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Wine Science: Designing Great Wines
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Wine Science: Designing Great Wines

Susan E. Ebeler
Department of Viticulture and Enology
University of California, Davis, CA

Wine Chemistry and Flavor is Complex

- Hundreds of compounds in wine – impact taste, aroma, mouthfeel, color
- Volatiles contribute to wine aroma—measure by gas chromatography

Wine Chemistry and Flavor is Complex

- Hundreds of compounds in wine – impact taste, aroma, mouthfeel, color
- Volatiles contribute to wine aroma
- Multiple compounds interacting together influence wine aroma and flavor
- Information processed in brain (context, memory, etc. influence perception)

Wine Chemistry and Flavor

- Designing Great Wines: What impacts wine flavor?

Adapted from Schreier, CRC Crit Rev Food Sci Nutr, 12(1): 59-111 (1979)
Wine Chemistry and Flavor

Adapted from Schreier, CRC Crit Rev Food Sci Nutr, 12(1): 59-111 (1979)

Grape Genetics

- Variety
- Aroma compounds produced in berry, not translocated from vine (e.g., methoxypyrazines, terpenes)

Koch et al., 2010, Phytochemistry, 71: 2190-2198
Grape Maturity

Koch et al., 2012, Physiologia Plantarum 145: 275-285

Methoxypyrazine concentration (pg/g fresh wt)

0 10 20 30 40 50
Jan Jul Aug Sep Oct

Koch et al., 2012, Physiologia Plantarum 145: 275-285

Grape Maturity

Koch et al., 2012, Physiologia Plantarum 145: 275-285

Methoxypyrazine concentration (pg/g fresh wt)

0 10 20 30 40 50
Jan Jul Aug Sep Oct

Koch et al., 2012, Physiologia Plantarum 145: 275-285
Light

Koch et al., 2012, Physiologia Plantarum 145: 275-285
Stevens et al., 2008, ACS Symposium Series #988

Vitispirane

Koch et al., 2012, Physiologia Plantarum 145: 275-285
Stevens et al., 2008, ACS Symposium Series #988

floridata.com
Climate/Temperature

MIBP in Cabernet from Australia and New Zealand

Allen et al., JAFC, 42: 1734-1738, 1994

Climate/Temperature

Terpenes
- Opposite effects relative to pyrazines
- ↑ warm climate (South Africa)
- ↓ cool climate (New Zealand)

Allen et al., JAFC, 42: 1734-1738, 1994  
Viticulture Effects on Chemistry and Flavor

- **Other…**
  - Vintage
  - Water stress/Irrigation
  - Soil and nutrition
  - Canopy management
  - Pest and disease pressures
  - ~18% of genes influenced by environment (Dal Santo et al. 2013, Genome Biology, 14:R54)

Adapted from Schreier, CRC Crit Rev Food Sci Nutr, 12(1): 59-111 (1979)
Robinson et al., Am. J. Enol. Vitic. (available on-line Dec 2013)

Viticulture Effects on Chemistry and Flavor

Phenotype = genotype + environment + (interaction of genetics x environment)

Focus of much current research is to identify the genotype + environment interaction and understand how that affects phenotype.
We know very little about this.....

Adapted from Schreier, CRC Crit Rev Food Sci Nutr, 12(1): 59-111 (1979)
Audience Question

- World-wide, where are most of the winegrapes grown?
  
  (A) Equally all over the world
  (B) Between 30°-50° latitude in north and south hemispheres
  (C) In California
  (D) In France

B. Between 30°-50° latitude in north and south hemispheres

(-10-20°C (50-68°F); sunlight/growing season; minimum temperature/winter kill effects; water availability/irrigation)

Implications for Global Climate Change?

www.thirtyfifty.co.uk
Wine Chemistry and Flavor

Adapted from Schreier, CRC Crit Rev Food Sci Nutr, 12(1): 59-111 (1979)

Changes in Flavor during Fermentation

- Compounds extracted from grapes
- New compounds formed
- Chemical reactions/hydrolysis
Changes in Flavor during Fermentation

- Compounds extracted from grapes
  e.g., methoxypyrazines, norisoprenoids, terpenes
  influenced by temperature, skin contact, mixing, etc.

From H. Hopfer, 2013

Changes in Flavor during Fermentation

- Compounds extracted from grapes
- New compounds formed
  Yeast (*Saccharomyces cerevisiae*) metabolism
  - alcohols (ethanol), esters

en.wikipedia.org/wiki/Saccharomyces_cerevisiae
Fermentation

Composition influenced by:

- Yeast Strain
- Nutrition (Sugar, Nitrogen, Vitamins)
- Temperature
- Grape Variety?

