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The production of fruit wines – a review

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ABSTRACT

Fruit wines production has been growing steadily in recent years, and its market potential is strong, which correlates with the demand for and development of new functional products. Likewise, the production of fruit wines has become an integrated component of fruit processing industry, often compensating for post-harvest losses. Fruit wines represent a value-added fruit product. They contain nutritionally important components like minerals and antioxidants, as well as aromatic nuances typically from the fruits used. The paper gives a general overview of the production of fruit wines with a particular emphasis on the quality of fruit to be used for wine processing, as well as fermentation and post-fermentation processes.

Introduction

Even though there is an ongoing interest in production, properties and health effects of grape wines, there are still far fewer data for fruit wines. However, non-grape wines have recently been gaining consumers' interest because they are considered as functional foods. Functional foods and nutraceuticals are among the top trends in the food industry, which are characterised by a steady increase in sales and the launch of new products. Croatian functional products are, at the moment, fairly underrepresented at the European functional foods market. Different fruit wines have proved to be an excellent dietary source of minerals, antioxidants, and phytonutrients, *e.g.*, carotenoids (carotene and lutein), phenolic compounds (anthocyanins, flavonols, flavan-3-ols, proanthocyanidins, ellagitannins, and phenolic acids) (Vasantha Rupasinghe et al., 2017). When selling fruit wine, one of the obstacles is the consumer perception that often associates fruit wines with lower quality "homemade" products. Marketing initiatives, including their educational component as well as consistent standards of quality, could help change this perception. The scale-up of fruit wines production from "homemade" small-scale to industrial-scale has been much slower compared to that of grape wines. Nowadays, wines made of fruits other than grapes are gaining full acceptance at the market (Rivard, 2009). In some European Union (EU) countries cider and fruit wines have exhibited one of the fastest growth rates. Proving the growing interest in this industry, most of the European countries have national stakeholders associated from 1968 in a professional organisation, named European Cider and Fruit Wine Association also known as AICV (*L'Association des Industries des Cidres et Vins de fruits de l'UE*, AICV). The total production of the members of the AICV in 2010 was over 14.5 million hectoliters, *i.e.*, over 14 million hectoliters of cider and perry, and 0.5 million hectoliters of other fruit wines (AICV, 2018). In the Eastern European countries, fruit wine is mostly locally produced, probably due to the fact that their legislation has only recently been aligned with EU laws. They produce fruit wines mainly from fruit berries (strawberries, blackcurrants, blackberries, raspberries) or pome fruits (apples, pears). According to the European

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regulations, fruit wines must be obtained by the fermentation of juices of fruits other than grape. Furthermore, the rules define the primary classification of fruit wines to still and sparkling, and the permitted alcoholic strength between 1.2% and 14% by volume (Kosseva et al., 2017). Grape and fruit winemaking technology are similar except for some variations based on the fruit used. Grape juice is naturally suited for making wine and needs a little adjustment before fermentation, while fruits other than grapes usually require modifications. Different fruit varieties, such as apples, pears, peaches or cherries give enough juice and have a desirable balance between acids and sugars, which are the main prerequisites for efficient winemaking. The type (regarding the fruit of which was made), production and consumption of fruit wines vary depending on the geographical area and fruit cultivars typically grown in that specific area. Fruit wines typical for our continental climate region are those produced from berries (blackberries, raspberries, strawberries, blueberries, currants), as well as from sour cherry and apple. In recent years, the production and intake of fruit wine (especially blackberry wine) in Croatia has increased. However, the vast majority of producers are small-scale family businesses that have difficulties providing quantities needed for the growing market. Therefore, fruit wines are still commercially underrepresented (Amidžić Klarić et al., 2017).

The objective of this paper is to give an overview of fruit wines production, with a special emphasis on the quality of fruit, as well as fermentation and post-fermentation processes.

