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RED WINE QUALITY PARAMETERS: LINK BETWEEN RED WINE COMPOSITION AND QUALITY

ANITA OBERHOLSTER

JUNE 4, 2018

WINE FLAVOR 101C: MANAGING RED WINE QUALITY
UC DAVIS CONFERENCE CENTER

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Introduction

- What is wine quality?
- Wine composition
  - Main phenolics in wine
- Sensory characteristics
  - Impact of phenolic compounds
- Color and tannin management

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What is wine quality?

- **Balanced wine with no faults**
  - Balanced
    - Good acid/pH, RS, body and flavor
  - ↑Quality with ↑complexity
    - Multi-dimensional

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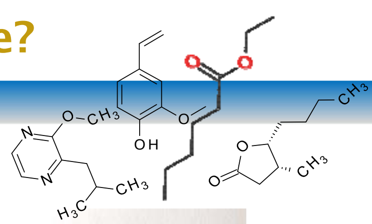
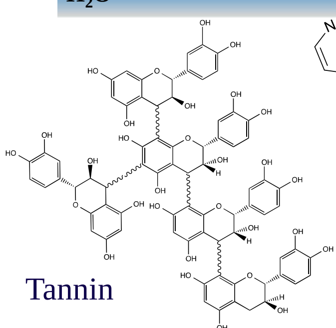
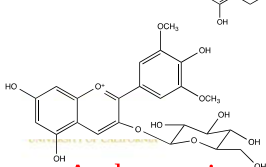
What is wine?

H_2O EtOH



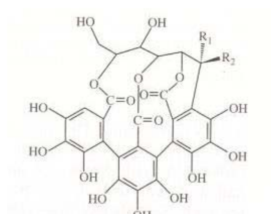


Tannin



Anthocyanins

- 1% Glycerol
- 0.4% Organic acids
- 0.1% Tannins and phenolics
- 0.5% Other compounds



Ellagitannin

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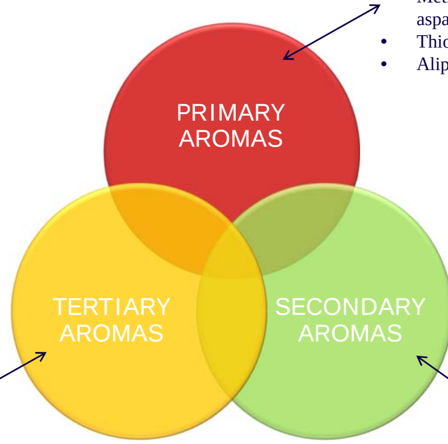
Wine Aroma

Grape-derived
- Monoterpenes (floral, fruity)
- Norisoprenoids (floral, perfumy)
- Methoxypyrazines (bell pepper, asparagus)
- Thiols (fruity aromas)
- Aliphatic phenylpropanoids



Fermentation & yeast derived
- Esters and higher alcohols (fruity aromas)
- Volatile phenols (leather, barnyard, medicinal, spicy)
- Sulfur (asparagus, corn, molasses, cabbage, onion, rubber)

Aging & Oak derived
- Furan derivatives (toasty and caramel)
- Lactones(coconut, woody, sweet, vanilla)

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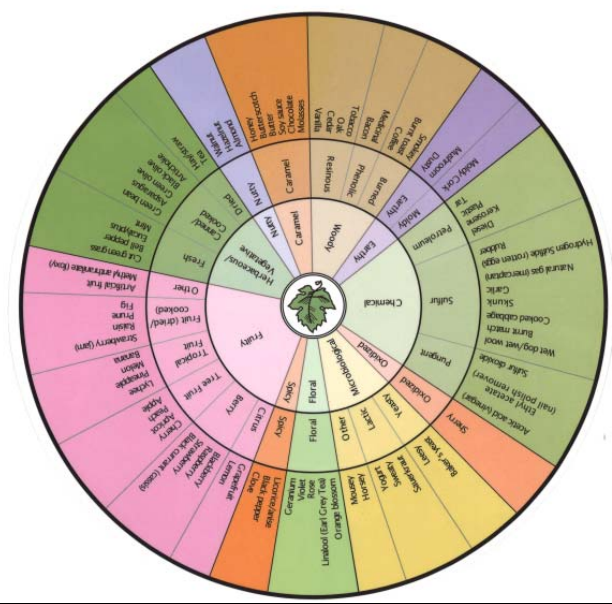
Aroma wheel



