Beer and Wine

Difference between wine, beer and liquor

Beer, wine and liquor – all the result of fermentation (aka metabolism aka respiration) of sugars. The source of the sugar, and how the fermentation is processed makes the difference between each type of ethanoic drink

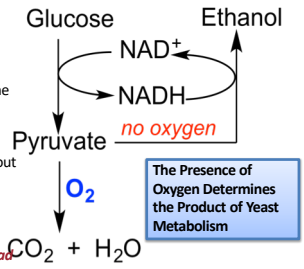
Beer – starches from seeds, adjuncts for flavor; un-processed
Wine – glucose and fructose from grapes; unprocessed
Liquor – Sugars from a variety of sources; ethanol concentrated by distillation

Alcohol	Raw Sugar Starting Material	Additional Processing
Wine	Grapes or Fruit	Aging for oxygen and tannin reaction
Beer	Barley, wheat, rice, corn	Added hops and adjuncts for flavor and minimal aging
Mead	Honey, some add fruit or spices	Solids are settled by gravity
Cider	Primarily apples, some other fruits	Pectin is removed by precipitation and solids settled
Sake	Polished white rice	Molds digest starches for yeast, additional alcohol added, solids filtered
Vodka	Potatoes, grains (wheat, rye), fruit	Distillation and rectification (repeated distillation for high alcohol content)
Tequila	Aguave cactus, sugars, pineapple	Distilled. Silver – bottled after distillation, Anejo/Reposado – aged in barrels
Rum	Sugarcane products, juice & molasses	Distilled and aged in oak casks for color and flavor
Whisky	Barley, corn, rye, wheat	Distilled using copper to remove sulfur and aged in oak barrels or casks

Fermentation is the metabolism of sugars producing ethanol – Catalyzed by yeast

Yeast are facultative anaerobic organisms

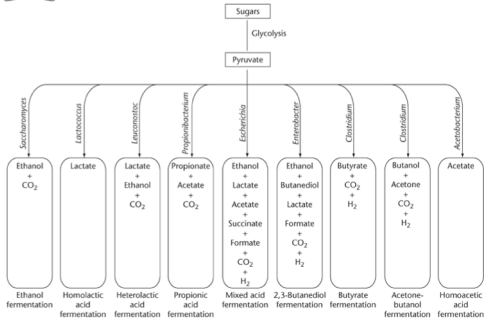
- Facultative anaerobes (bacteria, yeast and other organisms) can switch between metabolic pathways depending on the presence of oxygen.
- NAD+ / NADH is a limiting reagent forcing the switch between pathways.
- Without oxygen ethanol is produced
- In the presence of ethanol – NAD+ is regenerated producing more ATP than without oxygen
- Robust cell division requires oxygen – important for fermenting for alcohol



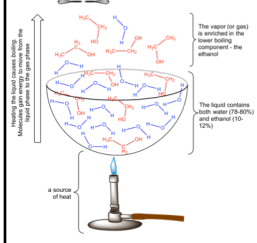
The Presence of Oxygen Determines the Product of Yeast Metabolism

Similar to when animals produce lactate instead of ethanol in the absence of mitochondria or oxygen!

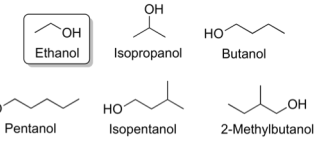
Types (strains) of yeast used in fermentation



More than just Ethanol



Liquors are the distilled spirits of sugar fermentation!
- Oh and any side products that also separate out – think volatiles



The problem with white-lightning!

Fusel Alcohols. A number of longer chain alcohols are produces during fermentation. Ethanol (2 carbon) is the substance commonly called alcohol. All of these compounds are chemically defined as alcohols due to the functional -OH group.

Beer

Fermented starches (typically 1-8% alcohol) from barley, rice corn or wheat.

