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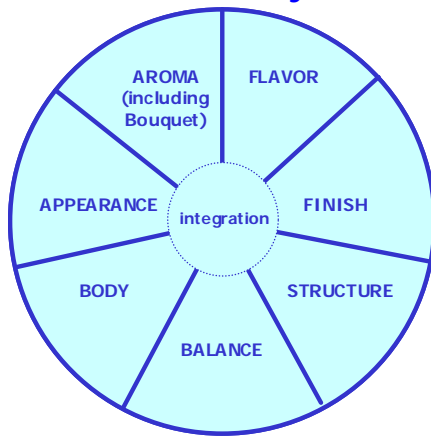
Part IV: Fermentation & Maceration

by
Reese C. Wilson

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Coordination Draft
Comments Welcome

Toward Quality Wine

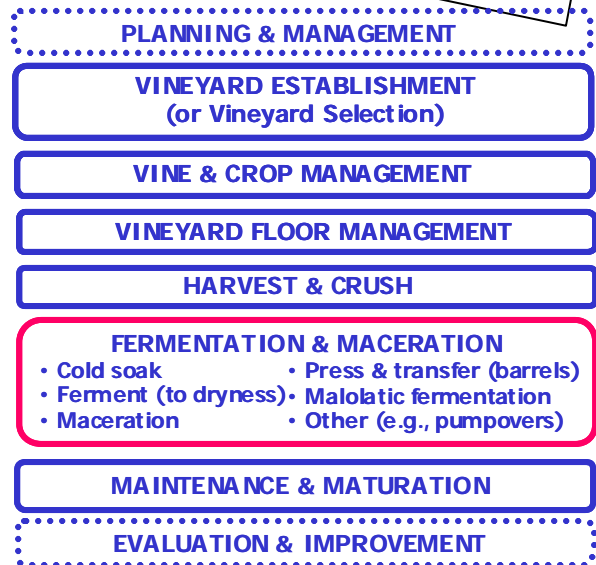


Quality—This paper is fourth in a series dealing with winegrowing and winemaking. The lead paper "Toward Quality Wine" suggests a pathway to wine quality and quality wine where quality includes the sensory components shown above.ⁱ The second and third papers—"Winegrowing" and "Harvest & Crush" address vineyard initial winery decisions and practices with primary emphasis on contributions of the berry to quality wine.

The stage that transforms juice or must to wine is "Fermentation & Maceration."

Wine Type—Typical steps within this stage vary:

Steps	Red	Blush	White
Starting point	must	juice	juice
Cold Settle	no	optional	yes
Cold soak	optional	no	no
Fermentation	yes	yes	yes
Extended Maceration	optional	no	no
Press off the skins	yes	no	no
Malolatic fermentation	optional	optional	optional
Transfer to storage	yes	yes	yes

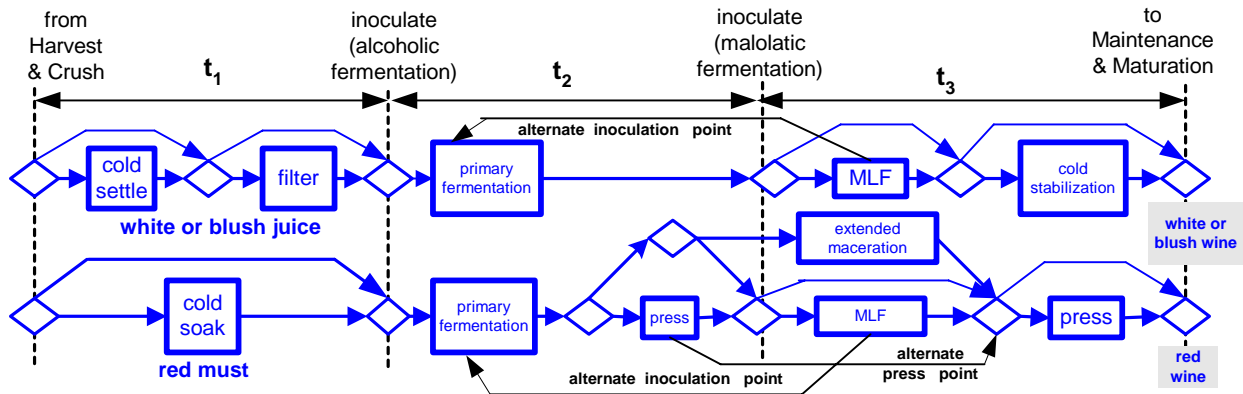


Extraction of Phenolic Compounds—White wines (as well as blush and sparkling wines) are treated much differently than red wines in this stage. The primary difference relates to the extraction of phenols from the skins (and seeds and stems) into the juice (or must) and wine.