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Ann Noble (1995) UC Davis

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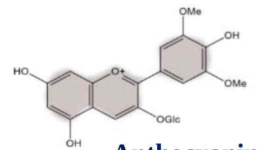
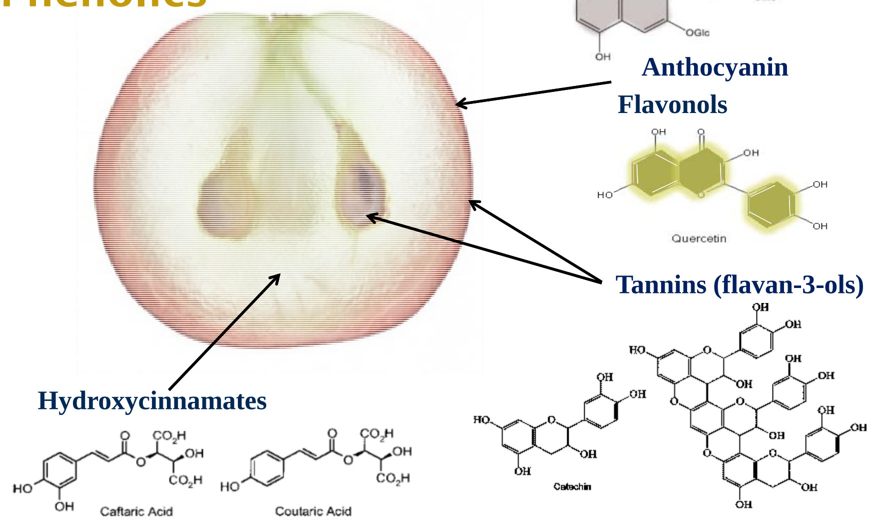
Grape and Wine Phenolics





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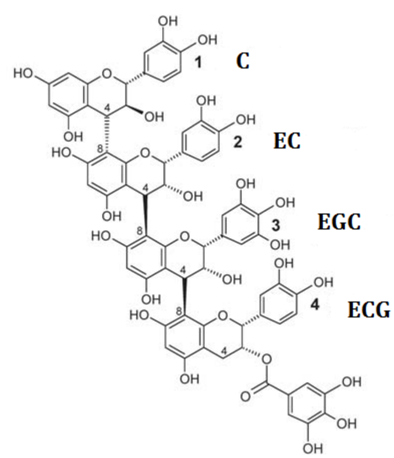
Closer look at tannins

- **Tannin building blocks**
  - **catechin (C), epicatechin (EC), epigallocatechin (EGC), and epicatechin gallate (ECG)**
- **Differences between skin and seed tannins**
  - **Mean degree of polymerization (mDP) for skin tannin are ~30; seed tannins are ~10** (Souquet et al. 1996)
  - **Proportion of ECG units is different in seeds (~30%) and skins (~5%)** (Cheynier et al. 2006)



Hypothetical tannin tetramer
(Adams 2006)

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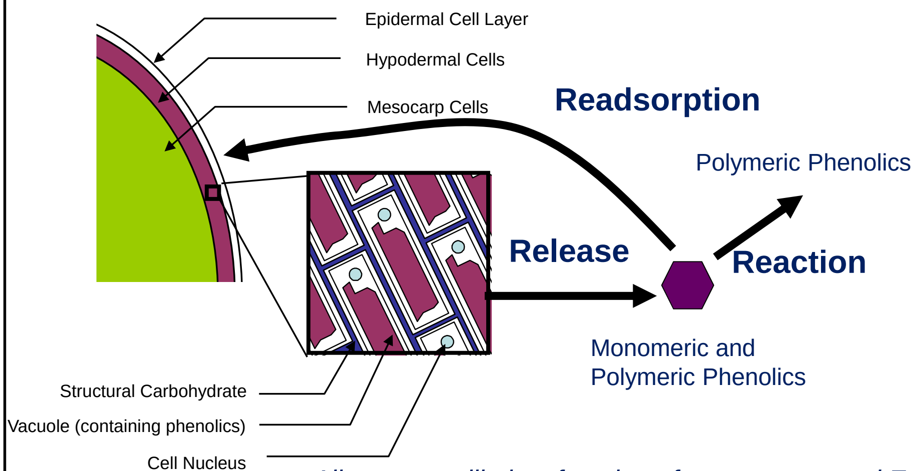
A Molecular Mechanism for Phenolic Extraction