1. The classification of fruit wines

According to the standard definition, wine is fermented beverage only produced from grapes. Otherwise, fruit wine is given the prefix of the fruit from which it originates (Voguel, 2003). Today, a wide variety of fruits which differ in shape, color, taste and nutritive value, are available at the market and many are widely utilized for production of fermented beverages (Jagtap and Bapat, 2015). Fruits used for the production of fruit wines in different parts of the world include: apples, berries, cherries, wild apricots, pears, kiwifruit, plums, peaches, strawberries, currants, bananas, pineapples, cashew nuts, pomegranates, lemons, tangerines, oranges, dates, and figs (Joshi, 2009; Joshi et al., 2017). Most fruit wines belong to still wines group, as they retain no carbon dioxide produced during the fermentation. Sparkling wines, on the other hand, contain a considerable amount of carbon dioxide (Kosseva et al., 2017). Apple and pear ciders are the most common representatives of sparkling fruit wines. When alcohol level of wine is considered, wines can be categorised as either table or fortified wines. Table wines usually contain 11–16% alcohol but can be as low as 7%. Fortified or dessert wines are generally very sweet, they include added brandy, with alcoholic content ranging from 16% to 23% (Kosseva et al., 2017). Regardless of designation, fruit wines are typically consumed in small amounts and are rarely wholly consumed shortly after opening (Jackson, 2014).

2. Production of fruit wines

The techniques used for the fruit wines production are analogous to those applied for production of grape wines (Joshi, 2009). However, differences arise from the fact that it is often difficult to extract the sugars and other soluble compounds from a pulp of some fruit varieties (in comparison to grapes), as well as from the fact that the juices obtained from most fruits are lower in sugar content and higher in acids than grapes (Amerine et al., 1980; Joshi et al., 1999; Joshi, 2009; Swami et al., 2014; Kosseva et al., 2017). General aspects of fruit wines production are given in Figure 1. The production of wines made from different fruit varieties is the same and includes alcoholic fermentation of the pulp or fruit. The main differences lie in the physicochemical characteristics of fruit varieties and the modifications undertaken prior to alcoholic fermentation (Kosseva et al., 2017).

The main steps of fruit wine production are the following: fruits (fresh or frozen) reception and preliminary preparation; fruits musts preparation by crushing, squeezing (pressing), clarifying, and amending; spontaneous or inoculated (using selected wine yeasts) fermentation of fruit musts; fruit wines maturation and conservation; and, finally, aging of fruit wines. The preparation of musts for fruit wine production depends on the fruit used. Sometimes it is enough to crush the fruits and in some cases the peeling, pulping and other operations need to be performed. When soft fruits like plums, apricots, cherries and citrus fruits are used for wine production, seeds or pits must be removed, since they contain bitter resins that can have a detrimental effect on fruit wine taste. To solve the problem of excess acid and sugar deficiency of some fruit musts, the addition of water to dilute the excess acid and the addition of sugar to balance the sugar deficiency is advisable. Ortiz et al. (2013) described the preparation of blackberry, blueberry and apple musts. Fruits were crushed, mixed with water to diminish the viscosity and acidity of the juices (and for economical reasons) and sulphited. The total soluble solids content of all musts was adjusted to 21 °Brix by the addition of sugar. Furthermore, maceration enzymes were also added. Duarte et al. (2010) successfully used Brazilian exotical tropical fruits cacao, cupuassu, gairoba, jaboticaba and umbu for the production of fruit wines. All the fruits were mechanically depulped, following the total soluble solids content adjustment to 16 °Brix and pH adjustment to 4.5. Reddy and Reddy (2005) described the preparation of the mango must. Mangoes were washed with 1% HCl and then peeled and pulped manually. The resulting musts were sulphited and treated with pectinase enzyme to achieve the better extraction of the pulp and higher juice yield. Kiwifruit was used as a raw material for the production of fruit wine by Soufleros et al. (2001). The kiwifruits were washed, peeled and pulped to accelerate the action of added pectolytic enzymes. The pulp was also sulphited and pressed in a hydraulic press to increase the juice yield. The saccharose syrup was added to the resulting juices in order to increase the total sugar content. The preparation of pineapple must was described by Pino et al. (2010). Fresh, healthy and ripe pineapples were peeled, cut into pieces and then pressed through a colloid mill. The milled fruit was added to wort containing sugar, dibasic ammonium phosphate and citric acid, thus achieving the total soluble solids content of 14 °Brix, pH 3.7 and total acidity of 6.0 g/L.

Potassium or sodium metabisulfite should be added before fermentation to avoid must spoilage by different microorganisms. The fermentation of some fruits is prolonged or may even interrupt before completion because of a lack of specific nitrogenous compounds or other yeast growth factors in some fruit juices (musts). Therefore, the addition of these factors to musts is recommended.

