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High hydrostatic pressure treatment: An artificial accelerating aging method which did not change the region and variety non-colored phenolic characteristic of red wine

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(−)-Epigallocatechin (PubChem CID: 72,277).
(−)-Epicatechin gallate (PubChem CID: 107,905).
(−)-Epigallocatechin gallate (PubChem CID: 65,064).
Gallic acid (PubChem CID: 370).
Protocatechuic acid (PubChem CID: 72).
Caffeic acid (PubChem CID: 689,043).
Ferulic acid (PubChem CID: 1,794,427).
Chlorogenic acid (PubChem CID: 1,794,427).

ABSTRACT

The effect of high hydrostatic pressure (HHP) treatment on the region and variety non-colored phenolic characteristics of red wine was investigated in this study. After HHP treatment, many changes occurred in the non-colored phenolic compounds in red wines. Changes in total phenolic acids and the contents of eleven phenolic acids among different regions and varieties varied and showed an overall upward trend, while chlorogenic acid decreased in several wines. The total flavan-3-ols and five flavan-3-ols largely decreased among the different regions and different varieties, while EGC slightly increased. In addition, HHP treatment did not change the grape variety and grape geographic origin discrimination based on phenolic acids and flavan-3-ols, which suggests that HHP treatment had no effect on the region and variety of non-colored phenolic characteristics of red wine. These results could expedite the use of HHP processing in the wine industry.

Industrial relevance: HHP is an important technology which could simulate the traditional aging process in wine industry and could shorten a lot of time and save great economic costs. However, no HHP-treated wine has been introduced in the market throughout the world so far. This is due, in large part, to the lack of correlation studies. In this study, we proved that HHP didn't change grape variety and grape geographic origin phenolic characteristics, hence it could be used in geographic indication wines and varietal wines. With these results, we hope HHP technology could be successfully used in wine industry as early as possible.

1. Introduction

Wine is a complex matrix that contains many classes of compounds such as alcohols, sugars, acids, tannins, minerals, proteins and many other secondary metabolites such as phenolic compounds, organic acids and volatile compounds (Li, Wang, Yuan, & Wang, 2007). Wine composition is influenced by many factors related to the specific production conditions, particularly grape geographic origin and grape variety (Li, Pan, Jin, Mu, & Duan, 2011; Li, Wang, Li, Li, &Wang, 2009; Tang et al., 2015). Actually, geographic origin and grape variety have become unique labels for wines. Additionally, the use of geographical designations allows wine producers to obtain market recognition and often a premium price (Romina et al., 2011). Monovarietal wines, which are popular in the new world, often bring wine producers a premium price (Ma et al., 2014).

Phenolic compounds are one of the main components of wine. Based on chemical construction, these constituents can be divided into the following two groups: flavonoid compounds and non-flavonoid compounds (Ma et al., 2014). Based on their contribution to wine color, these constituents can be divided into the following two groups: colored phenolic compounds and non-colored phenolic compounds (Li et al., 2007). As with other compounds in wines, the phenolic profile of wine varies according to grape variety and maturity, vineyard location, vine cultivation practices, wine-making and storage technologies (Fang et al., 2008; Fang, Li, Pan, & Huang, 2007; Rodríguez, Guillermo,

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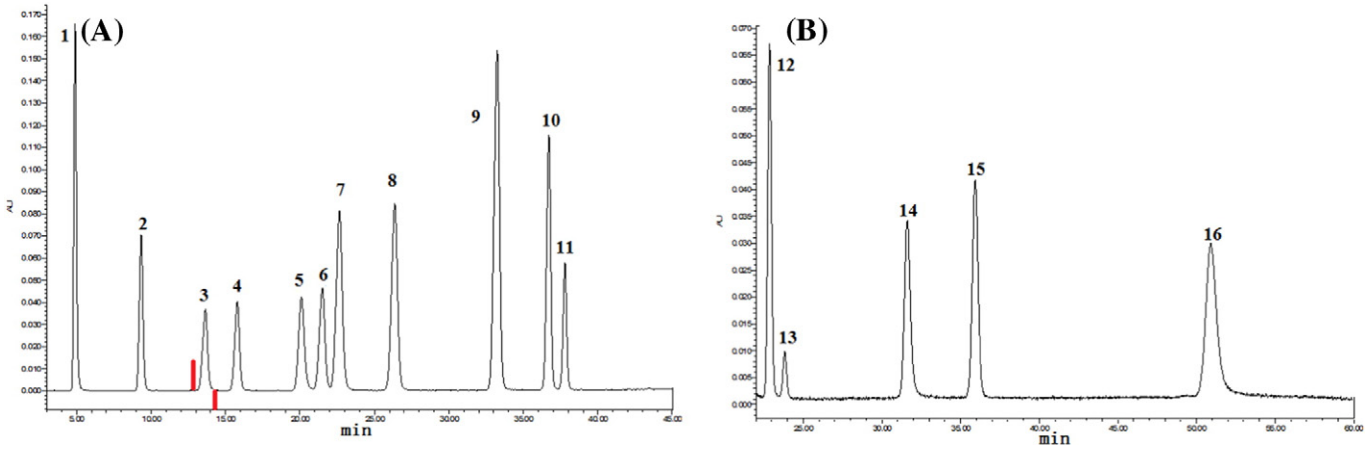

Fig. 1. HPLC chromatograph of 11 phenolic acids (A) (gentisic acid was detected at 320 nm, the others at 280 nm) and (B) 5 flavan-3-ol standards (280 nm). 1, gallic acid; 2, protocatechuic acid; 3, gentisic acid (320 nm); 4, p-hydroxybenzoic acid; 5, chlorogenic acid; 6, vanillic acid; 7, caffeic acid; 8, syringic acid; 9, p-coumaric acid; 10, ferulic acid; 11, sinapic acid; 12, (+)-catechin; 13, (−)-epigallocatechin; 14, (−)-epigallocatechin gallate; 15, (−)-epicatechin and 16, (−)-epicatechin gallate.

