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USE OF OAK ALTERNATIVE PRODUCTS IN VINIFICATION

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Abstract. Traditionally, the best wines are aged in oak barrels. It is generally accepted that the quality of wines and spirits depends on their aging in contact with oak wood. The selection of oak wood and its maturation are mandatory stages of barrel production. Considering the many factors involved in the selection of raw materials and the natural drying phase of oak wood, it is very difficult to determine the effect of drying time and the effect of wood selection factors. Wines aged in contact with wood are in great demand among consumers around the world. Oak wood allows you to change the organoleptic characteristics of wine. Numerous phenomena occur during aging in wood and affect the structure of the wine. These are mainly oxidation-reduction reactions, dissolution of volatile and non-volatile components of wood, which enrich wines. Aromas derived from oak wood contribute to the wine's aromatic profile, and the main extractable polyphenols ellagitannins can alter taste sensations such as astringency and bitterness. Thus, all the compounds derived from the wood contribute to the balance and quality of the wines. These phenomena themselves depend on numerous parameters, including the nature and conditions of barrel production, as well as the storage temperature or the ethanol content of the alcoholic beverages to be matured. Aging of wine in containers with the addition of alternative products from oak wood is becoming more and more popular in all wine-producing countries of the world. The main reasons for the development of such products are the optimization of their production, the reduction of the cost of wine aging, as well as the improvement of the level of hygiene in production. This review discusses traditional and alternative winemaking technologies and their impact on wine quality and sensory characteristics. The rapid spread of alternative aging technologies justifies a study evaluating the impact of the oak alternative on the chemical characteristics of wines and evaluating any differences from the traditional aging of wines and spirits in oak barrels.

Key words: barrel, oak alternative products, oenological wood, oak chips, vinification, alcoholic fermentation, aging, toasting, phenolic compounds.

Introduction. Formulation of the problem

The quality characteristics of oak barrels were first appreciated in Europe. France, northern Italy and Switzerland revolutionized cooperage in the early 19th century by using barrels to age wine precisely to give it a rich aroma and pleasant taste. A worthy successor to the amphora, the wooden barrel has held a virtual monopoly on winemaking for almost two millennia. Wines aged in barrels are traditionally considered to be high-quality wines. During aging, the various soluble components of the wood are released into the wine and enhance the intensity and complexity of its flavors [1-6].

Among all the existing containers for winemaking, the barrel remains the most expensive and the most difficult to use. What are the advantages of using such a complex container? The main goal is to create wines with complex flavors and the potential for long aging.

Over time, it became clear that this container has interesting properties in terms of wine aging; the barrel gives off phenolic compounds to the wine, which ultimately allows us to speak of a certain aromatic complexity.

The effect of wood on wine is the subject of much research around the world. Until the 50s of the 20th century, the art of winemaking was studied "in the field", and only after the end of the Second World War did the science of enology take shape. As Emile Peynaud (1988) notes: "Oenology is the daughter of young chemistry, not of old agronomy, as is commonly believed, it was born not in the darkness of cellars but in the scientific rooms of physics" [7]. At this time, winemaking and aging protocols began to develop, making winemaking not only an art but also a science. Various authors focused on studying the composition and function of oak wood for potential use in oenology [8-17].

The contact with oak wood allows the wine to stabilize its color, develop its structure and aromatic potential, revealing the expression of fruit notes and giving it body and roundness, enhancing its texture and mouthfeel, giving it a more elegant and complex flavor profile and reducing high aromatic notes. [18,19] In addition, a microamount of oxygen is released into the wine during aging due to the slightly porous nature of the oak fibers. This slow aging improves the quality of red wines, especially in terms of color, aroma and flavor [1,2,6,20, 21-24]. Thus, during aging in oak barrels, wines acquire a better color, more subtle aromas, and greater roundness, improve the harmony of the flavor profile, and reduce the excessive intensity of green and woody notes.

However, vinification in barrels has certain disadvantages, mainly when they are used for wine fermentation, such as difficulties with controlling the fermentation temperature or cleaning the barrels. In addition, not all wines are suitable for aging in oak barrels, as the micro diffusion of oxygen through the wood pores can oxidize the wine and the release of chemicals into the wine can completely mask its sensory characteristics [25].

Like barrels, alternative products can be used during fermentation or wine aging. Various authors have noted the advantages of fermenting wine in oak chips [26-31].

The number of wines produced in prestigious and high-quality containers, namely oak barrels, accounts for only a few percent of global wine production. Alternative oak products are a solution for cost-effective and environmentally friendly winemaking. These products are defined as materials derived from oak, such as oak chips, staves and cubes, which are widely used in the new world instead of traditional oak barrels [15,19]. Alternative oak products offer winemakers a cost-effective and flexible alternative to traditional oak casks, allowing them to achieve their desired flavor profile while reducing production costs and time to manufacture [18,26,28, 29,32,33].