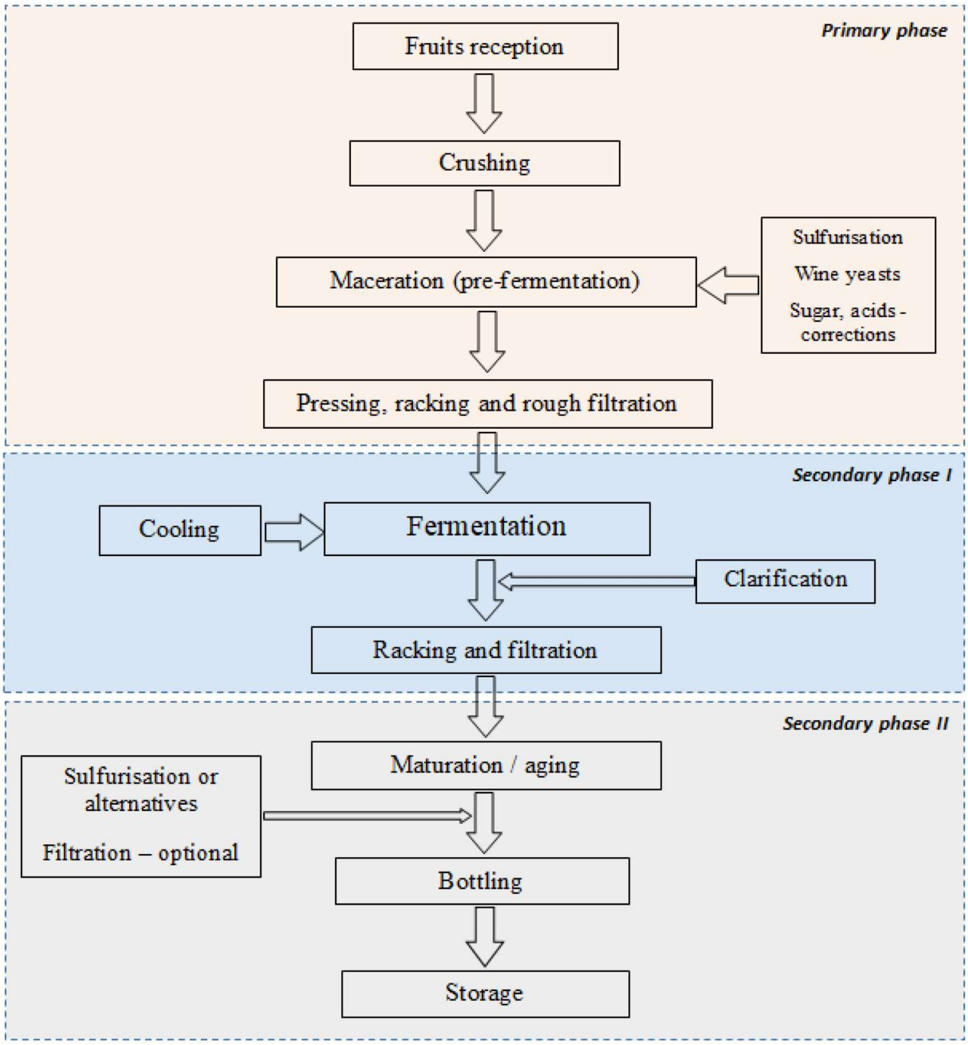

Fig. 1. General aspects of fruit wines production

2.1. Fruit quality

When considering fruit wine production, aroma and flavour of wines are mostly determined by the selected fruit variety. Therefore, the fruit selection is an essential step in fruit wine production. The fruit should have high sugar and low acidity, which should be adjusted when needed. As previously mentioned, if the fruit does not contain enough natural sugar, it can be added to must to speed up fermentation. The use of fruits that are very acidic in nature (*e.g.* raspberries, strawberries, cherries, and pineapples) for fruit wine production may result in very sour wine taste. The remedy to this is the addition of saccharose and water to balance the fruit's tart acidity (Kosseva et al., 2017). Harvesting maturity demands could be different for different fruit varieties. Sometimes it is better to use slightly overripe fruit, *e.g.*, apples or cherries. On the other hand, blackberries have higher pigment concentration toward the end of the season, leading to pigment deposits in the bottle. To avoid this, the blackberries should be picked before full maturity (Kosseva et al., 2017). The suitability of fruit for wine production is evaluated based on its physicochemical parameters, such as dry matter and total soluble solids, colour, pH and reducing sugars. The main constituent of fruit is water, while carbohydrates, minerals, proteins, lipids, organic acids, phenolic compounds, and vitamins making up the rest. Once the water is excluded, these constituents can be collectively designated as 'dry matter'. Fruit dry matter and total soluble solids content (determined by the index of refraction) primarily indicate the carbohydrate content of fruit, *i.e.*, they are a measure of fruit quality (Travers et al., 2013). Sugars are the main soluble solids in fruit juice. Other soluble materials include organic and amino acids, soluble pectins, and so forth. Colour is one of the leading parameters taken into account when evaluating the fruit and the wine quality (Kalkan Yildirim, 2006; Amidžić Klarić et al., 2017). The compounds responsible for almost all fruit colouration are anthocyanins, along with carotenoids and chlorophylls. Based on these pigments, consumers notice the difference between cultivars. The fruit colour could also imply the specific health attributes of fruits (Allan et al., 2008). The content of organic and inorganic acids in fruit depends on the fruit species, climate and soil geomorphological character and varies over a wide range. Reducing sugars, glucose and fructose are widely present in foods, especially fruits. During wine fermentation, both monosaccharides are co-fermented by yeasts, producing a wide range of compounds such as ethanol, carbon dioxide, and glycerol.

