Section 5 - Post-Fermentation Processing
Lesson 14: Introduction

Post-Fermentation Processing

In this section of the course we will cover the main operations in wine production that occur post-fermentation. This includes clarification, filtration, fining, stabilization, aging and blending of wines.

The first lecture will present an overview of all of the post-fermentation operations and focus on the complex issue of wine stability. Wines must be stable against microbial activity as well as undesirable chemical and physical chemical reactions from occurring in the bottle.

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Lesson 14: The Goals of Post-Fermentation Treatments

We will begin with a discussion of the goals or rationale behind post-fermentation winery operations.

The 5 Goals of Post-Fermentation Operations:

1. **Clarity**
2. **Stability**
3. **Compositional adjustment**
4. **Style**
5. **Packaging**

There are five goals of "finishing" a wine: clarity, stability, compositional adjustment, style development and packaging. It is important, especially in white wines, that the wine at the point of consumption not be cloudy or contain any haze or precipitate. In the United States, haze is a visual defect associated with spoilage in the eyes of the consumer. It is also important to prevent unwanted microbial growth from occurring in the wine after the primary fermentation is complete as this will impact the flavor and aroma profile in unpredicted ways. *Saccharomyces* autolysis will replenish nutrients in the wine making them available for other organisms. And, as noted in the yeast lectures, *Saccharomyces* does not consume all possible bacterial energy sources. Many spoilage organisms are obligate aerobes so the wine must be protected against exposure to air once the carbon dioxide blanket generated during fermentation has dissipated.

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Lesson 14: Wine Clarity

The 5 Goals of Post-Fermentation Operations:

1. **Clarity**

The goal of the clarification practices is simply to remove existing cloudiness.

Clarification

GOAL: to eliminate existing cloudiness

There are several methods by which this may be achieved. Existing haze may be removed by filtration or centrifugation. These topics will be discussed in the next lecture. It is also desirable to remove components from the wine that will lead to the development of cloudiness over time. Cloudiness can arise from microbial growth or from the polymerization and agglutination of macromolecular components of the wine. The macromolecular components or "haze forming potential" can be removed by fining agents. This will be discussed in detail in the lecture on fining. The potential for microbial turbidity can be eliminated by stabilizing the wine against bacterial and yeast growth. This brings us to the next topic of stability.

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Lesson 14: Wine Stability

The 5 Goals of Post-Fermentation Operations:

1. **Stability**

It is important that the wine be stabilized against unwanted changes prior to bottling.

Stability

> **GOAL: to stabilize the clarity and desirable sensory characteristics**

The objective is to stabilize both the clarity of the wine as well as desirable sensory characteristics. There are three types of problems that can impact the clarity of a wine post-fermentation.

Stability: Types of Problems

- **Microbial Stability**
- **Chemical stability**
- **Macromolecuar stability**

Loss of clarity can come from three sources: microbial growth and production of polysaccharides; precipitation of chemical compounds and denaturation and complex formation between macromolecules (proteins, polysaccharides and polyphenolics).

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Lesson 14: Microbial Instability of Wine: Bacteria

MICROBIAL STABILITY GOAL:

to prevent microbial growth and/or metabolism especially in the bottle to prevent both turbidity and off-character production

Prevention of microbial growth not only eliminates turbidity but also avoids the production of microbial off-characters.

Spoilage Organisms

- **Bacteria**
- **Yeast**
- **Molds**

Microbial spoilage may be caused by bacteria, yeasts or molds. There are several bacterial species that can be problematic.

Bacteria

- **Lactic Acid Bacteria**
- **Acetic Acid bacteria**
- ***Bacillus***
- ***Streptomyces***

The lactic acid bacteria can be considered as spoilage agents if the ML fermentation occurs in the bottle or if undesired characters are produced during the fermentation.

Lactic Acid Bacteria

- **Off-character production**
  - **Mousiness**
  - **Acetic acid**
- **Turbidity**
- **Effervescence (CO_2)**
- **Polysaccharides**
  - **Haze**
  - **Ropiness**

In addition to acetic acid, the lactics may produce other off-characters such as the mousy character from the degradation of lysine. Lactic acid bacteria may also produce histamine from histidine along with other amines. These amines have no sensory impact but have been associated with headaches in some individuals. Thus, winemakers would prefer that these compounds not be produced. This is a "defect" not associated with an off-odor or off-taste, but in many respects just as important. As noted in the previous section, the ML characters may be desired or not, depending upon the style of the wine. If a lactic bloom occurs in the bottle, visible turbidity will occur due to the growth of the organisms. Carbon dioxide will also be produced, which can be considered a defect. In addition the bacteria may produce polysaccharides, which can lead to a haze or the phenomenon known as ropiness. Ropiness is rare in wine production and limited to only a few lactic acid bacteria. In severe cases the wine can become semi-solid, with the consistency of poorly coagulated Jello.

Mousiness

Several compounds (oxidation products of lysine) have been implicated in this off-character:

2,4,6-trimethyl-1,3,5-triazine
2-ethyl-3,4,5,6-tetrahydropyridine
2-acetyl-3,4,5,6-tetrahydropyridine

Prevention:

Use of SO_2
pH adjustment
Control of ML

The growth of lactic acid bacteria in the bottle can be prevented by employing procedures to prevent growth of the organisms like use of sulfite. The pH can also be lowered to prevent growth of the organisms as long as this is compatible with the style of wine being produced. Finally, as mentioned in the last lecture, the best way to prevent this fermentation from occurring in the bottle is to encourage it prior to bottling. If this has not been done, then the wine needs to be sterilely filtered and sterilely bottled.

Acetic Acid Bacteria

- ***Acetobacter aceti***
- **Require O_2**
- **Acetic acid accompanied by ethyl acetate**

It is also important to prevent the growth of the acetic acid bacteria post fermentation. These organisms are obligate aerobes and will not grow in bottled wine unless the seal is compromised.

The principle organism involved is *Acetobacter aceti*. This microbe is responsible for the conversion of wine into wine vinegar. Acetic acid production is accompanied by formation of ethyl acetate. Acetic acid itself simply gives the burning sensation of pungency by nose; ethyl acetate is quite aromatic and objectionable. It has a strong solvent note. The French describe it as "glue" but in American culture it is more reminiscent of nail polish remover. Either way, it is not a desirable addition to the flavor and aroma profile of most wines!

Prevention:

Use of SO_2
Topping off to prevent O_2 exposure
Market it as wine vinegar!

Acetobacter is a problem in barrel aging of wines if a headspace develops. This allows oxygen to enter the barrel, which stimulates the growth of the organisms on the surface of the wine. This can be prevented by limiting headspace development by topping off of the barrels (adding wine to keep the barrels full). If this all fails, the wine can be marketed as vinegar.

Bacillus

- **Turbidity**
- **No off-character production**
- **Produces resistant spores**
- **Relatively rare**

Another bacterium that can cause problems post fermentation is *Bacillus*. This type of spoilage is not common, but is quite problematic if it occurs in a winery. This is because the organism can produce heat and chemical resistant spores that are able to survive the commonly employed sanitation regimes.

This organism does not produce any off-characters but can produce turbidity.

Prevention:

Use of SO_2
Limit O_2 exposure

The only preventive measure is use of sulfite and restriction of oxygen as members of this genus are also aerobes.

Streptomyces

- **Contaminant of winery filtration equipment**
- **Imparts a "soil" character**
- **Rare**

Another bacterium that can cause problems in wine production is *Streptomyces*. *Streptomyces* is a soil bacterium that produces compounds reminiscent of the "earthy" aroma of dirt. *Like Acetobacter*, this type of spoilage problem is completely preventable.

Streptomyces is not found in wine or in barrels but will infect cellulose-based filtration matrices. It is capable of degrading cellulose in the wild as a carbon and energy source and makes no distinction between native sources of this substrate and processed cellulose filtration sheets. It is a problem only if appropriate sanitation procedures are not being used in the winery.

Prevention:

Clean equipment *after* each use!

Cleaning and sanitizing equipment immediately after each use, not waiting until it is to be used again, can prevent this spoilage. This strategy prevents the build up of microbial populations. It is wiser to prevent the bloom of unwanted organisms rather than to attempt to reduce their numbers.

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Lesson 14: Microbial Instability of Wine: Yeasts

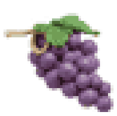
Prevention of microbial growth not only eliminates turbidity but also avoids the production of microbial off-characters.

Yeasts may also be the causative agents of wine spoilage.

Spoilage Yeast

- ***Zygosaccharomyces***
- ***Pichia***
- ***Candida***
- ***Brettanomyces/Dekkera***
- ***Saccharomyces***

Spoilage Yeast: Zygosaccharomyces



- **Turbidity**
- **Little to no off-characters**
- **Resistant to potassium sorbate**
- **Most common in semi-dry wines**
- **Predominant in juice concentrate**
- **More resistant to SO_2**

One of the principle spoilage yeasts of wine is *Zygosaccharomyces*. This yeast is tolerant to sulfite and sorbate at levels that are inhibitory to other yeasts and to bacteria. It is frequently mistaken for *Saccharomyces* because it has a similar aroma profile.

The problems associated with *Zygosaccharomyces* are turbidity and carbon dioxide production. It does not produce off-characters. It is very tolerant of high sugar conditions and will be found as a common contaminant in juice concentrate. It is important to analyze juice concentrate for the presence of this yeast prior to using it to adjust the residual sugar content of a finished wine.

Spoilage Yeasts: Pichia

- **Can produce turbidity**
- **Can produce off-characters**
- **Sensitive to SO_2**
- **Sensitive to dimethyldicarbonate (DMDC, "Velcorin")**

Another yeast that can cause wine spoilage is *Pichia*. There are several species that can be found in wine. Some are only problematic because of turbidity while others can produce off-characters and films.

These yeasts are sensitive to SO_2 and to other antifungals used in wine production.

Spoilage Yeasts: Candida

- **Some strains can produce off-characters**
- **Can form a film "*C. mycoderma*"**
    - **Oxidizes acid reducing acidity**
    - **Forms ethanal (apple)**
- **More common in barrel fermentations/aging**
- **Sensitive to SO_2 and DMDC**

Members of the genus *Candida* can also be found in wine post-fermentation. These yeasts are commonly found on the surfaces of grapes but they can also be part of the winery flora.

Some of these yeasts can also produce off-characters. A skin-like film may form on the surface of wine that results in acetaldehyde or "ethanal" (term used in the French literature) production. The French describes this as rotten apple and in low concentrations it does have this note. In higher concentrations it has the nutty character associated with sherry production. *Candida* infection is commonly associated with barrel aging. These organisms are sensitive to sulfite and to DMDC. Some of the

Candida species have been reported to be able to produce vinyl phenols usually associated with our next spoilage organism, *Brettanomyces*.

Spoilage Yeasts: Brettanomyces/Dekkera

- **Multiple off-characters**
  - **Vinyl phenols**
  - **Amino acids degradation products**
  - **Oxidation of wood aldehydes**
- **More common in barrel aging**
- **More common in red wines**

Brettanomyces is the imperfect name and *Dekkera* the perfect form of one of the most "celebrated" of the wine spoilage yeasts. Brett, as it is affectionately called, is the major contributor to the aroma profile of some high-end French wines. Many novice consumers find the traits quite objectionable, however.

This organism produces a wide array of interesting characters in wine. Off-characters can be derived from metabolism of phenolic compounds, from degradation of amino acids and from oxidation of wood aldehydes. It is commonly associated with barrel aging and fermentation in wooden casks. It is more common in red wines than in whites, probably because of the higher phenolic content. However, we have isolates in our culture collection that are quite content to grow in white juices. *Brettanomyces* produces acetate as the principle end product of sugar catabolism. Recall from the discussion of glycolysis, production of acetic acid does not allow the organism to regenerate NAD+ from NADH. Many of the Brett characters produced are reduction products that serve to regenerate NAD+ for this yeast. What compounds are produced will depend upon the composition of the wine.

The Brett Off-Characters

- **Horsy, Horse Blanket**
- **Barnyard, Fecal**
- **Wet Dog**
- **Tar**
- **Tobacco**
- **Creosote**
- **Leathery**
- **Pharmaceutical**
- **Mousy**

Brett can also produce the same spectrum of lysine metabolites as the lactic acid bacteria and can be a cause of mousiness. Which organism is responsible can generally be determined by noticing the other characters that are also present. Some of the characters listed above are highly valued in some wine styles, but not in others.

Control of *Brettanomyces*

- **Use sanitized cooperage**
- **Avoid topping off with contaminated wine**
- **Filtration of contaminated wine**
- **Use of SO_2**

Brettanomyces infection of the winery can be difficult to eliminate. It is important that sanitation procedures be developed that prevent the establishment of the organism. One common way that it is spread is by using Brett infected wines to top off other wines in the barrel room. Brett is a facultative organism and is not inhibited by the absence of oxygen. However, the presence of oxygen greatly stimulates acetic acid production because it can be used as a terminal electron acceptor. Contaminated wine will need to be sterilely filtered prior to blending with other wine in the winery. *Brettanomyces* is also difficult to eliminate because these organisms produce cellulases and are therefore able to degrade the complex polysaccharides in the barrel wood and use the resulting sugars as an energy source. This means they are able to persist, if not flourish, under conditions inhibitory to other spoilage microbes.

Spoilage Yeasts: Saccharomyces

- **Turbidity**
- **Effervescence (CO_2)**
- **More of a problem in wines with high residual sugar**
- **Can be prevented by use of SO_2 and sterile bottling**

Even *Saccharomyces* can be problematic if growth occurs in the bottle. Turbidity and CO_2 are the defects produced; off-character formation (hydrogen sulfide) generally does not occur. Wines with high residual sugar (glucose, fructose) are at risk for a secondary yeast fermentation occurring in the bottle.

Saccharomyces spoilage can be prevented by use of SO_2 post-fermentation, as they will not be able to detoxify this compound in the absence of sugar. However, if the goal is to produce a wine high in residual sugar, then the wine should be sterilely filtered and sterilely bottled. I emphasize the sterility of **both** processes: filtration and bottling - the wine must be protected from picking up organisms post-filtration but pre-bottling. A sterilely filtered wine that is transferred and held in a non-sterile tank, moved through non-sterile hoses and pumps, is no longer sterile. A check of the bottling line involves performing plate counts on samples of the wine before and after bottling. If the net number of organisms increases, then the wine is being infected during bottling. This means that there is a reservoir of organisms somewhere in the process and that line sanitation procedures are not effective.

Combinations of DMDC and SO_2 can be used which are more effective than either compound alone at the time of bottling. DMDC requires the use of a special dosing machine, so this might not be practical in all winery situations.

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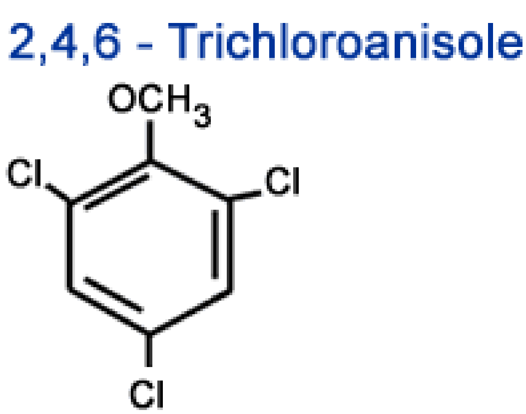
Lesson 14: Microbial Instability of Wine: Molds

Molds can also be a cause of wine spoilage. These organisms are obligate aerobes and sensitive to ethanol and sulfite, so are not a problem in wine or inside of barrels during aging. However they can grow on ethanol vapor so can be found on the outside of barrels and coating barrel room walls.

Molds

- **Not a problem if wines is protected against O_2 exposure**
- **Impart "moldy" taints**
- **Can produce "corkiness": 2,4,6-trichloranisole**

The molds can impart a moldy taint if the wine comes in contact with the mold growth, which would happen if the mold growth occurs in a bottling line for example. The principle mold spoilage characters are associated with corks. The corks may not appear moldy, they may have been exposed to mold at some point in their production or storage. It is important for wineries to develop a mechanism to evaluate the quality of corks being brought into the winery. This can be simply done by soaking a statistically significant fraction of the corks in a neutral wine over night. If the character is present it will be quite noticeable the following day. Some individuals are not as sensitive as others to the corky character, so the quality control personnel associated with evaluation of the corks should include individuals with a low threshold (parts per trillion) of detection for this compound.



The corkiness character is caused by 2,4,6-trichorloanisole. Other negative characters can also be produced by molds growing on cork surfaces. These compounds are produced as a means of detoxification of chlorine used in the cork bleaching process.

2,4,6-Trichloroanisole

- **Intense aroma of "moldy rag"**
- **Only one of several off-characters that can be associated with bad corks**
- **Can be formed in absence of cork if have the right conditions: phenolic compounds, mold and chlorine bleach**

TCA has the characteristic odor of a damp or moldy rag. Some describe it as an "old book" note. It can be formed anytime the mold is in contact with chlorine. Wineries using chlorine as a sanitization agent need to be aware that if mold populations are present TCA can be produced independent of cork contamination.

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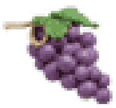
Lesson 14: Sources of Spoilage Organisms

The spoilage organisms arise from different sources in the winery. If a spoilage problem occurs it is critical that the source of the microbe be determined so that it can be eliminated.