- ***The trick – breaking down the complex carbohydrate (starch) into smaller pieces for yeast to ferment***

True origin is unclear:

- Likely started with a bowl of boiled or cooked barley which was exposed to environmental yeast – someone was interested in the look and smell of the bubbles forming and tried a sip

•Ancient hymns of the Sumerians gave a recipe for making beer

•Code of Hammurabi (Babylon 1795-1750) gave rules for fair price of beer and the punishment (drowning)

Beer

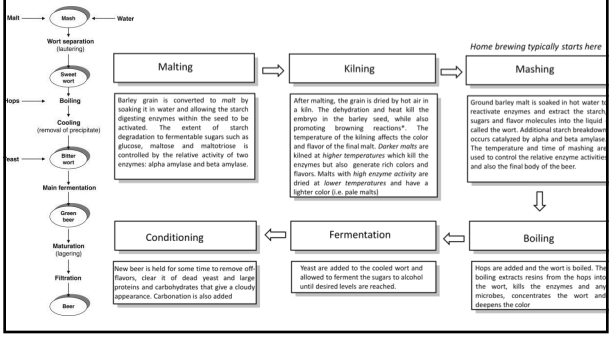
Fermented starches (typically 1-8% alcohol) from barley, rice corn or wheat.

- ***The trick – breaking down the complex carbohydrate (starch) into smaller pieces for yeast to ferment***

Ancient Methods to overcome this issue:

- Chica – Incan women chew corn to release starch digesting enzymes into saliva – spit and mixed with boiled-cooked (to break apart seed) to start fermentation
- Chhu/Jihu – Asian beer – used mold from rice to create enzymes to break down starches in fresh rice
- Near East (Mesopotamia to Egypt) allowed the seed to begin to germinate (grow) which produced it's own starch digesting enzymes (malting)

Process of Brewing



Categories of Beer

Key difference within the two major types of beers (Lager or Ale) depends on the yeast used to ferment the mash and the temperatures during fermentation

Ale – Use brewer's yeast which grow fast at higher temperatures. Typically considered top fermenters. Trap CO2 and "float" at the top of a fermentation

Lager – ferments slower with a yeast growing at low temps (bottom fermentation)

A "fusion" of three strains of yeast likely gave rise to the colder tolerant bottom fermenters – Bavarian GMO!

Types of Lager

Lagers "to store" longer fermentation at colder temps (bottom fermenter) resulting in a mile beer without esters of ale beer

1. American style pale lager
2. Pilsner – more distinct flavors than American pale lager.
3. Light lager – more carbonation than others
4. Dark lager

Types of Ale

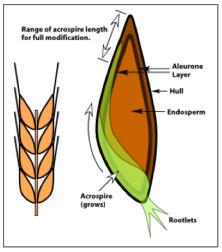
Top fermenters which ferment faster at higher temps giving more esters as flavors from yeast

1. Brown ale – red or copper colored, more mild in flavor
2. Porter – darker (browned and caramelized grains) with full body.
3. Stout – Nearly black in color high amounts of hops and barley

Barley

Beer can be made from many starch containing seeds but typically is Barley

- The starch in the endosperm is not ready for yeast to use
- Starch in endosperm, is enclosed by the hull
- Germination (malting) starts the natural processes of releasing the seed's own enzymes to break down the starch and soften the grain



Malting

Goal of malting is to produce enzymes from grain to digest starch to smaller sections – yeast doesn't metabolize starch but can use glucose (maltose and maltriose)!

Three steps of malting – steeping, germination and kilning.

1) Steep (soak) seed in warm water for several days.

