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Effects of geographical origin, varietal and farming system on the chemical composition and functional properties of purple grape juices: A review

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ABSTRACT

Background: Grape juice is a beverage derived from *Vitis* sp genus, mainly *V. labrusca, V. vinifera* and *V. rotundifolia* species, in which sales have increased steeply because of the alleged beneficial health effects it exerts when consumed regularly. However, the isolated and interlinked impacts of geographical origin, varietal, and farming system on the juice's chemical composition and functional properties still are not fully comprehended.

Scope and approach: This paper aims to assess how the producing region, variety, and farming system of grapes (conventional, organic, and biodynamic) affect the quantitative and qualitatively the chemical composition and the functionality (*in vitro*, *in vivo*) of juices.

Key findings and conclusions: Data have shown that the effects of botanical and geographical origins of purple grapes on the chemical composition (especially phenolic compounds) and functional properties of juices are remarkable. On the other hand, organic and biodynamic grape juices have very similar composition and functional properties in vitro, while organic and conventional are somewhat different. This evidence is in line with *in vivo* animal studies and human trials on healthy individuals have shown: differences in functional properties, especially antioxidant effects, between organic and conventional grape juices are negligible from the nutritional and biochemical perspectives.

1. Introduction

Grapes represent one of the most consumed fruits and this fact may be related to intrinsic sensory factors (taste, freshness, aroma) as well as commercial availability, reasonable price, and more recently because of their functional properties demonstrated by a vast number of *in vitro*, *in vivo*, and clinical/epidemiological studies (Chou et al., 2001; Jung, Wallig, & Singletary, 2006; Lima et al., 2014; Oliboni, Vanderlinde, Bonatto, Salvador, & Henriques, 2007; Toaldo et al., 2015; Vilas Boas, Henrique, Lima, & Neto, 2014; Vinson, Teufel, & Wu, 2001). In this sense, grapes and their products, such as jams, sauces, candies, wines, and juices are widely available worldwide as the production yield is relatively high. Besides wine, which is the most consumed grape-based product, grape juice has gained much attention as it does not contain ethyl alcohol and presents a relatively large amount of bioactive compounds, mainly phenolics, that display a considerable *in vivo* antioxidant, cardioprotective, and anti-inflammatory properties when consumed as part of the regular diet (Albers, Varghese, Vitseva, Vita, & Freedman, 2004; Fragopoulou, Antonopoulou, Nomikos, & Demopoulos, 2003). In addition, the consumption of grape juice has been shown to be linked to a higher cancer-protective effect in humans, as reviewed by Zhou and Raffoul (2012).

Grape juice is widely produced in China, United States, Italy, France, Spain, Turkey, and Chile. Furthermore, Argentina, Iran, Australia, and Brazil have emerged as potential producers within the last years (FAO, 2011). Every year, more grape-based products

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are launched on the market as the alleged positive health benefits of grape juice consumption have spread. In this scenario, the search for organic and/or biodynamic products has also increased. This is related to the consumer's demand of agricultural production without the use of pesticides, with minimal use of off-farm inputs and innovative agronomical management practices that restore, maintain, and enhance ecological harmony of the farm environment (Kuepper, & Gegner, 2004).

Research has shown that the pedoclimatic condition of the producing region highly affects the chemical compounds and quality traits of grapes and derived-products, mainly wines and juices. However, experimental results are controversial: while some works clearly report that the chemical composition and antioxidant activity is influenced by the region the grape is produced, some other authors state the chemical composition, and especially the functional properties of grape-based beverages, cannot be suitable markers to authenticate the geographical origin of the grape (Geana et al., 2014; Margraf, Santos, Andrade, van Ruth, & Granato, 2016).

The chemistry of grapes and juices depend on many factors, such as soil quality and composition, degree of ripeness of berries, water stress, bunch sunlight exposure, pathogenesis, type of farming system, agronomical procedures, pre-processing of berries, pressing method, among others (Genova, Tosetti, & Tonutti, 2016; Hopfer, Nelson, Collins, Heymann, & Ebeler, 2015; Iyer, Sacks, & Padilla-Zakour, 2010; Lachman, Sulc, & Schilla, 2007; Leblanc, Johnson, & Wilson, 2008; Natividade, Corrêa, Souza, Pereira, & Lima, 2013). With all these factors, differences in chemical composition seem to be obvious for grapes, juices and wines.

Although grape-based products, such as wine and juice, have been extensively studied in the last 30 years, it is still not known how the producing region and farming system management (alone or in combination) influence qualitatively and quantitatively the chemical profile and *in vitro* and *in vivo* functionality of grape juices. Based on these facts, the objectives of this work are to provide an overview on the chemical composition (phenolic compounds) and functional properties of grape juices produced worldwide and to verify how the producing region and agronomical systems (conventional, organic, and biodynamic) affect the chemical composition and the functional properties (*in vitro* and *in vivo*) of purple grape juices.