All steps are likely a function of temperature and EtOH

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In Mouth Perception

- **Compositional impact on mouthfeel perception**

Tannin		**Matrix**
Concentration	Composition	Acidity
Amount	Skin/Seed	Ethanol
	Size distribution	Residual Sugar
	Tannin Pigmentation	Mannoproteins
	Tannin Oxidation	Polysaccharides
		Flavor

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Sensory Properties of Phenols

- Tannins or proanthocyanidins
  - Main contributors to bitterness and astringency
  - Larger tannin more astringent and drying than smaller tannin
  - Ratio of astringency to bitterness increase with mDP

Gawel *et al.* (1998) Austr. J. Grape Wine Res.(6) 74; Vidal *et al.* (2003) J. Sci.. Food. Agric. (83) 564; Vidal et al. (2004) Food Qual. Pref. 15, 209-217

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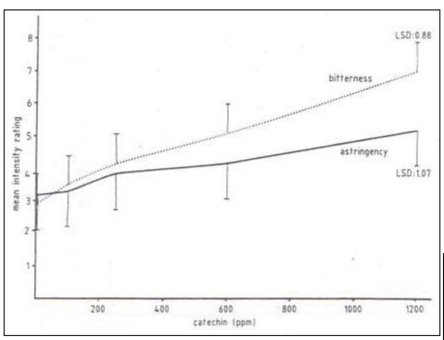
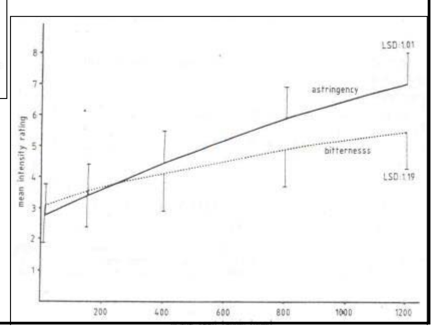
Bitterness and Astringency



- Monomers more bitter than astringent

- Ratio of astringency to bitterness ↑ with ↑ mDP



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Gawel *et al*. (1998) Austr. J. Grape Wine Res.(6) 74; Noble (1995) AJEV 46, p. 128-133

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Sensory Properties of Phenols

- **Only above tetramer major contributor to astringency**
- **Hydroxycinnamic acids – astringent and bitter**
- **Flavonols – maybe bitter**
- **Ellagitannins – close to sensory threshold in wine**
  - **Small astringency contribution**

Glasbania and Hofmann (2006) J. Agric. Food Chem. 54, p. 3380-3390; Hufnagel and Hofmann (2008) J. Agric. Food Chem. 56, 1376-1386; Saenz-Navajas et al. (2010) Anal. Chim. Acta 673, p. 151-159; Wan et al. (2014) Trends Food Sci. Technol. 40, p. 6-19

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Sensory Properties of Phenols

- **Tannins or proanthocyanidins (PA)**
  - Main contributors to bitterness and astringency
  - Larger tannin more astringent and drying than smaller tannin
  - Ratio of astringency to bitterness increase with mDP
  - **Seed tannin more astringent (coarse, dry) than skin tannin of equivalent size**
  - **Indicate – 'coarseness' and 'dryness' of astringency increase with galloylation**

Gawel *et al.* (1998) Austr. J. Grape Wine Res.(6) 74; Ferrer-Gallego (2014) Food Res. Int. 62, p. 1100-1107; McRae (2010) Molecules, 16, p. 2348-2364; Vidal *et al.* (2003) J. Sci . Food Agric. (83) 564; Vidal et al. (2004) Food Qual. Pref. 15, 209-217

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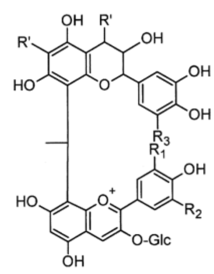
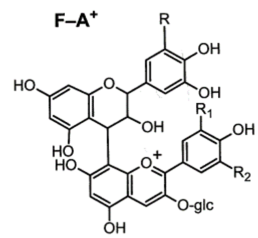
Polymeric Phenols and Astringency

- **During wine maturation and ageing**
  - **Anthocyanins and PA polymerise with each other by different mechanisms**
  - **Influenced by grape composition, presence of wood (hydrolyzable) tannins**



Flavan 3-ol-ethyl-anthocyanin (1)



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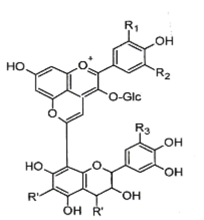
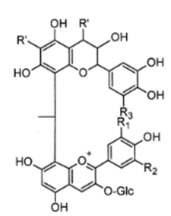
Different Polymeric Pigments

