Wooden Cooperage*

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Wooden barrels have been used in winemaking since the pre-Christian era. In early days, barrels were used for fermentation, storage, and transportation of wine. The winemakers realized that storage of wine in barrels improved wine quality. However, they also became aware of the problems associated with storage in barrels. The major concerns were the loss of wine due to evaporation, which led to oxidation and acetic spoilage of wine, and the difficulty in maintaining wooden barrels in good sanitary condition.

In recent years, stainless steel has become the preferred material for fermentation, storage, and bulk shipping of wine. There are several reasons for this change. Stainless steel is impervious, inert, and unlike wood (particularly new) does not contribute any extractives to the stored wine. A steel tank is easy to clean and sanitize, and more importantly, when equipped, it allows the winemaker to control the temperature of the wine during fermentation and storage. Although stainless steel containers are widely used nowadays, many wineries still continue to use wooden barrels, especially to produce certain styles of premium wine.

Whether a winery should use wooden barrels for wine storage depends on several factors. One needs to consider the style of wine. For example, light, fresh and fruitier styles of whites, roses, nouveau and picnic-style reds can be better produced with stainless steel cooperage. The use of wooden barrels offers little advantage when producing these kinds of wines. On the other hand, certain full-bodied, complex reds and whites (such as barrel fermented and/or barrel aged whites) would benefit from storage and aging in wooden barrels.

Public relations should be another consideration in deciding the use of wooden barrels. Many wineries sell a large portion of their wines on the winery premises. Visitors touring the winery are often favorably impressed with the sight of wine barrels neatly stacked in the cellar. Such a positive experience by the tourist usually translates into more wine sales.

Another important consideration in choosing wooden barrels for wine storage is the economics. Barrels are expensive on a cost per gallon basis. They can leak, resulting in loss of wine, and are costly to maintain in sanitary condition. Barrel extractives add complexity to the wine flavor, but with each filling the wood flavor constituents are depleted. Therefore, in order to maintain certain levels of wood extractives in wine, new barrels have to be purchased every vintage. Many wineries buy from 30% to 50% new barrels every year. This obviously increases the cost of wine storage.

It should be noted that the barrels do offer certain convenience when working with smaller lots of wine. Sound used barrels can be used for wine storage with reasonable cost. In brief, wine style, economic, and public relations factors should be considered in deciding the use of wooden barrels in the winery.

Different woods for cooperage and the importance of oak

To make wine barrels, the wood needs to have certain desirable properties. For example, the wood should be straight grained, strong, resilient, and easy to work. It should be free of defects that may cause leaks, and should not contribute undesirable flavors. When these qualities are considered, very few woods seem suitable for cooperage. A large number have been tried for making wine barrels.

In California, redwood has been used to make large tanks, but not small (50 gal) barrels because that wood is hard to bend. Redwood is a conifer and is high in extractable phenols. About 10% to 15% of the virgin heartwood is hot water extractable. The flavor imparted by this wood is not very pleasant; therefore, the wine is usually not stored in redwood tanks for a long period. Other woods such as Douglas fir, spruce, and pine impart a resinous flavor to wine. For this reason, tanks made out of these woods should be coated with wax or another material to minimize pickup of resinous odors.

Certain woods are not suitable for cooperage because they are more porous than white oak. This includes red oak, ash, gum, and chestnut. Because of their porous nature, tanks made from these kinds of woods should be coated to prevent leakage. Of the many woods tried for cooperage, oak appears to be the most suitable since it possesses all the desirable qualities needed to make a barrel.

Desirable attributes of white oak

Oak wood is strong and resilient. Because of its resilient feature, the wood is bendable, and therefore, can be shaped into a barrel. Oak grows as a large tree and yields straight grained stave bolts. There are two characteristics that make oak wood especially suitable for liquid tight cooperage: structure and chemical composition.

The desirable structural features include the medullary rays and tyloses.

Medullary rays
Medullary rays consist of elongated cells that extend radially from the pith to the bark along the trunk axis. The rays form diffusion channels for horizontal translocation of water and nutrients.

In conifers the rays are very small, one cell wide, and are called uniseriate. In oak the rays are multiseriate (more than one cell wide) and are larger than other hardwoods. The large, thick rays make oak wood tough and resilient. In various species of oak, the rays constitute about 19% to 32% of the volume of the wood. In American white oak they occupy about 28% of the volume, and in other hardwoods and conifers, they represent about 15% and 8% of the wood volume, respectively. Since a greater portion of wood volume is made up of rays, oak wood is relatively stronger than many other hardwoods. The rays also make the oak wood dimensionally stable. This means that they permit minimum shrinkage when the wood dries. It has been noted that the radius of the oak shrinks only about 4% from wet to air dry. This makes it easier to keep the barrel liquid tight when stored under alternate wet and dry conditions. The rays also make the stave impervious to liquids. When barrel staves are made, the stave bolt (trunk) is cut into four quarters (quarter sawn). The staves are cut from the face of each quarter sawn bolt. This positions the rays parallel to the width of the stave. In this arrangement, the rays oppose the diffusion of liquid through the sides of the barrel. It is estimated that a molecule of water will have to diffuse through (cross) about five or more large rays in order to directly escape through the side of the barrel. Thus, the large rays provide a formidable barrier to the diffusion of liquid and make the wood relatively impermeable.