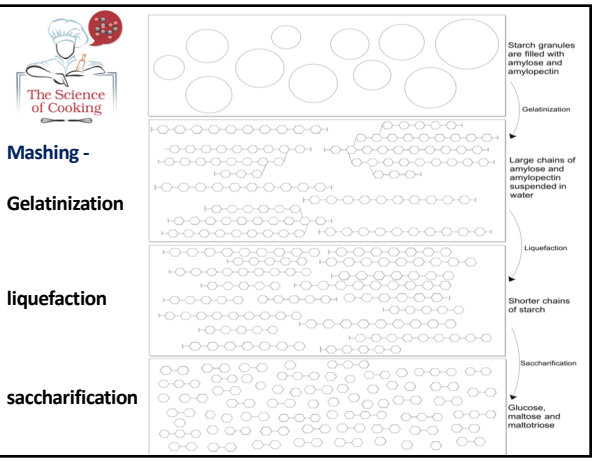
- The water starts the enzymes and hormones which control's a seeds breakdown of it's husk (cell wall) and starches
- Wake up the cells in the seed embryo as the seed begins to sprout and produce amylase (alpha and beta amylase)
- A very carefully timed event – too much enzyme action and most the starch will be digested
- Hormones from plant initiate and support the seed growth
- Malting Stopped by removing water, drying and heating.

Pale malts – must be stopped as soon as the kernel is softened
Darker malts - (simple sugars for browning) must be digested further and heated for longer time periods

Mashing

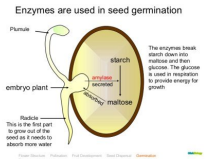
Mashing – activate amylase and other enzymes produced by seed in malting phase to create fermentable sugars from starch.

- These enzymes digest starch into smaller pieces (oligosaccharides, disaccharides and monosaccharide) of glucose
- Hot water helps to swell the starches into a gel for better reaction with the enzymes

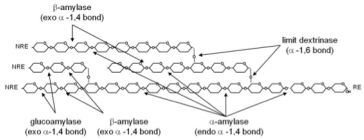


Amylase Reactions During Mashing

Enzyme name	Reaction	Substrates	Products	Optimum temperature
α-Amylase (EC 3.2.1.1)	Endohydrolysis of 1,4-α-D-glucosidic linkages	amylose, amylopectin	dextrins, maltose, limit-dextrin, glucose (low amounts)	65–75°C
β-Amylase (EC 3.2.1.2)	Successive exohydrolysis of the penultimate 1,4-α-D-glucosidic linkage at the non-reducing end of chains	dextrins, amylose, amylopectin	maltose	60–65°C
Glucoamylase (EC 3.2.1.20)	Successive exohydrolysis of the terminal 1,4-α-D-glucosidic linkage at the non-reducing end of chains	maltose, dextrins, amylose, amylopectin	glucose	35–40°C
Limit dextrinase (EC 3.2.1.142)	Hydrolysis of 1,6-α-D-glucosidic linkages	amylopectin	dextrins, maltose (smallest sugar released)	55–60°C
Invertase (EC 3.2.1.26)	Hydrolysis of sucrose	sucrose	glucose and fructose	58–62°C, 33–35°C*



Reducing Ends (RE)– mutarotatable anomeric carbon – one per "chain end"
- Beta amylase can only cleave from RE, mix of a/b amylase allows for digestion of starch to "metabolizable sugars)



Starch degrading enzymes are Expressed from aleurone cells – produce "fermentable sugars"

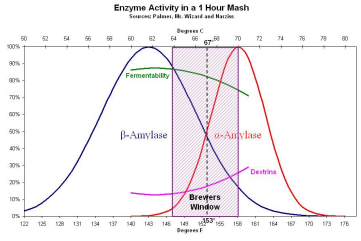
Alpha vs Beta Amylase

Alpha-amylase is denatured at higher temps (~80oC) with a pH optimum of 5.6-5.8

Beta-amylase is more active at lower temps and lower pH

The higher the temp for mashing the greater the proportion of unfermentable dextrins in the mash(beer or distilled liquors).

- Mashing at lower temps results in more fermentable sugars and higher alcohol production from fermentation

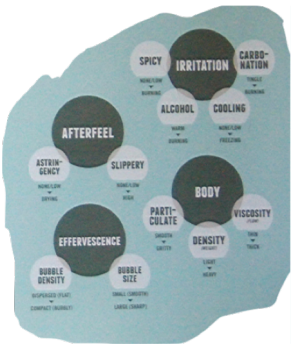


Find the balance for fermentation and dextran mouthfeel.
Other amylases are for "clean up" reactions and produce free glucose
Unsaturated fatty acids are also generated during mash

Mashing

Proteases from the seed are are activated.

