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Effect of pulsed electric field treatment during cold maceration and alcoholic fermentation on major red wine qualitative and quantitative parameters

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ABSTRACT

This work studies the effect of pulsed electric field (PEF) treatment at moderate and high field strengths (E = 0.8 kV/cm & 5 kV/cm) prior and during alcoholic fermentation (AF) of red grapes on improving different parameters of pre-treated extracts: pH, °Brix, colour intensity (CI), total polyphenols content (TPI) of Cabernet Sauvignon red wine. Similar trends were observed for treating grapes using moderate and high electric field strength on the enhancement of CI and TPI of the wine after AF. The application of PEF using moderate strengths at different times during cold maceration (CM) (0, 2 and 4 days) was more efficient for treatment during CM. The treatment during AF showed lower extraction rate compared to treating during CM and prior to AF. Our results clearly show that the best time for applying the PEF-treatment through the red fermentation is during the CM step.

1. Introduction

Phenolic compounds are important to define the quality of red wines because they influence properties like colour, mouthfeel, and aging ability (Sarni-Manchado, Cheynier, & Moutounet, 1999). The phenolic compounds present in grapes and wine can be classified into flavonoid (flavan-3-ols (catechins) and anthocyanins) and non-flavonoid compounds (mainly hydroxycinnamic acid derivates) (Galanakis, Kotanidis, Dianellou, & Gekas, 2015). The most abundant phenolic compounds present in red grapes are: anthocyanins and tannins. Anthocyanins (Glories, 1984), present in the grape skin, are mainly responsible for the colour of red wine which is the most easily recognized aspect of the red wine quality. Whereas, tannins, present in the seeds of grape berries (Pinelo, Arnous, & Meyer, 2006), are responsible for the astringency, a fundamental sensory attribute of red wines, contributing to their character and their quality.

In wine, instability and reactivity of anthocyanins, together with copigmentation reactions, are thought to be responsible for the changing colour of the wine (Boselli, Boulton, Thorngate, & Frega, 2004). According to the literature, copigmentation can account for up to 50% of a young red wine's colour and has been intensively studied in the past several years (Fei He et al., 2012). A wide range of different molecules has been found to act as copigments, including a large variety of structurally unrelated compounds, such as flavonoids and non-flavonoids phenols, amino acids and organic acids.

During traditional winemaking, phenolic compounds of grape skin can be just partially transferred to wine (40% of anthocyanins

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and 20% of tannins) (Cerpa-Calderon & Kennedy, 2008). Grape skin represent about 5–10% of the total dry weight of the grape berry. The extraction difficulties of polyphenols are mainly due to the resistance of cell walls and cytoplasmic membranes to mass transfer (Pinelo et al., 2006).

Recently, there have been important developments in technology intended to weaken cell walls to enhance the extraction of grape's phenolic compounds (López, Puértolas, Condón, Álvarez, & Raso, 2008a,b). For example, thermo-vinification has been developed to enhance the extraction of phenolic components during red fementation, by heating-induced cell disruption (Parenti, Spugnoli, Calamai, Ferrari, & Gori, 2004; Kelebek, Canbas, Cabaroglu, & Selli, 2007). However, this technique requires high temperatures implying high energy consumption and long application times that can degrade product quality (Spranger et al., 2004). Moreover, enzymatic hydrolysis is also conducted during the fermentation process by the addition of pectinases, hemicellulases and cellulases (Muñoz, Sepúlvedab, & Schwartzb, 2004). Enzymes break down cell walls improving thus the liberation of intracellular components such as polyphenols, ameliorating wine colour and aroma (Ducasse et al., 2010).

Prefermentative cold maceration, also known as cold soaking, is being increasingly used by enologists, as an alternative to the traditional maceration, in order to improve some important quality characteristics of wines such as colour extraction and intensity. The refermentative cold maceration consists in maintaining the crushed grapes at low temperatures (4–15 °C) for a variable period of time (from one to several weeks). Many studies have discussed the impact of cold maceration (CM) on the quality of wines. Alvarez, Aleixandre, Garcıa, and Lizama (2006) demonstrated an increase in polyphenols content, aromatic content, and anthocyanin concentration in wines obtained after Monastrell grape cold maceration. Parenti et al. (2004) showed an increase of colour and flavor intensities in the wine obtained after Sangiovese grape CM. The low temperature weakens the grape skin structure, allowing a better extraction of phenolic compounds and release of intensely colored juice.