Traditional oak barrels have long been used in winemaking to enhance the taste and aroma of wines during the aging process [4,5,27,31,34]. Alternative oak products can be more durable and environmentally friendly, requiring less wood and extending the life of the barrels by using inserts/micro-glue or chips.

Most studies have focused on the vinification of red wine in oak barrels or using alternative products such as staves, cubes, chips or oak powder [2-4,6,11,14,22,30,34-38]. In addition, for rosé wines, some recent studies have reported results using different woods, including oak, acacia and cherry [31,39]. Finally, for white wines, there are also several published papers on vinification using different types of wood, such as oak and acacia [26,30,34,39-47].

This review article presents a large amount of data on the use of oak wood pieces in oenology, summarising the large amount of information published over the past twenty years. Our research will be used to better understand the benefits and how to better harness the use of wood pieces for quality winemaking at the best price in a sustainable manner. To date, the optimal dosage and degree of toasting of enological wood for alcoholic fermentation and wine aging has not been determined.

The objective of our work is to determine the influence of oak wood on the organoleptic qualities of wine during alcoholic fermentation and aging, depending on the degree of toasting and dosage.

1. Oak in oenology

Numerous studies, including that of Andrej Prida and others [48], have been able to highlight the differences in aromatic characteristics between European oak (*Quercus Robur and Quercus Petraea*) and American oak (*Quercus Alba*) [49-54].

Some previous studies have also focused on oak wood in other regions: Spain, Austria, Hungary, Romania, Ukraine and others – with the aim of sustaining existing oak resources by finding new suitable alternatives [10,55,56]. Some results indicate that Eastern European oak contains more aromatic substances such as volatile phenols and phenolic aldehydes than French oak [11,20,48,55,57-59].

2. Oenological wood production

The selection of oak wood and its aging are essential stages in the production of barrels. After selecting the oak species, there are basic quality criteria for cooperage wood when choosing logs, including a minimum diameter of 40 cm, no knots, wood without rot, ring crack, steam, etc., density of annual rings, even wood grain, and others. Only the most noble part of the tree – the heartwood – known for its organoleptic qualities is used from oak logs. The sapwood (which provides coarse tannins) and the heart (which is firm and tannic) are removed.

2.1. Wood drying/ The natural drying phase of oak wood, in other words seasoning (or atmospheric drying), is essential for both barrel production and the production of wood for oenology. The natural maturation in the open air for at least 24 months guarantees the perfect preparation of the material: the astringent tannins are washed away, and the summer-winter temperature changes and precipitation ensure the perfect development of fungi (hyphae) on the wood surface. The chemical composition of oak wood changes during drying, which affects the chemical composition of wine aged in contact with oak pieces or barrels [16].

Artificial drying is also widely used in the woodworking industry. It involves the use of drying chambers, where the wood is left for about a month in a ventilated oven heated to 40–60°C [16,60,61]. Accelerated artificial drying of wood can affect the composition of its aromatic and phenolic substances. Here are the main points to consider when artificially drying wood.

Artificial drying can lead to an increase in the concentration of aromatic compounds in wood. This can be due to the evaporation of water, while a higher proportion of volatile compounds such as terpenes remain [61,62]. The drying process can affect phenolic compounds such as lignins. Molecular rearrangements may occur, which affects the structure and distribution of phenolic groups. Impact on wood quality: If the drying process is not well controlled, it can potentially lead to the loss of valuable volatile compounds. In addition, excessive degradation due to drying too quickly can change the quality and mechanical properties of the wood.

It is possible to use the two drying methods to combine the main advantages of each. Artificial drying is used for uniform and rapid dehydration of wood, and natural drying is used for deep modifications (the stage of wood "refining"). [16,63,64]

Numerous studies, including several by Nicolas Vivas and others [62,65], demonstrate the significant impact of oak wood drying on its chemical composition and the extraction of substances from wood into wine [5,10,16,36,66]. In recent years, oenological research, which used to focus on vinification in oak barrels, has also turned to the study of pieces of oenological wood.

The drying of wood for cooperage usually takes place in natural conditions in the open air over a period of 18 to 36 months. Drying reduces the high percentage of moisture in the wood until it is in balance with the ambient humidity, and at the same time causes the fibers to shrink. Natural drying also contributes to the maturation of wood, reduces bitterness and astringency, and improves aromatic properties by changing its chemical composition. Most often, this leads to the loss of water-soluble polyphenolic substances, such as ellagitannins, which can be the result of various physical and chemical mechanisms [36].