- Digest proteins to peptides and amino acids.
- Together with sugars "dextrins" create the foam and "mouthfeel"
- *Last steps help to break down cell wall of seed and high temp treatment kills the malt enzymes*



Mashing

Cereal Adjuncts – a second source of starch – corn, rice or unmalted barley

- Add additional sugar for fermentation
- Mostly done with pale and mild brews like American lager (reduce costs of beer production)
- Used to create variety beers – winter wheat…

•Result of mashing then extracting the liquid from the resulting solid is called "wort" which needs to be filtered and solid ppt removed

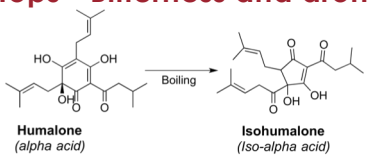
- Called "sweet wort" until hops are added, then called "hopped wort"

Hops

Cones of female flowers called hops

- Produce oils/waxs (resins) which are used to flavor beer
- Prior to hops – spices would hide off flavors
- Used to balance the sweetness of sugars of malt by adding bitter flavors– alpha acids and phenolics

Hops - Bitterness and aroma

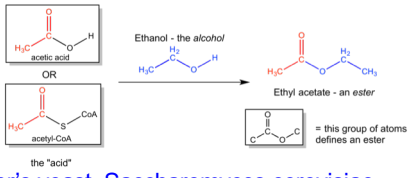


Humalone *(alpha acid)* **Isohumalone** *(Iso-alpha acid)*

The more hops are added the stronger the beer

- Many many varieties and ways of working with hops to give different flavors
- Alpha acids – give bitter taste to beer
- Noble hops – four key varieties with low bitterness and high aroma
- Boiled hops – alter the alpha acids to make more soluble in water (add the bitterness) but lose most of the aromatic oils

Top fermentation



Uses brewer's yeast, Saccharomyces cerevisiae

- Yeast grow at higher temps, for ale production
- Yeast trap the CO2 and rise to the top
- Yeasty foam is skimmed off top – often contaminated with bacteria producing lactic acid
- Produce strong flavors - produces esters; isoamyl acetate (banana) ethyl acetate (flowery aroma), ethyl caproate (fruity aroma)
- Takes only a few days to fully ferment

Bottom fermentation

Lager Fermentation - Slower colder temps using larger sized yeasts Saccharomyces uvarum

- Yeast fall to bottom of liquid at end of fermentation
- Lower temps and longer times (several weeks) produce a mild flavor
- This is mostly used in US – less harsh beers are produced this way

Conditioning

At the end of fermentation, diacetyl (buttery flavored fatty acid) is produced

Fermentations are often heated to reduce this compound (called Diacetyl rest)

- Important when using excess adjunct due to excess sugars
- Also when fermenting lagers – they are lighter flavored and can't hide the diacetyl

Sulfur gas is removed by bubbling gasses

Added hops for aroma may be added

Further filtering and removal of solids

- Often times fining agent (isinglass gelatin from fish bladder) to settle solids in cask or during rest.

Store at cold temps then filtered to convert green beer to finished beer after carbon dioxide is added

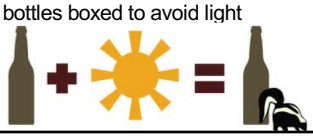
Keep it in the Dark

Beer will spoil with time – oxidation of sugars and fats will create harsh beers.

