

Review

Phenolic Compounds and Antioxidant Activity in Grape Juices: A Chemical and Sensory View

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Abstract: The search for food products that promote health has grown over the years. Phenolic compounds present in grapes and in their derivatives, such as grape juices, represent today a broad area of research, given the benefits that they have on the human health. Grape juice can be produced from any grape variety once it has attained appropriate maturity. However, only in traditional wine producing regions, grape juices are produced from *Vitis vinifera* grape varieties. For example, Brazilian grape juices are essentially produced from *Vitis labrusca* grape varieties, known as American or hybrid, as they preserve their characteristics such as the natural flavour after pasteurisation. Grapes are one of the richest sources of phenolic compounds among fruits. Therefore, grape juices have been broadly studied due to their composition in phenolic compounds and their potential beneficial effects on human health, specifically the ability to prevent various diseases associated with oxidative stress, including cancers, cardiovascular and neurodegenerative diseases. Therefore, this review will address grape juices phenolic composition, with a special focus on the potential beneficial effects on human health and on the grape juice sensory impact.

Keywords: grape juice; phenolic compounds; antioxidant activity; bioactive compounds; sensory analysis

1. General Introduction

Grape juice is a clear or cloudy liquid extracted from the grapes using different technological processes, being the main techniques employed “Hot press” (HP), “Cold press” (CP) and “Hot Break” (HB). It is a non-fermented, non-alcoholic drink, with characteristic colour (red, white, rose), aroma (characteristic of the grape variety that gave rise to the juice) and taste [1]. Grapes are one of the earliest fruits used in the human diet and grape juices have become an economical alternative for grape producing regions [2]. Grape juice can be produced from any grape variety once it has attained appropriate maturity. In traditional wine producing regions, grape juices are produced from *Vitis vinifera* grape varieties, while, in Brazil, the grape juices are essentially produced from *Vitis labrusca* grape varieties that present as the main feature the preservation of the natural flavour after pasteurisation. Most *Vitis vinifera* grape varieties have an unpleasant taste after the heat treatment, while the American grape varieties keep in the juice the characteristic aroma of the natural grape [3]. Due to consumers’ preferences for aroma, colour and flavour, grape juice is mainly made from American cultivars of *Vitis labrusca* species. However, cultivars of *Vitis vinifera* species, although being preferentially used for the wine production, are also used for the juice production [4], especially the ‘Cabernet Sauvignon’ cultivar [5]. Grape juices have been broadly studied due to their composition in phenolic compounds and their potential beneficial effects on human health, specifically the ability

to prevent various diseases associated with oxidative stress, including cancers, cardiovascular and neurodegenerative diseases [6–9]. Grape juices have a high level of phenolic compounds responsible for functional properties; however, the phenolic compounds present in grape juice may also contribute to defining sensory characteristics of this product. A market survey in USA, in 2007, revealed that sixty percent of consumers who purchased functional beverages chose them in part for the presence of antioxidants [10].

2. Grape Juice Production and Phenolic Composition

Grape juice world production is estimated to be between 11 and 12 million hectolitres, where the main producing and consuming countries of this beverage are the United States of America, Brazil and Spain [11]. In many European countries, grape juice is produced from *Vitis vinifera* grape varieties [12]. However, in the United States, the main cultivars used for juice production are mainly Concord and Muscadine (*Vitis rotundifolia*) cultivars [13,14]. Juices from Brazil are produced from American and hybrid grape varieties, the *Vitis labrusca* cultivars “Isabel”, “Bordô” and “Concord” being the base for Brazilian grape juices [15]. Among the grape varieties of *Vitis labrusca*, the Concord variety is the most used for the production of grape juice, due to its quality of producing a very aromatic juice with good nutritional properties and being well accepted by the consumers [16]. The “Isabel Precoce” (*Vitis labrusca*) originating from a spontaneous somatic mutation of the “Isabel” cultivar presents good productivity, early maturation and the same characteristics of the original cultivar [17,18]. On the other hand, hybrid cultivars “BRS Cora” and “BRS Violeta” are used for colour improvement in juices deficient in this sensory attribute, where it is recommended to mix in a proportion of 15 to 20% of the juice formulation [19,20].

