Polyphenolic Compounds in Wine/Beer

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Phenolic compounds present in beer and wine have shown high antioxidant and anti-inflammatory features, and in the last decades beneficial effects on human health due to moderate beer and wine consumption have been indicated by many research studies. Due to the different used raw material and technological processes, there are differences between wine and beer in the presence, as well in the concentrations, of phenolic substances. It was shown that some polyphenol classes can only be found in beer (chalcones and flavanones) and other are mainly found in wine (stilbenes, proanthocyanidins), while flavanols and flavan-3-ols are found in similar concentrations in both beverages. Both beverages represent natural fermented products, and minor changes within the growth of raw material and clime conditions, as well as within the used technology, will impact the final chemical composition of these products. The brewing industry and winemakers put a lot of effort in obtaining a final product that will be unique, with more potent antioxidant activity, and with satisfying sensory characteristics, to attract consumers, who are now more aware of alcoholic beverages influence on human health. From the winemaker's point of view, the aim is to produce wine that will satisfy all required safety conditions, and with this added value, and at the same time attempting not to increase the costs. In the brewing industry, besides changing hopping regimes and influencing other technology phases, craft breweries that have expanded rapidly all over the world, are doing their best to produce authentic beer, in terms of flavor and in same time improving the antioxidant capacity. Both industries should consider changes in clime conditions, and research on new modified technologies is always an open issue, like the use of some by-products and additives within the production.

Keywords: wine ; beer ; phenolic compounds ; antioxidants ; winemaking ; brewing

1. Introduction

Wine has existed on Earth for more than 6000 years [1], while beer has existed for over 5000 years [2]. Throughout history, both drinks were produced in Ancient Egypt and regions of Mesopotamia. Wine was used in various therapies and treatments, while beer was an essential part of diet, first to appear when people began agriculture. The brewing industry is more linked to northern Europe, where due to cold conditions viticulture development was inhibited. Both of these beverages are very complex in terms of their ingredients, and besides their long traditions, there are so many characteristics and parameters that determine their final quality, from the quality of raw material (malt and hop for beer and grape for wine), yeast, regimes of alcoholic fermentation, conditions of aging etc. However, the parameters of all the phases of production and composition of these two beverages have been very well studied by many researchers, since the early 20th century. Besides their flavor, which determines their use, wine and beer are known as rich with bioactive compounds, i.e., antioxidants that increase the interest in their nutritional profile. A great number of studies and comprehensive reviews have dealt with the bioactive compounds responsible for the possible health benefits due to moderate wine and beer consumption, and with the different methods of improvement of the antioxidant compounds in these two beverages [3][4][5][6][7][8][9][10][11][12][13][14]. Much of this research supports the thesis that moderate consumption of alcoholic beverages, such are red wine and beer, positively influences the decrease of cardiovascular disease [3]. Key roles as antioxidants in wine and beer belong to the phenolic compounds, and many of them, such as flavonoids, have an effect on cardiovascular and chronic degenerative diseases [15][16], non-flavonoids (stilbenes, hydroxycinnamic, and hydroxybenzoic acids) also positively affect the cardiovascular system [17]. In addition, it has been recently shown that there is a relation between beer consumption and higher protection against coronary diseases, compared to other spirits, and beer is also associated with bone density increase, and with immunological and cardiovascular benefits [18][19][20]. However, there are huge differences between the phenolic profile and content among red wine and beer, primarily due to the different raw material used in their production. The importance of phenolic compounds for wine and beer is very significant, as their presence influences the final quality of these products. Some polyphenol classes can only be found in beer (chalcones and flavanones) and others are mainly found in wine (stilbenes, proanthocyanidins), while flavanols and flavan-3-ols are found in similar concentrations in both beverages. In beer quality they play a key role, as they influence the time of transport and storage, flavor stability, clarity, and color of beer. Additionally, phenolic compounds are essential in wine, because they determine the sensorial wine characteristics (taste and fragrance), color, microbiological and oxidative stability, and chemical properties of wine, as they interact with other compounds including other polyphenols, proteins, and polysaccharides.