Alexandra Le Floch [16] studied the effect of wood drying time on the chemical composition and organoleptic qualities of wine aged in contact with oak wood. It is mainly about determining the chemical composition of the oak wood used for the production of barrels and oak alternatives, and in particular the composition of the main macromolecules and extractables that make up all of this raw material. This composition has been characterized at different wood maturation periods and according to different factors of oenological interest in order to assess the effect of drying time on the composition of macromolecules and extractable substances of dried wood, as well as the influence and importance of different selection factors on the evolution of this composition. The study observed the evolution of the chemical composition of wood taken during different drying periods: 12 months, 18 months and 24 months. The plan of the Merlot red wine experiment was created with oak wood samples taken for this purpose and cut into wooden segments (47*47*7 mm in size) during 3 months of aging. The proportion of extractable compounds from oak wood decreases significantly during the first year of drying and remains stable during 18 and 24 months of drying. These compounds are mostly washed out during the first year of oak wood aging. The analysis of molecular ellagitannins (the main compounds released from oak wood) also showed a decrease in their content between drying times of 12 and 24 months.

Natural drying affects the aroma profile of the wood. During this process, volatile wood compounds such as lactones, phenolic aldehydes or volatile phenols exhibit different properties; some increase in concentration, while others decrease or show little or no fluctuation. However, in general, natural drying has a positive effect on the volatile composition and sensory characteristics of oak wood. Artificial kiln drying or a mixed method that combines air and kiln drying results in a different evolution of the wood's chemical composition [36,67].

2.2. Wood toasting. *Le Bousinage* – Bousinage. Traditional cooperage is a specialized profession that involves making wooden barrels for storing and aging various types of liquids, such as wine, whisky, rum, etc. The heating and toasting of barrels in cooperage and oenological wood production is a crucial step in the production process. It makes it possible to shape the wood and give the future container certain specific characteristics. The wood is heated in a hearth or oven specially designed for cooperage *(French – brasero).* It can be heated by open flame or by thermal conduction. Heating or toasting with direct fire is one of the oldest and most traditional methods. The barrel is toasted directly over an open flame, usually fuelled by wood or gas. Each of these methods has its advantages and disadvantages, and the choice often depends on the preferences of the cooper, the type of liquid to be stored, and the specific requirements of the customer. Each toasting method also brings nuances of flavor and aroma to the final product, which can be an important factor for spirits producers and winemakers looking to create unique flavor profiles.

The last stage is the bousinage (*le bousinage* – toasting the inner surface of the barrel with fire). The bousinage has been and is the subject of in-depth research on the diversification of methods and the factor study of time and temperature parameters. Depending on the time of toasting, the intensity of the flame, and the temperature reached the organoleptic profile of wood changes in terms of its chemical composition. Wood pieces are exposed to the heat of the fire. Toasting can take from a few minutes to several hours, depending on the degree of toasting and the size of the workpiece. The cooperators closely monitor the temperature that the oak pieces reach. Tools such as thermometers or heat chambers can be used to ensure even toasting.

Toasting significantly changes the chemical composition of wood. Thermal degradation of macromolecules releases volatile molecules, while reactions due to toasting generate new aromatic compounds. The main products of linear pyrolysis are classified into guaiacol units (monomethoxylated) and syringyl units (dimethoxylated). Monomethoxylated derivatives include vanillin (vanilla smell), eugenol (clove smell) and guaiacol. As for dimethoxy derivatives, we find syringol (an intense smoke smell), acetosyringol and syrinaldehyde.

In cooperage, bousinage is a process that involves toasting the inside of oak barrels intended for wine aging. This operation gives the wines their aromatic balance and determines the complexity of barrel aging. To transfer the aromas of oak barrels to wines aged in neutral containers, it is ideal to toast oak blanks in a way that recreates the organoleptic qualities of barrel staves. The oak wood, toasted in the same way as in cooperage, is similar in every way to the first millimeters of the barrel's inside surface.

The thermal gradient in the wood mass allows for the maximum preservation of aromatic compounds at a low toasting temperature inside the wood and is fundamental to the complexity of the final product. Thus, all toasting conditions contribute to the production of toasted wood with a much higher content of aromatic compounds than when it is toasted in an oven or toaster, both in terms of the variety of molecules formed and the amount of each of them [36,43,66,68,69]. In contact with a wine, this characteristic places the wood thus treated as similar to the staves of a barrel.

Depending on the used toasting temperatures, a quantitative evolution of the products formed occurs. This is observed in particular for the most organoleptically important compounds. The results show that more dimethoxylated phenols are formed than monomethoxylated phenols. The ratio of strigil structures to guaiacol structures naturally decreases during toasting. At temperatures significantly higher than the normal toasting temperatures, acrolein is formed, a product with a particularly unpleasant frying odor. This observation shows the benefits of not exceeding a certain threshold and very strict control of toasting operations.