Different processing technologies are available at an industrial scale for grape juice production, the main techniques being the “Hot press” (HP), “Cold press” (CP) and “Hot Break” (HB) processes [13,21]. These processes have undergone continuous improvements to increase the quality and yield of the grape juice production. In the HP process, grapes are destemmed, crushed and heated to temperatures ranging from 60 to 62 °C to facilitate the extraction of the substances inside the grape cells (Figure 1). Pectinase enzymes are added to degrade pectins and facilitate juice separation. The heated grapes are deposited in stainless steel tanks equipped with internal stirring to facilitate the extraction of the compounds contained in the grape skins, a stage known as maceration. Maceration time ranges from 30 to 90 min, depending on the grape variety, agitation intensity, temperature and colour intensity desired [22]. The difference between the “Hot press” and the “Cold press” processes are small, the main difference being the performance of the maceration at room temperature and the addition of sulphur dioxide (SO₂) after grape crushing to inhibit the action of oxidative enzymes and undesirable microorganisms. Enzymatic preparations based on pectinases are also added in order to degrade the grape skin structures and facilitate the release of phenolic compounds in the juice. Lastly, in the “Hot Break” juice processing, the grapes are crushed and heated at temperatures higher than 75 °C, usually between 77 °C and 82 °C, for a short time to deactivate the polyphenoloxidases, and then cooled to 60 °C to add pectinase enzyme [1,14]. To enhance the juice phenolic and aromatic composition, maceration during juice extraction is performed [14]. In addition, heating of the crushed grape has the main objective to facilitate the release of the juice and anthocyanins responsible for the juice colour. After grape pressing, the cloudy juice is subjected to clarification treatments to remove the suspended solids, usually with the use of rotary vacuum filter or industrial centrifuges, following stabilisation, pasteurisation at 85 °C for three minutes and hot bottling [13,21].

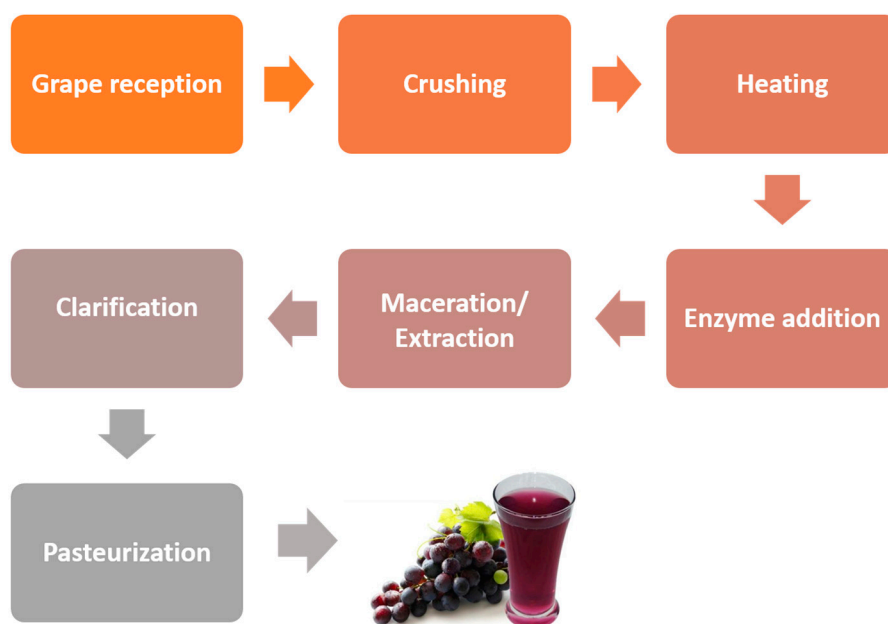


Figure 1. Simplified grape juice flow diagram of hot pressing.

From these technological processes, the continuous hot-pressing process is the most adopted technique worldwide since the cold press process extracts a very low juice yield (~18%) [22,23]. It is also important to consider, in the choice of the grape juice processing technology, the efficient extraction of phenolic compounds from skins, since these compounds are of extreme importance to guarantee a high quality level of the final product, namely its colour and antioxidant capacity but also juice astringency and bitterness [24]. Therefore, the extraction process is essential for the red grape juices' chemical composition and sensory attributes.