Source of Spoilage Organisms

- **Grapes**
- **Winery surfaces/equipment**
- **Airborne contaminants**
- **Barrels**
- **Corks/materials entering winery**
- **Blending wines**
- **Humans**

Any material entering the winery can be a source of microbes. This includes the grapes, barrels (especially used barrels), blending wines, any materials used in wine production. Some spoilage organisms, such as the molds, are airborne. Or can be spread by insects such as fruit flies. It is also important to consider winery employees as a potential source of microbial contaminants.

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Lesson 14: Strategies for the Prevention of Spoilage

Prevention of Spoilage

- **Do not allow biologically active waste to accumulate**
- **Clean equipment immediately after use, not just before next use**
- **Identify source of contamination promptly**
- **Minimize outside sources of contamination (know your bulk wine!)**
- **Use SO_2 or other anti-microbial**
- **Monitor O_2 exposure of wine**

Several practices can be employed in the winery that will reduce the chance of microbial spoilage. Biologically active waste should not be allowed to accumulate in the winery. Equipment should be cleaned immediately after each use. The source of contaminants should be determined promptly and it is important to know the microbial history of any wines brought into the winery from another location. Oxygen exposure of the wines should be carefully monitored. Sulfite or other antimicrobial compounds can be used as well.

Lesson 14: The Chemical Instability of Wines

Stability

- **Microbial stability**
- **CHEMICAL STABILITY**
- **Macromolecular stability**

Wines must also be stabilized against unwanted chemical reactions post fermentation.

Chemical Instabilities

- **Metal Ions**
- **Tartrate**
- **Polymerized Phenols**
- **Oxidation Products**

Chemical Instabilities: Metal ions

- **Fe and Cu can form a precipitate "casse"**
- **Caused by use of iron or copper containing materials in winery or from pesticides**
- **Elimination: Ferrocyanide precipitation (not legal everywhere)**

Metal ions can catalyze the formation of spoilage characters as well as lead to the formation of a haze or "casse".

Current industry practice is to use tank and line materials that do not lead to the presence of metal ions in the wine. Copper can come from the use of copper-containing fungicides. Casse formation is virtually unheard of in California wine production. Copper in the presence of sulfite will form colloidal copper sulfide, which will react with proteins forming a brownish-red sediment. Metal ions can be removed from wine by fining, using cation exchangers and other methods. Removal of the protein of wine also prevents casse formation. It is important to note if the technique being used to eliminate a problem is a legal treatment. Not all treatments are allowed in all countries.

Chemical Instabilities: Tartrate

- **At low temperature, tartrate will crystallize**
- **Mistaken for ground glass by consumers**
- **Unstable in presence of Ca++**
- **Solubility depends upon pH, K+, tartrate concentrations**
- **Can get co-crystallization with other organic acids**

Another source of chemical instability is the major grape acid tartrate. Tartrate can form crystals during aging of a wine. This is typically seen as the glass-like crystals that form on the surface of the cork. They are harmless, but frequently confused with ground glass by consumers so it is considered a potential problem that must be prevented from happening in the bottle.

Several factors influence the precipitation of tartrate. Crystal formation may be catalyzed by the presence of cations like calcium, and it may be nucleated by addition of tartrate crystals (cream of tartar). Solubility of tartrate is also dependent upon the pH and potassium ion concentrations. It is also a function of the concentration of the anionic species and of other acid species as co-crystallization may occur.

Tartrate: The Solution

- **Super-chill wine to catalyze crystallization**
- **Nucleate process with tartrate crystals**
- **Add cations to initiate crystallization**

Temperature also affects solubility, so a common method for catalyzing tartrate precipitation is super-chilling of the wine. The process can also be initiated by addition of cations or crystals.

Chemical Instabilities: Polymerized Phenols

- **Can precipitate during aging**
- **Undesired in bottle**

A precipitate or sediment may also form from the polymerization of phenolic compounds.

During aging of the wine a sediment will form. The sediment will coat the surface of the glass of the bottle if the wine is bottled prior to achieving phenolic stability. The exact composition of this material is not known, but it is likely mainly a mixture of tannin and protein. It is more common in red wines of moderate phenolic content that have not been aged in oak. Other compounds may also yield sediments.

Chemical Instabilities: Oxidation Products

- **Off-color**
  - **Brown**
  - **Pink**
  - **Orange**
- **Off-characters**
  - **Aldehydes**
- **Prevented by using antioxidants**

Undesired oxidation products may also form in wine during aging.

Off-colors may form from the oxidation reactions. Browning occurs from the oxidation of phenolic compounds. There are several ways in which brown pigments may be formed, as discussed in the textbook. Pinking is obviously a problem only in white wines as this off-color is undetectable in reds. It has been suggested that the pink character is derived from the oxidation of leucocyanidin to cyanidin, but several studies suggest that this is not the pink compound formed. The orange character is rare, and the source of the off-color is not known. Aldehyde also forms from the oxidation of phenolic compounds and will be discussed in the lecture on aging. Oxidative defects can be prevented by the use of antioxidants such as SO_2 and ascorbic acid, or fining agents such as PVPP that eliminates the "pinking potential".

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Lesson 14: Macromolecular Instability in Wine

Stability: Types of Problems

- **Microbial stability**
- **Chemical stability**
- **MACROMOLECULAR STABILITY**

The macromolecule proteins and polysaccharides can form complexes in wine leading to the appearance of a visible haze.

Macromolecular Stability

- **Protein**
- **Polysaccharides**

Macromolecular Stability: Protein Instability

- **Proteins involved are from grapes**
- **Denature over time causing visible haze**
    - **Hydrophobic regions interact**
    - **Aggluination complexes formed**
    - **Complex becomes visible**
- **Accelerated by treatment of wine at high temperature (HTST)**
- **Can be prevented by fining**

Over time proteins will denature in wine exposing hydrophobic groups. The hydrophobic groups will interact with other hydrophobic material in the wine leading to aggregation and production of cloudiness. There is not a good correlation between total protein content and haze formation, as a subset of the proteins of wine appear to catalyze this process. Protein denaturation is complex and a function of the temperature to which the wine has been exposed, the pH, and the composition of the wine.

The proteins causing haze are derived from the grape, not from microbial activity. Protein denaturation is accelerated at higher temperatures. The fining agent bentonite can be used to remove protein from wine, eliminating the "haze forming potential". HTST treatments remove significant amounts of protein but lead to the formation of a bentonite-resistant haze. This may be due to the fact that protective colloidal materials have also been removed.

HTST

- **"High Temperature Short Time"**
- **Used on juices with high oxidase levels**
  - **Polyphenol oxidase from plant**
  - **Laccase from *Botrytis***
- **Used on wines**
  - **Pasteurization (Kosher wines)**
  - **Inactivation of added enzmatic activity**

HTST treatments are used to eliminate laccase activity in white wines. Heat treatments are also used in the pasteurization of wines, which results in similar haze problems. Protein hazes are largely comprised of protein but can also contain phenolic compounds and polysaccharides. Polysaccharide hazes may also form. These hazes are largely comprised of polysaccharide but can contain some protein and polyphenolic material. A quick test that we use to distinguish between the two is to evaluate the solubility of the particulate matter in hot water. Denatured proteins are not soluble under these conditions, but polysaccharide will go back into solution due to the increase in temperature and reduction in ethanol content of the medium. Chemical assays can also be used to distinguish between the two.

Macromolecular Stability: Polysaccharide Instability

- **Polysaccharides come from either plant or microbial activity**
- **Insoluble at high ethanol causing visible haze**
- **Insoluble at low temperatures**
- **More difficult to prevent/remove**

Polysaccharides may derive from the plant or from microbial activity. Plant polysaccharide content is high under conditions leading to maceration of the skins. The microbial polysaccharides are produced by bacteria. Polysaccharides are insoluble in ethanol, which is increased at low pH. In contrast to protein hazes, fining agents effectively removing "polysaccharide haze forming potential" do not exist.

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Lesson 14: Compositional Adjustments of Wine

It is frequently desirable to modify the chemical composition of wine post-fermentation.

The 5 Goals of Post-Fermentation Operations:

3. Compositional Adjustment

Several types of adjustments may be made.

Compositional Adjustment

- **Acidity**
- **Sugar level**
- **Ethanol level**
- **Tannin removal**
- **Sulfide/mercaptan removal**

Compositional Adjustment: Acidity

- **To increase acid add:**
  - **Malate**
  - **Tartrate**
  - **Citrate**
- **To decrease acid add:**
  - **Calcium carbonate**
- **To remove volatile acidity**
  - **Reverse osmosis**

The acidity of the wine may be adjusted. This is desired for several reasons, to encourage the malolactic fermentation, to achieve balance to the wine, to prevent an instability from occurring. Acidity can be adjusted in several ways.

Malate, tartrate and citrate are all legal additions in the United States. Acidity can be reduced by treatment with calcium carbonate as was allowed for juice. Volatile acidity, or acetic acid, can be removed by the process of reverse osmosis.

Compositional Adjustment: Sugar level

- **Add juice concentrate**
- **Arrest fermentation**
    - **Fortified wine**
    - **Fortified juice**
- **Temperature shock**

Generally, final sugar levels are not altered in dry table wines. However, some styles call for a higher sweetness than usually remains a robust fermentation. Sugar can be adjusted in different ways, depending upon what is allowed for the region.

The fermentation may be arrested by addition of alcohol (if it is marketed as a fortified product) or by high temperature shock. Alternately, juice concentrate may be added. The wine may be blended with a wine that naturally arrested during fermentation. It is important to protect wines with a high residual sugar from undergoing a secondary alcoholic fermentation in the bottle. Concentrate users need to be concerned about *Zygosaccharomyces* infection.

Compositional Adjustment: Ethanol level

- **Evaporative removal with return/replacement of co-stripped volatiles**
- **Reverse osmosis followed by adjustment of flavors/aromas**

The ethanol level of the wine may also be adjusted, which is obviously especially important in the production of low ethanol wines or ethanol-free products. These methods can also be used to reduce the ethanol content if it has risen to an inhibitory level and has caused arrest of the yeast fermentation.

There are several procedures for the production of alcohol-free wines that depend upon some form of evaporative removal with the return of lost aroma compounds. Reverse osmosis can also be used. With table wines, ethanol content can be adjusted by blending.

Compositional Adjustment: Tannin removal

- **Time of aging: to allow polymerization to occur**
- **Ultrafiltration: 500-2000 mw cut-off**

Tannins are very important compounds in wine. Procyanidins are polymers of flavan-3-ols that range from 2 to 8 units in size. During aging, procyanidin molecules will polymerize and undergo condensation reactions leading to the formation of tannins. Tannins are responsible for wine astringency. But bitter compounds may be removed via the formation of tannins. Tannins will react with proteins and precipitate during aging reducing both bitterness and astringency.

Tannins can be removed simply by appropriate aging of the wine. Alternately they can be removed by ultrafiltration.

Compositional Adjustment: Sulfide/Mercaptan removal

- **Copper sulfate**
  - **H_2S**
  - **Some thiols**
- **Copper sulfate + SO_2 + ascorbate**
  - **Disulfide removal**
  - **VERY SLOW**

If off-characters have formed in the wine it is of course necessary to remove them prior to bottling. The most common off-characters are hydrogen sulfide and higher sulfides produced by the yeast during fermentation.

These compounds can be removed by copper sulfate treatment, depending upon the nature of the compound. Charcoal fining can be used to remove persistent off-characters, but such a treatment may strip the wine of positive notes as well.

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Lesson 14: Post Fermentation Operations for the Expression of Style

Several post fermentation operations are conducted to impart nuances to the wine or simply as a part of the style of the wine to be produced.

The 5 Goals of Post-Fermentation Operations:

4. Style

Stylistic factors include aging regime, blending and fining treatments. Some fining agents are not neutral and will add nuances to the wine. Others are designed to remove specific wine components.

Style:

- **Aging**
- **Blending**
- **Fining**

Each of these topics will be the subject of a following lecture.

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Lesson 14: Packaging

The final and ultimate post-fermentation process is packaging of the wine.

The 5 Goals of Post-Fermentation Operations:

5. Packaging

With respect to marketing, the packaging may be as important as the contents of the bottle. Many consumers are strongly influenced by the way in which the wine is presented. Wines served from screw-capped jugs are generally ranked as lower in quality than those from corked bottles, even when the identical wine is presented in each type of bottle.

Packaging:

- **Bottling**
  - **Sterile**
  - **Non-sterile**
- **Closure**
  - **Cork**
  - **Synthetic cork**
  - **Screw cap**
  - **"Bag-in-box"**

It is important to consider the type of closure that will be used. Corks are susceptible to contamination with mold taints, but are generally associated in the eyes of the consumer with "quality". The synthetic corks eliminate these problems and allow the winemaker or marketing folks to become quite creative in the use of colors and designs. Unless the wine is to be aged for a very long time such that cork integrity issues become a factor, consumers and experienced tasters alike cannot tell the difference wines bottle-aged with a cork or screw cap. The consumer perception of the level of quality associated with each type of closure cannot be ignored, however.

Lesson 15: Introduction

Clarification and Filtration

In this lecture we will cover the two principle means of removing particles from wine: centrifugation and filtration. Natural settling may be adequate to eliminate the particulate matter of wine. This depends upon the difference in density between the particle and the wine, the particle diameter and the viscosity of the wine. Frequently, however, natural settling is insufficient to clarify a wine. In this case centrifugal force can be used to remove particulate matter. Alternately, particles may be removed by filtration by the sieving action of the filter matrix or via adsorption.

Clarification Options

- **Natural Options**
- **Centrifugation**
- **Filtration**

Lesson 15: Natural Settling

Natural settling is the gentlest and most simple form of clarification. Particles are removed due to the action of gravity. This will be successful only if the density of the solids is sufficiently different from that of the wine.

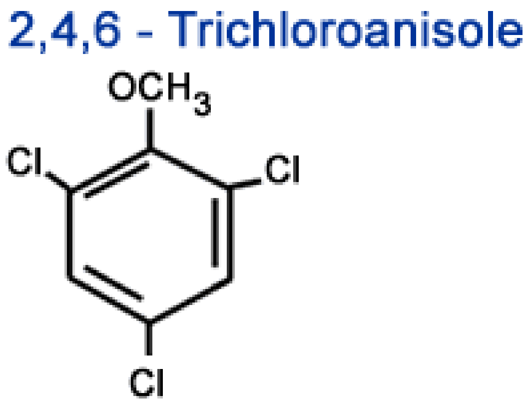
Natural Settling/Racking

- **Decanting wine off of solids**
- **May add a settling aid to "tighten" lees**
- **Volume loss high**
- **Gentle process**

The wine is then decanted or racked off of the solids or "lees". Racking is typically performed immediately after the alcoholic and malolactic fermentations unless extended sur lies aging is desired, after several months of aging in a barrel or wooden cask to remove sediment, following treatment with a fining agent, to disperse sulfite added to the wine post-fermentation, and prior to bottling or filtration. More frequent racking may occur depending upon the style of the wine being produced and the need to expose the wine to aeration, or simply because of tank management issues.

Excessive racking and movement of the wine should be avoided. Each time the wine is racked it is exposed to oxygen and there is a potential loss of volatile compounds due to the more exposed surface area of the wine as it is being transferred, depending upon how the racking is performed. To minimize oxygen exposure the wine can be racked from the bottom of one tank or barrel to the bottom valve of the new tank or barrel, allowing the liquid to fill from the bottom gently. Alternately the wine can be transferred to the new tank or barrel through the top or bung hole allowing the stream of wine to "splash" into the new container. If still more aeration is desired, a screen can be used on the top of the new tank or barrel making a fine spray of the wine exposing more wine surface area as droplets are formed.

A settling aid such as silica sols can be used to promote gravitational settling. The wine volume loss may be high. However, this process is the most gentle to the wine and does not expose the wine to as much oxygen or generate as large of a surface area as other clarification operations.



The rate of settling is a function of the terminal velocity of the particles in suspension. Settling rate can be increased using centrifugal force. This can dramatically increase the settling force several hundred fold.

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Lesson 15: Centrifugation of Wines and Juices

Centrifugation: Types

- **Desludging**
- **Decanting**

There are two types of centrifuges: desludging and decanting. Desludging centrifuges accumulate the solids material inside of the centrifuge bowl and are therefore batch operations. The solids are then removed by the process of desludging. Desludging may be done continuously, but this is not common practice. In contrast decanting centrifuges are operated continuously discharging both a paste of solid material and the clarified wine. If juice is to be centrifuged, decanting is preferred to desludging.

Centrifugation: Function

- **Removal of particles using centrifugal force**
- **Can be adjusted to remove larger or smaller particles**

The rate of speed of the centrifuge can be adjusted which will determine the amount of centrifugal force applied. The higher the force, the smaller or less dense the particles that can be removed. This allows the winemaker to determine the amount of solids remaining in the juice or wine.

Centrifugation: Problems

- **Aeration**
- **Cost**
  - **Modified atmosphere**
  - **Low temperature**

Centrifugation may expose the wine to aeration. Centrifuges represent a capital investment that may not be justified at moderate to small wineries. If it is necessary to conduct the operation under a modified atmosphere or under refrigeration, this will add to the cost of the production of the wine. On the positive side, centrifugation does not lead to the accumulation of a large volume of waste with a high biological and chemical demand for oxygen, and minimizes the loss of wine.