Production of wine and beer consists of many technological phases, which are influenced by many parameters, and the huge numbers of occurring variables; the changes in biochemistry are very complex. In both beverages, the composition of phenolic compounds is very diverse and depends on many similar parameters, first of all on the genetic factors of the raw material and the environmental conditions during their growth, as well as technological and aging factors [21]. In regards to beer, malt and hops represent the two main ingredients on which antioxidant compounds depend; actually 70–80% are derived from malt, and the remaining from hops [22][23], and this ratio also depends on the type of the beer [24]. Furthermore, during beer making, important technological phases, in which the change of polyphenolic compounds occurs, begins with the malting process (steeping and germination), kilning, mashing, wort separation and boiling, whirlpool rest, through to the fermentation, maturation, and at the end, to the stabilization/filtration and bottling. Primarily classification of beer is made based on the fermentation process [25], and in these terms there are lagers, ales, and lambic types of beer. The most consumed are lagers, produced by low fermentation at lower temperatures (6–15 °C), while in contrast ale-type beer is made by high fermentation at higher temperatures between 16–24 °C, and as a result of spontaneous fermentation there is lambic beer. Exclusively, grape is used as the raw material for wine production, and based on the color of the used grape varieties, wine is classified into red and white. The main difference, and at the same time the most important, between the making of red and white is that during the making of red, along with alcoholic fermentation, maceration i.e., extraction of color and other substances from grape skin and seed occurs, while within the process of the alcoholic fermentation of whites only colorless and clarified grape juice is used in the process of alcoholic fermentation. As for making rose wine, winemakers use limited skin contact in order to extract color and some compounds, depending on the desired degree of complexity. Due to this maceration, occurring along with alcoholic fermentation during red winemaking, in which the phenolic compounds are extracted from grapes, this step represents the key one in determining the content of polyphenolic compounds in red wine. Furthermore, because of this step, it is commonly known that red wine contains more antioxidant compounds, and has been more studied and reviewed by researchers in the last decades [14][26][27][28][29][30][31][32][33][34]. Another important step during winemaking in which it is possible to increase polyphenolic compounds is ageing in wood barrels, or with addition of oak alternatives.

2. Bioactive Compounds in Beer and Wine

The largest group within natural antioxidant compounds is the group of polyphenols, consisting of very diverse chemical compounds that can be classified in many ways, but that generally are divided into two main classes: flavonoids and non-flavonoids. Within the class of non-flavonoids, natural polyphenolic compounds can be present in chemical structures, such as: phenolic acids, stilbenes, lignans, chalcones, and tannins (hydrolysable and condensed) [34][35][36], Figure 1. Phenolic acids in wine act as copigments, and they do not impact odor and flavor. Stilbenes are the most well known as antioxidants, and within the chalcones group there is xanthohumol; present in beer, and of huge importance, as this compound possess high biological activity. Flavan-3-ols influence bitterness, astringency, and wine structure, and participate in the stabilization of color during aging. Tannins also contribute to the sensory characteristics, particularly of red wine, as they are related to the astringency, they also interact with other macromolecules (proteins and polysaccharides) influencing the colloidal behavior of wine. Condensed tannins (proanthocyanidins) in the brewing industry are interesting as they influence haze formation in beer. Anthocyanins are responsible for the color of red grapes and wines.