In the grape berries, the phenolic compounds are distributed in the different parts of the fruit, as shown in Figure 2. Consequently, the phenolic compounds present in grape juice are mainly those ones extracted from the grape skins and, to a lesser extent, those extracted from the grape seeds [21]. Pastrana-Bonilla et al. [25] found a total concentration of phenolic compounds of about 2178.8, 374.6 and 23.8 mg/g GAE (gallic acid equivalent) in skin, seed and pulp, respectively. Grape skins are the main source of grape phenolic compounds changing their content with grape variety, soil composition, climate, geographic origin, cultivation practices or exposure to diseases, such as fungal infections and reactions occurring during storage [1,26–28]. The total phenolic compounds content in grapes juices (400 to 3000 mg/L) depends on the grape variety, grape maturity, geographical origin and soil type, sunlight exposure, and many other factors [29], besides the grape juice processing technology, such as grape juice extraction, contact time between juice and the grape solid parts (skins and seeds), pressing, thermal and enzymatic treatments. Addition of sulphur dioxide and tartaric acid also interferes with the quantity and the nature of the phenolic compounds present in grape juice [30]. The thermal treatment of intact or crushed grapes enhances the release of phenol compounds, as a consequence of both the increase mass transfer [31] and the higher solubility of cell components [32]. Normally, the temperatures used in the extraction process are not lower than 60 °C [33,34] for different times according to the processing technology. As referred by Celotti and Rebecca [35], the combinations of time/temperature influenced in a different way the extraction yield of the phenolic compounds, according to the molecular type; therefore, at 55 °C, tannin extraction is favoured over red pigment extraction, but, at 63 °C, the maximum extraction of anthocyanins (red pigments) happens after 20 min. Given the importance of anthocyanin extraction during grape juice production, the adequate combination of skin contact time and temperature treatment during maceration is essential to achieving grape juice consumer's acceptable chromatic characteristics as well as antioxidant activity.

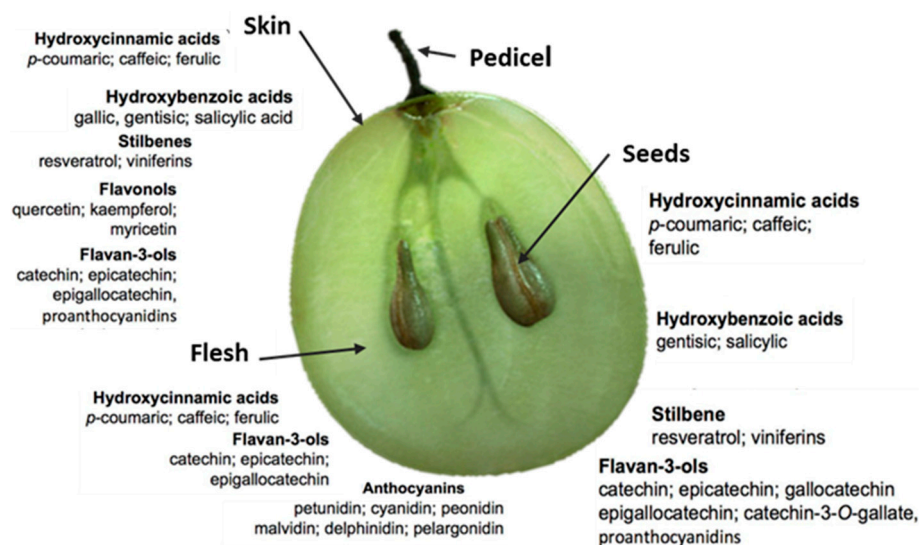


Figure 2. Schematic structure of a ripe grape berry and phenolic pattern biosynthesis distribution between several organs and tissues (indicated by arrows).

Total phenolic compounds according to their chemical structure are classified into flavonoid and non-flavonoid compounds.

Flavonoids are found mainly in grape seeds and skins. Proanthocyanidins in grapes are present mainly in the berry skin and seed. Grape seed proanthocyanidins comprise only (+)-catechin, (−)-epicatechin and procyanidins (Figure 3) [36], whereas grape skin proanthocyanidins comprise both prodelfinidins and procyanidins [37,38]. Procyanidins are dimers resulting from the union of monomeric units of flavanols [(+)-catechin, (−)-epicatechin] by C₄–C₈ (procyanidin B1 to B4) or C₄–C₆ (procyanidin B5 to B8) interflavane linkage. Among grape varieties, there are differences in procyanidins concentrations, but their profile remains unchanged among grape varieties; procyanidin B1 is usually more abundant in the skin while B2 is more abundant in seeds [39]. Prodelfinidins are only present in grape skin and their monomers are [(+)-catechin, (−)-epicatechin, (+)-gallocatechin and (−)-epigallocatechin units] (Figure 3). Proanthocyanidins (procyanidins and prodelfinidins) are the major phenolic compounds in grape seed and skins [39], about 60–70% of total polyphenols are stored in grape seeds [40–42]. According to several published works [43,44], on average and on the basis of fresh weight, the concentrations of proanthocyanidins are as follows: total monomers ((+)-catechin and (−)-epicatechin), 2–12 mg/g in seeds and 0.1–0.7 mg/g in skins; total oligomers, 19–43 mg/g in seeds and 0.8–3.5 mg/g in skins and total polymers, 45–78 mg/g in seeds and 2–21 mg/g in skins.