Lesson 15: Filtration of Wine

Suspended particles may also be removed by the process of filtration. Filtration works by trapping suspended particles, allowing the liquid to pass through the matrix. We will first discuss the types of filtration processes and then the types of units available.

Filtration

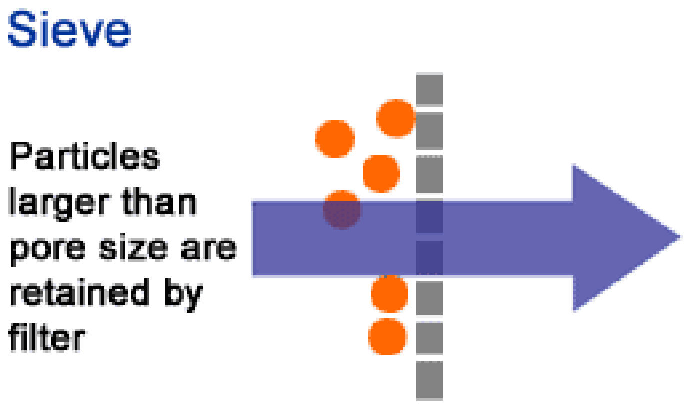
- **Types of filtration processes**
- **Kinds of filters units**

There are two types of forces at play in filtration: sieving and adsorption. Sieving refers to the exclusion of particles simply based on size. The matrix has a specific pore size and larger particles will not pass the matrix. In adsorption the particles adhere or attach to the matrix.

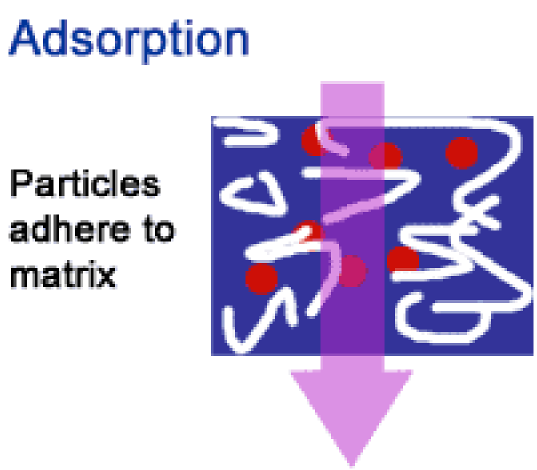
Filtration Processes

- **Sieve**
- **Adsorption**

The pore sizes of filter matrices can range from 0.45 to 200 mm. The lower pore sizes will exclude yeast and bacteria and comprise a sterile filtration if done properly. Large pore size filters are called rough filtration. Intermediate pore sizes might be called polished or tight filtration in the literature.



Adsorption can also be involved in the removal of particulate material of wine. This is typically based upon a charge interaction between the particles and the matrix or between the particles and other material excluded from the filter. The charge arises on the surface of the particles due to the flow of the fluid around the solid material.



Most filtration matrices involve both adsorption and sieving.

There are two types of problems associated with filtration: fouling and clogging. In clogging accumulation of the solid material at the pore surface blocks the openings preventing the liquid from passing into the matrix. In fouling, the applied pressure forces denaturation of the particles on the surface, which more completely plugs the pores.

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Lesson 15: The Types of Filters

There are four basic types of filtration processes used in wine production: Diatomaceous Earth (or depth bed), pad, membrane and cross-flow filtration.

Kind of Filter Units

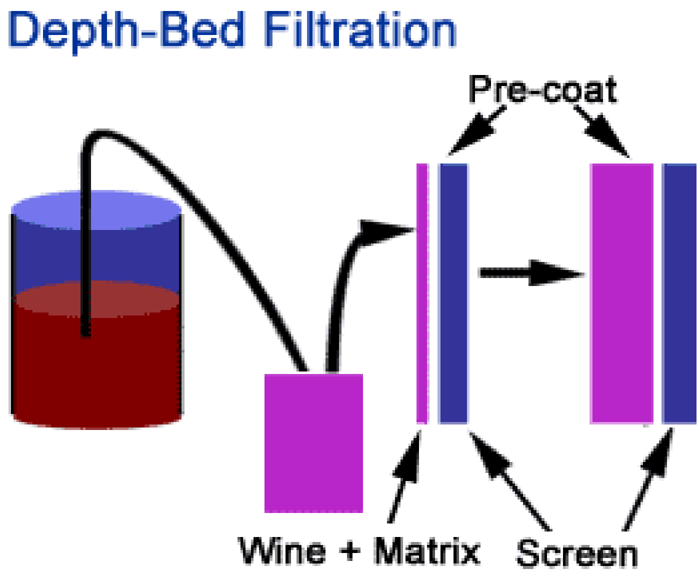
- **Depth-bed**

In depth bed filtration Diatomaceous Earth(DE) forms the matrix or porous cake through which the wine is filtered. It is a depth filtration because the DE is added continuously with the wine and the matrix thus grows in size during the filtration process. This is a rough filtration.

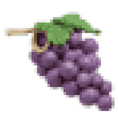
Depth-Bed Filtration

- **Filter matrix mixed with wine**
- **Filter matrix builds as wine is filtered through coated screen**
- **Constantly laying down new matrix with wine**

This type of filtration is the least susceptible to clogging and fouling. DE is derived from fossil algae shells of diatoms. Cellulose particles can also be used as a filter matrix in a depth-bed filtration. Perlite, the term for silicate particles made from the processing of volcanic rock, can also been used.



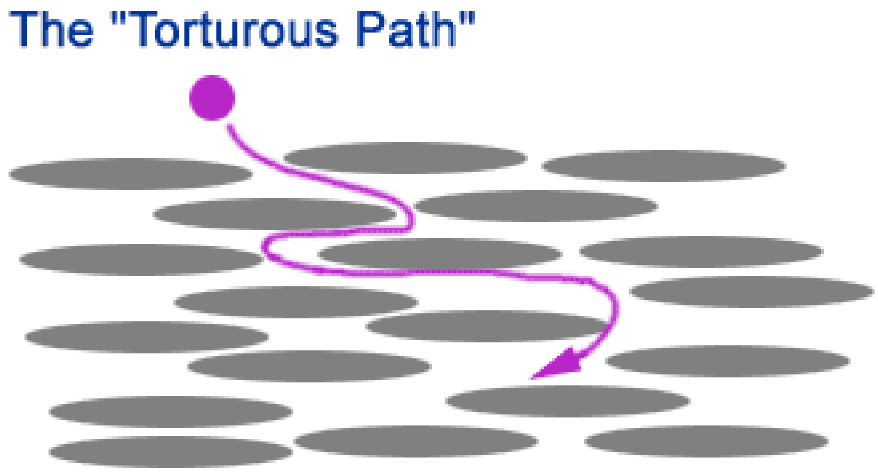
Perlite is more porous than DE but has a lower adsorbent capacity. Depth filters contain a screen upon which the cake builds. It is first necessary to precoat the screen, which is usually done using a material of a finer grade than the matrix used for the filtration. The screens or pressure leaf filters may be vertical or horizontal.



Depth-Bed Filtration

- **Diatomaceous earth; cellulose; perlite**
- **Cost effective**
- **Minimal clogging**
- **"Rough" filtration: sieving action is minimal**
- **Principle of "torturous path" for particles to travel**

These matrices can trap particles smaller than the exclusion limit of the pores. This is because of the length of time it takes a small particle to travel through the matrix that is established as the cake builds. This can be thought of as creating a "torturous path". In this case a certain percentage of the particles do not make it all the way through the matrix before the wine is completely filtered, because they are moving at a much slower rate. However, while this process may reduce the number of small particles present it will not remove them all. It is not a sterile filtration and should not be thought of as such.



The next type of filter process is pad filtration. As the name implies, in this case the wine is passed through a pad. The pad may be comprised of DE or cellulose and this is similar to depth-bed filtration, except new matrix is not being constantly laid down with the wine as it is filtered.

Kinds of Filter Units

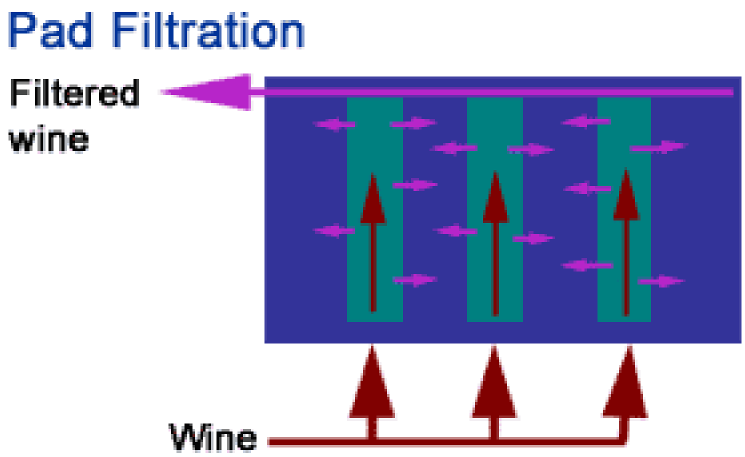
- **Depth-bed**
- **PAD**

Many of the same types of phenomena occur in pad filtration.

Pad Filtration

- **Filter matrix is a preformed sheet or pad**
- **Sieving as well as adsorption**
- **Pads come in a variety of porosities, but pore size is heterogeneous**
- **Flow of wine perpendicular to pad**
- **"Dead end" filtration**

As with depth-bed filtration the flow of wine is perpendicular to the pad. Pads come in a variety of porosities, but pore size is heterogeneous. This is also a dead-end filtration.

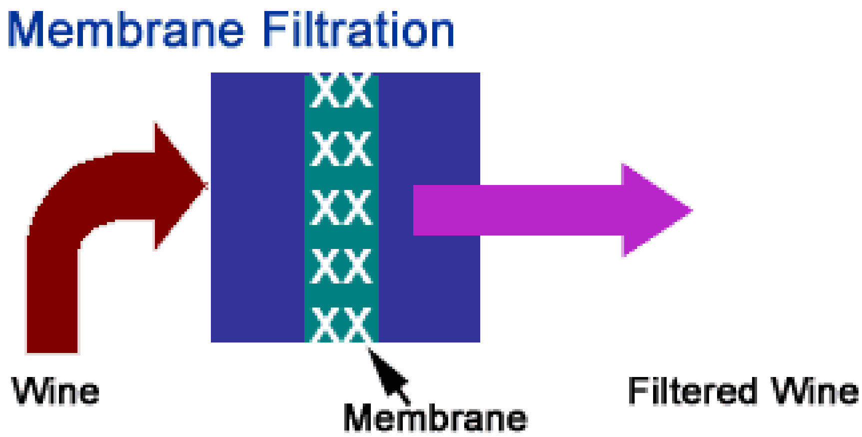


This is a simpler method, as it does not require pre-coating. However, pad filtration is more costly than depth-bed filtration. Filter pads are designed to collect particles in their interior rather than to develop a cake at the surface. In the diagram above the wine enters the bottom of the pads and flows through them to be collected. In plate and frame filters the name derives from the use of support plates to retain the filter medium and to collect the filtrate interspaced with frames, which distribute the wine across the filter medium. Pad filters operate much like the depth-bed filters in that particles are trapped using the same forces and principle of traveling a torturous path.

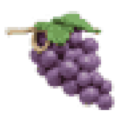
Kinds of Filter Units

- **Depth-bed**
- **Pad**
- **MEMBRANE**

The next type of filtration uses a membrane filter. Membrane or cartridge filters contain a synthetic polymer matrix. They are produced with more uniform pore sizes and are typically used for a finishing or sterile filtration. Particles collect on the surface rather than getting caught in the path. Therefore these filters clog and foul quite easily. Some adsorption to the matrix can occur, but the principle method of particle removal is exclusion or sieving.



Membranes are rated based on the largest pore size and therefore the size of the particles that can pass through the membrane. Pore size may vary, but what is most important is the largest pore size as this dictates the exclusion limits of the membrane.



Membrane Filtration

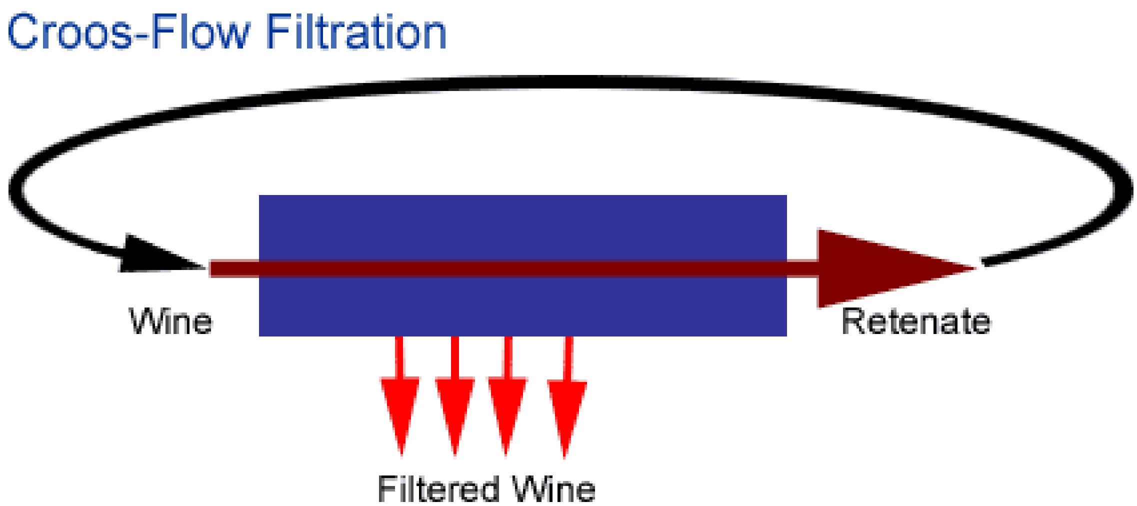
- **Like pad filtration, but uses a membrane**
- **Fixed pore size**
- **Sieving as well as adsorption**
- **Clog easily**
- **"Finishing" filtration**

The bubble test can be used with membrane filters to determine the intactness of the filter as well as the pore size. In this test, compressed gas (nitrogen) is passed into the filter unit loaded with wine. The pressure is increased until bubbles appear. The circumference of the pores of the membrane dictates the pressure at which bubbles are formed. The "bubble point" is the pressure at which bubbles are released. Other types of tests can be performed that are more amenable to automation and analysis, as shown on the CD. Other tests of cartridge integrity, such as pressure hold and diffusion, can also be used. These tests can be automated and linked to a computer program that will automatically determine if a unit passes or fails the tests based upon specifications for the cartridge.

Kinds of Filter Units

- **Depth-bed**
- **Pad**
- **Membrane**
- **CROSS-FLOW**

The final type of filtration unit is cross-flow. In contrast to the other types of filtration units, cross-flow is not a dead end filtration meaning that the wine does not flow perpendicular to the membrane but flows across the filter matrix, thus the name "cross flow".



The cross-flow minimizes clogging of the membrane, as there is a constant flow of particles across the surface. Fouling is also prevented, as there is no direct pressure against the particles causing them to denature and block the pores. The filtered wine is called the "permeate" and the fraction which does not pass through the filter is called the "retentate". There are several types of cross-flow units, and the filter medium can vary.

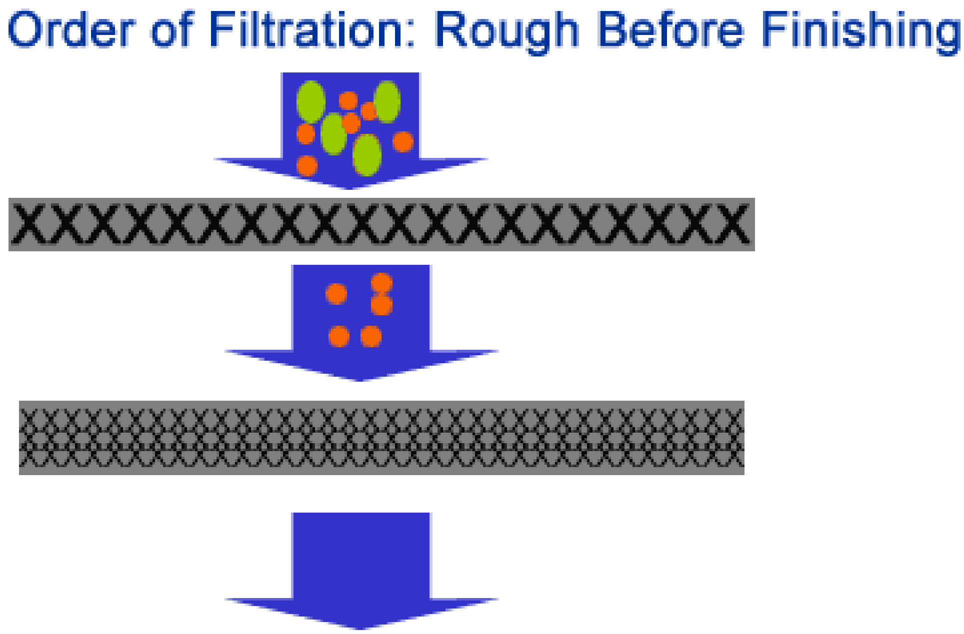
Cross-Flow Filtration

- **Same porosities as membrane filtration**
- **Wine flows across matrix, not through it**
- **Wine retentate can be re-circulated**
- **Back flux can be used to clear membrane**
- **Does not clog that easily**

Reversing the flow of the wine can be used to clear the membrane. Cross-flow filtration can also be used to achieve an ultrafiltration of the wine. Ultrafiltration is defined as the removal of large molecular weight solutes like proteins rather than large particles. Ultrafiltration can be used to remove proteins and thereby confer stability against protein haze formation. However, this can also remove phenolic polymers as well, which might not be desired. Lower molecular weight cut off filters can be used for tannin and color removal.