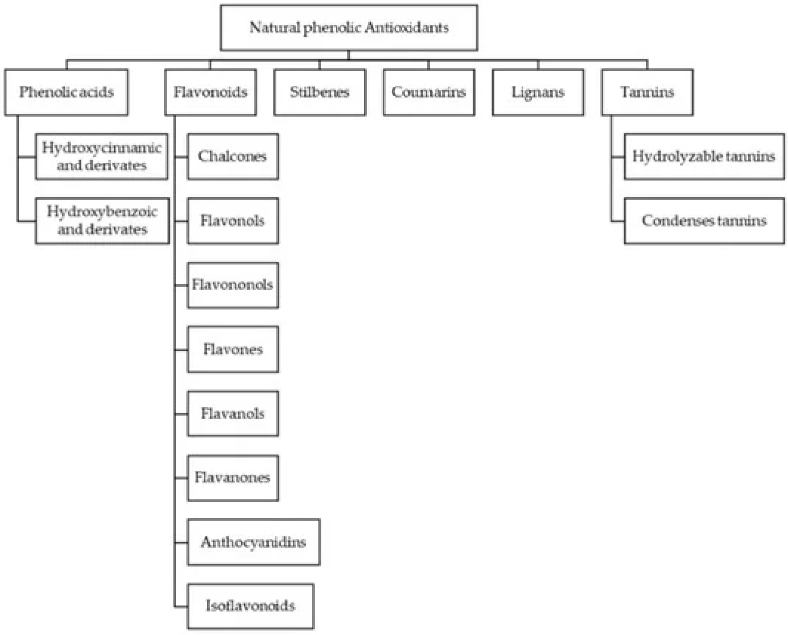


Figure 1. Natural phenolic compound classification [8].

As is expected, due to different used raw material and technological processes, there are differences between wine and beer, in the presence, as well in the concentrations, of phenolic substances. Moreover, the antioxidant compounds in beer belong to different groups of chemical substances such are: thiols [37], SO_2 [38] (product of the Maillard reaction [39][40]), α-acids derived from hops [41][42][43], and phenolic compounds [44][45][46]. Thiols have been suggested to correlate with sulfites in the antioxidative mechanism, and are important for beer's oxidative stability. Sulfites were found to be the only compound that was able to delay the formation of radicals [38], and actually give antioxidant and antimicrobe properties in wine too. The main product of the Maillard reaction is melanoidin, which affects the color, flavor, and body of beer. Hop α-acids (also called humulones) represent the main bittering compound in beer, and have shown a high ability to quench radicals, while *iso*-α-acids possess this activity to a lower extent. In addition, *iso*-α-acids can influence beer staling, but not to a high degree.

The polyphenol complexes of beer and red wine, additionally, represent a source of dietary antioxidants. As both beverages are very popular and widely consumed, benefits of the light-moderate consumption of wine and beer are supported by scientific literature data. Polyphenols from red wine and beer could act as antioxidants, and also as anti-inflammatory agents contributing to the defense against atherosclerotic pathologies [19][47]. The beneficial moderate consumption of beer is also based on antioxidant compounds present in beer, i.e., on their redox properties [48]. Antioxidants present in beer improve several diseases, and are associated with benefits to the cardiovascular and immunological system [19][20]. It was shown that after consumption of non-alcoholic beer, the decrease of several inflammation biomarkers, homocysteine, and systolic blood pressure occurred. These influences were mainly attributed to the polyphenolic compounds in beer. Furthermore, several studies have shown that the light-moderate intake of alcohol is associated with lower incidence of diabetes type-2, a higher level of high-density lipoprotein cholesterol, as well as with lipid oxidative stress reduction [49][50][51][52]. Torres et al. [53] reported that moderate wine intake, compared to other alcoholic beverages like vodka, rum, and brandy increased total antioxidant capacity, and decreased pro-inflammatory factors along with a fat-enriched diet that was consumed by young healthy volunteers. This is also supported by the phenomenon known as the "French paradox", which indicates that moderate daily drinking of red wine contributes to lower coronary heart diseases incidence, despite their diets possessing a higher amount of saturated fatty acids and total fat [54]. However, excessive intake of alcohol beverages is associated with chronic disease development and other very serious problems, representing the leading risk factor for mortality [55]. Roercke et al. [3] reported there is an important influence of drinking patterns, such are episodic heavy drinking within average moderate drinkers, and some other important influencing parameters in term of health issues like smoking status, age, body mass index, and physical activity, and all of them have to be considered in order to estimate dose of alcohol as well the risks. After all, chronic heavy and episodic drinking should be avoided. In the Dietary Guidelines for Americans (2015–2020), moderate intake of alcohol proposes up to one unit of alcohol per day for women and two for men [56].