Recently, several non-thermal emerging technologies (e.g. ultrasound, high voltage electrical discharges and pulsed electric fields) were suggested in order to decrease the processing time, enhance the recovery yield of polyphenols and the functionality of extracts (Galanakis, 2012, 2013). Pulsed Electric Field (PEF) (Boussetta et al., 2009; El Darra, Grimi, Maroun, Louka, & Vorobiev 2012; El Darra et al., 2015; Grimi, Lebovka, Vorobiev, & Vaxelaire, 2009; López et al., 2008a; Puértolas, Saldaña, Condón, Álvarez, & Raso, 2010a) was used as a pre-treatment for an effective weakening of fruit and vegetable tissues. Electrical treatments provoke membrane permeabilization, which is a key factor for the mass transfer enhancement (Grimi, Mamouni, Lebovka, Vorobiev, & Vaxelaire, 2011). The development of PEF in different fields is particularly attractive due to the non-thermal effect of this technology for extraction enhancement (Huang, Hongping, Gai, & Wang, 2012; Rajha, Boussetta, Louka, Maroun, & Vorobiev, 2014). PEF treatment was recently studied for the phenolic extraction during traditional maceration and fermentation of red must. López et al. (2008), Puértolas et al. (2010a,b), Donsi, Ferrari, Fruilo, and Pataro (2010), Delsart et al. (2012, 2014), Luengo et al. (2014) and Leong, Burritt, and Oey (2016) have examined the feasibility of processing red grapes by PEF in order to improve the extraction of anthocyanins and tannins during the maceration-fermentation stage of the wine-making process. These authors have shown that an increment in the electric field from 1 to 7 kV/cm increased the extraction rate of anthocyanins and total phenols for the three varieties investigated namely, Merlot, Syrah and Cabernet Sauvignon. However, the application time of PEF and their effects on the must characteristics haven't been studied before.

In a previous study, we showed that PEF treatment of red grapes, prior to cold maceration, improved the extraction of phenolic compounds and reduced the duration of cold maceration (El Darra, Nabil, Eugene, Richard, & Nicolas, 2013). In this work, we study the effect of PEF-treating red grapes at moderate and high PEF strengths (E = 0.8 kV/cm & 5 kV/cm) prior to and during alcoholic fermentation. The effect of PEF treatment time will be the main point of this study. The qualitative parameters of extracts: pH, °Brix, colour intensity, total polyphenols content, anthocyanins and tannins concentrations of Cabernet Sauvignon red wine have been assessed. The aim of this study is to determine the best time to apply the PEF-treatment through the red fermentation process.

2. Materials and methods

2.1. Plant material

The Cabernet Sauvignon red grapes were manually harvested in the vintage 2011, at optimum maturity from vineyards in the province of Bekaa (KSARA, Lebanon). In this study, the phenolic maturity of red grapes was conducted by means of Glories (Joutei, Bouya, Saucier, & Glories, 2006) and ITV (Institut Technique de la Vigne et du Vin, France) methods (Lamadon, 1995). The correlation between both methods was studied in terms of the resulting phenolic harvest dates, based on the extraction kinetics of different components from skins (such as anthocyanins and total phenolics) and seeds. At their optimum phenolic maturity, these grapes have both, a high content and extractability of phenolic compounds. Grapes were stored at 4 °C for a maximal duration of one week until their processing.

2.2. Wine making (micro-vilification)

The grapes of Cabernet Sauvignon variety were weighed (m = 4500 g), destemmed, and crushed. Potassium metabisulfite (10 g/hL) was added to the must. These grapes were sampled and then subjected to PEF pretreatments at different times of cold maceration and alcoholic fermentation.

2.3. Pulsed electric field pre-treatments prior to alcoholic fermentation

The experiments were carried out using a PEF-generator (5 kV-1 kA, Hazemeyer Company, Saint-Quentin, France) for the treatments with moderate electric field strengths (E = 0.8 kV/cm) (Fig. 1a), and PEF-generator (40 kV-10 kA, Tomsk Polytechnic University Russia) (Fig. 1b) for the treatments with high electric field strength (E = 5 kV/cm).

2.3.1. Treatment with moderate electric field strengths

A sample with a mass of m = 4500 g (grape skins + must), was treated in the rectangular PEF treatment cell supplied by two plane stainless electrodes (70 × 60 mm). The distance d between the electrodes was 6 cm. The value of the electric field strength E was evaluated as E = U/d, where U is the applied voltage. The PEF generator (5 kV-1 kA) provided pulses of a near-rectangular shape (Fig. 1a). The total time of PEF treatment was calculated as $t_{PEF} = n.N.t_i$, where N (=5–10) is the number of series of pulses, n (=100) is the number of pulses in each series, t_i (=100 ± 1 μs) is the pulse duration and the time intervals between two series of pulses is Δt_t (=10 s). The data were collected using a data logger and specific software, adapted by Service Electronique UTC, Compiegne, France.

2.3.2. Treatment with high electric field strength

A sample with a mass of m = 4500 ± 5 g (grape skins + must) was treated in the cylindrical one-liter treatment chamber. Both