Common Elements in Winemaking and Maturation

7

There are certain factors and processes that are common to all wines and these are explored in this chapter. It is important to get an appreciation of their roles in winemaking and maturation and how they influence the style and quality of wine in order to be able to understand why white, red, rosé and sweet wines are made the way they are.

DIFFERENT WINEMAKING APPROACHES

Winemaking is a process that starts with grapes and ends with wine. After harvest, the grapes are processed and prepared for alcoholic fermentation, at which point yeast convert the sugars in the grape juice to alcohol. Once this is complete, the wines need to be stored prior to packaging and sale. None of this can happen without the intervention of humans and the hundreds of choices they make along the way.

In recent decades advances in our scientific understanding of winemaking and the application of this knowledge has meant that many more options are now available for winemakers to choose from. As a result, very different views on what approach to take have now evolved.

There are some winemakers who choose to control each part of the winemaking process as much as possible. They have a particular stylistic goal, and they tailor their winemaking techniques to make sure they achieve this goal. However, there are some winemakers who choose to take a more hands-off approach. They may monitor the wine's progress throughout production, but overall the wine is produced with as little human intervention as possible. Compared with the majority of wines on sale, wines made with minimal intervention often have a very different taste profile. They are sometimes referred to as natural wines.

The approaches described above are at two ends of a spectrum with many winemakers taking a stance somewhere in between. In this chapter we will simply focus on the techniques that are used to make the vast majority of wines that are available today.

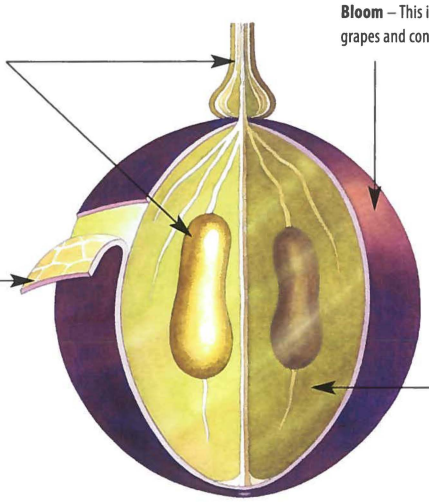
COMMON ELEMENTS THROUGHOUT WINEMAKING AND MATURATION

Oxygen

Oxygen is a gas that can react with grape juice as well as with many of the component parts of a wine during the winemaking and maturation process. The effect of these

CONSTITUENT PARTS OF GRAPES

This diagram shows the key parts of the grape and the role they play in winemaking.



Seeds and stems – Seeds and stems both contain tannins. Seeds also contain high levels of bitter oils. The stems are only available to the winemaker if grapes are hand harvested.

Bloom – This is the waxy surface that covers the skins of the grapes and contains yeast that can be used to ferment the wine.

Skins – A grape's skin and the area immediately beneath contains a high concentration of flavour compounds, which give each grape its signature varietal character. The skins also contain tannins (see below) and colour compounds. The amount of tannins and colour in black grapes is significantly higher than in white grapes.

Pulp – Water is by far the largest single component in a grape's pulp and consequently in the wine as well. Sugar is the second largest component in a grape's pulp and is of vital importance: the yeast will use it to make alcohol. Acids are also found in the pulp. The most abundant acid is tartaric acid followed by malic acid, and these grape acids are present in the finished wine.

Tannins – A large number of chemical compounds are classed as tannin. At *véraison* they taste very bitter and astringent and, as the grapes ripen, the level of bitterness and astringency falls. Note that oak can also contribute some tannins to both red and white wines.

chemical reactions, referred to as oxidation, is sometimes positive and sometimes negative.

Oxygen in winemaking – For any winemaker who wants to make a wine dominated by primary fruit characteristics, oxygen is an ever-present threat that needs to be countered. Antioxidants such as sulfur dioxide are used, and every effort is made to keep oxygen contact to a minimum. Grapes are picked at night when it is cooler and the effect of oxygen is reduced because chemical reactions occur more slowly at lower temperatures. The grapes are kept chilled until they reach the winery. Once there, all efforts are made to keep the grapes and juice away from oxygen by filling airtight winery equipment with either carbon dioxide or nitrogen before they are used for grape processing or winemaking. This process is sometimes referred to as protective or anaerobic winemaking.