Another type of filtration is **reverse osmosis**. Osmosis refers to the movement of water across a membrane from a solution of low solute content to one of higher salt content. Reverse osmosis is the opposite, the removal of water from solutions of higher salt content. This process can be used to make juice concentrate. These membranes have molecular weight cutoffs of 10 to 100 atomic weight units. Water has a molecular weight of 18 and will pass across the membrane. Sugar monomers have a molecular weight of 180 and will be retained. Very small molecules such as acetic acid or ethanol can also pass through the membrane in reverse osmosis. This process can be used to reduce the content of these molecules as well.

Filtration processes should be ordered so that the largest particles or particles that may foul a later type of filter unit are removed first. Thus, rough filtrations should be performed before finishing or tight molecular weight cut off filtrations.


Order of Filtration: Rough Before Finishing

Lesson 15: Impact of Filtration on Wine Quality

One frequently hears the statement that filtration should be avoided as this detracts from wine quality.

The Question:

Does filtration impact wine flavor and aroma?

The belief is that passage through the filtration matrix removes aroma and flavor components from the wine. Immediately after filtration the wine may appear to have lost aroma components. As equilibria are re-established the aroma compounds return with the same intensity.

The Belief:

Filtration removes flavor and aroma compounds and is therefore undesirable
"Unfiltered" wines are more complex than filtered

Unfiltered wines are thought to retain complexity, however, this conclusion has not been supported by controlled studies with blind sensory evaluations.

The Facts:

Several studies have shown that expert tasters are not able to recognize filtered versus unfiltered control wine
Unfiltered wine allows continued microbial activity, which may explain differences percieved in unfilterd wines in general.

Unfiltered wine may allow continued microbial activity, which may change the character of the wine if it is aged significantly post-fermentation.

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Lesson 16: Introduction

Fining

Particulate matter in solution deflects light making the solution appear hazy. The goal of the clarification operations discussed in the last lecture is the removal of existing cloudiness and sediment from a wine. This is obviously possible by the techniques of centrifugation and filtration if the particulate matter is already present. Frequently, however, the material that will form colloids and eventually agglutinate into particles is in the wine in a soluble form. In this case it is necessary to design operations to remove the "potential" for formation of a haze or sediment. This may be accomplished by removing one or more of the participants in colloid formation or the use of techniques to stabilize the colloids against agglutination. The latter approach is more risky than the former.

Fining refers to the addition of an adsorptive agent to wine or juice followed by settling or precipitation of the agent. Undesired wine components bind to and then settle with the fining agent and are thereby removed from the wine. As discussed below there are several different types of fining agents. In some wines it may be necessary to use more than one agent. Other wines might not benefit from fining at all. Many fining agents are not highly specific, meaning that if not appropriately used, positive and well as undesired characters may be removed from the wine. Fining can also be used to accelerate the conversion of colloidal substances into agglutinated complexes so that clarification processes can be used to remove the particulate matter. It is important that the winemaker understand the uses of fining agents to avoid unwarranted treatment of the wine.

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Lesson 16: The Fining Process

Goal of Fining

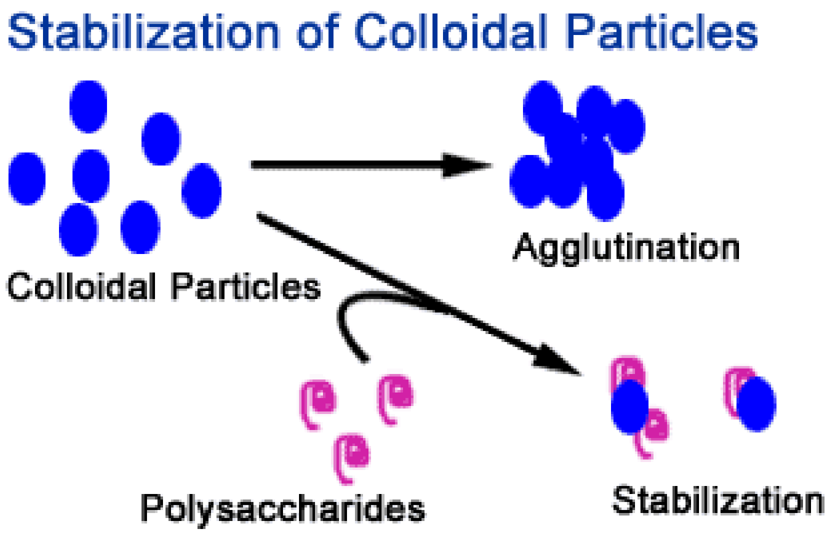
Removal of soluble components that are undesired stylistically or that will lead to an instability.

Fining can therefore be used to remove components that will result in instability of the wine or that are simply undesired from a stylistic perspective. This includes removal of proteins that would otherwise result in formation of a haze, tannins or phenolic compounds reducing astringency and bitterness, off-colors or off-color forming potential, metal ions, or off-flavors and aromas. Fining can also be used to add nuances, depending upon the agent used.

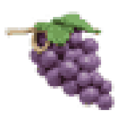
Components to Be Removed

- **Protein: "haze-forming potential"**
- **Phenolic compounds (tannin): soften wine by reducing bitterness and astringency**
- **Metal ions**
- **Off-character or off-character-forming potential**

The winemaker should carefully consider what agents will be used and in what order. It is important to conduct fining operations before clarification processes since some residual fining agents may impact wine clarity. Some clarification or fining treatments may lay lead to a destabilization of another component of the wine, so this must be taken into account. For example, it is thought that wine polysaccharides can coat the surface of colloidal protein-tannin complexes preventing those complexes from further agglutination and haze formation. Disruption of the coating effect of the polysaccharides will lead to the appearance of a visible cloudiness of the wine. Also, some proteins are stabilized by interactions ions on the hydrophilic or exposed surface of the protein. Removal of those ions can lead to unfolding and denaturation of the protein, which leads to colloid formation.



Fining agents operate by taking advantage of hydrophobic or hydrophilic interactions between the agent and the species to be removed. The fining agents used are generally not soluble in wine or are of limited solubility. The agents initially dissolve in the wine; interact with wine components then come out of solution bringing wine components with them.

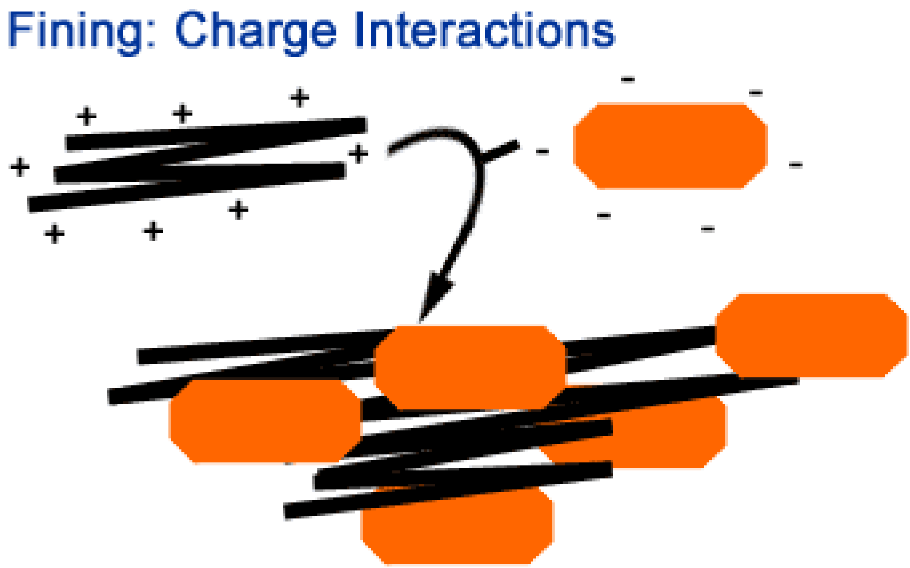


Mechanism of Fining

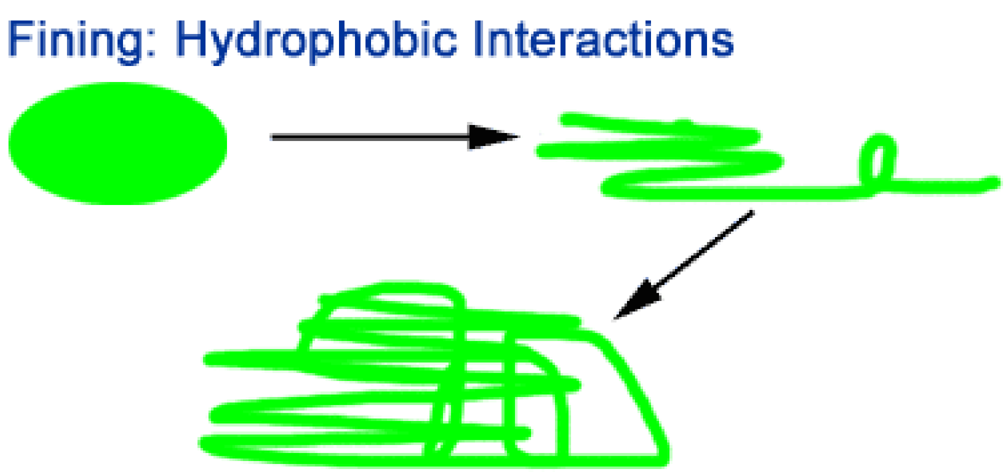
- **Take advantage of either hydrophobic or hydrophilic interactions to remove offending component**
- **Wine will initially be cloudy, but particles will eventually become large and sink**
- **Clarify by racking or filtration**
- **Add a charged component that will interact with oppositely charged components followed by precipitation of the neutral complex**
- **Add a denaturing component that will expose hydrophobic surfaces that will then interact allowing a hydrophobic complex to form**

The wine generally has to undergo a clarification treatment following addition of the fining agent.

Components of one charge may be used to remove components of the opposite charge. Due to the low pH wine proteins are generally positively charged and can be removed by negatively charged fining agents.



In this case, both the fining agent and the component to be removed carry multiple charges. This allows a large insoluble complex to form. Similarly, denaturation of proteins reveals non-polar regions or areas of hydrophobicity that strongly interact with other hydrophobic regions due to Van der Waals forces. Multiple domains are exposed capable of interaction with multiple components again leading to the formation of a large lattice or complex.



In some cases, more than one agent is added. The first agent may be responsible for denaturation of the undesired component allowing interaction with the stripping agent.

Lesson 16: Choice of Fining Conditions

Choice of Fining Conditions

- **Difficult to predict outcome due to complexity of process and number of unknowns**
- **Temperature influences process**
- **Amount and type of mixing critical**
- **Relative molecular weight and charge density of particles important for complex/lattice formation**

Fining is one of the most challenging of winemaking operations because the outcome is difficult to predict. This is due to the fact that many variables impact component solubility in wine and these variables are not easily measured. **Temperature** has a striking effect as it impacts rates of denaturation and the stability of complexes formed. At higher temperature denaturation or unfolding is favored while at low temperature many components are less soluble so will more likely precipitate. Since fining requires that the fining agent make direct contact with the components to be removed, how the fining agent is prepared and added to the wine is critical. It is also important to know that the undesired component will not just interact with the fining agent but will be capable of forming a lattice structure that will settle from the wine.

The efficiency of agglutination is also affected by the nature of the components present in wine and their relative ratios. There is not a linear relationship between total **tannin** content and protein content and colloid formation and agglutination. Tannin protein interaction occurs more readily at lower pH values, so the **pH** of the wine impacts stability of the complexes. Divalent as well as monovalent **cations** can catalyze flocculation and precipitation of tannins. The nature and content of **polysaccharides** is also important since these components can both participate in and dampen colloidal interactions.

The purpose of this discussion is to underscore the importance of conducting **fining trials** for each wine to be treated in the winery. This is generally done using small volume lots from the wine to be treated. It is important to remember that small scale or laboratory fining conditions may not mimic the actual behavior of agents on a commercial scale due to difficulties in the speed or extent of mixing. However it is possible to determine the relationship between small scale fining trial and commercial scale fining. This need not be done every time a wine is fined. We have found reasonable reproducibility in scaling up from a fining trial once the "scaling" factors are understood. It is also possible to adapt the small scale fining trial (adjust rates of agent addition and mixing) to **match that of the commercial operation**. Under typical winery conditions this has to be done empirically, by measuring loss of haze forming potential with step wise addition of an agent and repeating the step wise addition under a commercial scale and comparing the amount of undesired component (tannin, protein) remaining in the treated wine. This procedure can also be used to test for the potential of over-fining. **Over-fining** is a term that has different meanings in different regions. Many California winemakers consider over-fining to mean that there was a noticeable and negative effect on wine quality. This is usually due to the removal of desired flavor and aroma components. I prefer to call this particular problem **"stripping"**. The French use over-fining to mean that the wine has become destabilized in some way, that is, some of the added protein fining agent has not been removed and will lead to subsequent colloid formation upon interaction with tannins. This is especially problematic if the wine is exposed to tannins post fining, such as by blending or barrel aging. Over-fining is particularly problematic in white wines fined with gelatin. For the purposes of this class we will use the French definition of over-fining. Over-fining should not be confused with failure of the fining process or agent to remove existing components of the wine that will likewise lead to haze formation later on in the aging of the wine. We will call this phenomenon **incomplete fining**. It is important to note at this point that rarely does any fining operation reduce the concentration of the undesired component to the analytically undetectable range. The goal is to reduce the concentration to a value below which it will not be noticeable as a problem.

Problems Associated With Fining

- **Lack of specificity**
- **Over-fining**
- **Oxygen exposure**
- **Loss of wine volume to fining lees**
- **Expense and need for clarification**
- **Additions of flavors/aromas if process is not neutral**
- **Potential addition of microbes**

Two other consequences of fining also need to be mentioned. Fining agents are not sterile. Many are actually quite good carbon, nitrogen and energy sources for microbes. If the winery is experiencing problems with spoilage, the fining agents should not be ignored as a potential source of contaminants. This is usually not a problem unless the fining agent has not been stored properly (allowed to become wet, stored near other contaminated or possibly contaminated materials, splashed with wine during the fining operation then put back in storage, etc.). Some agents that are used in fining discussed below such as egg whites or spoiled milk can add flavor or aroma "nuances" to the wine. In this respect, many consider the wine to be **"over-fined" if the fining agent can be detected sensorially** in the wine. This is in the same spirit of the French meaning of over-fining, just a different type of problem caused by residual fining agent material remaining in the wine.

Lesson 16: The Fining Agents

There are several different classes of fining agents used in wine production. The most common agents are the proteins.

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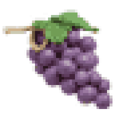
Lesson 16: The Fining Agents: Proteins

There are four protein fining agents that are used.

The Protein Fining Agents

- **Casein**
- **Gelatin**
- **Albumin**
- **Isinglass**

The Protein Fining Agents: Casein



- **Mixture of milk proteins**
- **Proteins have hydrophilic regions and areas of high negative charge due to extensive phosphorylation**
- **Insoluble in wine**
- **Can remove phenolics via hydrophobic interactions**
- **Can remove proteins via charge and hydrophobic interactions**

Casein is derived from milk and actually represents different protein species. These proteins are of low molecular weight (less than 30 Kd) and are not soluble at low pH.

The casein proteins have regions of net negative charge due to the fact that they are phosphorylated. These regions can undergo charge interactions with positively charged species in the wine. The proteins also have hydrophobic or nonpolar regions that are exposed when the caseins denature at wine pH. These regions can interact with phenolic compounds and other components. Finally, most proteins will have a net positive charge at wine pH due to the pKa values of the amino acid side chains. Thus casein has areas of both positive and negative charge density on the protein surface as well as nonpolar regions. Casein is generally used to remove phenolic compounds and off-colors or bitterness. Casein use is quite problematic however. Since the protein rapidly denatures at wine pH it will flocculate rapidly and with itself (due to the possession of areas of net positive and net negative charge). If this occurs then it can lead to incomplete fining. It is not soluble in water so must be used in a slightly alkaline solution (with ammonium hydroxide) so it is important to do this in a manner not impacting the pH of the wine.

Casein: The Problems

- **Tends to clump requiring good mixing**
- **Tendency to strip wine**
- **May impart characters to wine**

Casein does not lead to over-fining in the classic French definition, but can strip wine of aroma and flavor. It can also be detected depending upon how the casein was prepared and how pure the preparation is. Casein is generally produced from coagulated skim milk typically made from commercially unacceptable (that is, spoiled) milk.

The Protein Fining Agents: Gelatin

- **Animal by-product**
- **Net positive charge at wine pH**
- **Somewhat soluble in wine**
- **More neutral than other proteins**
- **Not as effective as other proteins**

Gelatin is derived from animal collagen (skin or bones). Gelatins are classified as heat soluble, cold soluble and liquid, based upon molecular weight of the principle species present and charge. The gelatins are produced in various ways (chemical hydrolysis or enzymatic degradation) and have many uses in food industries. Gelatins have a high content of glutamic acid and will therefore be slightly positively charged or neutral at wine pH. The pKa of the gamma-carboxyl group of glutamic acid is 4.25. It also contains a high percentage of nonpolar amino acids, glycine, proline and hydroxyproline.