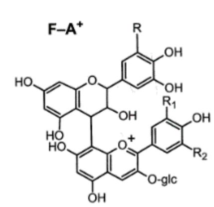
- **Pyranoanthocyanin**
- **Direct Condensation**
- **Aldehyde Bridged (methylmethine)**



Flavanylpyranoanthocyanin [redacted]



Flavan 3-ol-ethyl-anthocyanin (1)



Singleton and Trousdale (1992) AJEV 43, 63-70; Gawel et al. (1998) Austr. J. Grape Wine Res.(6) 74; Oberholster, Francis, Iland, Waters (2009) Austr. J. Grape Wine Res. (15) 59-69; ; Vidal et al. (2004) Food Qual. Pref. 15, 209-217

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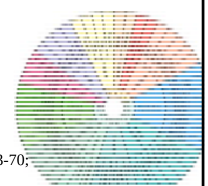
Polymeric pigments and mouthfeel

- Anthocyanins have no taste or tactile effect
- How do you explain differences between white wine and red wine?
- Wine pigments/polymeric pigments
  - Increases astringency fine grain attributes
  - Increase viscosity/mouth coating perception



Oberholster et al, (2009) Austr. J. Grape Wine Res. (15) 59-69; Singleton and Trousdale (1992) AJEV 43, 63-70; Vidal et al. (2004a) *Food Qual. Pref. 15*, 209-217; Vidat et al. (2004b) Food Chem. 85, 519-525

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Sensory Properties of Pigments

- Anthocyanins have no taste or mouthfeel
- How do you explain difference between white wine and red wine?
- New polymeric phenols/pigments – wine maturation
  - Methylmethine-bridged flavanols more bitter than similar tannins, lower astringency

Singleton and Trousdale (1992) AJEV 43, 63-70; Gawel et al. (1998) Austr. J. Grape Wine Res.(6) 74; Oberholster, Francis, Iland, Waters (2009) Austr. J. Grape Wine Res. (15) 59-69; ; Vidal et al. (2004) Food Qual. Pref. 15, 209-217

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Sensory Properties of Pigments

- DA of different 'model wines' made with and without added anthocyanins
  - Pol. Pigments add to astringency "dry", "grippy", "viscosity", "fine emery"

White free run juice | White free run juice + anth | White free run juice + white skins + seeds | White free run juice + white skins and seeds + anth | White free run juice + red skins and seeds | Red wine

Oberholster et al, (2009) Austr. J. Grape Wine Res. (15) 59-69

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Sensory Properties of Pigments

- Polymeric pigment fraction from wine
  - High molecular weight (HMW) highly pigmented - less astringency – mDP not known
    - Incorporation of anthocyanins into polymers decrease astringency
  - These conclusions are based on "dry tannin" rating
  - Study can't guarantee equal tannin conc – quantification methods not optimal
  - Known that mDP decrease with wine aging

Preys et al., (2006) Anal. Chim. Acta 563, p. 126-136; Ma et al. (2014) Trend Food Sci. Technol. 40, p. 6-19; Saenz-Navajas et al. (2010) Anal. Chim. Acta 673, p. 151-159; Weber et al. (2013) AJEV 64 (1), p. 15-25; Wollmann and Hofmann (2013) J. Agric. Food Chem. 61, 2045-2061

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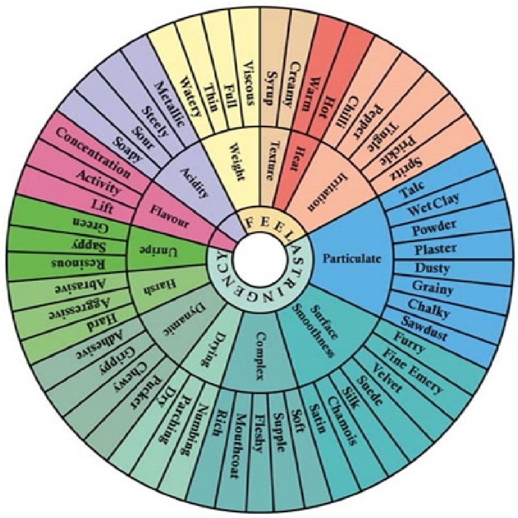
Astringency and other Mouthfeel Terms



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Gawel, Oberholster, Francis (2000) Austr. J. Grape Wine Res (6) 203-207