Some argue that wines made in this manner can be bland and uninteresting and that a higher level of contact with oxygen during the winemaking process helps to develop complexity and character in a wine. This ultimately is a question of winemaking style.

Oxygen in maturation – Wines that have been protected from oxygen during winemaking rarely if ever benefit from any contact with oxygen during maturation. In this instance the wines are stored in inert airtight tanks or vats that are kept completely full. These vessels are either made from stainless steel or from cement lined with epoxy resin.

Wines that are matured aerobically (in contact with oxygen) are stored in wooden vessels that are normally made of oak. Oak may be watertight but it is not airtight. Small amounts of oxygen can make it through the oak to react with the wine. This can help to soften tannins in red wines and gives more complexity to the flavours of the wine; primary fruit flavours gradually fade and tertiary characters start to develop, such as leather and earth. The wine may also change in appearance: red wines gradually become paler and gain a hint of brown; white wines become deeper in colour, and gain a hint of orange.

The amount of oxidation depends on the size of the vessel and the length of time the wine is stored in it. Small vessels such as 225-litre *barriques* have a greater oxidative effect than larger vessels as they present a proportionately larger surface area of wood to the wine. Consequently, wines are rarely kept in *barrique* for longer than two years. Wines kept in larger oak vessels may be matured for longer.

The effect of oxygen can be further enhanced if the container is not completely full. This technique is sometimes used for fortified wines that are deliberately oxidative in style such as *Oloroso* Sherry, Tawny Port and Rutherglen Muscat. This extra oxygen contact, which can sometimes last for many years, means that these wines develop a pronounced tertiary character of caramel, toffee and nuts.

For most wine, too much exposure to oxygen can be damaging. The resulting wine can lose much of its fresh fruit flavour and smell stale. In these instances the wine is said to be oxidised and is unfit for sale. In extreme cases, bacteria will use oxygen to change the wine into vinegar, rendering the wine undrinkable.

Sulfur Dioxide

Sulfur dioxide (SO_2) is almost indispensable in the winery. It acts as an antioxidant and an antiseptic. It can be used to protect freshly harvested grapes and levels are adjusted throughout the winemaking process. The upper levels of SO_2 in wine are strictly controlled by law because it can be toxic (although the concentrations found in wine lie far below toxic levels and are lower than those that can be found in dried fruit). It can also cause allergic reactions even at low levels. Although some SO_2 is produced naturally in fermentation, most winemakers agree that keeping additions of SO_2 as low as possible is preferable, not least because if levels become too high the wine can seem harsh and lacking in fruit. A very small number of winemakers go a step further and refuse to use SO_2 at all.

Antioxidant effects – SO_2 protects the grape juice and wine from the effects of oxidation. In doing this, SO_2 loses the ability to have any further protective effect and becomes what is known as 'bound'. Levels of SO_2 therefore need constant monitoring and replenishing to ensure the wine remains protected.

Antiseptic effects – SO_2 is toxic to the many strains of yeast and bacteria that can cause unwanted flavours in wines. Fortunately for winemakers the principal yeast involved in the alcoholic fermentation is able to tolerate levels of SO_2 that are toxic to these other species.

Oak Vessels

The vast majority of wooden vessels used in the winery for fermentation and maturation are made of oak. As stated above, oak vessels allow a small level of oxidation while the wine is maturing, allowing tertiary aromas to develop. However, the wine can also extract tannin and flavours from the oak itself. Oak tannins give more structure to both red and white wines, increasing their textural complexity. Oak can give aromas and flavours such as toast, vanilla, smoke and cloves. Hygiene is a particular challenge when using oak, because it is difficult to keep wooden vessels completely free of yeasts, bacteria and moulds. Wine can be ruined by tainted wood.

Oak vessels differ widely in their characteristics and many winemakers will purposely use many different types of vessels to enhance the complexity of the final wine. There are four important factors to consider:

Species and origin of oak – Different species of oak have different characteristics but it is also possible for

WINERY VESSELS

1. Oak; on the left new oak barrels, on the right large oak vessels.
2. A close-up of oak staves.
3. Concrete tanks. A rack of oak staves can be seen in front of the tanks.
4. Concrete vessels shaped like eggs have become fashionable in recent years. The shape of these vats is thought to aid the natural flow of the juice/wine, reducing the need for manual punching down and pumping over.
5. A large winery equipped with stainless steel tanks.

the same species of oak to show different characteristics depending on where it is grown. Most winery oak vessels are made from either European oak or American oak. European oak has broadly similar characteristics whether it comes from France, Hungary, Russia or elsewhere, although there are some forests, especially in France, that are considered to produce the finest oak.

