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Emerging technology to develop novel red winemaking practices: An overview☆

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ABSTRACT

Nowadays, making modifications to traditional practices and/or adopting novel processing technologies is of great interest in order to fulfill consumers expectations towards food products characterized by convenience, variety, adequate shelf-life and caloric content, healthy properties, reasonable cost, and environmental sustainability. In this perspective, the role of emerging technologies in winemaking is addressed towards reduced production time, optimized resources and spaces, extraction of high nutraceutic components through mechanical effects, high energy efficiency, extended shelf-life, lowering SO_2 addition and its final concentration. This paper is the outcome of an extensive and comprehensive literature review describing, by an integrated approach, the main characteristics and applications of three emerging technologies (US, MW, and PEF) alternative to the traditional winemaking processes. Their advantages related to the safety aspects of wine, such as the ability to improve nutraceutic and sensorial features are also described.

Industrial relevance: The food industry is currently interested in a variety of novel production and emerging technologies that may result in economical and quality products. This review shows as numerous researches have strongly demonstrated the great benefits of new emerging technologies, such as PEF, US, and MW, into the oenological industry, either increasing compounds extraction during maceration of the must or accelerating stabilization stage in the wine. Emerging technologies could offer better products to consumers with added value in terms of nutritional or sensorial characteristics, and guarantee higher profit for the industry, even reducing process time and use of natural resources, such as energy, water, and chemicals.

Contents

Abbreviations: US, ultrasound; MW, microwave; PEF, pulsed electric field; GC–MS, gas chromatography–mass spectrometry; PPO, polyphenol oxidase; UAE, ultrasound assisted extraction; SE, Soxhlet extraction; AAR, antiradical activity; TPC, total phenolic content; MWP, process variables microwave; MAE, microwave-assisted extraction; CSE, conventional solvent extraction; HPTE, high pressure and temperature extraction; CI, color intensity; AC, anthocyanin content; TPI, total polyphenols index; HPLC, High Performance Liquid Chromatography; HVED, high voltage electric discharges.

☆ In memory of Professor Ennio La Notte (University of Foggia, Italy).

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1. Introduction

Winemaking comprises a diverse set of factors that play a crucial role during the transformation of grapes to wine. The most important factors generally considered by winemakers include vineyard management, grape quality, winemaking practices, and the proper use of commercial selected yeasts and lactic acid bacteria. Increasing consumer demand for food and beverage with a highest added value (Azzurra & Paola, 2009; Kiesel, McCluskey, & Villas-Boas, 2011) led to the development of new alternative processes (Knorr et al., 2011) to enhance or substitute conventional winemaking techniques.

Recently, emerging technology, such as ultrasound (US), microwave (MW), and pulsed electric field (PEF), have been tested in order to develop novel red winemaking practices (Table 1), with different aims, such as increasing the product throughput and reducing the production run, that enable to the winery of optimizing resources and spaces, sales and turnover, by improving the cash flow (Martín & Sun, 2013). Moreover, they allow an environmentally sustainable management, in term of energetic efficiency (Toepfl, Mathys, Heinz & Knorr, 2006; Sun, 2014), and minor use of water and pollutants (such as the flowing detergents, adjuvants, etc.) (Clodoveo, 2013).

Two other aspects are very important to highlight: US, MW, and PEF are characterized by mechanical effects able (1) to increase the extraction of nutraceutic valuable components into the resulting wine, thus improving the quality and healthy value of the product (Vilkhu, Mawson, Simons, & Bates, 2008) and (2) to disrupt or damage the cellular membrane of either autochthonous yeasts and bacteria in grape must before primary fermentation or spoilage microorganisms in wine, thus markedly reducing the addition of SO_2, as antiseptic agent, during winemaking (National Advisory Committee on Microbiological Criteria for Foods, 2006; Cui, Lv, Liu, & Wang, 2012; Martín & Sun, 2013; Aneja, Dhiman, Aggarwal, & Aneja, 2014; Carew, Close, & Dambergs, 2015). Nevertheless, since SO_2 is commonly used in vinification also for its antioxidant properties (Santos, Nunes, Saraiva, & Coimbra, 2012) and because it can affect the activity of some grape enzymes which promote the loss of quality of the juice and its derivatives (e.g. polyphenoloxidases, including tyrosinase and peroxidase) (Popescu, Postolache, Rapeanu, Bulancea, & Hopulele, 2010), its addition cannot be completely avoided. However, the decrease of the final SO_2 concentration in wine is highly recommended, since it might cause sensitivity reactions such as dermatologic, respiratory, or gastrointestinal symptoms (Vally & Misso, 2012). Besides the direct application to grape must or wine, MW might be successfully used for the microbial sanitization of barrels (González-Arenzana et al., 2013) and US and PEF for assisting the wine aging process (Martín & Sun, 2013).