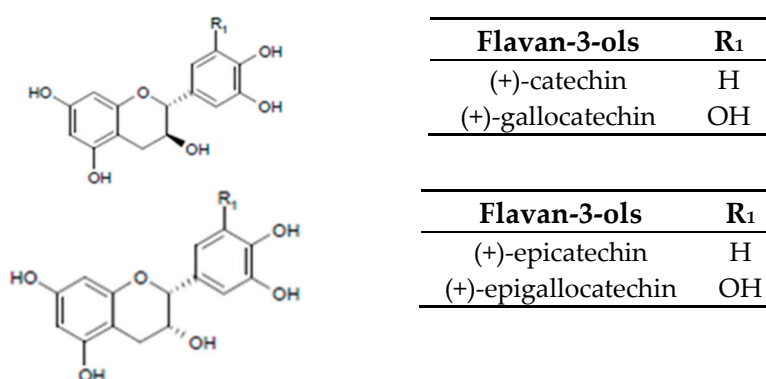


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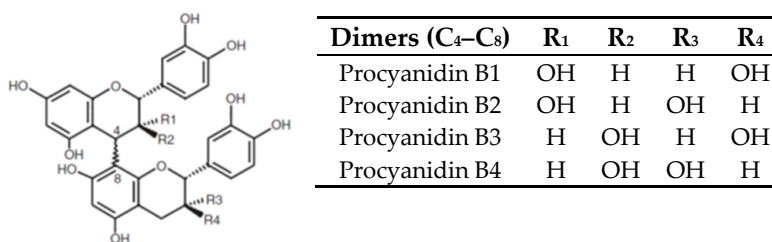


Figure 3. Monomeric flavanols and procyanidins structures found in grapes.

In grape skins, it is important to notice that each grape species and variety has its unique set of anthocyanins. *Vitis vinifera* grape varieties have only one molecule of glucose at the carbon 3 position forming the 3-*O*-monoglucoside anthocyanins. The glucose part of the anthocyanins can both be unsubstituted or acylated as esters of acetic acid, *p*-coumaric acid, or caffeic acid, Figure 4 (Mazza, 1995). In the species *Vitis labrusca*, *Vitis riparia* and *Vitis rupestris* hybrids, the glucose molecule appears in positions 3 and 5 of the carbon, forming the 3,5-*O*-diglucoside anthocyanins, this being an important factor in the differentiation of grapes [45,46]. Grape anthocyanins are flavonoids, and the monomeric anthocyanins are six in total: cyanidin, peonidin, pelargonidin, delphinidin, petunidin and malvidin, the latter being the main found in red grape juices [47]. Anthocyanins are the phenolic compounds responsible for the red colour of grape juices [48,49]. Anthocyanin biosynthesis is influenced by several factors such as climatic conditions, temperature, light and cultural practices [38]. The total anthocyanin content in the grape skins from nine grape varieties studied by Jin et al. [50] ranged from 1500 to 30,000 mg malvidin equivalents/kg dry weight of grape skin. However, the grape juice anthocyanins concentration depends on the factors related to the raw material, but the processing technology also exerts a significant influence on the anthocyanin concentration of the grape juice, where the use of heat treatments is fundamental for a greater extraction of the anthocyanins from the grape skins [51].