Size – Small vessels (commonly referred to as 'barrels'), such as the 225-litre *barrique* and the 228-litre *pièce,* have a much greater effect on the wine than larger vessels, which can reach sizes in excess of 2000 litres. This is because in smaller vessels more of the wine is in contact with the surface of the barrel.

Production of oak barrels – The way in which the barrel is made has a vital influence on how it will affect the wine. Arguably the toasting of the barrel is one of the most important procedures in this sense. The barrel production process involves heating the staves so that they can be bent into shape. This heating process also transforms the tannins and flavour compounds in the oak, giving notes of sweet spice and toast. The temperature and length of heat exposure, referred to as the level of toasting, affects what flavours the barrel contributes to the wine.

Age – The effect of toasting diminishes each time the barrel is used. A barrel that has been used once gives a wine less flavour than a brand-new one and, by the time a cask is on its fourth usage, it imparts little flavour or tannin. The flavours of new oak are not desirable for all wines and some producers choose not to use new oak barrels in order to make a wine with more subtle oak flavours.

Oak Alternatives

Oak vessels are not the only means by which oak aromas and tannins can be added to a wine. Small planks of oak known as staves or even smaller oak chips can be inserted into the wine during fermentation or maturation in inert winery vessels. Both methods can provide some oak aromas and tannins at a much lower cost than using casks. The oxidative effects of barrel ageing can be replicated by adding small, controlled quantities of oxygen to the wine vessel. These techniques are still the subject of much research. As yet, premium wines are not normally made using these techniques.

Inert Winery Vessels

These vessels do not add flavour to wines or allow oxidation and consequently they are frequently referred to as inert. Most of these vessels are made of stainless steel or concrete. They are widely used for fermentation and are also often used to temporarily store finished wine until it can be bottled.

Stainless steel – Most modern winery vessels are made from stainless steel. They are easy to keep clean and can be made in any shape and size. They can also incorporate temperature control mechanisms to control the juice or wine temperature. These may be sleeves on the outside of the vessels or internal coils through which cold or hot liquid can be circulated.

Concrete vessels – These vessels are usually lined with epoxy resin, which is inert and provides a waterproof barrier. They were commonly used before stainless steel vessels became available and many have now been replaced. They can be less easy to clean and maintain than stainless steel tanks. However, some winemakers prefer these vessels because the thick concrete shells help to regulate temperature during fermentation and maturation without the need to use expensive temperature control equipment.

Glass bottles are also inert vessels than can be used for storage and maturation in the winery (see section *Post-bottling Maturation* on page 53).

GRAPE PROCESSING

Grape Reception

The grapes usually receive their first dose of SO_2 as they arrive at the winery. If the grapes are destined for a premium wine they will usually be individually checked on a sorting table to eliminate unripe or rotten grapes. Such a careful selection is rarely possible in high volume wine production.

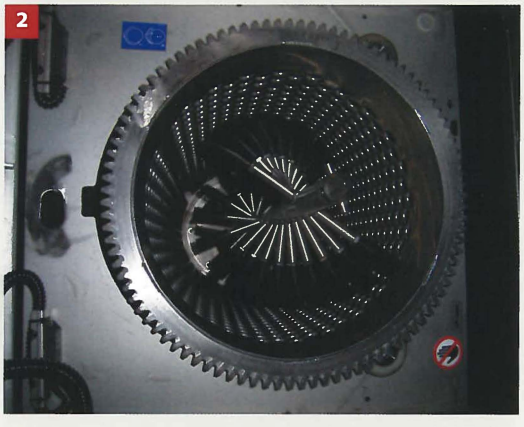
Destemming and Crushing

These are both optional processes. Machine-harvested grapes arrive without stems, and even if the grapes have been hand harvested, most winemakers choose to remove them. This is usually done in a machine that can subsequently crush the grapes. Crushing breaks the skins of the grapes and liberates a quantity of juice, known as free run juice, but it should avoid damaging the seeds. If seeds are crushed they will release bitter oils and tannin, and the wine may become unpleasantly astringent and bitter.

