external and internal food quality, have been extensively investigated. For instance, pulsed electric field (PEF) technology is a novel non-thermal technology that causes the degradation of nutritional and sensory characteristics to a less extent than traditional thermal processing (Buckow, Ng, & Toepfl, 2013; Rivas, Rodrigo, Martínez, Barbosa-Cánovas, & Rodrigo, 2006; Walkling-Ribeiro, Noci, Cronin, Lyng, & Morgan, 2010). Compared with traditional thermal processes, the PEF technology also exhibits several advantages, such as shorter processing time, lower treatment temperature, and continuous flow (Puértolas, López, Saldaña,

* Corresponding author.
E-mail address: jpwang@zju.edu.cn (J. Wang).
[1] These authors contributed to the work equally.

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Álvarez, & Raso, 2010; Walkling-Ribeiro, Rodríguez-González, Jayaram, & Griffiths, 2011). Thus, this application can save a considerable amount of time and increase production efficiency. Furthermore, the competitiveness of the food industry can be improved. For example, a low processing temperature reduces the risk of food quality degradation; as a result, economic benefits are provided for food producers.

In the PEF technology, an electric field in the form of short- or high-voltage pulses is applied to a food item placed between two electrodes for a short time, usually in the microsecond scale (Buckow et al. 2013). When an external electric field is applied to the food samples, a critical electric potential across the cell membrane is induced; this potential causes the rapid electrical breakdown and mechanical changes in the cell membrane. Consequently, membrane permeability drastically increases and pores are simultaneously formed in the membrane. Given that PEF treatment can change the cell membrane permeability, mass transfer or cell breakdown can occur. Thus, the PEF technology has been developed and promoted in various food processes, such as food dehydration (Wiktor, Sledz, Nowacka, Chudoba, & Witrowa-Rajchert, 2014), sterilization (Uchida, Houjo, & Tochikubo, 2008), promotion of extraction (Abenoza et al., 2013), reduction of pesticide residues (Zhang et al., 2012), and inactivation of enzymes (Zhao et al., 2010). Among these applications, the PEF treatments have been mostly used on liquid foods, such as fruit juices (Mosqueda-Melgar, Raybaudi-Massilia, & Martín-Belloso, 2008), dairy products (Bermúdez-Aguirre, Yáñez, Dunne, Davies, & Barbosa-Cánovas, 2010), liquid eggs (Monfort et al., 2010), and alcoholic beverages (Delsart et al., 2014). Liquid foods are electric conductors containing ions that function as electric charge carriers (Zhang, Barbosa-Cánovas, & Swanson, 1995).

Alcoholic beverages or drinks that typically contain 3%–40% alcohol (ethanol) play an important role in the daily lives of people, especially in an individual's social life; alcoholic beverages are also legally consumed in more than 100 countries. Moreover, the production and consumption of alcoholic beverages are of great importance in the economy (Campbell, Guibert, Palgrave Connect, & Management, 2007). The production of alcoholic beverages involve several process, such as crushing, vinting, brewing, fermenting, aging, packaging, and preserving (Gump & David, 1993). For instance, microbial growth control is a crucial treatment step during wine production and before packaging. In this process, the growth of microorganisms must be controlled; otherwise, the quality of wines becomes poor and storage problems likely occur. Thus far, the traditional treatments of microbial growth control include the addition of sulfur dioxide and the application of thermal sterilization. However, the addition of sulfur dioxide can lead to a reduction in the quality of the aroma and color of wines (Martin & Sun, 2013). Furthermore, the consumption of sulfites derived from sulfur dioxide may induce several symptoms, such as headache, anaphylactic shock, and nausea; in severe cases, these substances can even cause death. Thus, the concentrations of the added sulfur dioxide are limited in accordance with special regulations (Garaguso & Nardini, 2015; Santos, Nunes, Saraiva, & Coimbra, 2012). Thermal treatment can decrease the amount of aromatic compounds in wine and can degrade organic substances (Geffroy et al., 2015). As such, novel treatment methods involving the use of high hydrostatic pressure, ultrasound, ultraviolet radiation, and pulsed electric field have been used in wine production. Among these technologies, the PEF treatment is a new alternative to the traditional production of alcoholic beverages because this technology provides several benefits, such as control of microbial growth and enhancement of polyphenol extraction; this technology also protects and retains the heat-sensitive components of alcoholic beverages.

Currently, the PEF technology is mainly applied as pretreatment methods in the production of grape wines and as a control mechanism of microbial growth in grape wine, beer, and rice wine. This review aims to provide an overview of the two kinds of PEF applications in the alcoholic beverage industry; this review also aims to discuss the effects of the PEF treatment on the functional compounds, sensory and physicochemical characteristics, and microbial inactivation of these beverages. Furthermore, the main negative effect of the PEF technology is summarized.

2. PEF pretreatments in grape wine

2.1. Promotion effects on the main functional components

The organoleptic characteristics of alcoholic beverages are the key factors that affect consumers' decision to purchase them. Phenolic compounds are one of the most important kinds of chemical components of wine because they significantly contribute to the organoleptic characteristics of wine (Landete, 2012; Lesschaeve & Noble, 2005). Moreover, phenolic compounds are known for their antioxidant activity and radical scavenging capacity, which greatly promote one's health. Thus, phenolic compounds are usually regarded as an evaluation indicator. Phenolic compounds are not only associated with grape composition but also with the production of these grape-based beverages. They are mainly distributed in grape skins and exert high resistance to mass transfer because of the presence of skin cell walls and cytoplasmatic membranes (Darra, Grimi, Vorobiev, Maroun, & Louka, 2013). Thus, several traditional food processing techniques, such as thermal vinification and maceration time extension, have been applied to improve the extraction of phenolic compounds (Sacchi, Bisson, & Adams, 2005). However, these traditional methods also have several disadvantages when applied on grapes. Particular heat-sensitive compounds are degraded or disappear during thermal processing (Brianceau, Turk, Vitrac, & Vorobiev, 2014; Marangon et al., 2012; Park, Lee, Song, & Kim, 2013). A long maceration process can help increase the phenolic compounds content, but this process is also accompanied by a poor and unstable color of the product (Busse-Valverde, Bautista-Ortín, Gómez-Plaza, Fernández-Fernández, & Gil-Muñoz, 2012). Compared with the traditional methods mentioned above, the use of PEF pretreatment prior to fermenting has been proven to enhance intracellular substance transfer at room temperature. Previous studies reported the effects of the PEF treatment on phenolic content, in which the PEF treatment was applied as the pretreatment step for grapes or grape pomace. The total polyphenol content in the samples treated via PEF was influenced by several factors, such as electric field strength, storage time, and so on.

Based on the results of published studies, our conclusion is that the PEF treatment promoted the content of total phenolic compounds, and the effect depended on electric field strength, treatment time, storage time, and grape variety (Table 1). Overall, the increase in the total polyphenol index caused by the PEF applications ranged from 11% to 99%. The evolution pattern of phenolic families of the control sample was similar to that of the PEF-treated wine; this finding suggested that PEF did not affect the changes in the content of the principal phenolic families (Guadalupe & Ayestarán, 2008). Published articles have indicated that the total polyphenol index was not necessarily increased with increasing applied electric field strength (López, Puértolas, Condón, Álvarez, & Raso, 2008a, 2008b). Specifically, the total polyphenol indexes of Mazuelo grapes treated at 2, 5, and 10 kV/cm were 45.3, 46.87, and 49.57, respectively. The total polyphenol index in the control sample was 37.8 after 120 h of maceration-fermentation (López et al., 2008a). López et al. (2008b) indicated that the total

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