Blue-green light – reacts with hop's acids producing a sulfur product similar to skunk gland

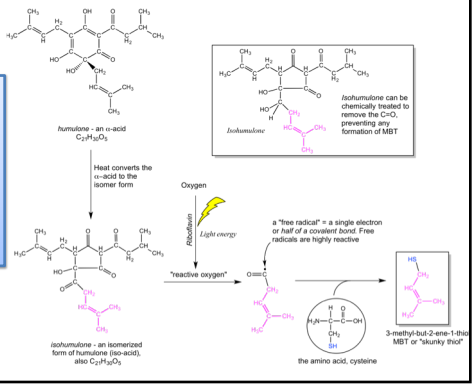
Clear and green bottles do not block this light which allows the reaction to happen quickly

- Miller Genuine Draft – adds a chemically modified hop to stop the production
- Corona keeps the bottles boxed to avoid light contamination

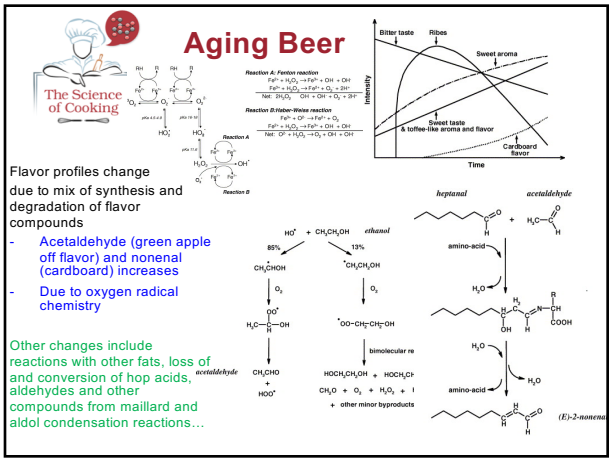


Off Flavors in Aging

Skunk-Proofing Beer. Conversion of isohumaone followed by light induced oxidation (free radicals) result in foul smelling sulfur compounds.



Aging Beer



Flavor profiles change due to mix of synthesis and degradation of flavor compounds

- Acetaldehyde (green apple off flavor) and nonenal (cardboard) increases
- Due to oxygen radical chemistry

Other changes include reactions with other fats, loss of and conversion of hop acids, aldehydes and other compounds from maillard and aldol condensation reactions…

Wine

People have enjoyed drinking wine for thousands of years. Like many other happy human discoveries, wine was likely discovered by accident. By 3000 BC, people in ancient Egypt and Persia were making wines. The art and science of winemaking has changed considerably since these early times.

Composition of a typical wine

- **85-88% Water**
- **10-16% Ethanol**
- **0.5% Acids** *(Tartaric and others)*
- **0.4-0.6% Volatiles**
  - *phenols*
  - *short chain fatty acids*
  - *fusel alcohols*
  - *ketones*
  - *esters*

Wine Grapes

Red and white grapes for a Shiraz or Chardonnay. Red or white wine has the color due to the time the skin color is extracted from the wine.

Grape Anatomy

Exocarp (Skin)

Terpenes
- Geraniol
- Terpineol
- Nerolidol
- Linalool

Norisoprenoids
- beta-damascenone
- beta-ionone

Thiols
S-3-(hexanol-Cysteine)

Mesocarp (Fleshy Fruit)

Organic Acids
- Malic acid
- Tartaric acid

Sugars
- Glucose
- Fructose

Wine Grapes

Sugars – mostly glucose and fructose
- up to 20-30%
- Color of grape is due to skin, not the sugar or other content, thus the wine color has little to do with the color of the grape

Acids – tartaric acid (skin) malic (sour like a green apple)
- Some fermentation converts malic acid to lactic acid (less tartness)
- Ripe grapes have less acid than younger grapes – winemakers sometimes add acid, others remove the acid by precipitating tartaric acid

Tannins – come from seeds and skins of grapes (also the stems if not picked clean)
- Tannins create an astringent feeling (the feeling that causes one to pucker the mouth)
- Is a preservative and together with acid is the "structure" of wine

Where they grow makes a difference

Terroir (land) – how soils and climate shape a grape and thus the wine
- This includes the entire Physical environment
  - Climate
  - Soil type
  - Water saturation
  - Slope and orientation
  - Shade or sunny