Pressing

Pressing separates the liquid and the solid constituents of the grape. In the case of white wines, pressing occurs before the start of fermentation, while for red wines this typically happens after fermentation. As with the crushing process, seeds should remain undamaged. Modern techniques are designed to achieve a gentle pressing of the grapes for this reason.

Traditionally, all wine presses were vertical, with the pressure on the grapes coming from above using a plate that was raised or lowered using a screw or a lever. These vertical 'basket' presses, now often fully automated, are still used by many wineries particularly, but not exclusively, in the Champagne region. Pneumatic presses are a more recent development. They consist of an inflatable rubber tube within a perforated, horizontal,



GRAPE RECEPTION

1. Sorting hand-picked whole bunches on their way to the destemmer.

2. A destemmer. The paddles spin round, knocking off the grapes, which exit through the holes in the drum.

3. Sorting destemmed grapes. The red structures at the bottom of the picture are the rollers at the top of the crusher.

stainless steel cylinder, which makes it possible to apply pressure over a larger area, in a controllable way. Some pneumatic presses are built within a closed tank so that the amount of oxygen in contact with the juice is kept to a minimum.

The liquid released at the start of pressing is very different from that released towards the end, in terms of flavour and texture. The winemaker may decide to separate the liquid into different pressings, called fractions, and treat them individually. The different components can then be tasted and blended in different proportions to create a certain style. Press wine is discussed in the section *Press Wine* in Chapter 9.

ADJUSTMENTS

Adjustments to one or more of the major components of the grape juice or wine are sometimes required for a variety of reasons. Adjustments can be made before, during or after fermentation. What is legally permitted varies from region to region. Note that grape juice is commonly referred to as 'must'.

Sugar and Alcohol

In cooler climates, there may be insufficient natural sugar in the grapes to give the wine a satisfactory level of alcohol. Depending on the level of sugar in the juice (often called the 'must weight'), the winemaker may decide to carry out enrichment. This process involves increasing sugar levels in the juice by adding Rectified Concentrated Grape Must (RCGM – a colourless, odourless syrupy liquid) either before or during fermentation. This in turn has the effect of raising the level of alcohol in the final wine because there is more sugar available for the yeast to turn to alcohol. Enrichment is forbidden in many parts of the world and where it is permitted it is strictly controlled. If carried out with care, enrichment may give a better wine. If abused, it can produce a wine that tastes hard and thin, because there are insufficient flavours to balance the artificially elevated alcohol. Where sugar from sources other than grapes is added, for example sugar beet, this process is called chaptalisation.

Another option is to remove water from the juice, which concentrates the sugars and can lead to a wine that is higher in alcohol. However, removing water also concentrates everything else, including tannins, acids, flavour compounds and unfortunately any faults. It also reduces the volume of the juice so less wine can be made and sold.

It is very difficult to remove sugar from the juice, but modern machinery can remove alcohol from the wine after fermentation is complete.

PRESSES

1. Vertical basket presses.

2. Three pneumatic presses. A bladder inside the press that can be filled with compressed air presses the grapes against rigid internal structures.

Acid

Acid levels can be increased if, during ripening, grape acid has fallen too far. Acidification is normally carried out by the addition of tartaric acid in powder form. In Europe, this treatment is permitted in warmer regions only, and it is common in many warm and hot regions around the world.

Deacidification (reducing acid levels) is more common in cooler climate regions when the grape acid levels have not fallen sufficiently during grape ripening. Excess acid may be neutralised by the addition of an alkali (the chemical opposite of an acid).

FERMENTATIONS

Alcoholic Fermentation

This is the conversion of sugar into alcohol and CO_2 through the action of yeast. The other by-products of this process are heat and flavour compounds. The yeast species that is responsible for the majority of wine fermentations is *Saccharomyces cerevisiae*, due to its tolerance of relatively high levels of alcohol and SO_2. Alcoholic fermentation will not start if the temperature is below 5°C and should continue naturally until all the sugar has been consumed.

Alcoholic fermentation may stop before all the sugar is consumed. This can happen if the yeast run out of the nutrients they need (other than sugar) or if the temperature reaches over 35°C. When the sugar concentration in the juice is very high, the combination of high sugar levels and alcohol can be enough to stop the yeast from functioning. In extreme situations the sugar level can be so high that yeast may even struggle to start the fermentation in the first place.

