Wine Aging*

By Dr. Murli Dharmadhikari

Wine aging refers to a group of reactions that tend to improve the taste and flavor of a wine over time. The term wine 'maturation' refers to changes in wine after fermentation and before bottling. During this period, the wine is subjected to various treatments, such as malolactic fermentation, clarification, stabilization, and bulk storage. The important feature of this phase is that the wine is periodically exposed to air where many oxidative reactions influence the changes in wine composition. The term aging should be reserved to describe changes in wine composition after bottling. After bottling, once the oxygen picked up at bottling is consumed, the wine is in the absence of oxygen. This is called the reductive atmosphere. Many reactions occur during this phase to contribute to the final bottle bouquet.

The aging plan or regime followed by a winery is governed by the style of wine desired. Some wines require only a short period to develop and generally do not benefit from prolonged maturation and aging. Fresh, fruity whites, picnic style blush, light reds, and nouveau style red wines are produced for early consumption and their quality peaks out in a relatively short time. These wines are generally released within a year of their production. Aging them longer is neither beneficial nor economical.

Premium varietal wines such as 'Chardonnay', 'Sauvignon blanc', 'Cabernet Sauvignon', 'Merlot', and 'Zinfandel' develop a complex flavor profile during maturation and acquire a pleasant bottle bouquet. Dry reds seem to age well for longer periods than the whites. These wines are often matured in oak barrels. The flavors from oak seem to complement the varietal aromas and the wines are rich, full-bodied, and complex. One can experience a diversity of flavors which are well integrated in a well-balanced wine.

Changes in wine due to maturation and aging

Many reactions occur during the maturing and aging phase which lead to significant changes in the composition of the wine. Many of these changes are subtle and, in some cases, so small that their impact on the sensory properties of wine is not noticeable. On the other hand, certain reactions have a noticeable effect on the various sensory attributes of wine, and they play a significant role in wine maturation and aging. Generally, during the process of maturation and aging, the most obvious change occurs in the color of the wine. In white wine, the color becomes golden, and later, can turn to brown if the wine is aged too long. In red wine, the purple and violet tints are progressively replaced by orange and brick red colors. The grape-derived aromas fade, and more complex and pleasing aromas develop. The taste of the wine also changes. Astringent and harsh tastes are replaced by smoother, rounder tastes. The various taste and aroma components integrate, yielding complex, rich, and delicious wines. (Let us take a closer look at some of these changes to gain a better understanding of the maturation process.)

Color

Color is one of the most appealing properties of a wine. The color of white wine is light yellow. During maturation, when the wine is exposed to air, the color becomes darker, and with over-aeration, becomes brown. Several phenolic compounds are involved in oxidative reactions. To minimize oxidation and browning, white wines are generally treated with minimum oxygen exposure. Besides phenolic oxidation, other reactions such as the Millard reaction and sugar caramelization may also contribute to color in white wine.

In young red wines, the bright red (with purple tint) color is due to monomeric anthocyan pigments which are extracted from the skin during fermentation. During maturation, these pigments are progressively replaced by the polymeric form, which results from the combination of anthocyanin pigments with tannin. Monomeric anthocyanins occur in various forms, such as the red colored flavylium cation, quinoidal base (blue), carbinol pseudo-base (colorless), chalcone (nearly colorless), and as a bisulfite addition compound (colorless). The various forms of anthocyanins are present in equlibrium, which is influenced by pH and other factors. An important point to note is that monomeric anthocyanins are susceptible to bleaching by $S0_2$ and with a lowering of pH, the equilibrium shifts from the colorless to colored form.

During maturation, the wine is exposed to air. Oxygen (from air) plays an important role in the condensation reaction between anthocyanins and tannins, which results in the gradual loss of free anthocyanins and the formation of stable polymeric (anthocyanin tannin) pigments. It has been observed that the poiymeric pigments account for 50% of the color density in one-year-old wine. As the wine matures and more polymeric pigments are formed, the color shifts from red to orange and brick red.

Color is often determined from optical density measurements using a spectrophotometer. The intensity of the color is measured by adding absorption values at 520 nm and 420 nm. The tint of color is measured by determining the ratio between absorption at 420/520 nm. In young reds, the absorption maximum occurs at 520 nm, the red color region. As the wine matures, the maximum absorption decreases at 520 nm and increases at 420 nm, the yellow color region. This explains the shift in well-aged wine from a red to an orange hue, and brick red color.

The condensation reaction between anthocyanins and tannins is accelerated by oxidation. If condensation continues (due to oxidation), precipitation of coloring matter occurs.

The condensation reaction mechanism includes participation of acetaldehyde under aerobic conditions. The polymerization of pigments also occurs in the absence of air. Oxygen is not involved in this reaction. In the absence of acetaldehyde, copigmentation between anthocyanin and d-catechin has been noted by many researchers.

Taste and mouth feel
With proper maturation and aging, the wine becomes mellower and smoother, and acquires a richer mouth feel. Many compositional changes contribute to the improved taste. The important changes include polymerization of phenolic compounds and reduction in acidity. Phenolic compounds play an important role in the taste and flavor of wine. White wines contain mostly nonflavonoid phenols; whereas, in red wines, flavonoid phenols dominate. Bitterness and astringency is primarily attributed to flavonoid phenols. The monomeric flavonoids are more bitter than astringent. As flavonoid phenols polymerize, they become less bitter and more astringent. With further polymerization, the molecules become too large, and finally precipitate. This leads to a reduction in phenolic compounds and also in astringency. During maturation, oxidative and non-oxidative polymerization and precipitation of phenolic compounds (of larger molecules) occurs. This results in a wine with reduced astringency and a smoother, softer taste. Maturation, therefore, plays a key role in improving wine's sensory appeal.