Making the Wine

Three stages:
- Crushing grapes for the Juice
- Fermentation by yeast (new wine)
- Aging or maturation of wine

Must

Must – (Latin for young wine) is the pressed, crushed extract from grapes that becomes wine
- The solid portion is pomace
- Pomace must stay with the juice to give the chemicals from the skins and solid portion of the grape their constituents
- Stems have bitter tasting resins
- Skin has phenolic compounds
- Both contain tannins and colorings
- Seeds have oils and tannins
- *Pressing will give the character of the final wine*

Added Substances

Many chemical additives are used to improve wines.
- Enzymes – added to fermenting wine to prevent unwanted disease causing yeasts from growing
- Polysaccharides – promote retention of color, tannin and flavoring compounds from grape skins
- Sulfur dioxide – used to inhibit other yeast and bacteria and preserves (antioxidant) flavor and color molecules
- Acid and simple sugars (glucose) – balance to recover what grapes may lack.
  - Grapes grown in a cool climate will have low sugar
  - Grapes grown in hot will have lost some of their acid

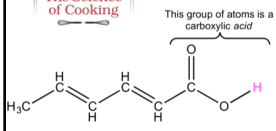
Sulfur and Wine

Both acts as an antimicrobial for sterilization (at high concentrations) and at lower concentrations will serve as an antioxidant – protecting color and aroma compounds from oxygen reactions while aging

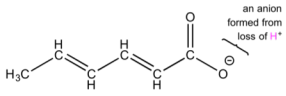
Molecular SO_2	Bisulfite HSO_3^-	Sulfite SO_3^{-2}	Bound vs. Free Sulfur
- Antioxidant and inhibitor of browning oxidizing enzymes - Gas, soluble in water - Only found in appreciable levels in pH<1	- More prevalent at the low pH of wine - Binds aldehydes, sugars and anthocyanins (bound SO_2) - Prevents browning enzymes (quinones) and chemical oxidation (reacts with R-C=O groups)	- Major form at pH greater than 7.5 - Strong antioxidant - Slowly reacts with oxygen and is one of the effects of aging.	Bound – sulfite bonds or interacts with carbohydrates, polyphenols and aldehydes Free – Unbound sulfur, in wine bisulfite in more pH neutral water a mix of sulfite and bisulfite. Only free forms of sulfites act as an antimicrobial

1-100 people are sensitive to sulfite. Headaches and some asthma attacks.

Sorbate as a preservative



Sorbic acid - dominant at low pH (< pH 4.75)



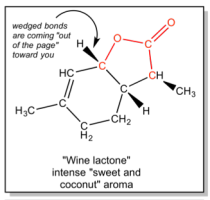
Sorbate - dominant at high pH (> pH 4.75)

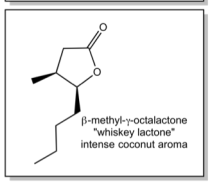
Used to stop yeast growth after fermentation – prevent gas (CO2) production and exploding bottles (beer too)
Two forms – sorbic acid is 20 times more effective than sorbate form – pH is important

Oak Flavoring

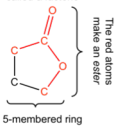
Lactones Provide Some of the Flavors of Wine and Whiskey. A compound with a ring structure containing a carbon double bonded oxygen aka ester is a lactone.

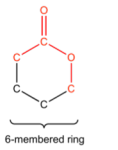
Two types of wine oak
- French oaks have high tannin content
- American oaks have less tannin but more lactones/aromatic content





When an *ester* is located within a ring, the ester is called a *lactone*



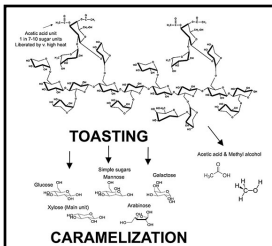


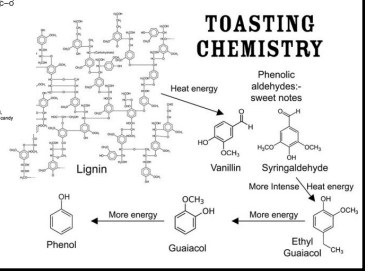
Charring (toasting) oak creates caramels and butterscotch flavors as well as maillard products