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Matrix effects

- Astringency ↓ with increased EtOH
  - Impact on protein-tannin interactions
  - EtOH ↑ viscosity
- Bitterness ↑ with increased EtOH
- Astringency ↓ with polysaccharides and proteins
  - Binds with tannin
  - Polysaccharides ↑ viscosity
- Glycerol
  - Similar to polysaccharides ↑ viscosity

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Gawel (1998) Austr. J. Grape Wine Res. 4, p. 74-94; Ma et al. (2014) Trend Food Sci. Technol. 40, p. 6-19

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Matrix effects

- Astringency ↑ with high acidity or high ionic strength (salt Na^+)
  - Acid astringent in own right
  - Acid and salts reduce viscosity of saliva
- Astringency ≈ with sugar content
  - Can be more difficult to perceive
- Bitterness ↓ with increasing sugar

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Gawel (1998) Austr. J. Grape Wine Res. 4, p. 74-94; Ma et al. (2014) Trend Food Sci. Technol. 40, p. 6-19

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Correlation Between Wine Composition and Sensory Descriptive Analysis

- Aroma profiles, some correlations to individual or group of compounds
- Acid ~ acidity, sugar ~ sweetness
- Alcohol ~ hotness

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Kassara and Kennedy (2011) J. Agric. Food Chem. 59, p. 8409-8412; Ma et al. (2014) Trend Food Sci. Technol. 40, p. 6-19

Correlation Between Wine Composition and Sensory Descriptive Analysis

- Bitterness and astringency on molecular level not explained
  - Contradicting results due to sample prep, sensory analysis methods?
  - Links between astringency and phenol conc
  - High skin tannin conc have been linked to higher ratings in red wines

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Kassara and Kennedy (2011) J. Agric. Food Chem. 59, p. 8409-8412; Ma et al. (2014) Trend Food Sci. Technol. 40, p. 6-19

Impact of Color and Tannin Management on Wine Composition

- Fruit processing
- Cold soak
- Heat treatment
  - Thermovinification
  - Flash détente
- Yeast
- SO_2
- Macerating Enzymes

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Impact of Color and Tannin Management on Wine Composition

- Tannin
- Fermentation temp
- Cap Management
- Extended maceration
- O_2
- Oak contact

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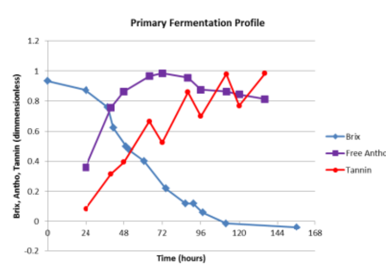
Extraction during Fermentation

- Anthocyanins from skins
  - Early during fermentation (3-5 days)
- Seed and skin tannin/proanthocyanidins (PA)
  - Increase extraction with temp, % EtOH
  - Polymerization reactions between anth and PA or between PA and PA



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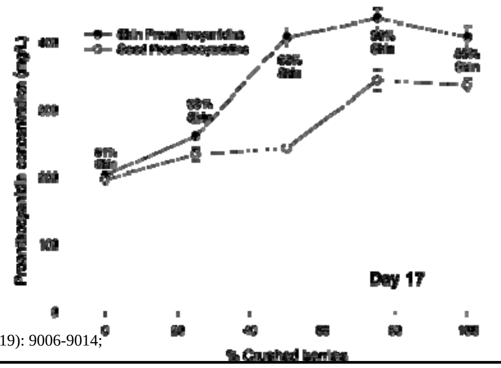
Fruit processing

- Crushing
  - Study with Merlot, 0 – 100 % crushed fruit, 25% increments (Cerpa-Calderon et al., 2008)
    - 75% fruit ↑ skin and seed PA (79%)



Cerpa-Calderon and Kennedy (2008) J. Agric. Food Chem. 56 (19): 9006-9014; Sacchi, et al., (2005). Am. J. Enol. Vitic. 56 (3): 197-206.

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Cold soak/maceration

- Must at 10 – 15°C for several days before fermentation
  - Results varies in and between varieties
    - Color ↑↔↓
      - Pinot noir show mostly no or neg effect
    - ↑ Seed tannin (Busse-Valverde et al., 2010, Moreno et al., 2013)
    - Potential factors: berry ripeness and starting grape composition (cultivar) as well as fermentation temp

Busse-Valverde et al., (2010) J. Agric. Food Chem. (58) 21: 11333-11339; Casassa et al., (2015) Food Chem. 50: 1044-1055; Damijanic et al., (2011) Croation J. Food Sci. Technol. 3 (2): 16-25; Gardner et al., (2011) Am. J. Enol. Vit. 62 (1): 81-90; Moreno et al., (2013) Eru. Food Res. Technol. 236: 473-481; Puertas, et al., (2008) Food Sci. Tech. Int. 14 (Suppl. 5): 21-27; Vásquez et al., (2010) Eur. Food Res. Technol. 231:789-802; Smith et al., (2015) Austr. J. Grape Wine Res.doi:10.1111/ajgw.12188.