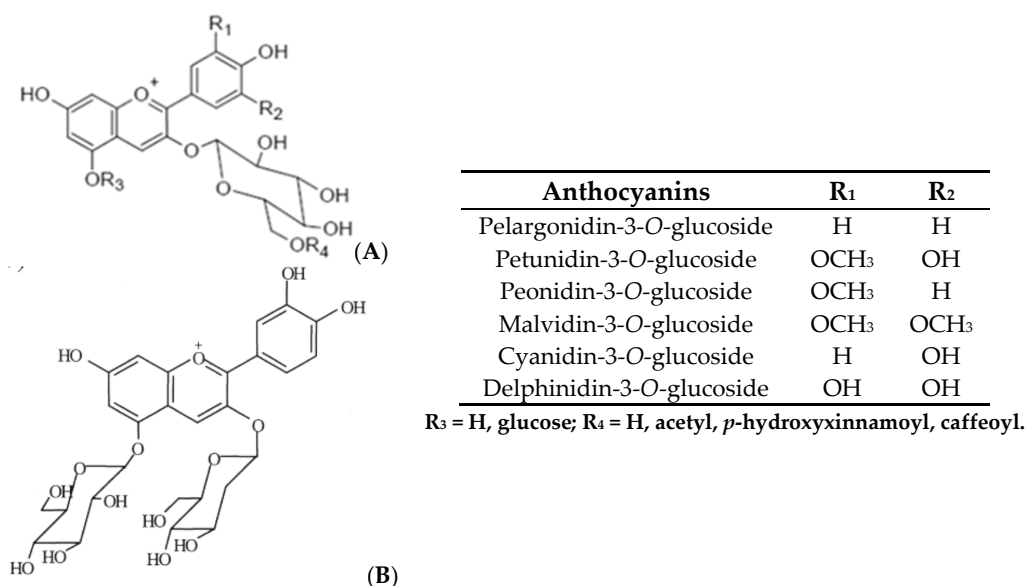


Figure 4. Anthocyanins structure found in *Vitis vinifera* (A) and in *Vitis labrusca* (B) red grape varieties.

Thus, anthocyanins are the main phenolic compounds in red grapes juices, while flavan-3-ols are more abundant in white grape juices [52,53].

The flavonols present in the grapes are mainly represented by kaempferol, quercetin and myricetin, and by simple *O*-methylated forms such as isorhamnetin [54]. Phenolic acids are divided into benzoic and cinnamic acids. In grapes, phenolic acids are mainly hydroxycinnamic acids found in the

skins and pulps, in the form of tartaric esters [45]. The most important benzoic acid are vanillic, syringic and salicylic acids, which appear to be bound to the cell walls and, in particular, gallic acid, which is in the form of the ester of flavanols. Other benzoic acids that are present in lesser amounts are the protocatechic and *p*-hydroxybenzoic acids. The most important cinnamic acids are ferrulic, *p*-coumaric and caffeic acids [45]. Grapes also contain C₆–C₃–C₆ stilbenes, such as *trans*-resveratrol, *cis*-resveratrol, and *trans*-resveratrol glucoside [47]. Since the 1990s, resveratrol has been extensively studied in grapes and their derivatives because of its bioactive activities, such as antioxidant, anti-inflammatory, antimicrobial, anticancer, antiaging, cardioprotective effects and inhibition of platelet aggregation [55,56]. Grape juice is considered a good source of resveratrol; however, the concentration of resveratrol in grapes and consequently in the grape juices depend on the climatic conditions, grape variety and grape growing conditions as well as on the juice processing method used. According to Sautter et al. [57], the concentration of *trans*-resveratrol in grape juice ranged from 0.19 to 0.90 mg/L.

3. Biological Activity of Phenolic Compounds Present in Grape Juices

Phenolic compounds are secondary metabolites, primarily located in the epidermal layer of grape berry skin and seeds and are known as important bioactive compounds, as well as major contributors of the biological activities in products derived from grapes, such as grape juice. Therefore, the evaluation of the beneficial chemical compounds and bioactivity of commercial grape juices is essential to consumer's knowledge in order to provide information about their possible health benefits and bioactivity. Many of these benefits are linked to the antioxidant compounds found in grape juice, such as flavonoids (anthocyanins, proanthocyanidins), phenolic acids and resveratrol among others [5,58]. Therefore, grape juice is consumed not only due to its appreciated sensory characteristics but also because it is a cheap source of phenolic compounds that exert beneficial health effects when consumed [59–61], as shown in Table 1.

The antioxidant activity of the phenolic compounds depends on their structure, particularly on the number and position of the hydroxyl groups and the nature of the substitutions on the aromatic rings [62]. Quercetin is considered to be one of the phenolic compounds with the highest antioxidant activity. Among the different flavonols, it is possible to establish the following decreasing order of antioxidant activity, quercetin, myricetin and kaempferol, which differ concerning their hydroxyl substitution pattern on the B ring. It is noted that the presence of the third hydroxyl group on aromatic B ring, at the C-5' position, did not result in antioxidant capacity of myricetin higher than quercetin. Catechin, which presented the same number of hydroxyl groups in the molecule as quercetin, presented significantly lower antioxidant activity. This is due to the fact that the structure of catechin does not have unsaturated bonds at the C2–C3 position in conjunction with the oxo (–C=O) on C ring, which comparatively gives quercetin a higher antioxidant activity. With the addition of a hydroxyl group on the catechin molecule B ring, this compound is called epigallocatechin and, with this new structure, there is an increase in the antioxidant activity, but not equivalent to quercetin [63]. In general, aglycones are more potent antioxidants than their corresponding glycosides [64]. In relation to the phenolic acids, it is possible to observe that hydroxycinnamic acids are more effective antioxidants than hydroxybenzoic acids. This is due to the conjugation through the double bonds of the ring to the –CH=CH-COOH of the cinnamic acid structure, which enhances the ability to stabilize free radicals. However, it must be emphasised that gallic acid has more antioxidant activity than catechin, which has five hydroxyl groups in its structure [63].