José-Elías, & Juan-Pedro, 2002). There is an abundance of evidence showing that polyphenolic profiles can be used to differentiate grape variety, geographical origin of wine and storage period (Recamales, Sayago, González-Miret, & Hernanz, 2006; Rodríguez et al., 2002). Non-colored phenolic compounds, a sub-set of phenolic compounds, including phenolic acids and flavan-3-ols, are an important group of secondary metabolites in grape berries that play an essential role in determining wine characteristics such as astringency and bitterness (Vidal et al., 2004). Non-colored phenolics can also be used to differentiate geographical origin and grape variety of wine (Pavloušek & Kumšta, 2013; Ramos et al., 1999; Tang et al. 2015; Tian et al., 2009). Hence, phenolic compounds are indicative of geographic origin and the grape variety of wines.

Aging is one of the most important steps in wine production. During the aging process, the organoleptic qualities of wine increases. In addition to changes in color, the aging process results in an increase in the complexity and finesse of aroma and flavor. Traditionally, wine is aged in oak barrels, which is a lengthy, expensive process with huge risks (Chen et al., 2012). In recent years, advanced technologies such as ultrasonic irradiation (Chang, 2004; Chang & Chen, 2002), gamma irradiation (Chang, 2003), high hydrostatic pressure (HHP, also called ultra-high pressure, UHP) (Chen et al., 2012; Li, Duan, Liu, & Yang, 2005; Morata et al., 2015; Tao et al., 2012, 2013; Tao, García, & Sun, 2014), nanogold photocatalyzed treatment (Lin et al., 2008), high-voltage pulsed electric field (Wang, Su, Zhang, & Yang, 2013), electromagnetic field (Zhang et al., 2013), microwave (Tao et al., 2014) and AC electric field treatment (Zeng, Yu, Zhang, & Chen, 2008) to simulate this process, which could save significant time and economic costs, have attracted more attention. Many researchers have reported on HHP treatment in wines. Their research can be grouped under the following three categories. First, the effect of HHP on the functional chemical composition, including phenolic acids, flavan-3-ols, proanthocyanidins (Chen et al., 2012), anthocyanins (Morata et al., 2015) and volatile compounds (Morata et al., 2015) were studied. Second, the effect of HHP on the stability of wines was studied (Gipsy et al., 2014). Third, the effect of HHP on pasteurization or substitution of the use of sulfur dioxide was studied (Buzrul, 2012; Mickael et al., 2013; Mok et al., 2006; Morata et al., 2015; Santos et al., 2013). Despite a range of food products, such as fruit juices, sea foods and meats, available on market shelves all around the world, no HHP-treated wine has been introduced in the market throughout the world so far (Buzrul, 2012; Matser, Krebbers, Berg, & Bartels, 2004). This is due, in large part, to the lack of correlation studies. In fact, just as other technologies, the detailed influence of HHP technology on the quality of wine has not yet been elucidated. Because geographic origin and grape variety are so important to wines, whether the geographic origin and grape variety characteristics of wine have been changed or not is one of the key factors in deciding if HHP treatment could successfully simulate traditional wood-barrel aging process in wine industry. However, to the best of our knowledge, to date, these topics have not been reported on. Hence, in this paper, we studied the effects of HHP treatments on the regional- and varietal-specific non-colored phenolic characteristic of red wine. We hope that our results expedite the use of HHP processing in the wine industry.

2. Material and methods

2.1. Wines

The Helan mountain east region, the Huaizhuo basin region and the Yantai region are three unique, protected geographic indications origin

Table 1
Detection wavelength, retention time, regression equation and limit of detection of eleven phenolic acid compounds.

Phenolic compounds	Detection wavelength λ/nm	Retention time t/min	Linear range w/(mg/L)	Regression equation	R^2	Limit of detection ρ/(mg/L)
Gallic acid	280	4.904	1–150	y = 65231x − 18,205	0.9995	0.0252
Protocatechuic acid	280	9.332	1.4–140	y = 73473x − 32,526	0.9993	0.6546
Gentisic acid	320	13.743	1.5–100	y = 152346x − 76,574	0.9998	0.2145
p-Hydroxy benzoic acid	280	15.788	0.5–100	y = 36453x − 13,256	0.9998	0.0643
Chlorogenic acid	280	20.102	0.5–100	y = 274682x − 76,543	0.9999	0.0155
Vanillic acid	280	21.508	1–100	y = 154654x − 63,263	0.9992	0.0145
Caffeic acid	280	22.656	1–100	y = 117543x − 16,473	0.9997	0.2261
Syringic acid	280	26.358	0.5–50	y = 86234x − 65,546	0.9998	0.0462
p-Coumaric acid	280	33.232	0.5–50	y = 153435x − 34,511	0.9998	0.0154
Ferulic acid	280	36.714	0.5–50	y = 765425x − 65,342	0.9995	0.0233
Sinapic acid	280	37.792	0.5–50	y = 91543x − 65,432	0.9997	0.0235