In some instances the winemaker may want to stop the fermentation before all of the sugar has been converted to alcohol. This can be achieved by either killing or removing the yeast. Yeast can be killed by adding SO_2 or by adding grape spirit (see section *Sweet Winemaking* in Chapter 8). Yeast can be removed using filtration and typically this will be done after the fermentation has been temporarily halted by chilling the fermenting wine to below 5°C.

There are two important ways in which a winemaker can control the fermentation: the choice of yeast and temperature management.

Yeast – The winemaker can choose between relying on the various ambient yeast strains found on the grape bloom and in the winery, or adding a cultured yeast strain to the must. Using ambient yeast strains can produce complex flavours in the final wine, but has the disadvantage that the winemaker cannot control exactly which yeasts are present. There may also be some variation between batches, which would be particularly unsuitable for high-volume wine production.

Commercially available cultured yeasts are individual strains of *S. cerevisiae* that have been specifically selected because they consistently perform and produce attractive flavours. However, some winemakers argue that using cultured yeast limits the potential complexity of the wine.

Temperature – Temperature management is important in winemaking because if fermenting wine becomes too hot, yeast are killed. However, by controlling the temperature, the winemaker can also influence the flavours of the wine being made. Fermenting at lower temperatures avoids the loss of the most volatile aromas which often have a floral character. It can also encourage the development of fruity flavours in white wines. Higher temperatures are necessary for the extraction of colour and tannins from black grape skins.

A fermenting vat is constantly monitored to make sure it is running at the correct temperature. Many vats now have their own heating/refrigeration system, making temperature control relatively easy. Excess heat can also be released by pumping over (see section *Cap Management Techniques* in Chapter 9). Precise temperature control during fermentation is an important development that has made a huge contribution to the quality and consistency of modern winemaking.

Malolactic Fermentation (MLF)

Malolactic fermentation usually takes place once the alcoholic fermentation has finished, and is carried out by lactic acid bacteria. They convert the tart malic grape acid (also found in apples) into the softer lactic acids (also found in milk). MLF softens and reduces acidity, as well as creating buttery flavours and producing CO_2. MLF may be encouraged by raising the temperature of the wine and by not adding SO_2 after the alcoholic fermentation. It can be avoided through storage at cool temperatures, the use of SO_2, or by filtering out the bacteria.

PRE-BOTTLING MATURATION AND BLENDING

Lees

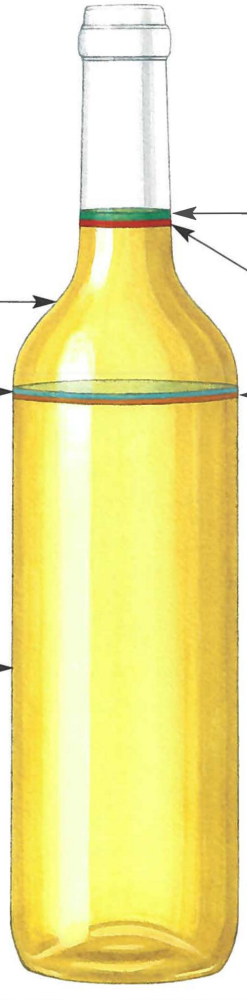
Directly after fermentation, wine can appear cloudy due to the presence of dead yeast cells and grape fragments. These suspended particles are usually heavy enough to fall to the bottom of the fermentation or storage vessel within a matter of hours. The sediment that forms is known as the gross lees and, if not removed, it can cause unpleasant aromas to develop in the wine. Smaller particles may settle more slowly. These are known as the fine lees and they are often removed gradually through the wine maturation process (see section *Sedimentation* on page 50). In some cases the winemaker may choose to keep a white wine in contact with the fine lees during pre-bottling maturation in order to add extra flavours and a richer texture to the wine.

Pre-bottling Maturation

Not every wine benefits from an extended period of maturation before bottling. If the winemaker wants to retain as many of the primary fruit aromas as possible then the wine is likely to be bottled after only a few

CONSTITUENTS OF WINE

This is a graphic illustration of a typical still dry wine that shows the relative volumes of a wine's constituents. The percentages given below cover a range that is typical for most wine. They are expressed as a percentage of the volume in a bottle of wine.



Sugars (0.1–20%)
The amount of sugar present in the wine will vary depending on the style of the wine. Sugar is obviously a major component in sweet wines but even dry wines may contain a very small quantity of unfermented sugar.