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Cold soak – other factors

- Reynolds et al. 2001 ↑ anth with low ferm temp (15, 20°C) not 30°C
- CS no sensory impact on Cab Sauv, Barbera, Syrah, Malbec, Merlot and Pinot noir (Casassa 2015)
- No signf diffr between control and cold soak aroma via sensory eval although chem diffr in Cab Sauv (Gardner et al., 2011)

Casassa and Sari (2015) Int. J. Food Sci. Technol. 50;1044-1055; Casassa et al., (2015) Food Chem. 50: 1044-1055; Gardner et al., (2011) Am. J. Enol. Vit. 62 (1): 81-90; Puertas, et al., (2008) Food Sci. Tech. Int. 14 (Suppl. 5): 21-27; Sacchi, et al., (2005) Am. J. Enol. Vitic. 56 (3): 197-206.

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Saignée (prefermentation juice runoff)

- After 4 months – Anth ↑ Flavonoid ↑, 9 varieties – 10% runoff (Zamora, 1994)
- After 6 months no diffr in Syrah with 10 and 20% run-off (Gawel et al., 2001)
- ↑ Anth ↑tannin with ~ 16% runoff in Merlot (Harbertson et al., 2009)

Gawel et al., (2001) J. Wine Res. (12 (1): 5-18; Harbertson et al., (2009) Am. J. Enol. Vit. (60) 4: 450-460; Sacchi, et al., (2005) Am. J. Enol. Vitic. 56 (3): 197-206

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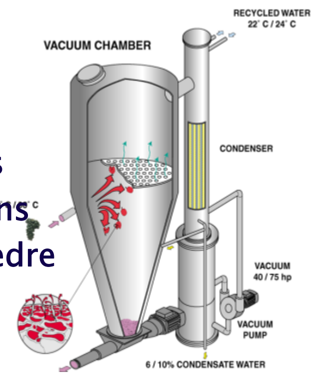
Heat Treatment

- Thermovinification (best effect Pinot noir)
  - Increase anth and skin tannin extraction
    - Need skins in contact with juice
  - Loss of varietal character
- New Technology: Flash-Détente (Flash Release)
  - Increase extraction of phenols up to 50% if ferment with skins
  - Tested with Grenache, Mourvedre Carignan



Morel-Salmi et al., (2006) J. Agric. Food Chem. 54: 4270-4276.

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Fermentation Additions

- Different levels of SO_2 additions
  - Can be a difference in color and anth extraction early on
  - After 6 months no significant effect

Ivanova (2009); Sacchi et al., (2005) Am. J. Enol. Vitic. 56 (3): 197-206.

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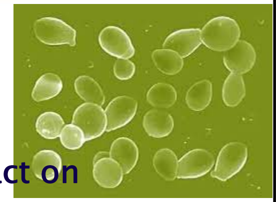
Fermentation Additions



- Yeast
  - Previously found no great impact on non-volatile composition (Sacchi, 2005)
  - Differences between strains/species
    - ↓Anth, ↑ tannin *Sacch cerevisiae* compared to *Sacch bayanus*
    - *Sacch Bayanus* ↑ color
  - Aroma profiles are influence by both grape composition, fermentation conditions and yeast (Styger, 2011)

Hayasaka et al., (2007) Austr. J. Grape Wine Res. 13:176-185; Sacchi et al., (2005) Am. J. Enol. Vitic. 56 (3): 197-206.; Styger et al., (2011)H, Ind. Micro. Biotech. 38: 1145; Blazquez-Rojas et al., (2012) World J Micro Tiotech 28:1-11.