2. Grape juices (*Vitis* sp): grape cultivation, juice manufacture, consumption, market and bioactivities

2.1. Grapes: cultivation and varieties

Grape (*Vitis* sp, Vitaceae) is a non-climacteric berry grown in different locations, in all continents, and its cultivation dates from 6000 to 8000 years in the Near East (Lacombe & Thomash, 2006). They usually grow in clusters containing 15–200 grapes and can be black, blue, yellow, green, orange, violet, crimson, and pink color (Mondavi & McGovern, 2007). The difference in color is related to the production of natural pigments, namely anthocyanins, which vary in content and chemical structures according to genetic, environmental, and agronomical factors (Brouillard, Chassaing, & Fougerousse, 2003). Obviously, these factors define the species and sub-species (varietal) that are better adapted to be commercially grown in different sites of the globe. In this sense, grapevines can be differentiated by the species and locations where they are cultivated: while *Vitis vinifera* L. varieties, such as Merlot, Cabernet Sauvignon, Airen, Tempranillo, Chardonnay, Garnacha Tinta, Syrah, Pinot Noir, Sauvignon Blanc, Trebbiano, and many others are basically grown for fine wine production in European, some African and American countries, *Vitis labrusca* L. varieties, such as Concord, Niagara, and Bordeaux, are grown in Eastern United States of America, Canada, and Brazil to be destined for derived-products manufacture (jams, juices, preserves, syrups, raisins, sauces) (Hugh & Robinson, 2013; Robinson, 2003). Herein, *Vitis rotundifolia* Michx. varieties, such as Muscadine, Supreme, Black Fry, Granny Val, Carlos, Noble, Black Beauty, and Thomas, are mainly grown in the south of the USA, Mexico, and some regions in Brazil for table consumption, juice and port wine production (Andersen, Crocker, & Breman, 2003), and *Vitis amurensis* Rupr. species is vastly cultivated in Asian countries (Japan, China, Korea) and have been crossed with other *V. vinifera* species because of their phytochemical profile (Huang & Lin, 1999).

Overall, in South, North and Central America, purple grape juices produced under organic, biodynamic, and conventional systems coming from *Vitis bourquina* and *Vitis riparia* (USA) (lesser extent) and principally from *V. labrusca* varieties, such as Bordeaux, Concord, Isabel, Niágara and Niágara Rosada, are used to produce juices and nectars (internal market) and concentrate (export). While in Brazil the production of grape juices is mainly based on *V. labrusca* grapes (80% of total grape production are from *V. labrusca*), in Chile, Argentina and Uruguay, noble grapes (*V. vinifera* destined for wine production) are also used to produce grape juices, such as Cabernet Sauvignon, Merlot, Cabernet Franc, Malbec, Tannat, Red Globe, Autumn Royal, Ribier, and Crimson Seedless (Lutz, Jorquera, Cancino, Ruby, & Henriquez, 2011).

In South America, especially in Chile, Uruguay, Brazil (South and Southeast regions), and Argentina, where the production of grapes is more intense, grape juices are widely consumed in the regular diet. For example, the Brazilian consumption of grape juices (mainly the purple type) was 10 million L in 2007, 50 million L in 2012, and 78 million L in 2013, with a *per capita* consumption of about 3 L per person every year, corresponding to four times more than table wines made from *V. vinifera* varieties (20 million L) and sparkling wines (15.8 million L). In addition, the marketing of grape juices in Brazil has increased annually and as compared to 2003, an increase of about 2000 was registered (Ibravin, 2014). Because of the quality traits of grape juices produced in South America, exports are significant and the main importers are Japan, the Netherlands, USA, Mexico, Dominican Republic, Thailand, South Korea, and New Zealand (Ibravin, 2014).

The annual *per capita* consumption of fruit juice is about 21 L in the EU compared to 27 L in North America, 5 L in South America and only 2 L in Asia Pacific. The total production of juices in European countries in 2012 was 10,387 million L, and as the consumption of grape juice is not a tradition and does not represent a habit from most Europeans, its production is relatively negligible as compared to American countries, representing only about 3% of total production of fruit juice (100% juice content) and nectars (AIJN, 2012, 2013). However, it is important to stress that a significant amount of grape juice (both white and purple) is used for blending with other fruit juices. Imports of grape juice from European countries (especially from Spain, Germany, and Italy) are common practice and the commercial products are often a mixture of two or three grape varieties (combination of *V. vinifera*, *V. labrusca*, hybrid grapes, and *V. rotundifolia*). Concerning grape juices, Muscadine (*V. rotundifolia*), Cabernet Sauvignon, Tempranillo, Trebbiano, Pinot Noir, Cabernet Franc, Riesling, and Merlot grapes (*V. vinifera*) are the main varieties used for the juice production in European countries. The main producers are Spain, France, Italy, Portugal, and Germany, while Germany, Finland, Austria, the Netherlands and Sweden are the largest *per capita* consumers of fruit juices in Europe (AIJN, 2012).

It is widely accepted that the sales of organic and biodynamic products (foods, cosmetics, feeds, among others) have increased steeply (28% increase in the past two years) because of consumers'