Table 1. Phenolic compounds (mg/L) from grape juice obtained in different conditions of maceration, from different grape varieties and from organic and conventional grape production [22,60,61].

Phenolic Compounds	Temperature/Enzyme		Grape Variety			Grape Production	
	50 °C/3.0 g	60 °C/3.0 g	Isabel Precoce	BRS Cora	BRS Violeta	Organic	Conventional
(+)-Catechin	9.9 ± 0.5	11.2 ± 3.4	4.7 ± 0.1	12.4 ± 0.3	19.8 ± 0.4	500.52 ± 12.33	79.89 ± 30.19
(-)-Epicatechin	0.8 ± 0.7	1.7 ± 0.3	1.0 ± 1.0	1.4 ± 0.5	0.6 ± 0.1	53.48 ± 19.78	14.40 ± 0.77
(-)-Epicatechin gallate	2.2 ± 1.2	0.8 ± 0.1	1.6 ± 0.1	1.2 ± 0.0	1.9 ± 0.2	-	-
(-)-Epigallocatechin gallate	2.1 ± 0.5	1.8 ± 0.3	-	-	-	-	-
(-)-Epigallocatechin	-	-	0.9 ± 0.1	4.7 ± 0.4	6.2 ± 0.1	-	-
Procyanidin A2	2.6 ± 0.2	3.0 ± 0.2	2.8 ± 0.2	2.9 ± 0.2	3.6 ± 0.1	-	-
Procyanidin B1	34.4 ± 2.4	36.8 ± 0.8	47.1 ± 0.1	37.2 ± 0.6	44.2 ± 0.3	-	-
Procyanidin B2	13.1 ± 3.1	16.1 ± 2.5	14.3 ± 0.1	16.3 ± 0.7	17.5 ± 0.5	-	-
<i>trans</i> -Resveratrol	0.90 ± 0.3	0.90 ± 0.4	-	-	-	3.73 ± 0.19	2.24 ± 0.07
Malvidin 3,5-diglucoside	5.2 ± 1.0	6.4 ± 0.1	1.8 ± 0.0	0.7 ± 0.0	11.7 ± 0.0	721.26 ± 20.99	189.43 ± 1.29
Malvidin 3-glucoside	8.1 ± 3.6	11.2 ± 0.5	0.9 ± 0.1	-	1.6 ± 0.2	23.91 ± 2.59	47.42 ± 0.73
Cyanidin-3,5-diglucoside	4.8 ± 1.0	5.6 ± 1.0	-	11.8 ± 0.1	38.0 ± 0.6	785.53 ± 39.56	152.02 ± 6.98
Cyanidin 3-glucoside	5.2 ± 3.2	8.0 ± 0.3	3.0 ± 0.0	1.4 ± 0.1	32.7 ± 0.5	21.72 ± 4.17	7.17 ± 0.59
Delphinidin 3-glucoside	3.3 ± 2.8	6.0 ± 1.2	-	11.7 ± 0.2	73.7 ± 1.2	17.79 ± 1.01	12.15 ± 0.09
Peonidin 3-glucoside	2.2 ± 1.0	3.0 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.2 ± 0.0	2.45 ± 0.66	10.84 ± 0.11
Pelargonidin 3-glucoside	2.4 ± 1.4	3.6 ± 0.4	-	6.7 ± 0.1	6.7 ± 0.1	-	-
Gallic acid	2.3 ± 0.4	2.8 ± 0.5	1.8 ± 0.1	13.6 ± 0.1	10.5 ± 0.8	16.96 ± 0.39	11.51 ± 0.10
Caffeic acid	15.7 ± 1.0	17.2 ± 1.6	8.6 ± 0.1	35.8 ± 0.5	28.9 ± 0.4	29.95 ± 1.57	14.08 ± 0.17
Cinnamic acid	1.2 ± 0.7	2.0 ± 0.2	0.5 ± 0.0	0.6 ± 0.2	1.9 ± 0.1	-	-
Chlorogenic acid	2.3 ± 0.1	2.5 ± 0.3	4.1 ± 0.1	8.3 ± 0.3	21.3 ± 0.6	-	-
<i>p</i> -Coumaric acid	1.4 ± 0.0	1.7 ± 0.1	2.6 ± 0.1	4.5 ± 0.4	9.0 ± 0.1	11.23 ± 0.16	10.73 ± 0.51
Kaempferol	0.9 ± 0.2	1.2 ± 0.2	-	-	-	2.67 ± 0.02	3.01 ± 0.67
Myricetin	0.2 ± 0.1	0.3 ± 0.1	-	-	-	7.99 ± 0.99	6.98 ± 0.90
Isorhamnetin	1.2 ± 0.6	1.6 ± 0.2	-	-	-	-	-
Rutin	1.5 ± 0.1	1.8 ± 0.3	-	-	-	-	-
Quercetin	0.10 ± 0.00	0.17 ± 0.06	-	-	-	3.91 ± 0.08	4.27 ± 0.54
DPPH (TE mmol/L)	-	-	-	-	-	54.19 ± 0.24	40.76 ± 0.71
ABTS (TE mmol/L)	-	-	-	-	-	51.90 ± 0.33	31.09 ± 0.17