The more highly charged the gelatin the more active it is in removal of tannins from wine. Gelatin can be dissolved in hot water and is frequently used in conjunction with silica sols. The purpose of the silica gel is to prevent over-fining with gelatin (high residual levels of gelatin).

Gelatin: The Problem

- **Overfining: requires use of an additional fining agent to get rid of it**

The next protein fining agent is albumin.

The Protein Fining Agents: Albumin

- **From egg whites**
- **Net positive charge at wine pH**
- **Removes bitter phenolics**
- **Softens astringency**

Albumin is produced from egg whites. In powder form it is obtained from the drying of egg whites. It is comprised largely of two protein species, ovalbumin and conalbumin. Fresh egg whites can also be used, but these will have a different composition than the dried product. One to as many as eight egg whites may be used per barrel. Most experienced tasters can detect egg whites at two to three per barrel, depending upon the wine, however. Egg white protein can be dissolved in water, but excessive mixing should be avoided as this will lead to significant foaming. Better solubility is obtained if a little potassium or sodium chloride is added to the water.

The albumin proteins also have a net positive charge at wine pH and can remove phenolic compounds. Egg white fining is often mentioned as the method of choice for the production of high end red wines. The only problem with egg white fining is as noted above, if overdone, expert tasters will be able to detect it, and this may be considered a fault or defect of the wine. The egg white character is similar to the aroma of meringue

Albumin: The Problems

- **Not neutral, especially if egg whites rather than pure albumin is used**
- **Experienced tasters can tell if a wine has been fined with egg whites**

The final protein agent is isinglass.

The Protein Fining Agents: Isinglass

- **From fish air bladders**
- **Net positive charge at wine pH**
- **Large surface area**
- **Forms stable, tight lees**
- **Least tendency to over-fine**
- **Neutral, does not add nuances**

Isinglass is a protein produced from the air bladder of fish. Like the other proteins, it has a net positive charge at wine pH. It also tends to denature into "sheets" or strands and thus has a large surface area for adsorption.

It has the least tendency to over-fine, and forms more stable (tight) lees than the other agents. It is also neutral, not adding any nuances to the wine. There are two main problems with isinglass, expense and availability. It is commonly produced from sturgeons so its availability depends upon the availability of the fish. Some other types of isinglass (or fish protein products) are available, but these tend to have lighter lees and offer no advantages over other protein fining agents.

Isinglass: The Problems

- **Expense**
- **Availability**

Which protein fining agent is used should be decided after a fining trial. With respect to removal of phenolic compounds, they are equivalent so the decision should be based on other considerations. Some winemakers feel particular proteins are easier to use or better in terms of diminished stripping or over-fining problems, but this will differ on a case by case (wine by wine) basis.

There is intense research interest aimed at identifying plant proteins that may substitute for animal proteins as wine fining agent. This is being fueled by concern over contamination of animal based products with the agent causing mad cow disease in the European community.

The removal of soluble components such as protein by the protein fining agents is facilitated by the presence of tannin. Tannins can be added to wine in conjunction (the day before) protein fining agents. This practice is commonly used in France to increase the efficacy of the protein agents and to guard against over-fining. Tannin fining has other effects as well. Tannins can function as oxidation targets reducing oxidative loss of wine components. Tannins may form complexes with negative characters, and enhance removal of oxidative enzymes. Because tannin dramatically impacts wine structure, additions should be made several weeks prior to bottling.

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Lesson 16: The Earths

The next class of fining agents are the earths.

The Fining Agents

- **Proteins**
- **EARTHS**

The most common fining agent in this category is bentonite. Bentonite is a natural montmorillonite clay.

The Earths

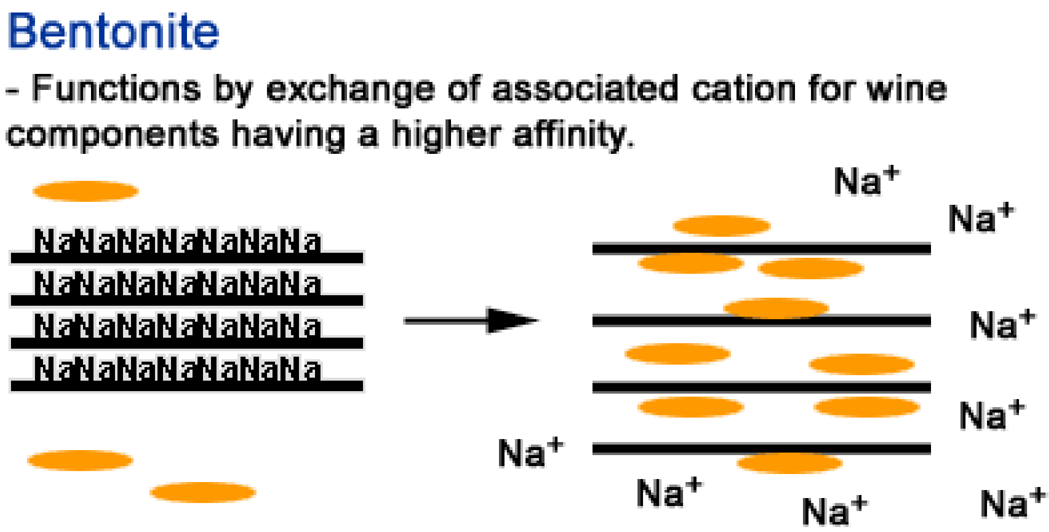
- **Bentonite**

It is an aluminum silicate that also contains magnesium, calcium and sodium. Bentonite composition differs depending upon the source of the clay, and may contain higher calcium or higher sodium.

Bentonite

- **Silicate (SiO_2)**
- **Large surface area: occurs in sheets**
- **Net negative charge at wine pH: ideal for interaction with wine proteins**
- **Different forms occur differing in salts associated with silicate: Na^+, K^+, Ca^{++}**

Bentonite dissociates into large sheets and has a net negative charge at wine pH. It will exchange the calcium, magnesium and sodium ions for positively charged proteins in wine.The cation exchange mechanism means that the displaced cation will be in the wine.



Bentonite is not specific, and will bind many wine components.

Bentonite Levels

- **Typically 1-4 lbs/1000gal (0.12-0.48 g/L) is ample to remove wine protein**
- **If >10 lbs/1000 gal (>1.0 g/L) is needed, haze problem might not be due to protein!**

Because of its affinity for protein, it is not surprising that bentonite is most commonly used to achieve protein stability in wines. It is typically used in the range of 1 to 4 lbs/1000 gal or 12 to 48 g/hL. If significantly higher concentrations are needed, then the haze is likely not proteinaceous in origin or the proteins involved are not highly charged at wine pH. This is rare, but we have seen it happen in white wines made from juices that have undergone a high temperature short time treatment to eliminate laccase. Bentonite is less effective in the removal of proteins protected by polysaccharide components. The heat treatments may lead to the appearance of protective polysaccharides that prevents full agglutination of the proteins present. It is our experience that these types of colloids are very difficult to remove from the wine, but will eventually agglutinate during aging so will be a problem if the wine is bottled.

Bentonite: The Problems

- **Must swell properly in water or water/wine mixture before use**
- **High lees volume**
- **Addition of ions that may encourage tartrate instability**

Bentonite can be challenging to swell properly. It will form cement especially with insufficient mixing. It is typically prepared as a 5 to 15% slurry. Swelling is faster at higher temperatures. Some winemakers prefer to swell the bentonite in wine, but it will coagulate much faster and loses some adsorptive capacity. Other winemakers feel that the bentonite is more effective at removal of protein if juice rather than wine is treated, but this appears to be juice-specific and not a general finding. It may be necessary following bentonite fining to add a protein such as casein to fully strip the bentonite from the wine. Bentonite fined wine can typically be clarified by racking, but in some cases filtration might be necessary. Since bentonite adds cations to the wine, it is wise to tartrate stabilize post bentonite treatment. Bentonite has a tendency toward a high lees volume, perhaps as high as 20% of the volume of the wine treated depending upon the conditions used. Some winemakers recommend bentonite treatment be done in shallow versus deep tanks. This provides an initial larger surface area of bentonite to wine which can improve adsorption

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Lesson 16: The Colloids

Colloidal materials can also be used as fining agents.

The Fining Agents

- **Proteins**
- **Earths**
- **COLLOIDS**

Polysaccharide material can be used in a fining treatment. The polysaccharides generally derive from agar or gum Arabic.

Colloidal Fining Agents

- **Natural polysaccharides**
- **Agar**
- **Gum Arabic**
- **Sparkolloid: alginate based**
- **Ferrocyanide colloidal preparations**
- **Naturally dispersed or "protective" colloids can hold proteins, tartaric acid crystals, other colloidal materials in suspension**
- **Colloidal fining agents neutralize surface charges on naturally dispersed colloids thereby allowing them to dissolve or coagulate**

In the United States, one proprietary colloidal preparation is known as Sparkalloid. Colloidal fining agents can neutralize surface charges on other naturally dispersed colloids causing agglutination or dissolution of the existing particles. They aid in the removal of more finely suspended particles. It is important to know the mechanism of action or stability of a colloidal preparation in wine, as some effects may be temporary.

We also include ferrocyanide preparations in the section on colloids. These preparations are used to remove transition metal cations such as residual copper from copper fining. In some countries non-colloidal forms of ferrocyanide are permitted, but only colloidal forms are allowed in the United States. Wines treated with ferrocyanide must be assayed for residue levels. Use of colloidal ferrocyanide preparations is prohibited in many countries. It is generally thought that it is best to adjust winemaking operations so that ferrocyanide treatment is unnecessary. It is rarely used in the United States. Use is so rare that commercial preparations are no longer routinely available.

Lesson 16: Synthetic Polymers

Wines may also be treated with synthetic polymers.

Fining Agents

- **Proteins**
- **Earths**
- **Colloids**
- **SYNTHETIC POLYMERS**

These agents are used to remove specific phenolic components.

The principle synthetic polymers used are polyglycine, polyamide and polyvinyl-polypyrrolidone (PVPP). The carbonyl oxygen atoms on the surface of these polymers act as adsorption sites for phenolic compounds.

Synthetic Polymers

- **Polyglycine**
- **Polyamide**
- **Polyvinylpolypyrrolidone (PVPP)**

All have carbonyl oxygen atoms on surface that act as adsorption sites

These agents remove subsets of phenolic compounds and are particularly effective at removal of monomeric phenolics that will oxidize to off-colors.

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Lesson 16: Silica Suspension

Silica suspensions (sols or gels) were mentioned previously as being a useful adjuvant to gelatin fining.

The Fining Agents

- **Proteins**
- **Earths**
- **Colloids**
- **Synthetic polymers**
- **SILICA SUSPENSIONS**

The silica sols are principally used to accelerate fining processes as well as to remove excess fining agent. This can improve filterability of the wine.

Silica Suspensions

- **The "sols"**
- **Used primarily with gelatin**

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Lesson 16: Activated Carbon

Activated carbon can also be used to remove unwanted components from wine. Carbon is very effective at stripping wine so should be used only as a last resort.

The Fining Agents

- **Proteins**
- **Earths**
- **Colloids**
- **Synthetic polymers**
- **Silica suspension**
- **ACTIVATED CARBON**

Activated carbon is not very selective and will remove a wide range of compounds. It is the method of choice for highly tainted wines.

Activated Carbon

- **High and broad affinity**
- **Removes color, wide range of phenolics**
- **Strips wine: used only as a last resort to salvage a wine for blending**

If activated carbon is used, then the wine is frequently not of the quality needed for production of a varietal wine. It can be used in blends.

In contrast to filtration, fining can impact the flavor and aroma profile of a wine. Production levels used are typically low enough to have little to no impact, but it is possible to strip a wine if the winemaker is not judicious in the use of these agents.

In contrast to filtration, finnig can have an impact on the flavor and aroma of wine.

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Lesson 17: Introduction

Aging

In this lecture we will cover the very important topic of aging of wines. The age-ablity of a wine needs to be considered even if the wine is destined to be consumed young. Many authors define aging as the time between the end of fermentation and bottling. However, the wine continues to change in the bottle so we define aging as **the period post alcoholic and malolactic fermentation but pre-consumption** and include a discussion of events that can happen in the bottle.

Chemical changes occurring during aging strongly impact the flavor and aroma profile of the wine. Aging can be divided into two stages, **bulk** and **bottle**. Bulk aging is usually conducted in wooden cooperage allowing limited contact with air while bottle aging occurs in the absence of oxygen. Wine can be aged in stainless steel tanks, which would be similar to bottle aging with respect to exposure to oxygen. Many important aging reactions are oxidation-reductions, some of which are dependent upon the presence of molecular oxygen. Other important chemical reactions are independent of oxygen. These reactions may still occur in the presence of oxygen versus those that require a chemically reduced state.

There are basically **three** goals of aging of a wine: to assure stability, to correct a defect or problem in the wine and to evolve the wine style or complexity. The first two clearly must be considered prior to bottling. Complexity will continue to increase with age post-bottling up to a point beyond which the wine begins to lose complexity. Bottle bouquet refers to the components that appear during aging in the bottle. The most characteristic notes of bottle age are described as cedar and sun-dried sheets. Some of the classic French wine styles do not owe their celebrated woody character to oak but to bottle aging.

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Lesson 17: Aging as a Means of Achieving Stability

As mentioned in the lecture on fining agents, components that form hazes and precipitates or sediments denature over time forming colloids and then large agglutinated complexes. If sufficient time is allowed for these polymerization and agglutination reactions to occur during the aging of the wine and, depending upon the conditions of aging, the particulate matter that forms can be removed using clarification techniques. This may reduce the need for fining agents, and may allow racking to be the only clarification method needed. This process will remove the unstable components and the wine will therefore be stabilized.

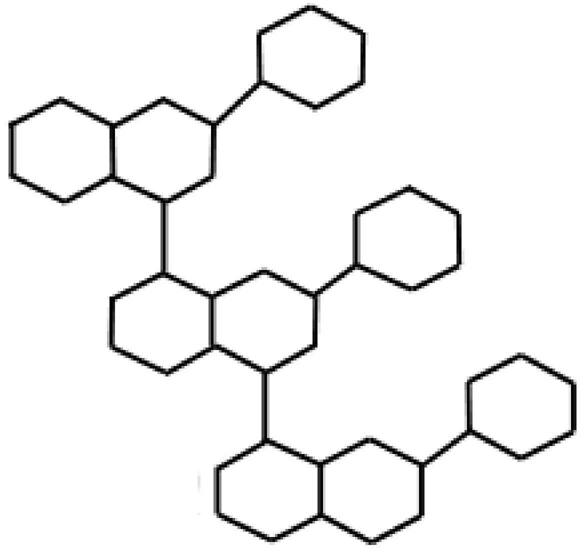
Aging can therefore be thought of as a means of achieving wine stability.

Aging: To Achieve Stability

- **To allow reactions that are going to happen to occur before bottling**
    - **Polymerization of tannin**
    - **Polymerization of pigment**
    - **Stabilization of color**
    - **Loss of volatile esters**

Aging in the presence of a limited amount of oxygen encourages polymerization of phenolic compounds, which leads to stabilization of color and softening of the tannins (from bitter to astringent, then loss of astringency due to degree of polymerization). Volatile compounds can also be lost during this process.

Polymerization



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Lesson 17: Aging as a Means to Correct a Wine Problem

Aging can also be used to correct a problem in the wine. For example, loss of volatile esters may be desirable for full evolution of wine characters. Ester loss may be desired for multiple reasons: because these compounds are not stable, they are too dominating of wine character masking other components, or they simply are not desired sensorially. These characters are largely microbial in origin, not deriving from the grape and therefore not considered to be components of varietal character. If the goal is to produce a true to type varietal wine, esters may detract from the perceived quality of the wine.

In addition to esters, aging may be used to allow other negative characters to disappear from the wine through one or more of the chemical reactions described below.

Aging: To Correct a Problem

- **Allow "negatives" to disappear**
  - **Volatilization**
  - **Hydrolysis**
  - **Oxidation**
  - **Precipitation**
  - **Other chemical reactions**

In addition to volatilization compounds may be lost due to hydrolysis, oxidation, precipitation or other chemical reaction. Bitter and astringent phenolic compounds may form larger complexes thus sedimenting from the wine.

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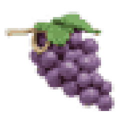
Lesson 17: Aging to Achieve Style and Complexity

Aging may be done to allow evolution of wine style and complexity. It may be done under conditions (oak) that are not neutral and add nuances to the wine. Allowing time to lose fermentation or microbial characters so that varietal character is more dominant is also an example of aging to achieve style. Sometimes it is desirable from a stylistic perspective to age wine to lose some of the "forward fruit" traits that originate in the grape, again because these notes tend to mask other characters in the wine, and therefore the complexity.

New characters can also be derived from yeast lees if they are present during aging.