This range covers most sweet wines. Some luscious wines, such as PX Sherry, may have even higher levels of residual sugar.

Acids (0.3–1%)
The most important acids in wine are tartaric, malic and lactic.

Ethanol (8–22%)
Ethanol is the main alcohol in wine. Smaller quantities of other alcohols are also made during fermentation. (This figure includes fortified wines.)

Tannins and Colour (up to 0.4%)
Tannins and colour are particularly important in red wines.

Aroma and Flavour Compounds (up to 0.2%)
Hundreds of different compounds have been found to contribute to the aromas and flavours of wines. They are present in very small amounts.

Water (70–90%)
Water is the most abundant component in wine.

Note: These percentages are included for reference only and students will not be expected to know these numbers for the examination.

months, having been stored in an inert vessel. This is true for both inexpensive red and white wines and some premium wines too. For example, a premium Australian Riesling rarely benefits from any contact with oak or oxygen and will be stored before bottling in similar inert vessels to an inexpensive Californian White Zinfandel.

To survive medium- or long-term ageing, wines need sufficient levels of tannin, acidity and/or alcohol, and importantly, they must have flavours that will develop in an interesting way in order to make such ageing worthwhile.

Many changes can occur to wines that undergo pre-bottling maturation. The maturation vessel itself can affect the flavour by either adding oak flavours or by allowing oxidation to take place. Over time, components in the wine react with each other, which can further alter the flavour or balance of the wine. Sometimes this can lead to the formation of particles that fall to the bottom of the vessel under the force of gravity, creating a sediment that is periodically removed.

Blending

Blending plays a vital role in the winemaking process for virtually every wine, including those made from a single grape variety. Blending can take place at any stage during the winemaking process but is mainly carried out after fermentation or during the maturation process. It can be used to improve balance, attain consistency or achieve a certain style. When blending involves wines from different grape varieties, vineyard locations or vintages, the winemaker will need to be aware of any constraints imposed by local winemaking regulations (see section *Label Integrity* in Chapter 11).

Balance – Blending allows the winemaker to adjust the balance of the wine, enhancing its quality. For example, when making a red wine, free run wine may be blended with press wine to increase the tannins in the final product.

Consistency – Significant variation among the bottles of a single product will in most cases be viewed as a fault, and thus blending to attain consistency is a vital process in wine production. Wines matured in small barrels often develop in subtly different ways from one barrel to another and thus need blending together in a large vat before bottling to smooth out inconsistencies. Even without the influence of oak, different vats may need blending for consistency either due to variations in the fruit (different vineyards or different harvesting times) or due to slight inconsistencies that arise during winemaking.

Style – Blending is also very important in deciding and maintaining the style of a wine. Although variations in the weather may cause the wines of different vintages to vary, many winemakers aim to produce their wines in a certain house style. This style may range from simple and easy-drinking, to very complex and designed for long-term cellaring. In some cases the winemaker may actively seek to create as many blending options as possible throughout the winemaking process in order to achieve this style. This may include separating different press fractions, fermenting or maturing the wine in different vessels, or only allowing a proportion of the wine to go through malolactic fermentation. Using wines from different grape varieties, vineyard plots and vintages may also help to achieve this goal.

CLARIFICATION

The vast majority of customers expect their wines to be perfectly clear. There are three main techniques a winemaker can use to achieve this: sedimentation, fining and filtration. Some premium wines do not undergo all of these treatments because the winemakers believe some of them can harm the character of the wine. Their consumers often value the concept of minimally treated wines and as such are unconcerned by sediment.

Sedimentation

Most wine will undergo sedimentation after the fermentation has finished. Once the gross lees have settled in a deposit, the wine can then be slowly and gently pumped into a different vessel leaving the sediment behind, a process known as racking. The wine will continue to throw a deposit of fine lees during maturation and the clarity of the wine can be gradually improved by repeated rackings. For some fine wines, sedimentation and racking is the only clarification that will take place.

Sedimentation relies on gravity to pull the suspended particles to the bottom of the liquid but gravity is a weak force and acts slowly. This process can be accelerated by putting the wine in a centrifuge; however, this piece of equipment is generally very expensive.

Fining

Sometimes hazes or deposits may only appear in wine after a period of time in bottle. This is because some wine constituents slowly clump together over time, eventually becoming large enough to become visible. Fining is a process that speeds up this process so that these particles can be removed from the wine before bottling. It involves adding a fining agent to the wine – a substance that forms bonds with certain wine constituents and causes visible clumps to form. These clumps can then be removed by filtering.