The thermal decomposition of sugars (polysaccharides) mainly leads to the formation of other volatile compounds characterized by the aroma of caramel (5-hydroxy-methyl-2-furaldehyde), toasted almonds (methyl-5-furfural) and fresh almonds (2-furaldehyde, 3-furaldehyde) [70-73]. The Maillard reaction requires the presence of sugars, amino acids and high temperature. Decomposition by depolymerisation of lignins produces a large number of volatile odorous phenols (guaiacol, methyl-4-guaiacol, eugenol, syringol, cresol, etc.), phenyl alkyl ketones (butyrovanillone, acetovanillone, propyvanillone, etc.) and phenolic aldehydes (vanillin, coniferaldehyde, syrinaldehyde and synapaldehyde) [70,73,74]. According to research by Sarni and others [6], four phenolic aldehydes are formed at 120°C. The monomethoxylated derivatives (vanillin and coniferaldehyde) then decompose from 165°C, while the dimethoxylated derivatives (syrinaldehyde and synapaldehyde) decompose only from 25 °C. As the intensity of toasting increases, elagitannins undergo degradation, which ultimately adds oak tannins to the wine's flavor [75].

After the toasting is complete, the pieces of wood are removed from the hearth and cooled. The sudden cooling of the wood after toasting allows for the rapid condensation of volatile substances with a low boiling point, such as furfural, O-cresol, guaiacol and their derivatives.

2.3. Degrees of toasting and their impact on the organoleptic characteristics of wines. There are different degrees of toasting that affect the aromas and characteristics of the wine that will be aged in the barrel. Depending on the method of toasting, wood can impart notes of dried fruit, vanilla, coffee, toast, spices, nuts, smoke, coconut, almonds, etc. to wines.

The main degrees of toasting:

Light toasting that is suitable for wines that require minimal aromatic enhancement and a higher tannin content. The light toasting provides a delicate vanilla hue, reduces the amount of broken down lignin and allows fresh flavors to develop.

Medium toasting is ideal for concentrated and matured wines, both red and white. This toasting produces much more complex and toasty flavors; the longer toasting period results in greater lignin degradation, creating a more powerful vanilla flavor.

Heavy toasting ensures almost complete decomposition of the chemical components of oak. This level of toasting is ideal for wines that require a strong influence of complex aromas with less tannin contribution to the wine structure. Heavy toasting gives the wine a taste and aroma of smoke and black pepper.

The effect of the degree of toasting on the extraction of phenols from oak wood is well described in the literature. Some studies on phenolic composition have also focused on the composition of ellagitannin depending on the degree of toasting, but they only determined the ellagitannin content by quantifying the ellagic acid released during acid hydrolysis [68].

L. Le Grottaglie et al. [69] conducted aging tests on control samples of wine with oak chips of different degrees of toasting. These results show that the content of C-glycoside ellagitannins is higher (41.76 mg/l) and is achieved earlier (after 7 days) when using pieces of wood with a light degree of toasting. In the samples containing oak chips with a medium degree of toasting, the maximum concentration of total ellagitannins (18.89 mg/l) was reached after 21 days. The lowest content of C-glycosidic ellagitannins was found in contact with oak chips with a high degree of toasting, and the maximum concentration of this sample (1.92 mg/l) was reached later (after 28 days).

Marie Courregelongue [66] studied the aroma characteristics of oak (Q. sessilis) wood at the molecular level during its toasting using various chromatographic methods. The research allowed to highlight the effect of toasting intensity on the macromolecular structure of oak wood.

Toasting profoundly changes the structure of wood and its chemical composition. It is important to note that the choice of the degree of toasting depends on the style of wine the winemaker wants to produce, as well as the characteristics of the grapes used. Each winemaker may have their own toasting preferences based on their experience and philosophy of the vinification process.

3. Different types of alternative products used in the vinification process

Since the 1990s, the technology of wine production using alternative oak products (pieces of oak of various sizes and shapes that have undergone preliminary heat treatment) has become widespread. This product is approved for use during fermentation and aging by the International Organisation of Grapes and Wine (OIV) under Oeno 3/2005, Oeno 430/2010, Oeno 406/2011, 1507/2006 and 606/2009.

This technology is becoming increasingly popular in all wine-producing countries of the world due to the optimization of the vinification process, reduction of aging costs without compromising the quality of wines, and improvement of hygiene at wineries. It is also important to note the importance of each producer's responsible attitude to nature, especially in the context of the environmental crisis, as the use of barrels for wine aging contributes to the massive deforestation of oak trees around the world.