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Macerating Enzymes

- Breaks down skin cell walls
- Increase juice yield (skin:juice ratio)
  - Enzymatic activities
    - Pectolytic – polygalacturonase, pectin methyl esterase, or pectin lyase
    - Cellulase – thought to release tannin
    - Hemicellulase – thought to release tannin
    - Acid protease

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Macerating Enzymes

- Varied effect depending on enzyme used
  - Due to enzyme activity or grape composition?
- In general
  - ↑ Color intensity or no effect
  - ↑ or no effect on tannin conc
  - ↑ Extraction rate

Baurtista-Ortín et al., (2005) Int. J. Food Sci. Technol. 40: 867-878; Keulder et al., (2006); Romero-Cascales et al., (2012) 130 (3): 626-631; Sacchi et al., (2005) Am. J. Enol. Vitic. 56 (3): 197-206; Vásquez et al., (2010) Eur. Food Res. Technol. 231:789-802; Casassa and Harbertson (2014) Rev. Food Sci. Tech. 5: 83-109; Smith et al., (2015) Austr. J. Grape Wine Res.doi:10.1111/ajgw.12188.

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Use of Exogenous/Commercial Tannin

- **Tannin addition for following purposes or problem correction:**
  - **Contribute to mouthfeel/taste**
  - **Protect against oxidation enzymes,**
  - **Assist to precipitate proteins,**
  - **Modify aromas including vegetative aromas**
  - **Increase aging potential**
  - **Stabilize wine color**
- **Few scientific publications about effect of commercial tannin addition**

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Versari et al., (2013) Austr. J. Grape Wine Res. 19: 1-10.

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Fermentation with oak

- Am or French oak chips (4 or 8 g/L) or Am or French barrels
  - Analysis by descriptive analysis
    - Am oak chips ↑coconut, vanilla, bitterness, astringency compared to barrels
    - Oak origin more visible in chips compared to barrels
    - Quantity of chips used greater impact then oak source
    - All oak treatments vegetative aroma ↓

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Afonso (2002) J. Food Sci. 67: 2415

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Fermentation Temperature

- ↑ Temp, ↑ color + phenol extraction + pol pigments
- Lower temp preserve more fruit character
- Opt temp ±30°C (86F) (Pinot noir, Pinotage)
- Other studies looked at lesser known varietals
  - Ex. Vranac (opt temp 24–27 °C)

Marais, et al. (2003)S. Afr. J. Enol. Vitc. 24:70-75; Pajovic et al., Acta Agric. Serb.(2011)16 (32): 145-154; Sacchi, et al., (2005) Am. J. Enol. Vitic. 56 (3): 197-206.

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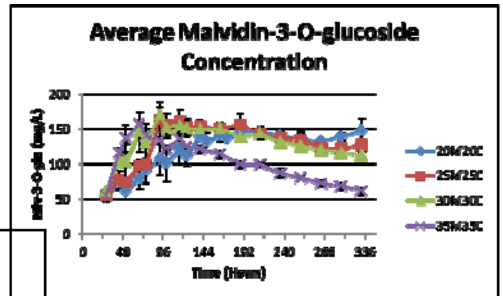
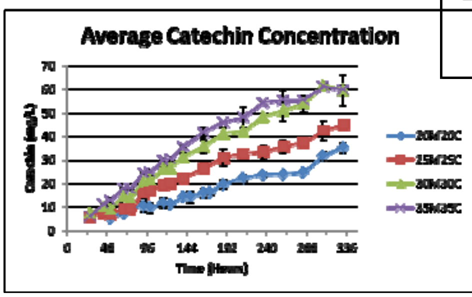
Influence of temp on extraction

- Cabernet Sauvignon
- ↑Temp:
  - Increase flavanol extraction + rate
  - Increase malv-3-gluc extraction rate





Lerno et. al., (2015) Am. J. Enol. Vit. 66:4, p. 249-255

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Cap Management

- Why?
  - Keep cap moist for yeast activity
  - Reduce temp gradient between cap and liquid for yeast activity
  - Increase skin contact for phenol extraction etc.

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Influences on extraction: Cap Management Techniques

- Punch-down, pump-over (*various irrigators*), rotor, delestage, submerged cap, timed gas-pressure release (Ganimede), pneumatage
  - Studies compared punch-down, pump-over, rotor and delestage
    - Variable effect with cultivar
    - Rotor > mechanical punch down >pump over > submerged cape>manual punch down > delestage > Ganimede (*order of phenol extraction)*

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Vásquez et al., (2010) Eur. Food Res. Technol. 231:789-802; Marias et al., (2003) S. Afr. J. Enol. Vitic. 24:76-79; Sacchi, et al., (2005) Am. J. Enol. Vitic. 56 (3): 197-206, Ichikawa et al. (2012) Food Sci. Tech. Res. 45: 200-207; Smith et al. (2015) Austr. J. Grape Wine Res doi:10.1111/ajgw.12188