However, the positive influence of single polyphenols on human health occurs at higher concentrations than those found in beer and wine, indicating the synergistic action of different polyphenolic mixtures [57]. Ranges of some of the most important phenolic compounds, found in red wine and beer are presented in Table 1. Phenolic acids also possess antioxidant and anti-inflammatory properties [58]. Based on literature data, beer has shown higher upper values for content of *p*-coumaric acid, and all hydroxybenzoic acids, while for other polyphenolic compounds it was mainly the opposite, and higher concentrations dominated in red wine. Flavonols are considered very important bioactive compounds, and have shown positive effects against certain cancers and cardiovascular diseases in some epidemiological studies [59][60]. Concentrations of all three presented flavonols (quercetin, myricetin, and kaempferol) were much higher in red wine than in beer. Stilbenes, particularly resveratrol, are the most associated with wine's beneficial properties. Resveratrol is recognized as an antioxidant, anticancer, cardioprotective, and anti-inflammatory agent. Due to its bioactivity, trans-resveratrol was proposed for many diseases as a therapeutic agent [61]. The content of stilbenes is not comparable for wine and beer, as based on literature data these compounds are rarely, or never, found in beer. It was also indicated that flavan-3-ols may show cardioprotective activity, and their antioxidant activity was shown in some studies [59]. Flavones are also recognized as molecules with important biological activity (anti-tumor, antioxidant, and anti-inflammatory), and were used as treatment for some neurodegenerative disorders and coronary heart diseases [62]. Flavanones also belong to antioxidant agents and the found concentrations in wine and beer were very low, while a lower content of naringerin was found in red wine compared to beer. Tannins also showed potent radical scavenging, anti-inflammatory, and antioxidant activity [63], and much higher levels of condensed tannins were found in red wine. Besides the presented polyphenolic compounds there are also some compounds found in wine and not in beer and the opposite. Within the compounds found in beer, two very important ones are xanthohumol and melanoidin. Both, xanthohumol and melanoidin have shown antimicrobial properties, melanoidin also possess antihypertensive, prebiotic, and antiallergenic properties [64], while xanthohumol showed anti-cancer, anti-inflammatory, anti-obesity, etc. properties [65][66]. Depending on the raw material and brewing process, the content of melanoidin ranges from 0.58 mg/L in alcohol free beer to 1.49 mg/L for dark beer, while in blond beer 0.61 mg/L was determined [67][68]. In wine, among the phenolic compounds with biological activity, there are also anthocyanins. The most common anthocyanins found in red wine, malvidin-3-glucoside and malvidin-3-galactoside, have shown anti-inflammatory effects, and their synergistic activity was observed [69].

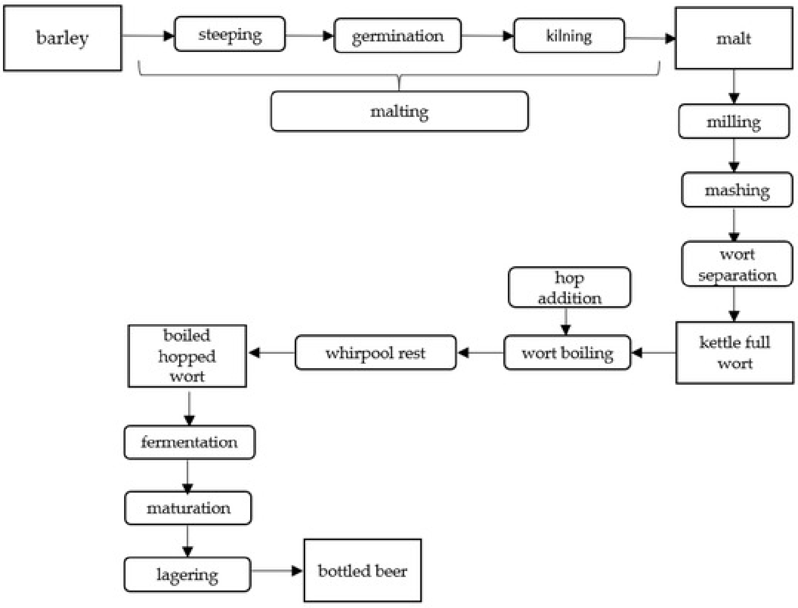
Table 1. Ranges of some phenolic compounds in red wine and beer.