In recent decades, many technologies have been developed around the world to produce alternative oak products. The manufacturers fire pieces of wood of various shapes and sizes in different kilns and roasters. Today, there are traditional fire toasting, infrared toasting, gas, electric, ceramic and other technologies. Therefore, each technology produces a different result in the vinification process. Alternative oak products are becoming increasingly popular in the wine industry due to their cost-effectiveness and simplicity of use.

There are several main types of alternative products used in the winemaking industry to facilitate the rapid exchange between wine and wood: staves/tank-staves, mini-staves or barrel inserts, sticks, cubes, dominoes, blocks, chips, oak powder, etc (Fig. 1). The current market offer is very rich and complex [15,19,32,76,77].

Oak staves or tank staves, are pieces of wood that can be used to simulate any desired barrel aging with a higher extraction rate. They are particularly recommended for aging in containers and can work like a new barrel. It is advisable to use staves to achieve the same quality and complexity as traditional barrel aging. They are slowly extracted into the wine, creating very subtle woody notes. The number of staves is calculated according to the desired intensity.

Barrel inserts or mini-staves, are pieces of wood specially designed to enhance the aromatic and organoleptic properties of an old oak barrel and extend its service life. They are assembled with flexible and stable fasteners, inserted into he opening of the barrel and secured with a plug. The mini-staves are slowly extracted over months with a very subtle woody note that is harmoniously integrated into the wine. At the same time, the wine continues to benefit from micro-oxidation through the exchange of air through the pores of the barrel wood.

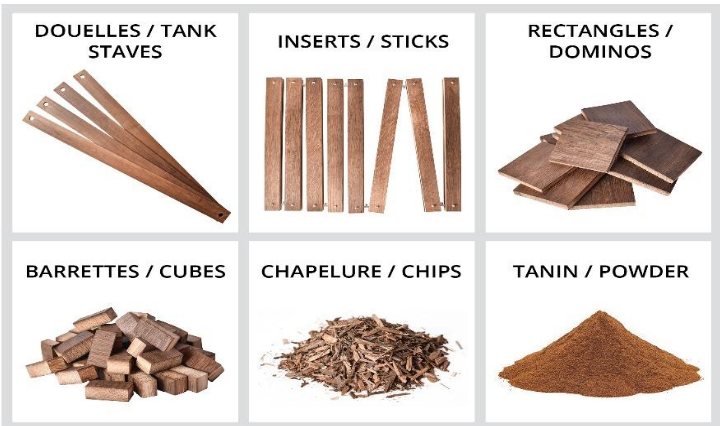

Fig.1. Different types of alternative products used in winemaking

Cubes or dominoes, are pieces of wood that are used to give the wine the flavor and aroma of aging in oak barrels for a shorter time. Their main advantage lies in the perfect extraction according to the 3 axes, which ensures complexity, structure and regularity. For both white and red wines, the cubes help to develop the aromatic potential, bringing out the fruit notes and giving a full-bodied and rounded mouthfeel. The cubes are quickly extracted into the wine due to their excellent contact surface. However, a minimum of 3 months of aging is recommended to obtain soft and harmonious oak notes.

Chips, are thin pieces of wood that are an extremely versatile and economical tool for winemaking. They can be used for both fermentation and aging. The chips are added to the harvested crop, wort or wine when they are placed in the vats. They extract very quickly in wines due to their sufficiently high contact surface. In the process of alcoholic fermentation, the chips enhance the aromatic potential of wines, revealing fruity notes, while adding fat and roundness. They also reduce herbal and vegetal notes and help to stabilize the color of red wines.

Oak powder is another alternative oak product that is made by various methods of extracting tannin from oak billets or chips. Oak powder is often used in small quantities to add a subtle oak aroma to wine. A powder or tannin that is an organic substance from the polyphenol family, most often water-soluble, of plant origin and which has the ability to precipitate proteins, alkaloids and polysaccharides from their aqueous solution. There is a wide variety of them, differing in size and chemical structure. The use of tannins in the production and processing of wines has been practiced worldwide for many years.

The type of wood and dosage of the oak alternative should be selected according to the type of wine, the desired purpose and the period of use. The dosage can range from 0.25 to 15 g/l. When aging wine on alternative oak products, it is very important to take into account the peculiarities of oak extraction into wine. At the beginning of aging, the extraction is very intense, and the wine may seem to be overwhelmed by the taste of oak, but it is very important to observe the time required for full aging. For optimum balance and aromatic complexity, it is necessary to carry out a full cycle of wine aging on alternative oak products.