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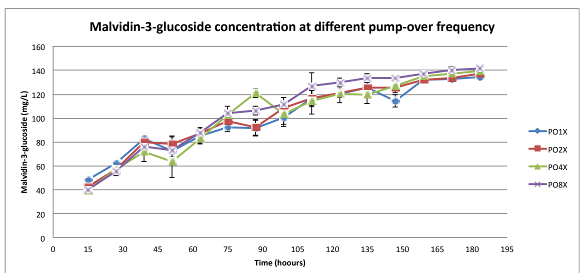
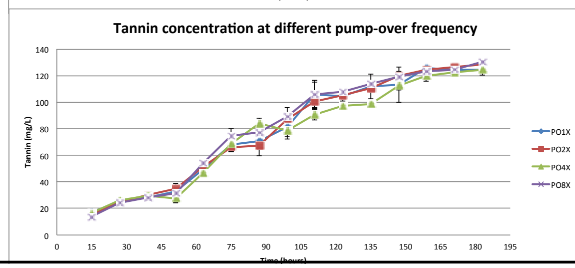
Pump-over frequency/volume

- PO 0.5V, 1V, 2V 2x per day
  - Similar extraction
- 1, 2, 4, 8 PO, tot 4 vol
  - Similar extraction rates





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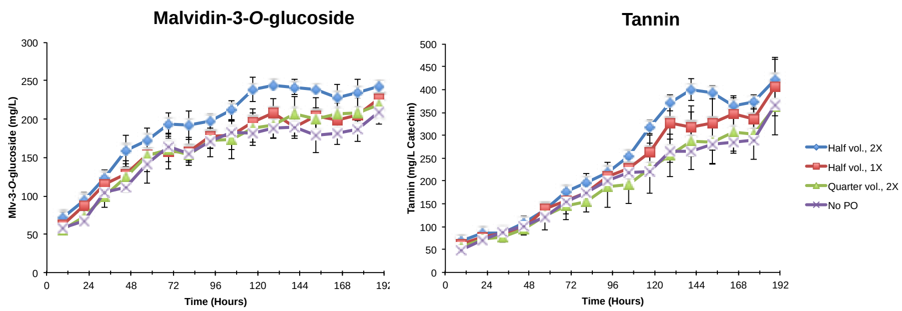
Even lower levels of pumpovers do not have much effect on phenolic extraction



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Extended Maceration

- Jim Harbertson ……………………

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Gomez-Plaza et al., (2001) Am. J. Enol. Vitic. 52: 266-270; Mazza and Ford (2005) Austr. N.Z. Grapegr. Winemaker, 56-61; Puertas, et al., (2008 Food Sci. Tech. Int. 14 (Suppl. 5): 21-27; Yokotsuka et al., (2000) J. Wine Res. 11: 7-18.

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Micro-oxygenation (MOX)

- **Dosages:**
  - Pre-MLF MOX MLF 10-30 mg/L/month
    - 10-25 days
  - Post-MLF 2-5 mg/L/month
    - 56-252 days
- O_2 penetration through the barrel estimated at 1.66 and 2.5 $ml.L^{-1}.month^{-1}$
  - Mostly used in conjunction with wood alternatives
  - ↑ Color density, similar to barrel aging (Gómez-Plaza and Cano-López, 2011)
- ALW

Cano-López (2010) Food Chem. 119: 191-195; Del Ãlamo et al., (2010) Anal. Chim. Acta 660:92-101; Gómez-Plaza and Cano-López (2011) Food Chem. 125: 1131-1140; Nevares and Del Ãlamo et al., (2008) Anal. Chim. Acta 621:68-78; Schmidtke et al. (2011) Crit. Rev. Food Sci. Nutr. 51:115-131.

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MOX oak alternatives

- **Only two studies compare barrel aging directly with MOX**
  - Oberholster (2015) found that although chemical difference, panel found MOX + chips similar to Am oak barrel and MOX + staves similar to Fr barrel after 6 months treatment
  - Similarities driven by oak aromas
  - MOX > color, pol pigm

Oberholster et al., (2015) Food Chem. 173: 1250-1258

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Summary

- Skins are extracted early; seeds later
- Temperature and extended maceration affects seed extraction more than skin extraction
- Pumpover vol/freq small impact
- Cold soak does not seem to have lasting color impact, long periods could increase seed tannin
- MOX and oak alternatives could replace short term barrel aging
  - Will improve polymeric pigment formation and color density

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Thank you

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