The quality of fruit could also be affected by the mode of cultivation, *e.g.*, organic or conventional. Consumers' awareness of the relationship between foods and health, together with environmental concerns, has led to an increased demand for organically produced foods. In general, organic foods are often perceived by the consumers as being healthier and safer than those produced using conventional agricultural practices (Brandt and Mølgaard, 2001; Woese et al., 1997). Even though some characteristics of conventionally and organically grown food could be significantly different, the data on the impact of the practices mentioned above, on nutritional quality are often contradictory (Vinković Vrček et al., 2011).

Organic agriculture, in general, is characterised by restriction against the use of synthetic pesticides and fertilisers. Organic production emphasise the accumulation of soil organic matter and fertility over time using composts and green manure crop. On the other hand, fertilisers containing soluble inorganic nitrogen and other nutrients are used in conventional production (Vinković Vrček et al., 2011). Nutrients present in synthetic fertilisers are more directly available to plants, which lead to accelerated plant development - all the resources available to plant are consumed for growth purposes and not for the synthesis of secondary metabolites (Popa et al., 2018). According to the available literature, organically produced fruits may contain higher levels of phenolic compounds. Phenolics represent endogenous defence substances of plants that are more intensively synthesised (as a part of plant defence mechanisms) in the absence of synthetic pesticides and fertilisers commonly used in the conventional production system (Carbonaro and Mattera, 2001; Faller and Fialho, 2009; Popa et al., 2018). Letaief et al. (2016) reported a higher antioxidant capacity of organic fruits because of enhanced synthesis of phytochemicals produced as a part of the biotic and abiotic stress response. These facts are of great importance to scientists, as well as consumers, who try to compare the nutritional quality of conventional and organic foods (Mditshwa et al., 2017). The results of the research on the composition of Croatian grape wines (organically and conventionally grown grapes) have indicated a higher antioxidant capacity of organic wines (Vinković Vrček et al., 2011). Amidžić Klarić et al. (2016) examined mineral and heavy metal content of blackberry wines made from conventionally and organically grown blackberries. The comparison between the two groups of investigated blackberry wines showed the statistically significant difference in the content of Si and Li, whereas the organic wines group contained higher levels of these compounds. Furthermore, Amidžić Klarić et al. (2017) also evaluated the quercetin content, colour and selected physicochemical quality parameters of the same two groups of Croatian blackberry wines. Quercetin content of organic wine samples group was slightly higher than that of conventional wine samples group. No significant overall differences were found between the conventional and organic group of samples in case of colour and selected physicochemical quality parameters. When comparing conventional and organic cultivation practices with respect to food safety, organic products show some clear advantages when it comes to well-established toxicants, such as pesticides, mycotoxins and nitrates (Pussemier et al., 2006). The research conducted by Vitali Čepo et al. (2018) on organic grape wines indicated significantly lower total concentrations of pesticide and the average number of pesticides per sample. Furthermore, the majority of ochratoxin A positive wines originated from conventional wine producers.