Aging: As Stylistic

- **Allow formation of new characters**
- **Addition of new characters from cooperage**
- **Addition of new characters from yeast lees/autolysis**
- **Increase/Decrease complexity depends upon varietal/composition**

How the wine changes depends upon the composition of the wine. As new characters develop, complexity increases. Thus aging can be used to subtract or add characters and to increase complexity. The increase in complexity can be considered as a multiplication effect. This is because a single compound can interact with several others, producing a spectrum of reactants. For example, if one compound can react with six others, the wine may contain the original seven compounds plus six reactants for a total of thirteen compounds from the original set, assuming the reactants are not completely consumed in the process. If some of the reactants can undergo further reactions, complexity is greatly amplified. This of course requires that the compounds be subtle rather than dominating for the complexity to be enhanced.

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Lesson 17: The Chemical Reactions Occurring During Aging

Oxidation-reduction reactions are important components of wine aging. Oxidation is defined as an increase in the oxidation number and an apparent loss of electrons by an atom, molecule, compound or ion. Reduction is the opposite: the apparent gain of an electron. We have discussed in the lectures on microbial metabolism the role of the cofactor NAD+ in biochemical reactions. NADH, which has gained an electron, is called the reduced form of the cofactor and NAD+ 'which has "lost" the electron and now has a positive charge, is the oxidized form. We learned that microbes must maintain a balance and **for every biological oxidation a reduction must occur**. The same is true in chemical oxidation-reduction reactions. For one compound to be oxidized another must be reduced.

The chemical that gains the electron is called the **oxidizing agent** and that which loses the electron is the **reducing agent**. Atoms that react with oxygen donating an electron to the oxygen atom are said to be oxidized. Therefore molecular oxygen gains electrons and is an oxidizing agent. Other more reactive species of oxygen are important oxidizing agents in wine. **Antioxidants** are reducing agents that react with oxidizing agents more readily than other compounds. Sulfur dioxide is an important antioxidant because it will react with, that is donate electrons to, oxidizing species thereby becoming oxidized. **Ascorbic acid** is also an important antioxidant because it can react with oxidized molecules converting them back to their reduced form. Ascorbic acid will reduce quinones back to hydroquinones and become oxidized itself in the process. Ascorbic acid is consumed, that is, it remains oxidized. Reaction with an oxidizing agent may lead to the formation of a covalent bond between the molecules that may be difficult to reverse or it may be freely reversible. In many cases reaction with a reactive oxygen species "fixes" the oxygen on the atom on the compound. The reversibility of oxidation-reduction reactions depends upon how energetically feasible the reactions are. Oxidation-reduction reactions can be balanced using the principle of conservation of charge. Extensive oxidation is an important component of some wine styles such as Sherries and Ports. It is considered a defect in many other styles, particularly in white wines. For most wine styles there is an optimum level of oxidation and further oxidation detracts from wine quality. This may be due to simple loss of complexity or to the appearance of undesired compounds. It is frequently difficult to predict the optimum oxygen exposure for a specific wine lot. How a wine responds to oxygen is dependent upon wine composition. Several other factors also impact the aging reactions occurring in wine.

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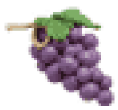
Lesson 17: Variables Affecting Wine Aging

Several factors impact the processes occuring during aging.



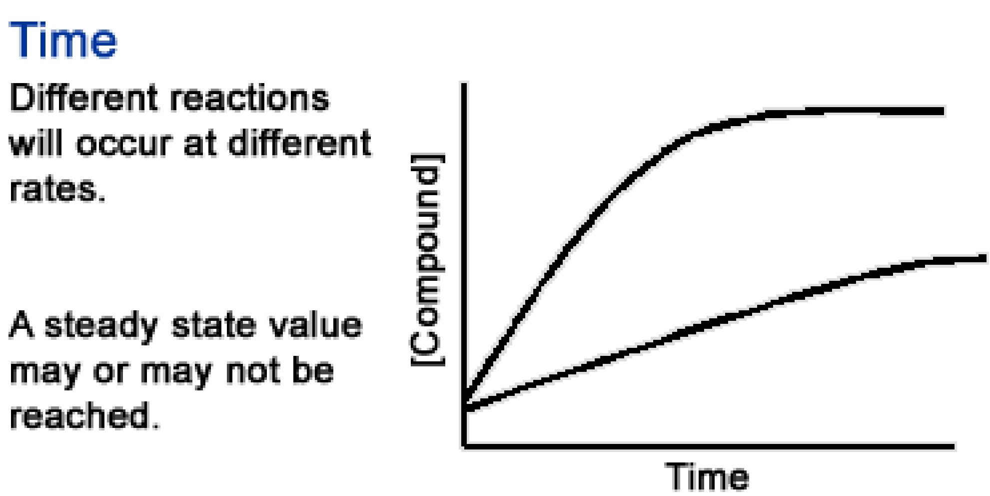
Aging Variables

- **Time**
- **Temperature**
- **Oxygen**
- **Cooperage**
- **Yeast lees**
- **pH**
- **Catalysts**
- **Chemical composition of wine**

Aging Variables: Time

One of the most important factors affecting the composition of a wine is the length of time of the aging process, that is, the time between the end of microbial activity and human consumption.

Rates of reactions differ, so the composition of the wine may change dramatically over time.

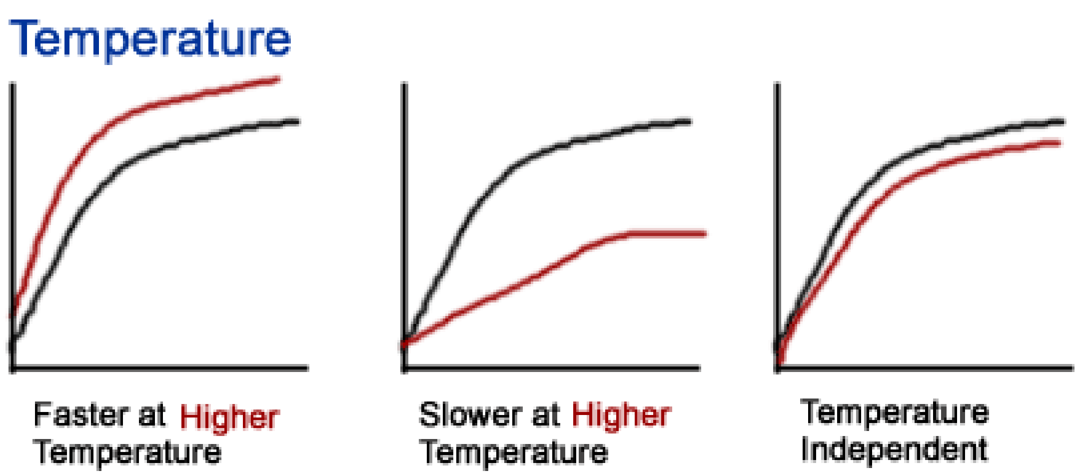


Depending upon the concentration of initial reactants and the rate of the reaction, the wine may require a long time to achieve a steady state concentration of a particular component. In the graph above, the two components that are appearing in the wine do so with different kinetics. If both are detected sensorially, the aroma and flavor profile of the wine will differ depending upon the time at which it is consumed.

Aging Variables: Temperature

As is true of all chemical reactions, the aging reactions occurring in wine are influenced by temperature.

In general, the rate of a reaction will increase with an increase in temperature unless the reaction becomes energetically unfavorable at high temperature. These kinds of reactions are rare in wine, but increasing temperature may appear to be inhibitory to product formation for other reasons discussed below. The magnitude of the increase in rate with increasing temperature may be difficult to predict. A general rule of thumb is that the typical reaction rate will double for a 10°C increase in temperature, but this is highly variable. Some reactions may show a much stronger dependence on temperature and others may appear to be fairly temperature independent.



Some of the variation in response to temperature may be because reactants are affected. For example, if one of the reactants were volatile, loss of the reactant from the wine would be greater at higher temperature thus reducing the concentration of the compound in the solution. In this case, the reaction would appear to be inhibited by temperature. Instead the reaction may be stimulated by temperature but product levels fall because of loss of one of the reactants. Similarly, temperature may more strongly favor one type of reaction that a specific compound can undergo. As an example, if hydrolysis of a compound is more strongly temperature dependent (meaning it is greatly stimulated at higher temperature) than the reaction between two molecules, higher temperatures lead to preferential reaction of one of the components with water and therefore decrease the level of production of the other product. Aging is generally conducted at moderate temperatures (7 to 24°C) to **achieve a balance between formation of desired products and loss of reactants**.

Aging Variables: Oxygen

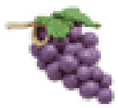
One of the most important variables of wine aging is oxygen exposure. Molecular oxygen (O_2) is able to catalyze many key oxidation-reduction reactions directly or through the generation of a reactive species such as hydrogen peroxide (H_2O_2).

Saturation of a typical table wine with air results in a dissolved oxygen content of 6 ml/L (8 mg/L). In practice this level of saturation is not achieved during normal transfer from tanks and barrels, but a wine can be more fully oxidized if a splashing technique is employed or the process of **micro-oxidation** is used. In micro-oxidation the wine is deliberately oxidized using a device that releases very fine bubbles into the wine. The dissolved oxygen is consumed by reaction with the oxidizable components of wine such as the **phenolics**. Since red wines have a higher phenolic content, they can "consume" more dissolved oxygen.

Air Saturations

- **One "saturation" = 6mL O_2/L**
- **Capacity for O_2 is dependent upon the phenolic composition**
- **A single saturation occurs with each air exposure**
  - **Racking**
  - **Fining**
  - **Filtration**
  - **Centrifugation**
  - **Movement to tank/barrel**

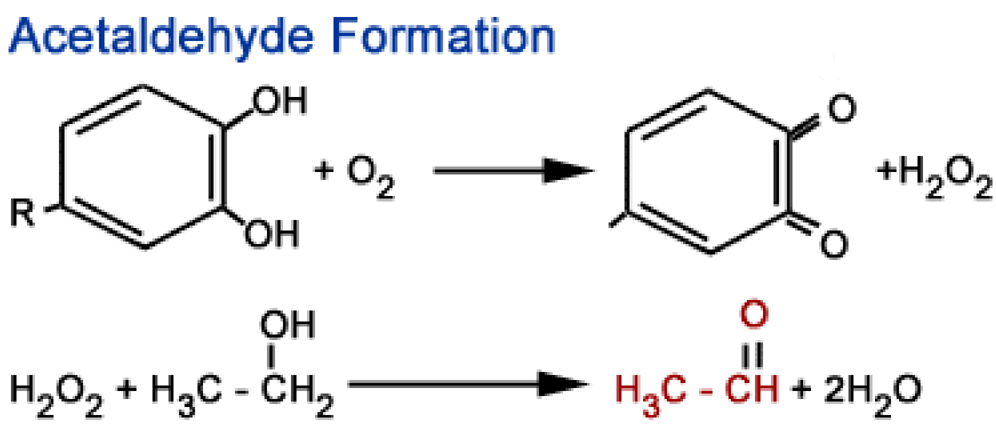
Red wines can also tolerate a higher amount of oxidation because the off-colors produced (brown, pink, orange) do not detract from wine quality and are indeed desired. The amount of molecular oxygen in a typical saturated wine falls to undetectable in approximately one week at room temperature. Oxidation reactions may continue once the molecular oxygen is gone, as not all oxidation-reduction reactions require molecular oxygen as one of the reactants.



Oxygen Exposure Leads To:

- **Polymerization of phenolics**
  - **Good: softens astringency**
  - **Bad: too much loss of color**
- **Browning/Pinking**
  - **May be desirable or neutral (reds)**
  - **May be undesirable (whites)**
- **Acetaldehyde**
- **Stabilized color**
- **Oxidized flavors**

Oxygen can have many effects in wine. We have discussed browning and pinking, but oxygen also stimulates polymerization of phenolic compounds. Oxygen can also lead to the formation of aldehydes, principally acetaldehyde.



This occurs in a two-step process. A polyphenolic compound reacts with molecular oxygen donating two electrons (via hydrogen) to the oxygen species. This forms hydrogen peroxide, which is still very reactive as an oxidizing agent in spite of having picked up the electrons. Hydrogen peroxide can then interact with ethanol, gaining an additional electron (via hydrogen) for each oxygen atom. This forms **acetaldehyde** and water. Acetaldehyde is the principle aldehyde formed because ethanol is the principle alcohol, but other aldehydes can also be generated via the reaction of alcohols with hydrogen peroxide. The appearance of acetaldehyde indicates oxidation of the wine. It is an odor all winemakers should know. Hydrogen peroxide can react with many other wine chemicals. It is more reactive than molecular oxygen. The quinone also produced from the oxidation of the phenolic compound is also electrophilic and reactive. Thus this oxidation-reduction reaction produces two reactive species that then further impact the composition of the wine.

Stabilization of Color Reaction of oxygen with anthocyanins leads to polymerization and stabilization of red color.

Anthocyanin compounds also react with oxygen and oxidizing agents. Oxidation of anthocyanin monomers converts them to a colorless form. Polymerization of anthocyanin monomers can produce colored species with enhanced color. The polymerized pigments are stable against bleaching by SO_2 and against other reactions leading to loss of color. Alternately, excessive polymerization may lead to loss of color as sediment.

Oxygen may dissolve into the wine through a wine:air interface. If there is an air space or "head space" above the wine post-fermentation the wine will be exposed to and "pick up" oxygen. Oxidation reactions can then happen at the surface of the wine. If this is undesired, then the winemaker must eliminate the air interface by **topping off** tanks or barrels. Space will form due to the loss of volatile components, principally water and ethanol, during aging. The amount of volume lost depends upon relative humidity as well as temperature.

Control of Oxygen Exposure

- **Use inert gas flush**
- **Limit headspace**
    - **Top-off barrels**
- **Monitor saturations**

Inert gas blanketing, argon, nitrogen, carbon dioxide, can be used to limit oxygen exposure of wine. It is also important to note the number of oxygen exposures a wine has undergone (number and nature of rackings for example). This will allow the winemaker to determine the optimum amount of exposure desired and to plan for it during the processing of the wine.

Aging Variables: Cooperage

- **Glass**
- **Stainless steel**
- **Wood**

The cooperage used to age the wine is obviously very important. In some cases the wine may gain characters from the cooperage itself, the cooperage may reduce or increase the likelihood of specific reactions occurring in the wine. Finally, some types of cooperage may allow better temperature control thereby indirectly influencing wine composition and aging.

We will consider three primary types of aging containers: glass, stainless steel and wood. Glass and stainless steel are neutral, not adding any nuances to wine. Both are impermeable to air and are more readily sealed therefore trapping volatile components and reducing volume loss. Both equilibrate with external temperatures rapidly.

Wood Variables

- **Source of wood**
  - **French**
  - **American**
  - **Other**
- **Aging of wood**
- **Toasting level**
- **Number of times it has been used**
- **Barrel, Staves, Chips**

Wood on the other hand is not necessarily neutral and can impart important flavors to wine. A full discussion of the uses and impact of wood on wine composition and perceived quality is beyond the scope of this course. We will be limited to a brief overview.

Phenolic compounds can leach from the wood into the wine that can affect oxidation-reduction reactions and participate in polymerization of other components. These compounds can have an indirect rather than direct role in wine aroma and flavor. The source of the wood is important but this may be more related to processing than composition. The length of time the wood has been aged prior to being used to construct the barrel, upright or vat, impacts the composition of the wood and therefore the characters that can be contributed to the wine. The process of wood bending has a strong influence on wood composition. There are four basic bending techniques or processes used to heat the wood so it is more flexible: direct flame bending, dry heat oven bending, wet heat (steam) bending and hot water bending. In direct flame bending the length of time the wood is exposed to the flame or toasted is important as this will lead to the development of different kinds of characters in the wood. Direct flame bending is somewhat inexact, meaning that there will be considerable variation within the same "lot" of barrels.

Wood exposure is not limited to aging in barrels. There are many **barrel alternatives** on the marketplace: oak chips, oak sticks (barrel "renewal" systems), and tank inner staves - planks of wood that can be used inside of a stainless steel tank. These alternatives allow extraction of wood components but not the oxygen exposure that can occur in a barrel that is not topped off regularly. Wine appears to pick up little oxygen directly through the staves of the barrel so most of the oxidation that occurs is due to the headspace. Other woods may also be used such as the redwood tanks in California or Acacia in Europe. A neutral wood is preferred.

Wood

- **Allows limited oxygen exposure**
- **Allows some evaporative loss**
- **Adds nuances**
- **Surface area versus volume of wine important**

Obviously the amount of wood components that are extracted into the wine will depend upon the surface are of the wood exposed to the wine as well as the age of the wood, prior usage and treatment.

Aging Variables: Yeast Lees

- **Yeast autolysis adds flavors**
  - **Long chain esters**
  - **Stimulates Malolactic Fermentation**
- **Activity of yeast enzymes continues post-lysis**
- **Impacts mouth feel**

Another important factor affecting wine composition during aging is the presence of the yeast lees. Yeast autolyze in wine releasing yeast components, particularly long chain esters. These components may have a direct impact on wine flavor, aroma or mouth feel or an indirect effect via chemical reaction with other wine components. The yeast also release enzymes, which have been shown to persist in the aging of sparking wines. The role of these enzymes in table wine aging is unclear.

Yeast autolysis can stimulate the growth of other microbes, such as the lactic acid bacteria, so some of the characters appearing in the wine may be due to microbial activity rather than aging per se.

Aging Variables: pH

- **Affects rates of some reactions**
- **Phenolic oxidation 9 times faster at pH 4.0 versus pH 3.0**
- **Affects microbial persistence and activity**

A frequently overlooked variable during wine aging is pH. Wine pH can affect the oxidation-reduction potential of wine, which influences oxidation-reduction reactions.