Yeast Strain

However, these chemical differences may not translate to sensory effects, particularly over storage time.
Nutrition

**Nitrogen** Diammonium Phosphate (DAP) or Amino Acids (AA) added to ~500mg N/L; Strain 254D; Chardonnay N sufficient (~300mg N/L) must as control

![Graphs of Isoamyl acetate and Ethyl Octanoate](image)

Half of the total weight (mg/L) remained at the beginning of the fermentation process, and all of the remaining weight was lost in the end product. The DAP and Amino acid control groups showed no significant weight loss, while the Chardonnay N sufficient group showed a significant weight loss.

Miller et al., AJEV, 58(4): 470-483, 2007

Changes in Flavor during Fermentation

- Compounds extracted from grapes
- New compounds formed
- Chemical reactions/hydrolysis

- Many compounds exist in grapes as nonvolatile precursors (glycosides, cysteine/glutathione conjugates)


Proposed TDN Glycoside Precursor
Changes in Flavor during Fermentation

- **Enzyme/Acid hydrolysis**
  - Releases ‘free’ aglycone during fermentation

![Diagram showing changes in flavor during fermentation](image)

Francis et al., ACS Symposium Series #714, 1999
(slide courtesy of Dr. Ann Noble)

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Audience Question

- **Which food fermentations do NOT involve *Saccharomyces cerevisiae***?

  (A) Beer
  (B) Bread
  (C) Sour Cream
  (D) Olives

[en.wikipedia.org/wiki/Saccharomyces_cerevisiae](en.wikipedia.org/wiki/Saccharomyces_cerevisiae)
Audience Question

- Which food fermentation do NOT involve *Saccharomyces cerevisiae*?

(A) Beer

(B) Bread

(C) Sour Cream-malolactic fermentation/lactic acid bacteria

(D) Olives—typically a lactic acid fermentation, but also may include yeast (Hurtado et al. 2012, Food Microbiology, 31: 1-8)

Wine Chemistry and Flavor

Adapted from Schreier, CRC Crit Rev Food Sci Nutr, 12(1): 59-111 (1979)
Oak Flavor

- **Volatile (influence aroma)**
  - **Carbohydrate derived**: Furfural, 5-methyl furfural
  - **Lignin derived**: Guaiacol, 4-methyl guiacol, 4-ethyl guaiacol, 4-vinyl phenol, 4-ethyl phenol, eugenol, isoeugenol, vanillin, syringol
  - **Lipid derived**: cis-\(\beta\)-methyl-\(\gamma\)-octalactone, trans \(\beta\)-methyl-\(\gamma\)-octalactone (oak lactones)

  See also [http://acswebinars.org/barrels-of-chemistry](http://acswebinars.org/barrels-of-chemistry)

Aging Reactions

- **Oxidation**
  - e.g., ethanol oxidized to acetaldehyde, acetic acid

- **Hydrolysis and rearrangements**
  - e.g., glycoside hydrolysis, terpene rearrangement

- **Off-flavors**
  - e.g., cork taint (haloanisoles), geosmin, 1-octen-3-one, acetic acid/ethyl acetate (uncontrolled oxidation)
Aging Reactions

- Dependent on
  - Temperature
  - Time
  - Closure type
  - Storage/Packaging container

See also http://acswebinars.org/ebeler

Hopfer et al., 2012, J. Agric. Food Chem. 60: 10743-10754
Hopfer et al., 2013, J. Agric. Food Chem. 61: 3320-3334
Robinson et al., 2010, Am J. Enol. Vitic. 61: 337-347

Linking Composition to Sensory Properties

Flavor perception

- Multiple sensory inputs
taste, aroma, color, mouthfeel, etc
- Receptors activated
- Brain processes information

See also http://acswebinars.org/ebeler and http://acswebinars.org/noble-grapes
Linking Composition to Sensory Properties

- Flavor perception is integrative
- Perceptual interactions—additive, masking/suppression, enhancing effects—Difficult to predict
- Physical/chemical interactions with matrix influence volatility and release
- Perception is influenced by context, training/experience, genetics, etc.

See also http://acswebinars.org/ebeler and http://acswebinars.org/noble-grapes

Summary: Designing Great Wines

- Wine chemistry and flavor is complex
- Great wine begins in the vineyard—but effects of vineyard practices depend on compounds and variables studied
- During fermentation, flavors are extracted from grape and new flavors are formed (by yeast and via chemical reactions)
- Aging reactions further alter composition
- Flavor = interaction between consumer and product
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- [http://wineserver.ucdavis.edu](http://wineserver.ucdavis.edu)
- B.S. in Viticulture and Enology
- M.S. in Viticulture and Enology
- PhD in Various Disciplines (Agricultural Chemistry, Food Science, Microbiology, Plant Biology, Horticulture, Genetics, Engineering, etc....)
- Certificate in Winemaking for Distance Learners
- University Extension 1- and 2-Day Shortcourses

References/Information Sources

- Polaskova et al., Chemical Society Reviews, 2008, 37: 2478-2489, DOI: 10.1039/b714455p
- Journal of Agricultural and Food Chemistry
- American Journal of Enology and Viticulture
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