Types of Oaks

Vanillin	Vanilla aroma
Fresh oak	Trans- lactones
Coconut	Cis- lactones
Spice and clove	Eugenol and isoeugenol
Caramel, butterscotch and sweet	Furfural and 5-methylfurfural
Cinnamon and spice	Coumarin
Charred and smoky aromas	Guaiacol and 4-methulguaiacol

Toasting Oak – Lignin formation of flavors

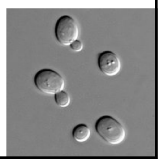




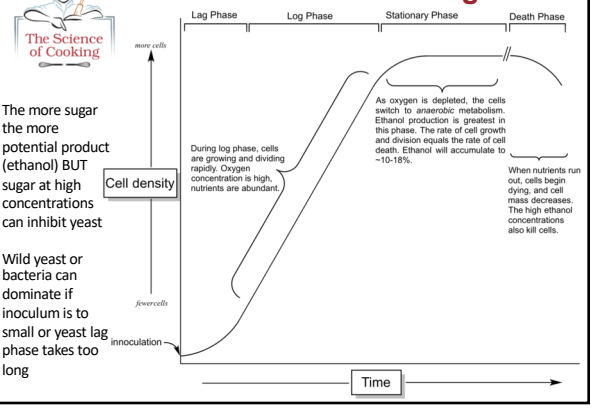
Fermentation

Many vineyards use the yeast from the skins on the grapes – others use *Saccharomyces cerevisiae* (brewer's yeast)

- Brewer's yeast can tolerate higher levels of alcohol and heat – thus they keep making ethanol!
- Other alcohols are also made
- Some of the acids made by yeast create the aroma and flavor of wine



Fermentation - stages



The more sugar the more potential product (ethanol) BUT sugar at high concentrations can inhibit yeast

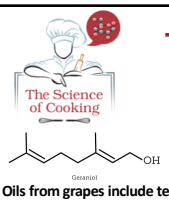
Wild yeast or bacteria can dominate if inoculum is to small or yeast lag phase takes too long

Temperature and time

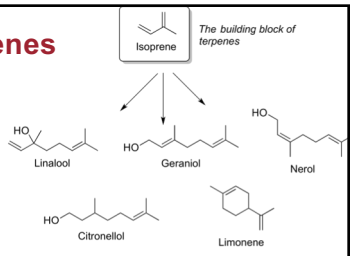
Fermentation temp and time are part of the art of wine making

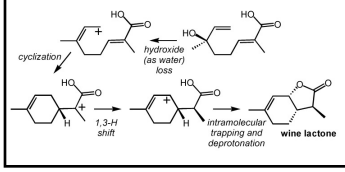
- White wines – 4 to 6 weeks at 60ºF
- Red wines – need more time in contact with skins to get structure at higher temps (65-80ºF)- then the solids separated and a second fermentation for 2-3 weeks.
  - White wines – low skin and seed contact during formation, red wines – extended extraction time during formation (alcohol draws out tannin and phenols from skins, seeds and stems)
- Long fermentation at low temps generate more aromatic molecules
- Fermentation is finished when sugar is consumed by yeast.
  - The less sugar remaining, the more dry the wine
  - Some sweet wines are stopped early or some of the juice (saved in reserve is added back)

Terpenes



Oils from grapes include terpenes (isoprene polymer)
- Yeast and fungi metabolizes terpenes into the small volatile compounds responsible for odor and flavors of wine

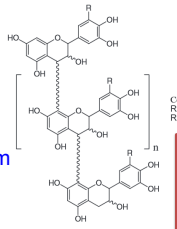




Linalool loses a water to form an allyllic carbocation. Subsequent cyclization to form an α-carboxyl carbocation was proposed to be followed by a 1,3-hydride shift and intramolecular carbocation trapping