In his numerous studies, Alexander Lukanin [78-81] describes the effect of extraction and rapid saturation of wines and spirits with oak aromas, as well as methods of treating wine diseases using various types of alternative oak products.

The use of alternative oak products in winemaking has a number of advantages, one of which is cost-effectiveness. Wine producers can achieve the flavor and aroma profiles of barrel-aged wine at a fraction of the cost. Thanks to the wide range of oak-based products, it is easier to control the final product and tailor the wine to the specific preferences of the consumer. In addition to being cost-effective and flexible, alternative oak products also offer consistent product quality.

4. The influence of oenological wood on the olfactory perception of wines

Oak wood is widely used in winemaking because of its influence on the taste, aroma and structure of wine. When wine is aged in oak barrels, it comes into contact with wood compounds such as vanillin. This contributes to the aromas of vanilla, caramel and spices that are often associated with wines aged in oak barrels. The toasting process of oak wood during production can release compounds that give wine toasty aromas. This can include notes of toast, coffee, chocolate and hazelnut. Some oak tannins can add notes of walnuts and hazelnuts to a wine. In addition to the aromas associated with aging wines in contact with oak, the wood itself can contribute floral and spicy aromas, although these are generally more subtle than those derived from toasting. The use of oak wood adds complexity and harmony to the wine. The components of the wood combine with the characteristics of the wine to create a richer and more balanced flavor profile. The time that the wine is in contact with the oak will affect the intensity of the woody flavors and how they blend with the characteristics of the wine.

It is important to note that the effect of oak wood on olfactory perception will depend on several factors, including the type of oak used (e.g. European or American oak), the degree of toasting, the length of aging, and the characteristics of the wine itself. Ultimately, the use of oak wood in winemaking is an important element of the creative process of winemakers who seek to achieve a balance between the properties of wood and the natural characteristics of grapes [26-31].

5. The chemical composition of oak wood and its impact on the sensory quality of wines

During the production of barrels and alternative oak products, the surface of the wood goes through a stage that is important for the quality of its production, namely toasting. This stage contributes to the formation of numerous volatile compounds resulting from the thermal degradation of certain elements. These compounds can be studied by measuring them by liquid and gas chromatography. Knowledge of the chemical composition of oak wood, in particular the content of volatile compounds and ellagitannins, is of great importance for selecting the oak wood most suitable for wine aging. During aging, several chemicals are transferred from the wood to the wine, which determines the sensory characteristics of the final product.

The volatile compounds extracted from oak play a crucial role in the aging process of wine, as well as in the development of its aroma and complexity. These can include a variety of aromatic molecules that contribute to the characteristic aromas and flavors associated with oak barrel aging [82-86].

5.1. Non-volatile compounds.

High-performance liquid chromatography allows us to isolate the non-volatile compounds in oak that are transferred to the wine. We distinguish between gallic, ellagic, vanillic, ferulic, and syringic acids, vanillin, syringic, coniferic, synaptic aldehydes and coumarins (escutin, scopoletin). These compounds are polyphenols, meaning they contain one or more phenolic functions. Thus, we can see phenolic acids, phenolic aldehydes and coumarins. European oak and American oak contain few phenolic aldehydes (vanillin and syrinaldehyde). Burnt wood, however, has much more of them. Lignin is a complex neutral phenolic polymer that is present in the polysaccharide matrix of the cell walls of the oak heartwood.

Phenolic aldehydes are obtained from lignite, which is very abundant in oak. Under aerobic pyrolysis (toasting), the end units of lignite are most likely to break and rearrange in a T-shaped bond, forming aldehyde structures: vanillin, syringaldehyde.

These compounds especially enrich the aromas of wine as they provide a vanilla flavor (vanillin). Their amount depends on the duration of the toasting. But if it is too long, they will, in turn, break down into phenolic acids and volatile phenols, which can bring out the "board and sawdust" flavors.

Phenolic acids are of little interest because their organoleptic role is not very important. However, ellagitannins (ellagic and gallic acids) play an active role in the gas exchange between wood and wine during malolactic fermentation, consuming some oxygen.

Coumarins, including scopoletin, are phenolic compounds present in wood that integrate into wine over time. The concentration of scopolotene is higher the longer the contact with oak. Thus, it is a very good marker of wine aging. In addition, it does not affect the taste.

However, there are many other volatile phenols that cannot be analyzed by CLHP. Here is another chromatography method: gas chromatography. This analysis will identify volatile fatty acids that wood gives off to wine and very volatile odorous compounds of a pyrolytic nature [82-86].