Another factor contributing to improved taste is loss of acidity. This occurs due to acid precipitation and ester formation. Acidity enhances the astringency and loss of acidity makes wine taste less astringent and more mellow.

Aroma
Significant changes in wine aroma occur during maturation and aging. These include the loss of certain grape or yeasty aromas, retention of the varietal aroma, formation of new aromas, and above all, integration of all flavors to produce a harmonious and pleasing fragrance. Many esters and higher alcohols formed by the yeast's metabolic activity contribute to the fermentation aroma. During wine storage, the esters are hydrolyzed and the fresh and fruity aroma is lost. Concurrent with the degradation of esters, a synthesis of new esters occurs. For example, the formation of isoamyl acetate and diethyl succinate.

In wines with strong varietal flavor, both qualitative and quantitative changes in aroma take place. For example, in muscat varieties, terpenes are the main odorous compounds. During maturation and aging, the concentration of monoterpene alcohol declines and monoterpene oxides are formed. This leads to the loss and alteration of floral aroma. In Riesling, linalool is found in significant amounts. This terpene compound gives a floral aroma to the wine. The oxide terpene derivatives, such as alphaterpineol, have a pine like odor; whereas, its precursor linalool, as indicated earlier, has a floral fragrance.
It should be noted that terpene compounds also occur in a bound form. In an acidic medium, such as wine, the bound terpenes are slowly converted to free volatile terpenes over time. When these reactions occur, the fruity aroma of a wine is enhanced during maturation.

Bouquet of bottle aged wine
The bouquet of a wine is very complex and consists of many aroma compounds. In Reisling wine, the bottle bouquet has been closely identified with 1,1 ,6-trimethyl-1 ,2-dihydronaphtalene (TON) and dimethyl sulfide. TON has a 'kerosene-like' odor and OMS has an odor of reduced sulfur compound. OMS aroma, however, is perceived as a part of mature bottle bouquet.

Other changes
Other aromas resulting from oak aging are important and are considered in greater detail later in this paper.

Some undesirable changes occur during wine maturation and aging. Aldehyde or nutty aromas can develop due to oxidation of wine. Many off odors are formed due to spoilage by yeast and bacteria. These odors, however, should not be a part of a well made wine.

Factors affecting wine aging

Oxidation
Oxidative changes are an important part of wine maturation. These changes include the development of a

golden brown tint during aging, loss of varietal character, and the development of aldehydic aroma. These reactions are common to both white and red wine, but they are more noticeable in white wine.

The rate of oxidation depends on pH, temperature, concentration of dissolved oxygen, and the phenolic composition. Oxidation is greater at high pH and high temperature. Wine maturation can be accelerated with storage at higher cellar temperatures. However, such treatment can have an adverse effect on the quality of a premium wine.

Oxidation also depends on the phenolic composition of the wine. Hydroxycinnamates, which include caftaric acid, coutaric acid, and fertaric acid, are major nonflavonoids found in grape juice. They are common to both white and red wines. Caftaric acid is quickly oxidized. It plays an important role in the browning of white wine. Gallic acid, though present in wine in relatively small amounts, also serves as a substrate for oxidation. Catechins are flavonoid phenols and are major components of red wine phenolics. Catechin and epicatechin are both oxidizable phenols and able to condense into polymers in the absence of air.

The amount of oxygen in wine has an important influence on oxidation. When exposed to air at room temperature, a wine can dissolve 6 ml of oxygen per liter. Thus 6 mill can be considered one saturation. It is crucial to know the amount of 02 a wine can take before a loss of quality becomes apparent. Generally, fresh and fruity white wines are best handled with minimum exposure. For this reason, they should be protected during maturation with the help of inert gas(es), such as nitrogen and C02. Full-bodied, more complex white wines may improve in quality with an 02 exposure of five saturations or 30 mi/L. At 60 mill of 02, a white wine begins to show oxidative character. Red wines can consume more oxygen and typically improve with 02 pickup, up to 60 ml/L. The perception of quality remains until twice the amount (120 ml/L) of 02 is consumed. It appears that 02 consumption in the range of 50 to 100 mill may be best for maturing typical red wine.

Temperature
Temperature affects various reactions involved in wine maturation. Since many reactions are physiochemical in nature, they are accelerated at elevated temperatures. To prevent rapid aging and loss of quality, fresh, fruity and young white wines should be stored at a cooler (<10ºC) cellar temperature. To accelerate aging in certain styles of wine, high temperature storage under anaerobic conditions has been tried. Such a maturing practice may be useful for certain wines, but its wide scale application seems doubtful.

Light
Light exposure has been known to affect wine aging. Particularly, wine exposure in the ultraviolet radiation range can initiate an oxidative reaction. A light-struck aroma is a good example of the type of reaction mentioned above.

*Previously published in *Vineyard & Vintage View*, Mountain Grove, MO