	Red Wine	**References**	**Beer**	**References**
Cinnamic Acids (mg/L)				
ferulic acid	0.05–10.43	[30][70][71][72]	0.01–5.04	[12][45][46][73][74][75][76][77][78][79][80][81][82]
p-coumaric acid	0.02–8.00	[27][30][70][71][72]	0.003–55.80	[9][12][45][73][78][79]
caffeic acid	0.02–644.50	[27][30][70][71][83]	0.00–23.50	[9][45][46][73][74][75][76][77][78][79][81][82][84]
Hydroxybenzoic Acids (mg/L)				
gallic acid	27.10–66.10	[28][71]	0.00–142.20	[9][46][73][74][75][76][77][78][80][81][82]
protocatechuic acid	0.91–1.78	[28][30]	0.01–5.10	[12][75][76][77][78][80][81][82][84]
p-hydroxybenzoic acid	2.75–6.20	[28]	0.00–16.84	[12][45][73][75][76][78]
Stilbenes (mg/L)				
resveratrol	0,51–11.70	[28][85]	0.002–0.081	[86]
trans-resveratrol	0.21–23.00	[27][70][71][87][88][89]	-	-
cis-resveratrol	0.01–7.00	[71][87][88]	-	-

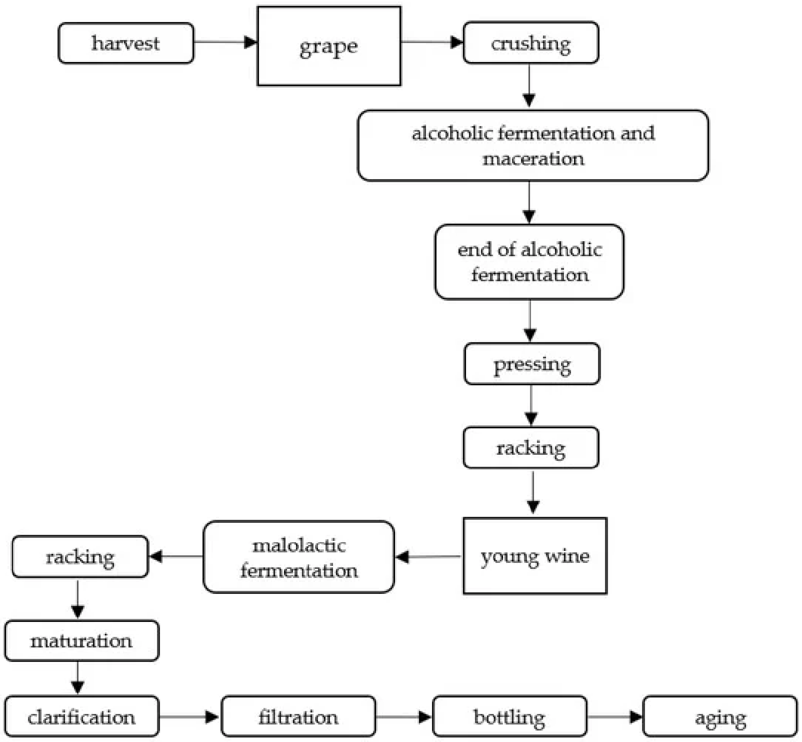
total stilbenes	1.00–5.50	[71]	-	-
Tannins (mg/L)				
hydrolysable tannins	0.4–50.0	[90][91][92][93][94]	1.5	[81]
Flavan-3-ols (mg/L)				
catechin	6.98–91.99	[27][30][36]	0.03–6.54	[12][73][74][75][77][80][81][82]
epicatechin	8.07–52.85	[27][30][36]	0–4.55	[9][74][75][80][81][82]
Flavones (mg/L)				
luteolin	0.20–1.00	[95][96][97][98]	0.10–0.19	[82]
apigenin	0.00–4.70	[99]	0.80–0.81	[82]
Flavonols (mg/L)				
myricetin	0.70–30.40	[27][30]	0.15–0.16	[82]
quercetin	1.27–65.90	[27][30][36]	0.06–1.79	[74][80][82]
kaempferol	0.61–26.80	[27]	0.10–1.64	[80][100]
Flavanones (mg/L)				
naringenin	0.90 to 4.20	[89]	0.06–2.34	[80]