5.2. Volatile compounds.

The aromatic compounds present in burnt oak wood are, on the one hand, natural compounds of the raw wood, in particular polyphenols, and, on the other hand, substances formed from certain wood components under the influence of heat. These notes are pyrolytic in nature, resulting from the thermal degradation of elements already present in the wood. This is how we find the thermal degradation of sugars, volatile phenols and lipid derivatives (lactones).

Wood has volatile compounds (derived from lipids and volatile phenols), such as eugenol, which it releases into wines. Eugenol is a volatile phenol produced by the thermal degradation of lignins. It is found in toasted wood and its concentration increases with the degree of toasting. It is responsible for the aromas of cloves, pepper, leather, and crumpled grass. Thus, it enriches the woody character of the wine. Other volatile phenols can introduce unpleasant odors, such as sweat or stable odors, if the toasting is too long.

The tree also enriches the wine with cis-3-methyloktano-4-lactone, better known as whiskylactone. Indeed, toasting tends to increase the amount of fatty acids already present in the wood. Compound fatty acids are odorless, while volatile fatty acids enhance the overall aroma. The thermal decomposition of lipids (hydroxy fatty acids) by the spontaneous loss of a water molecule produces lactones. Lactones are cyclic esters of 5 or 6 atoms, stable and very common in plants. In the case of oak, the only lactones present are two isomers of A-methylcannono-B-lactones. The cis-isomer is much more aromatic than the trans-isomer. These substances disappear if the toasting is too strong and are important for the woody aroma of the wine, as they contain hints of coconut or freshly cut wood.

In terms of fatty acids, wood, like almost all organic elements, contains polysaccharides that dissolve in wine, which contribute to the wine's fatty feel and reduce its astringency. As a result, we can see a strong increase in polysaccharide derivatives (sugars) due to toasting. In fact, toasting wood sugars can produce several compounds through direct pyrolysis. The main derivatives are furan aldehydes with a roasted almond aroma. Other highly odorous molecules can also be identified that result from the thermal degradation of carbohydrates: oxygenated heterocycles responsible for fried and burnt odors. We also find nitrogenous heterocycles such as pyrazine, which are known to give off an intense smell of cocoa, praline, and fresh bread at very low concentrations.

These dosages thus allow the main aromatic compounds in the wine to be extracted, which originate from the oak wood. This enhances the typicality of the wine, which develops its woody character during aging. This is how we find the popular flavors of coconut, freshly cut wood, vanilla, clove, roasted pepper or caramel.

Oak wood consists of two main types of constituents: high molecular weight compounds that make up the cell wall (cellulose, hemicellulose, lignins) and low molecular weight compounds (extracted organic compounds, minerals). Various authors have quantitatively analyzed the composition of oak wood (macromolecules and extractables:

coumarins, lactones, phenols and phenolic aldehydes, triterpenes, oak wood tannins) [82-86].

Pascal Chatonnet et al. [60,70-72] studied the effect of oak wood toasting intensity on some extracted compounds. By knowing both the thermal parameters that characterize the different toasting operations and the evolution of compounds extracted from wood depending on the toasting intensity, it is possible to provide better control of the barrel production process. This should make it easier to adapt the level of barrel toasting to different types of wine.

The study was conducted by groups of oenology consultants, members of the Vino Latino association [32] (Laboratoires Dubernet, Groupe Oenoconseil&Cœ, Laboratoire Rière) after the use of ecological wood was authorized under CE 2165/2005 and CE 1507/2006. The aim was to measure the organoleptic and analytical significance of the criteria provided to characterize the different scion lots and to assess their impact in terms of oenological results.

The results obtained were statistical in nature:

- the wine matrix significantly affects the content of volatile substances in the extracted wood;
- toasting of oenological wood is the most influential parameter on the content of a certain amount of aromatic compounds in wood, as well as on certain taste characteristics;
- the oenological quality of the wood chips must be established and made available to users of oenological wood;
- the intensity and methods of wood drying as well as the management of toasting are certainly factors that strongly influence the quality and typology of oak wood for oenological use, and in particular the saturation of whiskey lactones.

As part of this study, chemical analyses were carried out at Dubernet laboratories accredited by COFRAC for the analysis of volatile compounds in wood. Three methods of wood chip maceration for the search for such compounds were analyzed:

- Furfural
- Methylfurfural
- O-cresol
- Guaiacol
- 4 Methyl Guaiacol
- Trans-Whiskey Lactone
- Cis-Whiskey Lactone
- Eugenol + Isoeugenol
- Vanillin

The research was conducted on 29 types of wood chips from 8 suppliers, 3 vinification methods and highlighted the importance of wood toasting technology. The "bousinage" toasting makes the wood pieces rich in aromatic compounds, closer to the barrel, unlike other toasting technologies.