DPPH—2,2-diphenyl-1-picrylhydrazyl; ABTS—2,2'-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid).

Grapes are one of the richest sources of polyphenols among fruits [25], being rich in a wide range of phenolic compounds, many of them renowned for their therapeutic or health promoting properties [65,66]. The bioactive compounds from grapes juices mainly include simple phenolic, flavonoids (anthocyanins, flavanols, flavonols), stilbenes (resveratrol) and phenolic acids, shown to have benefits related to human health by conferring the ability to sequester reactive oxygen species (ROS), such as hydroxyl radical and singlet oxygen [67]. Several clinical studies on grapes and their derivatives have demonstrated these properties, including protection against cardiovascular diseases [68,69], atherosclerosis [70], hypertension [71], cancer [72], diabetes [73] and neurological problems [74]. The mechanism of action has been attributed to antioxidant activity [75], lipid regulation [76,77], anti-inflammatory effects [78], anti-cancer, antimicrobial, antiviral, cardio protective, neuroprotective, and hepatoprotective activities [1,40,41,48,79–83].

In general, grapes produced under organic farming system are increasing around the world, since they are perceived by the public as safer, and healthier, than those produced by conventional agriculture, as they do not use chemical pesticides and fertilizers for growing. These grapes are more susceptible to the action of phytopathogens, inducing the syntheses of higher amounts of phenolic compounds as protection and defence [84]. Dani et al. [59] observed that the choice of agricultural practice (organic versus conventional) resulted in different amounts of resveratrol, anthocyanins, and tannins in grape juices. This difference is due to the fact that no pesticides are used in organic vineyards and by the fact that usually they have a longer ripening period than conventional vineyards, and as flavonoids are formed during this period, it is believed that organic vineyards yield grapes with a higher phenolic content [85,86].

4. Sensory Characteristics of Grape Juices

During grape juice processing, heat treatments can adversely impact grape juice flavour [87]. Other physical treatments, applied to grape juices, can also interfere with their sensory quality. According to Treptow et al. [88], the storage period and irradiation promoted few physicochemical changes in juices from 'Niagara Branca' and 'Trebiano' grapes, whereas, sensorially, irradiation reduced the intensity of flavour and colour attributes for both cultivars. While in juices made from white grapes, UV-C irradiation does not improve juice quality, in juices from red grapes UV-C irradiation influenced the physicochemical parameters of 'Isabel' cultivar. Good results were obtained with dosages of 2 kJ m^{-2} (improved of aroma and colour intensities). According to these authors [88], UV-C irradiation can keep the juices microbiologically stable, without spoiling their sensory quality.

Grape juices are known to have high concentration of phenolic compounds that contribute to define sensory characteristics of grape juice [89], namely their colour, taste and flavour.

Colour is the most important attribute used, along with other variables, as an indicator of the grape juice quality observed by the consumers. This characteristic is directly dependent on the juice phenolic composition, namely on the anthocyanins present in the grape skin. Anthocyanins participate in many reactions that promote changes in grape juice colour, mainly through copigmentation and formation of polymeric pigments [90]. Hue and colour intensity can provide information with respect to possible defects or quality of the raw material [91]. The colour of grape juices can vary according to the origin and region of the grapes, juice processing technology [92] and physical and chemical characteristics of pigments (anthocyanins) that are present in the juice [93]. Concentrating a grape-juice, by reverse osmosis, may lead to an increase in total acidity, colour intensity, anthocyanin and phenolic compounds, proportional to the volumetric concentration factor. The increase in soluble solids may be associated with browning of the concentrated juice [91]. Moreover, and according to Gurak et al. [91], as a consequence of the buffer characteristics of fruit juices, the stability of anthocyanins was favoured by the low pH, lack of vitamin C and high concentration of sugar and the pH of the concentrated juice, compared to single-strength juice. In a work performed by Meullenet et al. [94], to compare the use of an internal density plot method to the external response surface approach by optimizing the formulation of muscadine grape juices, the authors found that a red juice appearance is, on average, preferable by consumers to white juices.