The pH can also affect the rate of some chemical reactions as well as the activity of the microbial flora, which may be present during aging. In general pH effects are not important if the wine is to be aged to chemical equilibrium, but are important if it is not.

Aging Variables: Catalysts

- **Metal ions can increase rates of some chemical reactions**

The oxidation-reduction reactions of wine can be strongly influenced by the presence of catalysts such as metal ions.

The presence of metal ions such as iron can strongly influence the rate of some reactions and can catalyze reactions that might not otherwise occur. Since wines are currently largely protected against the pick up of metal ions due to the use of inert materials, (stainless steel) their influence is minimal in modern wine production.

Aging Variables: Chemical Composition of Wine

It's what in there that counts!

We will end this discussion of aging by noting that the most important variable impacting the changes in wine during aging is the composition of the wine itself. Products cannot form in the absence of their reactants. For example, terpene glycosides are hydrolyzed during aging then undergo further pH, oxygen and time dependent reactions. If there are no or only very low levels of terpene glycosides, these products will not be produced at levels above the threshold of detection. The relative ratios of reactants will dictate what components are produced. The other variables considered merely impact these reactions.

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Lesson 18: Introduction

Blending and Sensory Evaluation of Table Wines

In this lecture we will cover the important topic of blending of wines. Blending can be used to achieve many goals in winemaking. The text makes the statement that blending is "where art replaces science in winemaking". In many respects this is actually quite true. It is in blending that a winemaker can best showcase her/his talents versus those of Mother Nature. We will also discuss the sensory evaluation of wines. It is important to use a statistically valid and robust method to determine if the wine composition is truly dependent upon winemaking operations, especially if those operations are costly.

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Lesson 18: The Objectives of Blending

There are many reasons to consider blending of wines. Blending can increase the complexity of wines within a vintage and can correct a deficiency or excess in the wine. Blending across vintages can freshen an old wine or age a young one.

Blending Objectives

- **Complexity within vintage**
- **Correct a deficiency or excess**
- **Freshen old wine**
- **Age young wine**
- **Fortification**
- **Amelioration**
- **As part of style**

Blending may also be done for a very specific stylistic purpose such as fortification or sweetening of a wine, or simply as a matter of style.

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Lesson 18: Labeling Regulations in California

It is important to know the regulations of a region with respect to the labeling of wine prior to blending of the wine. The regulations vary in different wine producing regions of the world.

Varietal Wine Labeling in California

- **Vintage: 95% must be from that vintage**
- **Varietal: 75% must be from that varietal**
- **Viticulture appellation: 85% must be from that growing region**
- **"Produced and Bottled By": must control 75% of the fruit**
- **"Estate Bottled": 100% must be from that appellation controlled by the winery**

In California, to be labeled as a vintage wine, 95% of the wine must be from that vintage. To be labeled as a varietal, 75% of the wine must be derived from that varietal. If the wine is a varietal vintage, the 75% does not have to comprise the 95%, meaning that both criteria must be met, but 5% of the varietal could be from a different vintage if desired. To be labeled with an AVA or viticultural appellation, 85% of the wine must be from that region. If the wine is to be labeled "produced and bottled by" the winery must control 75% of the fruit. Control in this case means direct all vineyard operations, but does not mean the vineyard must be owned by the winery. In the case of "estate bottled" 100% of the fruit must be controlled by the winery.

"Controlled by the Winery"

Do or direct all vineyard work-do not have to own all vineyards

Therefore there are many factors that must be considered in making a blend. In addition to the desired labeling, compositional features of the blend have to be well thought-out.

Factors to Consider When Choosing a Blend

- **Acidity**
- **Residual sugar**
- **Alcohol**
- **Appellation**
- **Flavor**
- **Style**
- **What are the most critical components?**

Residual sugar, alcohol and acidity are very important considerations for the finished wine. These characters must be in balance in the wine. Flavor and aroma traits must also be evaluated, and matched to style of the winery. The winemaker may have to compromise goals in producing the final blend so a critical first question is to decide what the most significant factors are.

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Lesson 18: The Blending Process

The Blending Process

- **Bench tasting to "guesstimate" best blends**
- **Make trial blends in a small scale**
- **Period of "marrying": 3 weeks to 6 months depending upon style**
- **Re-evaluation of blends**
- **Determination of final blends**

Blends are first made on a bench scale and evaluated. Blends considered desirable are produced in larger quantities and aged for a period of time (several weeks to several months). At the end of the "marrying" period the blends are re-evaluated and the final blend determined. This is an oversimplification of the process in many wineries. The blends may be tasted over a much longer period of time and readjustments made if a problem appears. Others simply blend their entire production based on a target goal such as ethanol concentration. Blending need not be confined to wines. Some winemakers believe that the flavors of the wine are better integrated if the juices or musts are blended rather than the finished wines. It depends upon the size of the winery and the style of wine being produced.

Why Do Blends Need to "Marry"?

To determine if an unexpected problem develops over time

There are several reasons for the marrying period. Some unpredictable changes may occur, which would create an instability or other problem in the blend that was not apparent in either of the original wines.

Types of Unpredictable Changes with Blending

- **Instability**
  - **Protein/polysaccharides haze**
  - **Microbial: bringing microbes and nutrients together**
  - **Tartrate: bringing tartrate and ions together**
- **Flavor changes**
  - **Masking**
  - **Unmasking**
  - **Creation of novel characters**

Instabilities may arise because components are brought together. Examples would be bringing proteins and tannins or polysaccharides together resulting in colloid formation and agglutination. It is also possible that both parent wines are microbially stable but the blend is not. This would occur if one wine contains microbes but no nutrients and the other nutrients but no microbes. Once brought together in the blend, growth can occur. A final example would be brining tartrate and ions together leading to crystallization.

Unexpected flavor changes can also arise in the wine. Flavors or aromas can "disappear" in the blend. This may be due to masking, that is the blocking of the perception of a character by another component or it may be due to simple dilution of the trait. If the concentration falls below the threshold of detection, it will no longer be perceived in the wine.

Masking

One flavor is masked by another: seems to disappear in the blend
Due to dilution
Due to competition for detection

Characters may still be present above the threshold of detection but go unnoticed if there is another compound present that competes with that compound for detection by our taste and olfactory receptors. Characters may be masked by a dominating trait in one of the blends.

The converse situation also occurs; blending may dilute a dominant character so that it is no longer chemically dominant. In this case other characters that were already present in one of the original wines but undetected, become unmasked and are now apparent in the flavor and aroma profile of the wine. Existing characters in one of the wines can be lost (masked) or gained (unmasked) in the blend.

Unmasking

A character present in one of the wines becomes more noticeable in the blend
Dilution of a competing factor that prevents/limits detection
Character due to a combination of chemicals and the concentration of those components increases in the blend

Factors may be diluted in the blend revealing other traits that are perceived more strongly. In this case the first compound has not dropped below the threshold of detection, but is now lower and therefore not competing with the second compound that now appears "unmasked". Alternately the dominating character may arise due to a combination of components in the blend giving the appearance of a new component. Some flavors and aromas are not due to a single compound but are the consequence of the presence of multiple compounds.

Novel Characters

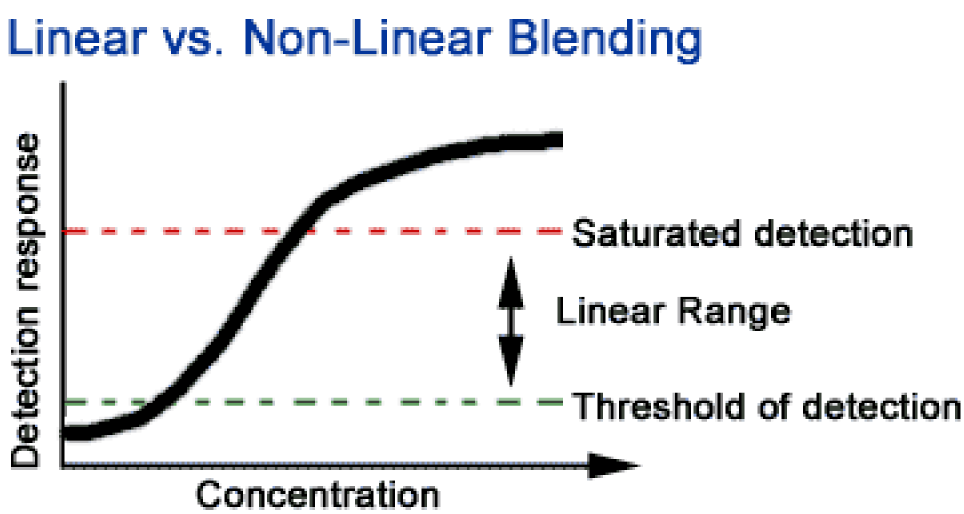
Chemical reactants brought together resulting in new aromatic products
Chemicals brought together that are percieved as something other than the original aromas.

Novel characters may also arise in the blend that were not apparent in the parental wines. This may be due to the fact that two reactants have been brought together that have formed a unique product or that the chemicals in combination are perceived as a different character.

Types of Unpredictable Changes with Blending

- **Some aromas are not linear with dilution**
  - **Below or above threshold of detection**
  - **Trait due to mixture of components**
  - **Matrix (acidity) effects**

Some traits are not "linear" that is they do not respond to dilution in a linear fashion. In this case a 1:1 dilution might not produce a wine with half of the intensity of the character. This is similar to the phenomenon of co-pigmentation. Dilution may drop the compound below the level of detection, which would obviously eliminate it from the aroma profile of the wine. The character may be due to a mixture of chemicals and dilution of the mix may drop one below detection thus eliminating the entire character. There may also be matrix effects that impact the appearance or volatility of the component. Also, a character may be present in both wines, but below the limit of detection in one of them, the blend may then be above the limit of detection because it contains the average amount of the chemical originally present in the parental wines, as weighted by the ratio of the wines in the blend. In each of these cases the component will not appear to display a linear effect upon dilution. The specific chemicals themselves respond in a linear fashion, our perception of them is not linear.



Even with a trait that shows a linear response it is important to be in the linear range of detection of the component. At some concentration the character will be present above our threshold of detection at lower concentrations we cannot detect the character. At a certain point the character reaches saturation - until it is diluted to the linear range we will not notice a decrease in the level of the character with dilution. In contrast, ethanol, residual sugar and total acidity are linear factors because they are determined by quantitative chemical means rather than by taste or perception.

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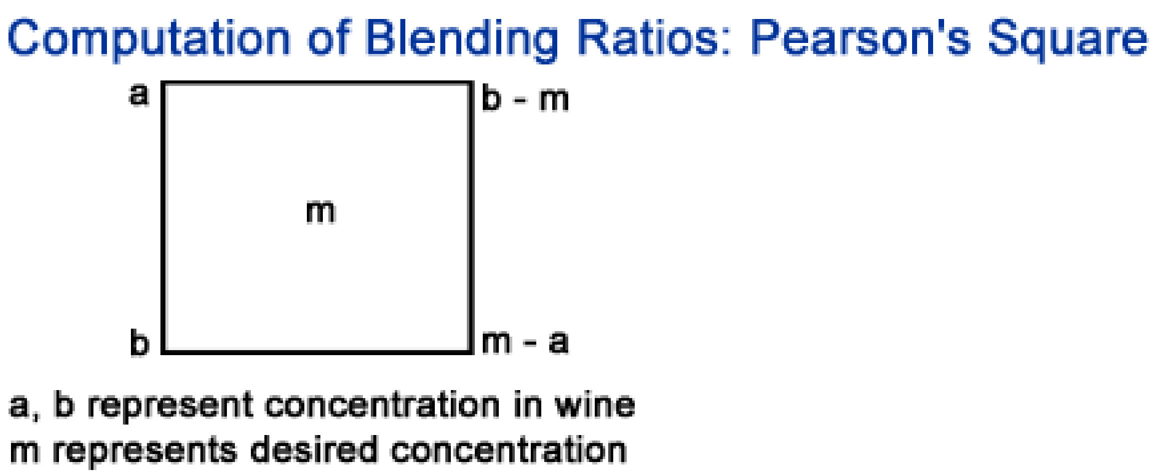
Lesson 18: Calculation of Blend Ratios

There are several different methods that can be used to calculate blend ratios for linear factors. A simple method described in the text is called Pearson's Square.

Computation of Blend Ratios

- **"Pearson's Square"**
- **By algebraic equation**
- **Graphical method for multiple components**
- **Software program**

The Pearson's Square method is based upon a simple algebraic equation of the relationship between the ratio of the two volumes, the initial concentrations of the compound in question in each of the parent wines, and the concentration in the blend.

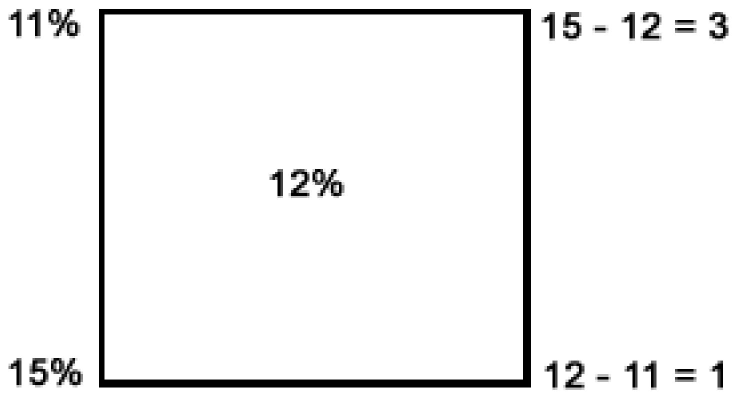


In this case "a" and "b" represent the lowest and highest concentrations in the two parental wines respectively, and "m" is the desired concentration in the blend. The concentrations are subtracted from each other as indicated. "b-m" gives the ratio of "a" to be added, and "m-a" the ratio of wine "b" for the blend.

Let's consider a specific example. Two wines are available with 11 and 15% ethanol. What ratio of the two wines must be blended if the desired final ethanol content cannot exceed 12%?

Pearson's Square: Example

Wine "A" is 11% ethanol, Wine "B" is 15%.
The desired final ethanol concentration is 12%.



A blend of 3 parts of A (11%) to 1 part of B (15%) will yield the desired ethanol concentration.

The proper blend is a mix of 3 parts of wine "a" to 1 part of wine "b". This is logical, as more of the wine that is closer to the final desired ethanol content is used in the blend.

Instead of a square, a series of algebraic equations can be solved:

Algebraic Equation

$$V_A + V_B = 1 \qquad V_A = 1 - V_B$$

$$11V_A + 15V_B = 12(V_A + V_B)$$

$$11(1 - V_B) + 15V_B = 12((1 - V_B) + V_B)$$

$$11 - 11V_B + 15V_B = 12 - 12V_B + 12V_B$$

$$4V_B = 1$$

V_B = 1/4 = 1 part of V_B to 3 parts of V_A

Multiple equations can be solved if needed. It is a good idea to check all calculations to be sure an error has not been made.

Always Check Calculations

3 parts of 11 = 33
1 part of 15 = 15

4 parts total = 48

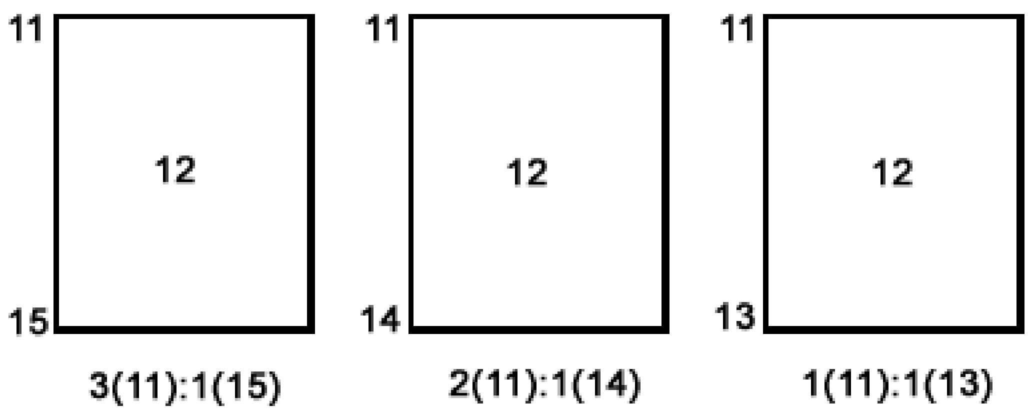
48/4 = 12

This can be done simply by multiplying the concentration by the ratio (number of "parts" of that wine) of the wines then summing the concentrations and the total number of "parts", and then dividing.