Another study as part of the VINAROMAS project [19] assessed the matrix effect, the influence of wood type, the stage of introduction into the wine, wood sorting and the degree of toasting by monitoring aromatic markers in the wood and through sensory analysis. The wood is an important element in the creation of a wine's aromatic profile. Due to its different composition, it can be subjected to processes that give it very different characteristics, which will have an impact on the wines and allow the profiles to be orientated in several ways:

- By balancing the taste.
- By enhancing the sensation of sweetness (increased sweetness, reduced greenness) with elements low in furan compounds.
- By reducing piracy notes and enhancing ripe fruit, woody notes and flavor structure.

It is important to note that the amount and type of volatile compounds extracted from alternative oak products depends on various factors, such as the type of oak, the type of wood treatment, the degree of wood toasting, the duration of contact between wine and wood, etc. Besides, volatile compounds can interact with the components of wine or other beverages during aging, adding an additional dimension to the aromatic complexity of the final product. By using oak wood during wine aging, producers can influence these volatile compounds, creating specific flavor profiles and adding complexity to the wine. This is why the choice of oak wood and the aging process are crucial elements in wine production.

Conclusions

Wood is an important element in creating a wine's aromatic profile, but like any oenological technique, it can only bring out the intrinsic qualities of the grape. Wine quality is first and foremost the result of the quality of the grapes, and no trick, especially wood, can ensure it. Wood cannot replace the original quality of grapes. Therefore, it is extremely important that the winemaker takes care of his grapes first. For wines to remain enjoyable, they must retain the flavor of the fruit of the vine.

The attitude towards alternative oak products is changing. Nowadays, the term "chips" is hardly used and has been replaced by the term "alternative oak" or "oenological wood", as "chips" has a somewhat derogatory attitude. It is important to let the consumer know that this is a noble raw material that is a real high-tech know-how of the old industry. Quite often, winemakers and consumers imagine that these products are made from sawdust. The reality is quite different; this alternative to oak is a refined, complex and useful product.

Currently, alternative oak products have become a powerful tool for the oenologist. A wide selection of wood pieces allows the winemaker-technologist to adapt the use of wood to the goals of his wine (aroma, structure, sweetness), to develop the fruity character of wines, masking their defects (dilution, grassy notes).

The controlled use of alternative oak products allows to minimize the significant difference between aging wines in oak barrels and in neutral containers with the addition of pieces of wood.

With neutral containers, oenological oak wood is the vinification technology of the future in a sustainable way.

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ВИКОРИСТАННЯ ДУБОВОЇ АЛЬТЕРНАТИВНОЇ ПРОДУКЦІЇ ПРИ ВІНІФІКАЦІЇ

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Анотація. Традиційно витримування кращих вин проводиться в дубових бочках. Загальновизнано, що якість вин та міцних залежить від їхнього витримування в контакті з дубовою деревиною. Відбір дубової деревини та її дозрівання є обов'язковими етапами виготовлення бочок. З огляду на значну кількість факторів, залучених до вибору сировини та фази природного сушіння дубової деревини, дуже складно визначити їхній вплив на якість отриманого вина. Вина, витримані в контакті з деревом, користуються великим попитом у споживачів у всьому світі. Деревина дуба дозволяє змінити органолептичні характеристики вина. Численні явища виникають під час витримування в деревині та впливають на структуру вина. Це в основному окислювально-відновні реакції, розчинення летких і нелетких компонентів деревини, якими збагачуються вина. Аромати, отримані з деревини дуба, сприяють формуванню ароматичного профілю вина, а основні екстраговані поліфеноли елагітаніни можуть змінювати смакові відчуття, такі як терпкість і гіркота. Таким чином, усі сполуки, отримані з деревини, сприяють збалансованості та якості вин. Самі ці явища залежать від численних параметрів, включаючи характер і умови виробництва бочок, а також температуру зберігання або вміст етанолу в алкогольних напоях, які підлягають дозріванню. Витримування вина в ємностях з додаванням альтернативних продуктів з дубової деревини стає все популярнішою в усіх винbackробних країнах світу. Основними причинами розроблення таких продуктів є оптимізація їхнього виробництва, зниження собівартості витримування вин, а також підвищення рівня гігієни на виробництві. У цьому огляді йдеться про традиційні та альтернативні технології виноробства та їхній вплив на якість і сенсорні характеристики вина. Швидке поширення альтернативних технологій витримування виправдовує дослідження з оцінки впливу дубової альтернативи на хімічні характеристики вин і оцінки будь-яких відмінностей від традиційної витримки вин та спиртових у дубових бочках.

Ключові слова: бочка, дубова альтернативна продукція, енологічна деревина, дубова стружка, вініфікація, спиртове бродіння, витримування, обпалення, фенольні сполуки.