Several isomers of wine lactones give the mature wine fruit odor/flavor

Tannins



Long polyphenol polymers – come from bark and woody portion of wine grape

Tannins are part of the flavonoid phenolics (4 classes: catachins, flavanols, anthocyanins and tannins)

Defense and immune system in plants – bitter taste to insects and animals – also inhibitor to microbial/fungal contamination once skin is damaged

In wine– higher in red than white whines. Will ppt with proteins (hydrophobic interactions)

Flavor– proteins in saliva are rich in prolines – bind well to tannins. This removes lubricant protein from mouth and is responsible for the rough irritated sensation called astringency.

Aging Wine– reaction with oxygen and ethanol leads to acetaldehyde which will react and ppt with flavinols (tannin monomers), tannins and anthocyanins and precipitate out. Thus tannins protect during aging and why aging wine is smooth – less astringency

Barrel or Bottle Aging

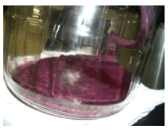
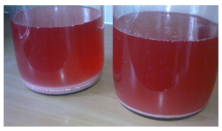
Additional time is needed for more reactions to finish and mature the wine

- Wood barrels provide vanillin and other organic like molecules to the wine
- Current trend is to use oak barrels
- Wood can absorb some of the phenolics and tannins – (doesn't happen in bottle aging)
- Bottle aging alone limits some of the reactions with oxygen and other molecules
- Oxygen in barrels react with tannins and other compounds reducing astringency

Filtering/Fining

The last phase in wine making

- Racking and fining – removing the last bits of solids by settling then drawing off the liquid into a new container (dead yeast – "lees" and pulp)

Fines

Removes fine mist of solids found even after good racking

- Some solid particles will attract other particles and precipitate into fine solids
- Fining is adding compounds to speed up the process and precipitate insoluble small particles
  - Historic fining agents include: Ox Blood, egg whites, milk casein, fish bladders, seaweed or clay.
  - Modern methods include using a centrifuge or filter small enough to catch microorganisms, silicon clay…

Champagne and Sparkling Wines

Bubbles come from excess CO_2 which dissolves in the liquid.

- Extended fermentation under closed conditions create a supersaturated gas condition that when pressure is released, CO_2 escapes as a gas.
- Bubbles form on small imperfections on glass
- best to pour champagne down the side of the glass to preserve a slow release of bubbles (fizz)
  - Saves twice as much CO_2 for later release
  - Colder temps also maintains bubbles better

Sweet Wine

Fermentation until completion (little or no sugar left) will create a dry wine

- Sweet wines have added sugar – dry wine with juice added back with SO_2 or
  - Increasing the amount of sugar in the grape by decreasing the water content then stop the fermentation early
  - Noble rot: is a mold which infects the grape vines and fruit – causes perforations where water evaporates (concentrating the sugar)
- Fortified wine – 18-20% alcohol – added spirits to sweet wine for higher alcohol content
  - Often times brandy is added. Examples include vermouth, Sherry, Madeira and Port.

Enjoying the Wine - Taste

Flavor: Intensity and length of flavor reflect quality of the wine. Wines have a definite flavor that is strong and easily recognized, a mild flavor, or an obscure, faint flavor.

Dry or Sweet: Sweet wines have a taste similar to a solution of water and sugar. Degrees of sweetness range from very sweet to semi-sweet. Dry wines have an absence of sugar and range from semi-dry to very dry.

Enjoying the Wine - Taste

Tart: Tart wines have an agreeable degree of acidity caused by tartaric acid. The tart taste in wine can be compared to the tart taste of orange juice. Degrees of tartness vary from very tart, tart, slightly tart to lacking tartness.

Astringent: Astringent wines have a bitter taste, similar to cold coffee. A highly astringent wine will cause the mouth to pucker. The astringency is produced by the tannin in grape skins, and varies from very astringent to slightly astringent to lacking astringency. Reds are usually astringent; whites lack astringency.