Pearson's Square can also be used for multiple wines as shown:

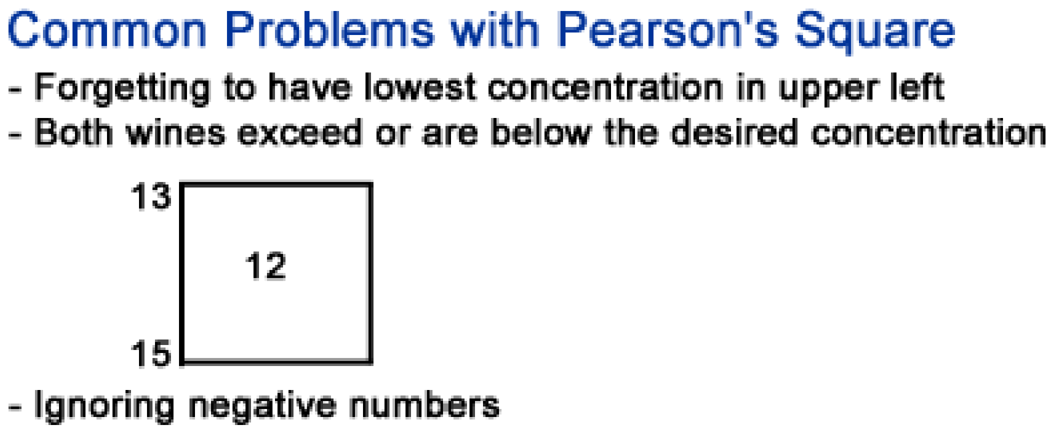
Dealing with Multiple Wines

A = 11%; B = 15%; C = 14%; D = 13% and want
12% ethanol for final blend



TOTALS: 1(15):1(14):1(13):6(11)

A common error in use of the Pearson's Square is to ignore negative numbers. Negative numbers would arise if both wines on the left side of the square exceeded or were less than the desired content of the blend, or if the wine values were placed in the wrong order.



If a group of wines is to be blended it is then important to determine the maximum volume that can be produced. One of your assignments will test your skills in this area. In some cases the ideal blend might not be possible to make. For example the appropriate blend giving the desired ethanol concentration might not give the desired residual sugar concentration or acidity. In this case, the winemaker has to make a judgment call as to which of the factors is the most important for the blend. It is also important to evaluate all possible blends that will generate a wine of the desired composition and to maximize yield. In the example above, the next step would be to evaluate the relative volumes of each of the wines to optimize yield. The 13% alcohol can be used in a 1:1 ratio with the 11% while the 15% ethanol wine requires 3 times the volume of the 11%.

Dealing with Multiple Components

Frequently, blend decisions are made considering multiple wines and multiple components (sugar, ethanol, acidity, etc.). In this case, graphical methods can be used to estimate the best overall blend. However, the ideal value of each component might not be attainable.

Graphical methods for determining the optimum blend of several factors exist (one is described in the text) and there are now several blending software programs that are on the market.

There are no set rules for the blending of table wines unless the winemaker is emulating a particular blend style such as Chianti. Subtle differences in blending ratios can have a strong impact on the aroma profile of the resulting wine. This is why blending is considered to be more of an art than a science.

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Lesson 18: The Sensory Evaluation of Table Wines

Our next topic is the sensory evaluation of table wines. It is important that sensory evaluation be done correctly. There are different methods that can be used, depending upon what the goal of the analysis is.

Sensory Analysis

> **It is important to use scientifically sound procedures for the evaluation of wines**

It is important to not bias the sensory evaluation in any specific direction. This can be quite innocently done for example like asking tasters or judges which wine has the highest concentration of citrus character versus first determining if citrus character is detectable in either wine.

Wine Attributes for Analysis

- **Appearance**
- **Odor**
- **Taste**
- **Aroma**
- **Flavor**

Wines can be evaluated for their appearance: color, clarity, presence of sediment. They can also be evaluated for odor and taste. For a compound to be detected as an odor it must be volatile. The primary tastes are: sweet, sour, salty and bitter. Astringency can be perceived but is not actually a taste. Taste can be discriminatory, for example, sweet and sour can be detected at the same. This can be more challenging with odors - the combination may be perceived as a different character rather than the sum of the two initial odors. Therefore wine aroma - the synthesis of the individual odors can be evaluated. Similarly, flavor has been defined as the interaction of taste and aroma, and this can be assessed in wines as well.

The temperature of the wine may influence taste, depending upon what components are present. Temperature also has a dramatic affect on aroma as it affects compound volatility. The time the wine has been in the glass prior to evaluation is also important. If too long of a period of time has elapsed, many of the more highly volatile components may be lost from the aroma profile. Much has been written about the shape of the glass and how the aroma is "presented" to the nose - this is usually not an issue with an experienced taster as experienced tasters know how to evaluate aroma regardless of the shape of the glass, but it may be important with a novice.

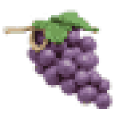
Lesson 18: Methods for the Sensory Evaluation of Wine

There are several techniques for the evaluation of wine. Which technique is most appropriate depends upon the aim of the analysis and what kind of information is being sought.

Sensory Evaluation of Wines

- **Descriptive analysis**
- **Difference tests**
- **Intensity rating**
- **Hedonic tests**

Descriptive Analysis



- **Goal: to describe the aroma and flavor profile of a wine**
- **Using panel discussion decide upon flavor/aroma characters of wine**
- **Train tasters using standards (wine spiked with characters of wine)**
- **Blind tasting to determine if characters can be reproducibly recognized in wines**

Descriptive analysis can be used to determine which compounds are present in a given wine. This technique profiles the primary aroma and flavor components of a wine. It is critical that real descriptive terms (cherry, wet dog, plastic) be used rather than esoteric expressions (finesse, arrogant, petulant) since the goal is not to win a creative writing award but to evaluate the wine. Since sensory receptors and therefore the ability to perceive components vary across the human population, it is important to perform the descriptive analysis with a group of individuals (10 to 15).

The panel of tasters initially taste and smell the wine and make note of the primary components that they detect. The tasters then compare notes and determine the consensus description of the wine. Standards are then generated using the descriptors in neutral wines and the wines evaluated again by the tasters after they become thoroughly familiar with the character in the control wines. Discussions by the panel again occur after this process. The ultimate goal is a strong consensus of the foremost aroma and flavor traits of the wine. Blind tastings are then done to evaluate wines based on the characters identified in the descriptive analysis and to confirm their importance.

Sensory analysis, if done correctly, can be time-consuming but is well worth the effort. It is important to be aware of the problem of fatigue and to not attempt to analyze too many wines at once. Tasting is generally more fatiguing than smelling of the wine. This is because taste may continue to be perceived after the wine has been expectorated.

Difference Tests

- **Use trained judges**
- **Determine if two wines are reproducibly selected as different**
- **Requires statistical analysis**

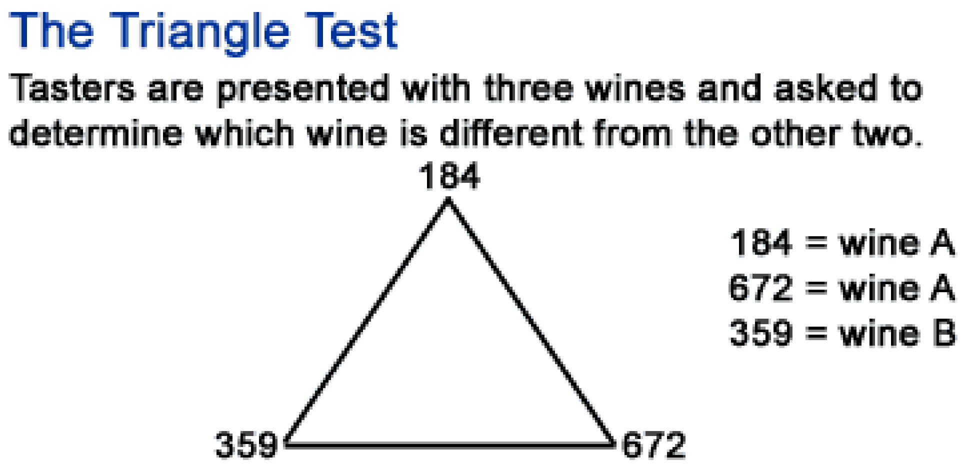
Another type of sensory evaluation is difference testing. In this case the goal is to determine if two wines can reproducibly be identified as different from each other. These types of tests are important when trying to determine if a vineyard or winery treatment has had a significant impact on the flavor or aroma of the wine. Significant in the statistically reproducible sense, not in the magnitude of the change in the character. One is frequently evaluating wines for quite subtle changes in aroma or taste.

Difference testing uses trained judges and involves a statistical analysis of the data. Two types of difference tests are commonly employed in the analysis of wine. One is called the triangle and the other the duo-trio.

Difference Tests for Wine Evaluation

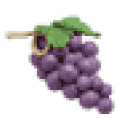
- **TRIANGLE**
- **Duo-Trio**

In the triangle test, the taster is presented with three wines. Two of the wines are identical and one is different. The taster is told this and is asked to identify the wine that is different.



Statistical tables can be used to determine if the percentage of correct answers is significant or not, that is, is unlikely to have occurred by chance.

In setting up these kinds of tests it is important to use a random numbering scheme so that the tasters are not biased by some numerical consistency of the analysis. Students frequently ignore my direction to use randomly generated numbers and come up with a pattern to the code that is convenient for them to use. However, tasters usually detect the patterns either consciously or sub-consciously in the evaluation of the wines. For example, one student group in performing a triangle test made sure that the two wines that were identical had the same middle number: 306, 407, 658; most tasters keyed in to this and were selecting as different the wine that did not have the identical middle number. No patterns in the "random" three digit codes should ever be used.



The Triangle Test

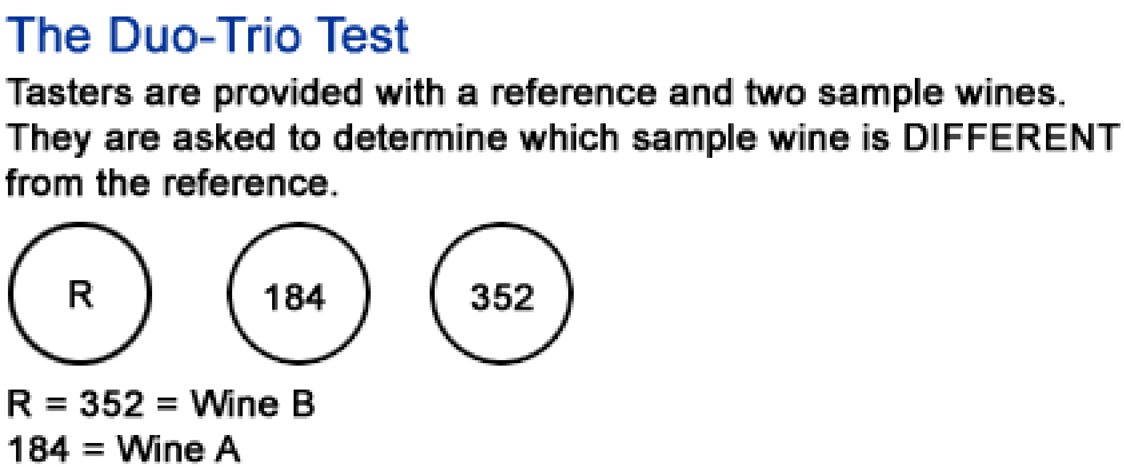
A statistical analysis can then be used to determine if the number of times wine 359 was selected as different is significant or not.

The next test is the duo-trio. This test also involves comparison of two wines. But in this case one is a reference wine and two are samples.

Difference Tests for Wine Evaluation

- **Triangle**
- **DUO-TRIO**

The taster is told that the reference is identical to one of the sample wines and asked to select the wine that is different from the reference.



The taster can also be asked to describe the magnitude of the perceived difference or to note the component that is most discriminating for the wines.

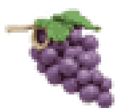
The Duo-Trio Test

A statistical analysis can then be used to determine if the number of times wine 184 was selected as different is significant or not.

As with the triangle test, a statistical analysis can be performed to show that the correct wine was selected with a frequency much higher than expected from random chance. Alternately, is it just as important to learn that the wines are not significantly different. These tests can be fatiguing. The triangle is more fatiguing than the duo-trio. The order of presentation may also be important so should be evaluated in the analysis by having replicate sets with differing orders of presentation (i.e. reference-identical sample-different sample versus reference-different sample-identical sample). It is important to include a test of fatigue - present two identical sets one early and one late in the presentation of wines and determine if the judges have lost the ability to discriminate the second set.

Wines can also be evaluated for the relative intensity of a specific character. This is called intensity rating.

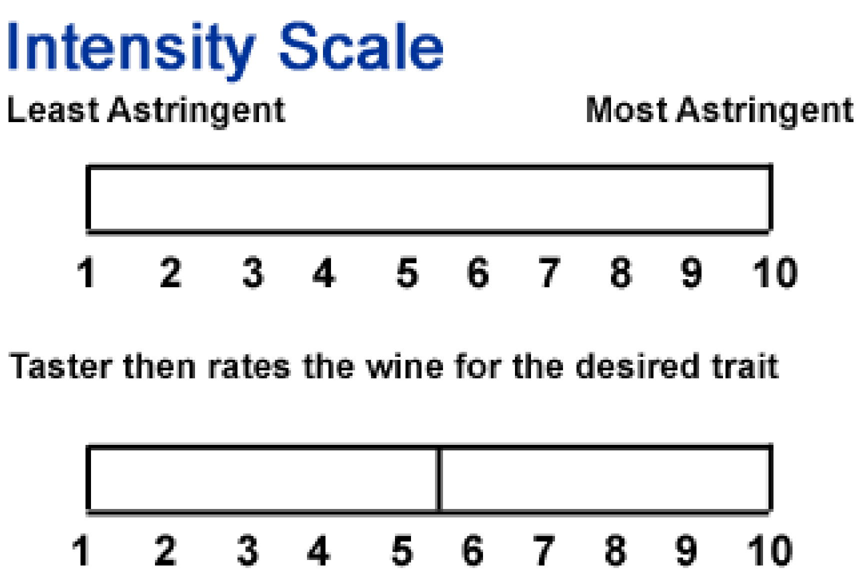
Intensity Rating



Important to train judges to know what a term is and what value they will assign to specific intensities in wines
Can then convert rating into a numerical score for statistical evaluation

This involves extensive training of the tasters or judges. The judges need to know what the term means, and they need to be shown different concentrations in a base wine to determine the linear range of detection. The linear range may vary by the judge, and it is important to know this prior to the start of the analysis.

The judges then need to translate an impression of the concentration into a numerical value. In the beginning this is done with standard solutions of varying strength to "train" the judge, before the real samples to be evaluated are presented.



The statistical analysis of the data generated from an intensity analysis is more involved than the descriptive analyses and unfortunately beyond the scope of this course. More involved analytical methods, such as principle component analysis, can be used in the evaluation of wine, but this is beyond the scope of this course as well.

The final type of sensory analysis is hedonic or preference testing. This simply asks the tasters which wine they prefer. The test must be done under appropriate conditions so that preference is genuine and not influenced by other factors (such as the packaging) unless that is part of the study. It should not be done in a busy, noisy, public tasting room at the winery.

Hedonic Tests

Uses untrained consumers
Evaluates whether a taster likes a particular wine or not
Can use an overall evaluation scale

Frequently this is the method of choice for determination of consumer preference with respect to style of a wine. It is important that the consumers not be pre-biased by the individual conducting the analysis. For example, "I hope you pick my favorite wine, the one with the citrus character".

An overall evaluation scale can be used such as the one that follows:

Overall Evaluation Scale

Assign wine to one of the following categories:

1. **Like intensity**
2. **Like moderately**
3. **Like slightly**
4. **Neither like nor dislike**
5. **Dislike slightly**
6. **Dislike moderately**
7. **Dislike intensely**

One common "rookie" mistake with this type of analysis is the attempt to use cute or attractive phrases to describe the wines. This can lead to consumers selecting their favorite phrase rather than evaluating the wine. The following scorecard was used by a student group in the evaluation of their research wines in VEN124:

Please check the appropriate box: 1 = excellent 7 = horrifying	
1	LOVE this stuff!!
2	Sure, I'd drink this stuff.
3	Well...if there is no other stuff...
4	Hey, it's stuff...
5	This stuff's a little freaky.
6	What's going on with this stuff?
7	Gross...You call this stuff???

Most tasters were attracted to one of the phrases indicated by numbers 5 through 7. The terms are too close to each other and too vague in exact meaning to be discriminatory. I let them use the scorecard knowing that they would realize they had a problem when they did the analysis of the data.

Selection of Type of Sensory Analysis

- **What are you trying to determine?**
- **Judge/taster fatigue**

The tests presented above are obviously geared towards providing different types of information. Difference testing is used to determine if wines produced using different methods are detectably different in character. This does not mean one is bad and the other good, just that they are different and the difference is detectable. Intensity tasting can be used to determine if the composition of a specific character has changed by treatment, such as determining if the aging regime has lead to a detectable difference in astringency. Preference testing may be used to refine style either using expert tasters with a clear stylistic goal in mind. It can be used (with caution!) to allow consumers to direct the winemaking style toward a more marketable product. You will no doubt notice that I have not included a numerical ranking. I refer you to the article by Ann Noble "Missing the Point" in your readings. These numerical scales are excellent training tools, but are difficult to use for the sensory evaluation of wine without very extensive training of the judges. They are most frequently used as indicators of commercial acceptability rather than as a formal sensory analysis

Finally, the combination of consumer preference profiling (a hedonic test) with descriptive analysis by trained judges can be quite powerful. In this case these two processes are independent. The consumers processes are independent. The consumers are not involved in the descriptive analysis but simply indicate wine preferences. A statistical analysis combining the preference and descriptive analysis data can be conducted to determine if there is a general consensus of preference for a given style of wine.

This ends our section on post fermentation processing. The final section of the course will focus on the flavor and aroma compounds of wine, their sources and means to manipulate wine composition and character.

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