3. Impact of Technologies in Order to Increase Phenolics in Wine and Beer

The only material for wine production is grape, while for beer production there is malt (sometimes along with some adjuncts such as rice, sugar, corn, and wheat), water, and hop. The process within both the production of beer and wine is alcoholic fermentation and, for that purpose, usually commercial dry yeasts are used. Basic brewing and winemaking technology are presented at Scheme 1 and Scheme 2, respectively.



Scheme 1. Basic steps in brewing technology.



Scheme 2. Basic steps in winemaking technology.

4. Conclusions

Phenolic compounds present in beer and wine have shown high antioxidant and anti-inflammatory features, and in the last decades beneficial effects on human health due to moderate beer and wine consumption have been indicated by many research studies. In this survey, a comparative overview of qualitative and quantitative phenolic compound profiles in wine and beer was evaluated. As was expected, due to the different used raw material and technological processes, there are differences between wine and beer in the presence, as well in the concentrations, of phenolic substances. It was shown that some polyphenol classes can only be found in beer (chalcones and flavanones) and other are mainly found in wine (stilbenes, proanthocyanidins), while flavanols and flavan-3-ols are found in similar concentrations in both beverages. Both beverages represent natural fermented products, and minor changes within the growth of raw material and clime conditions, as well as within the used technology, will impact the final chemical composition of these products. Considering the literature data, the obtained results favor wine as the beverage with a higher content of bioactive compounds, particularly phenolic compounds, and as was expected, with higher antioxidant activity. Overall, in order to decide which of these two alcoholic beverages represents the better choice as a functional drink, a lot of parameters should be considered (social occasion, quantity, individual tolerance, etc.). As it was mentioned, drinking pattern is very important, only light-moderate drinking is recommended, and it should not be forgotten that the choice firstly depends on individual preference.

Nowadays, the brewing industry and winemakers put a lot of effort in obtaining a final product that will be unique, with more potent antioxidant activity, and with satisfying sensory characteristics, to attract consumers, who are now more aware of alcoholic beverages influence on human health. Winemakers began even from the vineyard, applying new additives that would improve phenolic composition in the grape, and afterwards, taking care through every step to the final product. After all, from the winemaker's point of view, the aim is to produce wine that will satisfy all required safety conditions, and with this added value, and at the same time attempting not to increase the costs. A good solution to this, is the use of all by-products, which occur during grape processing and winemaking. In the brewing industry, besides changing hopping regimes and influencing other technology phases, craft breweries that have expanded rapidly all over the world, are doing their best to produce authentic beer, in terms of flavor. Research on using different kinds of fruit in order to obtain special beer with added value, with a focus on sensory improvement and differentiation, has been performed. Both industries should consider changes in clime conditions, and research on new modified technologies is always an open issue, like the use of some by-products and additives within the production.

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