2. Conventional red winemaking systems

The basic steps of red wine production is shown in Scheme 1. Red winemaking is firstly based on the maceration, which is the process of soaking crushed grape skins, seeds, and, eventually, stems and whose management is one of the most critical aspects; indeed, it is fundamental to extract the colorful and tannic components into wine, but it should not be too prolonged because it could cause an excessive bitter and astringent taste in wine of some varieties, often not well appreciated by consumers (Ribereau-Gayon, Dubourdieu, Doneche, & Lonvaud, 2000; Pinelo, Arnous, & Meyer, 2006; Sokolowsky, Rosenberger, & Fischer, 2015).

After the chosen maceration period, which can depends on the aging purpose of wine, the only partly fermented must is separated from skins and seeds by using a press and the alcoholic fermentation can be completed to almost eliminate sugar residue in the wine (Ribereau-Gayon et al., 2000).

Subsequently, wine may undergo malolactic fermentation, a biological decarboxylation carried out by lactic acid bacteria (species of the genera *Lactobacillus*, *Pediococcus* and *Oenococcus*), able to confer a rounder and fuller mouthfeel to the wine; it can take place spontaneously, if favored by different parameters (such as temperature, concentration of SO_2 and nutrients), or by inoculating selected lactic acid bacteria strains (mainly belonging to *Oenococcus oeni* species).

The last phase is the wine aging, that generally consists of different steps (Ribereau-Gayon et al., 2000) including maturation (oxidative aging) and bottling (reductive aging). Moreover, clarification processes and storage in oak barrels (which requires considerable time and financial investment), might be carried out; if the young wine has a lot of grape tannins, the aging in barrels and then in bottles aims to reduce the strength and bitterness of these tannins and rounds out the flavors of the resulting wine (Martín & Sun, 2013).

3. Some new technologies applied to winemaking

3.1. Principles and mechanism of US

Ultrasound is a relatively low-cost, non-hazardous, and environmental friendly technology, commonly used in the food industry (Mason, Paniwnyk, & Lorimer, 1996). Ultrasounds (i.e., mechanical waves at a frequency above the threshold of human hearing) can be divided into three frequency ranges; power ultrasound (16–100 kHz), high frequency ultrasound (100 kHz–1 MHz), and diagnostic ultrasound (1–10 MHz). These sound waves are transmitted through any substance, solid, liquid or gas, which possesses elastic properties and travel either through the bulk of a material or on its surface at a speed depending on the nature of the wave and propagating material (Jambrak, 2011). The fundamental effect of ultrasounds on a flowing fluid is to impose acoustic pressure in addition to the hydrostatic pressure already acting on the medium. The acoustic pressure is a sinusoidal wave dependent on time (t), frequency (f) and the maximum pressure amplitude of the wave, $P_{a,max}$, which is directly proportional to the power input of the transducer:

$$P_a = P_{a,\max} \sin(2pft)$$

If the treatment is characterized by higher intensities, the local pressure in the expansion phase of the cycle falls below the vapor pressure of the liquid, causing tiny bubbles to grow producing new cavities due to the tensioning effect on the fluid and the negative transient pressures within the fluid. Within a critical size range the oscillation of the bubble wall matches that of the applied frequency of the sound waves causing the bubble to implode. As shown in Fig. 1, the compression and rarefaction of the medium particles and the consequent collapse of the bubbles determines a phenomenon called cavitation. During the implosion, very high temperatures (circa 5000 K) and pressures (circa 2000 atm) are reached. The implosion of the cavitation bubble also results in liquid jets up to 280 m/s. The resulting shear forces break the cell envelope mechanically, producing turbulence in the cavitation zone. Since the frequency is inversely proportional to the bubble size, low frequency ultrasound (that is, power ultrasound 16–100 kHz) generate large cavitation bubbles resulting in higher temperatures and pressures in the cavitation zone.

The combination of factors such as heat, pressure, and turbulence, is used to accelerate mass transfer in chemical reactions, to create new