Huckleberry and co-workers [95] studied 14 traditional wine grapes grown in Arkansas, aiming to find their suitability for varietal grape juice. Chemical and sensory analyses were performed. The preferred treatments for white grape juices were the immediate pressing treatment of Niagara and Aurore and the 24-h skin contact treatment of Niagara, Verdelet and Vidal. A trained sensory panel ranked the flavour of Verdelet and Aurore as high as the Niagara. In general, a non-heat treatment was ranked highest for flavour of the red juices, with the exception of Gewürztraminer (a pink juice when heated), while white grape varieties were closely ranked for colour (Vidal and Chardonnay grape juices were ranked lowest after storage). For red and pink juices, heat treatments were ranked higher than non-heat treatments in terms of colour attribute [95].

Grape juice consists of 81 to 86% of water and a high concentration of sugars (glucose and fructose). It may also present high acidity due to the existence of tartaric, malic and citric acids. These acids guarantee a low pH value, assuring the equilibrium between sour and sweet tastes [91]. Among the bioactive compounds present, phenolic compounds are of great importance because their characteristics are directly or indirectly related to the juice quality and affect its colour and astringency [96].

Meullenet et al. [94] in Muscadine grape juices found that the attribute “Musty” was also correlated with the perception of Muscadine flavour. Juices perceived as having a general “grape flavour” were also found to be high in metallics. Green/unripe flavour was associated with sour and astringent juices. Products perceived as high in sweetness were also high in floral and apple/pear flavours.

A typically sour grape juice is made from unripe grapes. They can be processed into two products: verjuice and sour grape sauce. In the “Middle Ages”, verjuice was widely used all over Western Europe. The verjuice (“verjus” or “agraz”) is obtained by pressing unripe grapes, while sour grape sauce is derived from verjuice that undergoes an additional concentration step followed by salting [97]. In Tuscany (Italy), there is a similar product called, “agresto” [98]. In Iran and Turkey, it is called “abe ghureh” (Persian) and “koruk suyu” (Turkish), respectively [99]. In Iran, it is used in salad dressings and digestive drinks [100]. Recently, unripe grape juice has been used as an alternative to vinegar or lemon juice [97,100]. Unripe grape juice can also be used as a food preservative due to its high organic acid content [101] and high concentration of phenolic compounds [102].

Unripe grape juice is characterised by high acidity, low sugar content and a sour/tart taste. It also presents a high content of phenolic compounds, the latter of which have an astringent character [103]. The concentration of most polyphenolic compounds in general, and astringent tannins in particular, reaches a maximum of around 45 days after flowering [45], a time approximately corresponding to the harvest date for producing unripe grape juice.

In the sensory evaluation of verjuice done by Matos et al. [104], the most frequently used descriptors perceived for taste were “acid” (74.19%), “astringent” (51.61%), “salty” (35.48%) and “sweet” (25.80%), while the most common aroma terms were “herbaceous” (50.00%), “cooked apple” (43.55%), “pear” (29.03%), “floral” (29.03%) and “green apple” (25.81%) (Figure 5).

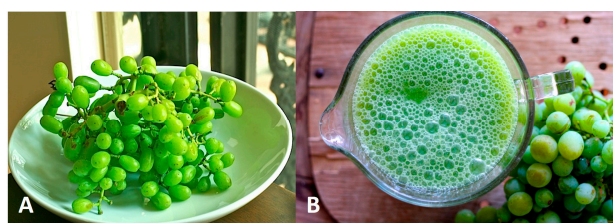


Figure 5. To make verjuice, sour grapes, very small and very sour, are used (A); a grape vinegar is made in Lebanon with sour grapes (B) in order to have something acidic to add to salads and stuffed vegetables. This vinegar is called “husrum” or verjuice. The grapes are crushed and the juice collected; the sour juice is salted and simmer over medium heat, skimming the foam until it disappears. After cooling, it is poured into a glass or clay bottle, adding a thin layer of olive oil on top to prevent microbial contamination and oxidation. The traditional recipe retrieved from: [105]

5. Conclusions

The unique combination of grape phenolic compounds, including flavonoids (anthocyanins, proanthocyanins), and stilbenes, makes grape, and grape juices, a promising source for the development of novel nutraceutical products.

The grape juices' high concentration of phenolic compounds contributes to defining their sensory characteristics in terms of colour, taste and flavour.

In the last few years, there has been a wide range of food additives and nutritional products originating from grapes, distributed in the worldwide market; however, we must retain that the consumers search not only the nutraceutical products characteristics, but also their palatability.

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