2.2. Must preparation

2.2.1. Maceration

Maceration is the release of fruit pomace (seeds, skins, and pulp) constituents after crushing, which is aided by the release and activation of hydrolytic enzymes from crushed fruit cells. It has been observed that the maceration improves must fermentability, thus enhancing the yeast activity (Jackson, 2014). Most of the maceration studies so far have put the focus on the extraction of pigments. Temperature and contact time are essential parameters that determine the course of the maceration process. In that sense, Parenti et al. (2004) reported that the lower maceration temperatures yielded better maceration results. Cold pre-fermentative maceration is a promising technique that improves the pigment extraction as well as the fruit aroma and flavor transfer to the must (González-Neves et al., 2015). During cold pre-fermentative maceration, the must temperature is maintained at 10–15 ºC for several days. At low maceration temperatures the start of fermentation is postponed, so the contact of fruit parts (pulp, skin, and seeds) takes place without the presence of ethanol (Gómez-Míguez et al. 2007). Furthermore, the maceration temperature determines the solubility of water-soluble components, thus increasing the extraction of tannins and anthocyanins (Sacchi et al., 2005; Álvarez et al., 2006; Ortega-Heras et al., 2012). The primary barrier that averts the polyphenols release into the must is the skin cell wall of fruit. To efficiently extract the polyphenols middle lamella walls should be degraded, thus releasing the cells and enabling the subsequent break of cell walls to extract the cell contents into the wine (Amrani Joutei & Glories, 1995). The increase of porosity of this barrier can be achieved by partial hydrolysis of the polysaccharide compounds (pectins, hemicelluloses, and cellulose) which can be achieved either by mechanical maceration, the use of chemicals such as SO_2 or the use of different maceration enzymes (Razungles et al., 1988). The use of maceration enzymes has become a widespread practice during winemaking. When commercial maceration enzymes are used at the early stage of fruit extraction and later on during pressing and clarification, they ensure high quality of fruit wines. The commercial maceration enzyme preparations include pectinases (mainly polygalacturonase, pectinesterase and pectin lyase), as well as small amounts of cellulase and hemicellulase to obtain better cells break down and extraction of cell contents (Ortega-Heras et al., 2012; Río Segade et al., 2015). Investing in industrial oenological enzymes, in general, has a cost-effective mark because it increases wine filterability and prevents the qualitative and quantitative losses.

2.2.2. The use of sulfur dioxide and alternatives in must and wine treatment

Sulfur dioxide (SO_2) is still one of the most common preservatives used in wine production because of its antioxidant and antimicrobial properties. Moreover, sulfur dioxide seems indispensable in winemaking because of its features. Besides its use for the control of undesirable microorganisms, SO_2 is also used to inhibit polyphenol oxidase activity during wine production (Guerrero and Cantos-Villar, 2015). Thus, oxidative processes and unwanted spontaneous fermentations are both controlled by SO_2 addition (Ribereau-Gayon et al., 2006). However, the exposure to SO_2 through consumption of wine can have unfavourable health effects, *e.g.*, diarrhea, urticaria and abdominal pain (Ferrer-Gallego et al., 2017). Therefore, the International Organization of Vine and Wine (OIV) has been gradually reducing the maximum advisable levels of total SO_2 in wines (OIV, 2016). In a constant quest for healthier products, the consumers are demanding high-quality wines which are SO_2-free. The application of new technologies to replace the use of SO_2 in winemaking is one of the challenges for scientists and manufacturers who are striving to meet today's consumer demands (Costanigro et al., 2014). In recent years, several studies have focused on finding the alternatives to SO_2, thus reducing the use of SO_2 in wines (Abramovič et al., 2015; Nagy et al., 2017; Lužar et al., 2017). The chemical treatments, such as lysozyme, dimethyl dicarbonate (DMDC) and phenolic compounds, are more versatile than the use of physical methods from an economic and technical point of view (Santos et al., 2012). OIV (OENO 445/2015) recommends the addition of reduced glutathione in concentrations up to 20 mg/L (Ferrer-Gallego et al., 2017). This compound has an essential role in the control of oxidative spoilage of wine, preserving thiols, as well as protecting wine against browning and flavour loss (Kritzinger et al., 2013). Furthermore, the addition of commercial oenological tannins resulted in the flavour enhancement and inhibition of browning (colour stabilisation). Sonni et al. (2011) monitored the effects of substitution of SO_2 with oenological tannins and lysozyme in the pre-fermentation phase, on the volatile constituents of white wines. They found that SO_2 has the most significant influence on the development of alcohol and esters during wine storage. It was also noted that the presence of tannins had a role in maintaining the number of esters in a specific range during the one-year storage of wine. Reddy and Reddy (2011) reported that the addition of SO_2 induced acetaldehyde formation by yeast in mango wine fermentation, while Herrero et al. (2003) reported similar results for cider production. The formation of volatile sulfur compounds, as a part of sulfur metabolism, results in the production of off-flavours. The central problem of high-quality wine production is the formation of off-flavours, whereas the acetic acids, sulfur-containing volatiles, and free amino nitrogen are among the main components responsible for off-flavours (Kosseva et al., 2017).