Fining is widely practised and is generally considered an important step in ensuring wine stability. However, some winemakers choose not to fine their wines as they believe it can adversely affect flavour and texture.

Filtration

This is a process that physically removes particles from a wine as it is passed through a filter. Wines can be filtered after fermentation and during maturation to remove the

FILTERS

1. Equipment used for surface filtration. The replaceable filter membrane is positioned inside the metal casing.

Two examples of depth filters:

2. A rotary drum filter.

3. A plate and frame filter.

gross and fine lees quickly, and are usually filtered prior to bottling to ensure that the wine is clear. There are two methods of filtration:

Depth filtration – The filters used in depth filtration are made from a thick layer of material. As the wine passes through the filter the solid parts become trapped inside this material. These filters are able to handle very cloudy wines and can be used to remove the gross lees.

Surface filtration – The filters used for surface filtration resemble very fine sieves. The solid particles are trapped on the surface of the filter as the wine flows through it. The filters are very expensive and clog up extremely easily, so are generally used for wines that have already been passed through a depth filter. Where the pore size is small enough to remove yeast and bacteria that might still be present in the wine, this is referred to as sterile filtration. This can be used as a final treatment prior to bottling.

As with fining, some winemakers believe that filtration can negatively affect a wine's character, especially its texture. For this reason, some wines are bottled unfiltered.

STABILISATION

All wines change with time and so a winemaker will consider a wine stable if, over a specified time frame, it changes in a slow, predictable manner. The time frame and the amount of change deemed to be acceptable will vary from wine to wine. For example, a high-volume inexpensive red wine that should be consumed within a year of production should not throw a deposit in bottle, whereas a mature Vintage Port would be expected throw a thick deposit over the course of the 50 to 60 years it may spend in bottle. Fining, which helps with clarity, can therefore also be seen as a stabilisation process because it aims to produce a predictable outcome after bottling. There are three other important areas that require stabilisation:

Tartrate Stability

Tartaric acid is less soluble in wine than in grape juice and over time it can form crystals called tartrates. These appear as clear crystals in white wine but as purple crystals in red wine because they are stained by the colour compounds. These crystals are harmless and flavourless but for most consumers they spoil the appearance of the wine. Cool temperatures accelerate the formation of tartrate crystals and if a wine undergoes a long maturation period in a cool cellar prior to bottling, it will deposit some of its tartrates during maturation. In situations where a long maturation is inappropriate, winemakers can force the crystals to form prior to bottling by chilling the wine down to below 0°C for a short period

of time. The crystals that form are removed by filtration. As with fining and filtration, some winemakers choose not to stabilise their wines in this way.

Microbiological Stability

Many different forms of yeast and bacteria can spoil a wine and make it completely undrinkable and unfit for sale. These microorganisms can thrive in grape and wine residues, and therefore it is very important to keep winery equipment completely clean. The only wines that are not at any risk from microbiological contamination are fortified wines because the high level of alcohol they contain is toxic for all microorganisms. However, a dry, high acid wine that has undergone MLF is naturally quite resistant to microbiological spoilage. The alcohol, acidity and the lack of nutrients mean that most yeast or bacteria struggle to survive. This is not a complete guarantee, but some winemakers prefer to take this risk rather than sterile filter their wine, as described on page 51.

Wines that have not undergone MLF, as well as wines that have low to medium alcohol, low acidity and a little residual sugar, are particularly at risk from yeast or bacterial spoilage. Consequently, very careful handling and an appropriate amount of SO_2 is required to keep these protected at all times. They are also sterile filtered prior to packaging.

Oxygen Stability

If excessive levels of oxygen are dissolved in the wine, or if oxygen can enter through the packaging, the wine will oxidise, losing its fresh fruit aromas, and gradually turn brown. The risk of oxidation can be minimised by avoiding exposure to oxygen and keeping SO_2 levels topped up. The winemaker must take a number of extra precautions during packaging to ensure that oxygen does not come into contact with the wine. For example, bottles can be flushed with either carbon dioxide or nitrogen before filling to eliminate oxygen.

PACKAGING

Bottles and Alternatives

The majority of wine worldwide is packaged in glass bottles. They are portable, cheap to produce and quite strong. Importantly, they do not allow air to get into the wine, and they do not taint the wine's flavours. They remain the consumer's preferred form of packaging.