Tyloses
Oak is ring porous wood. Each annual ring consists of spring growth and summer growth. The pores (xylem vessels) formed during spring are larger than those produced in summer. These pores permit the flow of water and nutrient up the tree during the growing season. In white oak these pores become plugged with cellular inner growth called tyloses as the sapwood differentiates into heartwood. Tyloses development is so extensive in white oak that it effectively renders the wood impervious to the movement of liquid. It should be noted that in the absence of tyloses development, the pores would remain open. If such a wood is used to make a stave, then the wine would seep out through the end of the stave. In many oaks, the pores remain open and therefore, cannot be used for cooperage, for example, cork oak.

Chemical composition
The structural features such as rays and tyloses discussed above are important for the construction of a barrel. The chemical composition of the oak wood is important because of its effect on wine flavor. Oak wood contains many chemical constituents that contribute to the complexity of wine flavor. Many of the constituents are modified by seasoning and toasting the wood during the process of barrel making. The compounds extracted from wood into wine can further be modified during the maturation and aging of a wine.

Thus the flavor of the wine is influenced by many volatile and nonvolatile oak wood extractives and their interaction with wine constituents. A sound understanding of the oak derived compounds and their effect on the wine's sensory properties is essential to successful maturation of wine in wood barrels.

Oak wood is composed of four principle constituents. These components, along with their concentrations, are given in the following table.

Table 1. Principle constituents of oak

Principle constituent	Amount as % dry weight
Cellulose	45-50%
Hemicellulose	20-25%
Lignin	25-35%
Tannin	5-10%
Others	1-5%

Cellulose

Cellulose is the major component of the cell wall. It is made up of (2500 to 3500) glucose units bonded together by 1 to 4 linkages, forming a long structural polymer. It contributes to the strength of the wood and undergoes little change during the processing of wood.

Hemicellulose
Hemicellulose is made up of mostly 5 carbon sugars, primarily xylose and some arabinose, and small amounts of 6 carbon sugars, such as mannose and galactose. The hemicellulose polymer is smaller, about 75 to 100 sugar units, than cellulose fiber. It acts as a binding agent and holds cellulose and lignin together. When in contact with wine, hemicellulose can be hydrolyzed into sugar and the acetyl group, which can subsequently be converted to acetic acid during wine maturation.

Heat treatment of wood (toasting) causes decomposition of hemicellulose, yielding several compounds. Some of these substances include furlural, maltol, cyclotene, and ethoxylactone. The aroma of the toasted chips has been attributed to maltol and cyclotene. Ethoxylactone has been noted to give a sweet and fruity aroma to some wines (Sefton, et aI., 1990).

Lignins
Ugnins have been described as branched chain phenylpropanoid polymers. During seasoning and toasting lignins undergo substantial chemical changes. Many compounds resulting from the thermal degradation of lignin play a key role in influencing wine flavor. Some of the important lignin breakdown products and their aromatic properties are given in the following table.

Table 2. Lignin breakdown products.

Compound	Characteristic Aroma
Vanillin	vanilla
Guaicol	smoky
4-ethyl guaicol	carnation, smoky, spicy and medicinal
Ferulic acid	possible aroma precursor
Eugenol	spicy, clove-like
4-methyl guaicol	smoky
4-ethyl phenol	horsy, medicinal
p-coumaric acid	possible aroma precursor

Tannin
As the sapwood matures into heartwood, phenolic compounds are deposited in the cells. Of the phenolic compounds present in heartwood, oak tannins are the most common. Tannins protect the wood against fungal attack and help in the preservation of wood. Oak tannins are referred to as hydrolyzable tannins.

They are chemically different from the condensed tannins found in grapes and wine. They are polymers of gallic acid, ellagic acid, and glucose. In an acidic medium such as wine, these tannins hydrolyze into mostly ellagic acid and gallic acid. There are conflicting reports regarding the effect of hydrolyzable tannins on the sensory properties of wine. It is suggested that these compounds are present in concentrations too low to have a significant effect on wine flavor. However, some people believe that these substances contribute to the astringency and bitterness in wine.

Other Constituents
Some of the other compounds found in oak heartwood include resins, sterols, fats, and lactones. Oak lactone, also known as whiskey Iactone, is present in oakwood in small amounts, but its concentration has been found to increase with toasting the wood. There are several factors that influence the concentration of oak lactones in wood. At low (but detectable) concentrations, it imparts a pleasant woody aroma that enhances wine quality. At high levels, it gives a resinous and coconut-like character to wine which can be unpleasant.

References
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