2.3. Fermentation

2.3.1. Alcoholic fermentation – the importance of yeast

Even though aroma and flavour are mostly determined by the fruit variety, as already mentioned, a careful selection of wine yeasts and alcoholic fermentation (AF) conditions can also have a profound effect on the wine aroma and flavor, as well as on the overall wine quality. Wine yeasts produce metabolites known to influence sensory characteristics of wine, *e.g.* higher alcohols, esters, volatile acids, carbonyl compounds, volatile phenols and sulfur compounds (Swiegers and Pretorius, 2005). Except for the preliminary research on the impact of commercial yeast strains on blackberry wine production on a small scale (Petravić-Tominac et al., 2013), selected yeast strains were not included in previous studies of Croatian fruit wines. Due to the differences in fruit composition, yeast strains used for AF of fruit wines have to adapt to different environments, *e.g*., sugar composition and concentrations, the presence of organic acids, *etc*. The majority of fruit wine elaboration is based on the use of *S. cerevisiae* strains that allow for rapid and reliable fermentation, reducing the risk of sluggish or stuck fermentation, and microbial contamination (Duarte et al., 2010; Berenguer et al., 2016). The use of commercial wine yeast can affect the wine composition and sensory attribute and can consequently affect the fruit wine quality (Ginjom et al., 2011; Duarte et al., 2009).

Fast and complete AF of fruit juice sugars to ethanol concentrations above 8% v/v are essential requirements of selected yeasts strains. The chosen wine yeasts should be sulfur-tolerant, cause minimal foaming and settle down quickly at the end of fermentation (Fleet et al., 2008). Knowing the potential differences in volatile biosynthesis between various wine yeast strains is important and should be taken into account during selection of the best yeast that will produce a high-quality wine (Duarte et al., 2010).

The fermentation and maturation process of fruit wine can increase the release of flavonoid aglycones that are more active phytochemicals than their conjugated forms (Pinhero and Paliyath, 2001).

2.3.2. Malolactic fermentation

Apart from yeast, lactic acid bacteria (LAB) also play a very significant role in carrying out a secondary process, known as malolactic fermentation (MLF) where L-malic acid is converted to L-lactic acid. MLF usually takes place during or at the end of AF. Lactic acid has a softer, more mellow flavor that can create a beverage with a more desirable flavour profile (Herrero et al., 2005), reduced wine acidity as well as improved quality and stability in high-acid wines (Davis et al., 1985). Furthermore, LAB simultaneously causes changes of the chemical and physical composition of wines, *e.g*., different studies have reported changes in the volatile aroma profile of wines after completed MLF (Sumby et al., 2010; Bartowsky and Borneman, 2011). Several oenological parameters namely, alcohol content, temperature, must/wine pH, and sulfur dioxide (SO_2) concentration affect the implementation of MLF (Lerm et al., 2010). *O. oeni* can tolerate harsh environment. It is a fastidious organism, requiring group B vitamins, organic nitrogen and amino acids, most of which can be derived from yeast autolysis.

Lack of any of these nutrients will inhibit growth (Fuller et al., 2011). MLF can occur spontaneously due to the indigenous LAB present at the fruit (in musts that have not been subjected to sulfur addition before fermentation) or can be induced by the addition of LAB starter cultures. The principal genera of LAB responsible for conducting MLF are *Lactobacillus*, *Leuconostoc*, *Oenococcus* and *Pediococcus* (Ugliano et al., 2005; Boido et al., 2009; Sumby et al., 2010; du Toit et al., 2011; Bartowsky, 2014; Cappello et al., 2017). However, *Oenococcus oeni* is currently the primary species used in MLF as LAB starter (Bartowsky and Borneman, 2011; Bartowsky, 2005; Sun et al., 2016). There has been limited literature available regarding the MLF of fruit wines. When it comes to fruit, flower and vegetable wines, the emphasis is placed on the character of the primary ingredient ("fruit" or varietal). Therefore, MLF has been traditionally avoided in respect to the mentioned wines. However, many non-grape wines may be suitable for malolactic fermentation. Some winemakers routinely conduct MLF on apple wine, but red wines, such as blackberry wine are also suitable candidates (Rotter, 2008). MLF performed by *Oenococcus oeni* was successfully used as a technique for deacidification of hard apple cider (Reuss et al., 2010), thus proving the suitability of MLF for apple wines. Sun et al. (2016) compared the adequacy of an autochthonous *Lb. plantarum* SGJ-24 strain and *O. oeni*, 31 MBR strain, to conduct MLF in cherry wines. Furthermore, Sun et al. (2018) investigated the interaction between different LAB starter cultures and different pH on the malolactic fermentation of cherry wine. Under mild wine conditions, *Lactobacillus plantarum* promoted malolactic fermentation more efficiently than *Oenococcus oeni*. Furthermore, the increase of biogenic amines content, as well as the reduction of cherry wine color was also noticed.