The main disadvantages of bottles are that they are heavy and rigid. Weight adds to transport costs, and their rigidity means that they cannot be packed to make

A line up of different packaging options; (from left to right) two sizes of plastic bottles, a bag-in-box and two sizes of glass bottles.

A line up of different closures; (from left to right) a cork for still wine, a cork for sparkling wine, a stopper cork, a synthetic cork and a screw cap.

the best use of the available space. To lower these costs, a number of producers have started using lighter weight glass bottles. Others now transport their wines in bulk to be bottled in (or nearer to) the country where the wine is to be sold.

The rigidity of glass bottles also means that once opened, a part-filled bottle will contain a space for air, at which point the wine is vulnerable to oxidation.

Plastic bottles are much lighter than glass. Unfortunately, the plastics used for these allow small amounts of air to pass through the plastic into the wine. This means that wines packaged in plastic bottles can lose freshness and fruitiness over a period of months. Bag-in-box packs are another form of packaging often used for large volumes of wine. The bag collapses as the wine is consumed, preventing air from entering. However, some air can still get through the wall of the bag and as a result most bag-in-box packs need to be used within approximately 18 months of being filled. Plastic bottles and bag-in-box packs are adequate for most wines, since they are intended for early consumption, but for long-term storage and ageing, glass bottles remain the best option.

Closures

A bottle, whether glass or plastic, will need some form of closure to seal it. The closure must protect a wine from harm until it is consumed. For many wines this will be within a year of bottling and therefore a type of closure may be chosen based on consumer factors such as ease of use, or practical factors such as which closures a bottling line is designed to use. For wines that are intended for bottle maturation, however, the closure must also allow the wine to mature positively. Different types of closure vary in the amount of oxygen they allow to enter the bottle over a set period of time. Similar to maturation pre-bottling, a slow entry of very small amounts of oxygen allows more tertiary flavours. In contrast, by avoiding any contact with oxygen the wine retains its fresh fruit flavours for longer. It is increasingly clear that the closure is a winemaking choice specific to the particular wine and the flavour profile the winemaker wants to achieve. Some consumer markets have very strong preferences on closure types and these may sometimes override the choice of the winemaker.

Cork – This is the original wine bottle closure and it is still the mostly widely used. It remains the closure of choice for many wines that are intended for bottle maturation as it allows a small amount of oxygen to gradually enter the bottle achieving what many winemakers would consider to be an optimal balance between primary and tertiary characteristics. However, a small but declining percentage of bottles with a cork closure suffer cork taint, and a further proportion (which increases with the age of the wine) allows too much oxygen in, oxidising the wine. Cork taint is caused by a chemical called TCA (trichloroanisole) which is present in some corks and gives the wine a mouldy, cardboard-like aroma. Cork producers have invested considerable sums in developing treatments designed to prevent the formation of TCA with varying degrees of success.

Synthetic corks – These are generally made from some form of plastic. Although these closures only used to be suitable for wines to be consumed within a year of bottling, there are now several premium versions on the market that allow longer term storage.

Screw caps – This closure was championed by producers from Australia and New Zealand and their usage has grown rapidly in the past decade. They do not taint the wine and they can provide an impermeable seal from the air. Trials have shown that they preserve the fruit flavour in the wine longer than cork. Consequently, they are becoming increasingly popular for both white and red wines where the winemaker wants to preserve primary aromas. The lack of oxygen transfer means that there is still some debate over how well wines that are destined for long bottle ageing mature under screw cap. As a result some screw caps do now permit some oxygen transfer and research in this area is ongoing. Consumer acceptance of screw caps can vary considerably depending on the national market and the market sector.

POST-BOTTLING MATURATION

The majority of wines are best consumed within a year of bottling and ageing them results in a loss of fresh primary fruit flavours. However, there are many wines

that can mature in bottle for several years and are not at their best in the years immediately after bottling. Some notable examples include Vintage Port, the finest German Rieslings and *crus classés* Bordeaux. The chemistry involved in this maturation process is still poorly understood. However, it is widely agreed that any ageing time should be spent undisturbed in a cool dark place, with a constant temperature, ideally around 10–15°C. There should also be constant humidity and, if sealed with cork, the bottles should be stored lying on their side, so that the corks remain moist and an optimum seal is maintained.