2.4. Ageing and maturation

The fresh wine usually tastes harsh and has a yeasty flavour. During wine maturation, changes in aroma and development of a bouquet take place (Jackson, 2014). Wine ageing process is often divided into two phases: maturation and reductive ageing. Maturation, the first phase, refers to changes that occur between AF and bottling and frequently lasts from 6 to 24 months. During maturation, the wine may undergo the above-described MLF, be stored in oak cooperage, racked, and treated by one or more filtration and clarification procedures. The second phase of aging begins with bottling. The second stage is called "the reductive ageing" because it occurs mostly in the absence of oxygen. The maturation of some fortified wines and sherries, on the other hand, is described as oxidative and biological ageing (Jackson, 2014). According to some studies, the maturation of fruit wines could be extended from 6 months to 2-3 years, resulting in a clarified wine of mellow taste and fruity flavour (Kosseva et al., 2017).

2.4.1. Sur lie maturation

Sur lie maturation is achieved by leaving the wine and lees in contact for periods from 3 to 6 months. Sometimes the procedure involves "bâttonage" (periodic stirring of the wine) (Charpentier, 2010). It is primarily used to add flavours and extract mannoproteins from dead and dying yeast cells (lees). Wine ageing on lees usually begins after AF, when a young wine is left on wine lees for several months. Since wine lees contribute to the antioxidative potential of wine, less sulfur dioxide is used for the protection of wine. The positive effects of this practice include the reduction of bitterness and astringency, increase of protein and tartrate stability, as well as the enhancement of body and roundness of wines (Charpentier, 2010; Lužar et al. 2017). Wine ageing also affects the preservation of antioxidants and increases their content. Yeast lees bind oxygen, thus preventing the oxidation of phenolic compounds (Lužar et al. 2017; Nagy et al., 2017). According to Salmon (2006), lees have significantly higher potential and affinity for oxygen consumption compared to polyphenols in wines. A more straightforward technique for *sur lie* maturation is the addition of pre-soaked oak chips to wine. However, it is important to ensure adequate exposure of the wine to the chips, but still avoid the release of oak dust which can clog the equipment (drains, pumps and filters) during the removal of chips. This procedure has been investigated in cider production (Fan et al., 2006).

2.5. Fruit wine stabilisation and clarification

Clarification procedure of fruit wine is similar to that of grape wine. Pasteurisation is performed before wine bottling, with or without the addition of preservatives (according to requirements). A wine that is not clear after racking and maturation can be clarified by the use of filtering aids (*e.g.* bentonite, tannin/gelatin treatment) and filtration (Kosseva, 2017). Bentonite is montmorillonite clay, widely employed as a fining agent. It exists in a negatively charged state at wine pH, and removes positively charged colloids such as proteins, including enzymes such as oxidases, vitamins, and amino acids, thus increasing microbial and heat stability. This involves the separation of liquid (wine) from any sediment deposits or suspended particles through filtration and adsorption mechanisms. The size and nature of the particles which have to be removed will determine which filtration system and grade are required (Fuller et al., 2011). Wines are usually cooled and filtered to improve clarification and stability. Proteins and other dissolved materials from the wine are removed before bottling. Otherwise, they may cause haziness, especially when the wine is heated (Jackson, 2014). Vitamin C may be added during or after fermentation to some wines to prevent the oxidation of wine. Alternatively, fruit wines can be preserved by the addition of preservatives like SO_2, sodium benzoate, sorbic acid, and so forth.

3. Chemical constituents of fruit wines

The composition of fruit wines includes mainly water, alcohols, sugars, organic acids, and minor ingredients such as higher alcohols, esters, polyphenols, etc. (Johnson and Gonzalez de Mejia, 2012). As a primary product of alcohol fermentation, ethanol has a multiple role in wine: it acts as an cosolvent (along with water) in extracting compounds present in fruits, it serves as a reactant in the synthesis of important volatile compounds (*e.g.* ethyl esters) and is critical to the sensory properties, stability and ageing of wine (Jackson, 2014). The third major fermentation product of alcoholic fermentation, besides ethanol and carbon dioxide, is glycerol. Glycerol is important because it can indirectly contribute to the aromatic character of the wine (du Toit et al., 2011), emphasising the sweetness, as well as the full and round mouthfeel of wine and wine texture (Nieuwoudt et al., 2002). Various yeast strains produce different amounts of glycerol, so the glycerol production ability should be considered in the selection of wine yeast strains (Petravić-Tominac et al., 2013). Higher alcohols, also known as fusel alcohols are the secondary metabolites of yeast, found in (fruit) wines in small quantities (Amerine et al., 1980).

The sugars present in fruit wines correspond to major sugars present in fruits, *i.e.* fructose, glucose and, in some fruits, saccharose. They are fermented by yeast, producing already mentioned major metabolites: ethanol, carbon dioxide and glycerol. Furthermore, sugars can also be metabolised to higher alcohols, fatty acid esters, and aldehydes, which mostly define the primary aromatic character of wine (Jackson, 2014). The sugars that remain unfermented (*i.e.* the sugars in wine) are referred to as residual sugars.

Similar to sugars, the content of organic acids in fruit wines corresponds to the content of organic acids in the respective fruits. The acidity of fruits affects the fruit wine acidity, which is often expressed as total acidity. The acidity of wine influence the wine taste and the overall quality. Major organic acids present in fruit wines include malic acid, citric acid and acetic acid. Acetic acid is the predominant volatile acid, that can detrimentally affect the organoleptic properties of wine when present in higher concentrations (often as a result of the secondary infection with acetic acid bacteria during vinification or after bottling) (Jackson, 2017; Ribéreau-Gayon et al., 2006). Malic acid also significantly contributes to the acidity of wine, which can be reduced by degradation of malic acid by malolactic fermentation (MLF), as mentioned previously.

Volatile compounds present in fruit wines mostly determine the aroma of fruit wines and can be produced by the fruit itself (varietal wine aroma), as by-products of alcoholic and malolactic fermentation (fermentative wine aroma), and formed during bottling, ageing, and storing (post-fermentative wine aroma) (Lambrechts and Pretorius, 2000). The groups of volatile compounds that most commonly contribute to the flavour and/or aroma profile of fruit wines include esters, higher alcohols, organic acids, and other compounds. There are also many minor volatile and non-volatile compounds adding to the aroma of fruit wines, such as aldehydes, ketones, lactones, terpenes, and phenols (Zhu et al., 2016).

Fruits contain various dietary phytonutrients with strong antioxidant capacities, such as phenolics and vitamins. Phenolic compounds, namely phenolic acids, anthocyanins, flavonols, catechins and other flavonoids present in fruit wines significantly influence the wine quality, since they have an impact on the sensory characteristics of wines, mainly astringency and colour (Kalkan Yildirim, 2006). The concentration of vitamins initially present in fruits decrease during the winemaking (fermentation and ageing), so their levels in fruit wines are inadequate to be of significance in human nutrition. However, vitamin C is sometimes added as a preservative in organic fruit wines production.

Besides phenolics, various minerals in readily available forms can be found in different fruit wines. The total amount of minerals in a sample of fruits and fruit wines can be expressed as the ash content. Higher ash content in a fruit wine implies a higher amount of minerals and a higher quality of the wine (Amidžić Klarić et al., 2016).

Conclusions

Fruits have a significant role in human nutrition either as fresh or in processed form, due to the presence of numerous high-value secondary metabolites that provide inherent nutritional quality. The past decade has seen the rapid development of fruit wine production in many countries. Such form of fruit processing tends to preserve and exploit the original nutritional properties of fruit as much as possible and to develop new desirable features of the final product. The scale of fruit wines production in Croatia and elsewhere is still far from the production of grape-wines. However, the consumers' demand for high-quality fruit wines is growing and consequently so is the market.

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