According to Emile Peynaud: The better white wines contain none of the elements originating in the skin, the seed, and even less from the stems. (KMW, p. 197)ⁱⁱ Extracted phenols are generally considered undesirable. (OCW, p. 1,063)ⁱⁱⁱ

On the other hand, for reds, extraction of phenols through relatively lengthy contact between juice and skins (and even seeds-stems) is essential for color, *flavor*, and other components (e.g., contact may last for several weeks and may include cold soak, fermentation, and extended maceration).

Reese C. Wilson engages in home winegrowing and winemaking within the Napa Valley, and accepts occasional RWA strategic management consulting assignments. He holds M.S. degrees from Stanford and Syracuse Universities, a B.S.E.E. degree from the University of Southern California, and is currently active in the Viticulture and Winery Technology Program at Napa Valley College.



Some Critical Variables & Factors

Fermentation & Maceration Stage	
Variable/Factor	Potential Contribution
Turbidity and suspended solids	In whites, low turbidity contributes to quality; too high suspended solids can cause increased vegetal <i>flavors</i> , less fruity <i>aroma</i> and <i>flavor</i> , higher risk of enzymatic oxidation and microbial spoilage; too low can cause stuck fermentations, less fruity character
Sugars/alcohols	Major factors governing palate <i>balance</i> are quantity and quality of alcohol (and tannins and acidity) (WAP p. 123) ^{iv}
Acids	Acids (and tannins) contribute to longevity in bottle, <i>balance</i> .
pH	Affects microbial stability (higher pH causes lower stability), color
Phenols (including tannins) 1,000s of phenolic compounds	In reds, 15% non-flavonoids (hydroxycinnamates) and 85% flavonoids (procyanidins, anthocyanidins, condensed tannins). Phenols contribute to all <i>sensory components</i> with positive impact if and only if concentration is <i>above</i> sensory threshold but <i>below</i> undesirable threshold (i.e., you sense it and like it)
Phenol extraction	Alcoholic fermentation after destemming and crushing extracts up to 60% of phenols in berries (WAP p. 115)
Contact time	Skin (and seed-stem) contact time increases flavonoid phenol content (including tannins and anthocyanins) thus increasing all <i>sensory components</i> along with potential increases in vegetal <i>aromas</i> and <i>flavors</i> , bitterness, and astringency. Decreases acidity and pH.
Temperature	Increased temperature during fermentation increases flavonoids (see Phenols above)
Oxidation	In whites, low oxidation (low exposure to air) maintains delicate fruit <i>flavors</i> .
Additions	SO ₂ to protect against oxidation and microbial spoilage; acid to adjust <i>flavor</i> , <i>body</i> , <i>balance</i> , <i>structure</i> ; enzymes to increase extraction of <i>flavors</i> ; bentonite to whites for clarification, etc.

Additional source: VWT 180 Fundamentals of Enology

Pre-Fermentation (t₁)

General Discussion—White (or blush) juice or red must is available from the Harvest & Crush stage. Time, t₁, varies from zero (all steps are optional) to several days (but is generally less than a day for whites). Sulfur added at crush will soon become bound (if it isn't already) and unavailable to prevent spoilage. Care must be taken to avoid oxidation of juice and must.

Cold Settle (Optional-Whites)—For clarification, white free-run and press-juice is often allowed to settle—say overnight at 5-15 °C /41-59 °F—with the juice often being racked off the lees (unless *sur lies* aging is used; see Part V: Maintenance and Maturation).

Filter (Optional-Whites)—White (or blush) juice may be run through a filter to remove the finer particles taking care not to remove *flavor*.

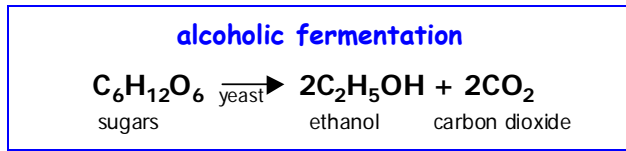
Cold Soak (Optional-Reds)—Red wine must—juice, skins, seeds, stems—is allowed to soak for one, two, or more days at a temperature between 10 °C/50 °F to 20 °C/68 °F prior to the initiation of fermentation. Punch down (or pump-over) once or twice a day to enhance extraction of phenols.

The purpose of cold soak is to encourage oxidative polymerization of phenols; important to color stability (WAP, p. 288). A heavily colored juice is obtained within 24 hours (PPW, p. 222).^v The longer extraction goes on, the more color and tannins from the skins end up in the juice (UWC, p.131).^{vi} Extraction increases during fermentation.

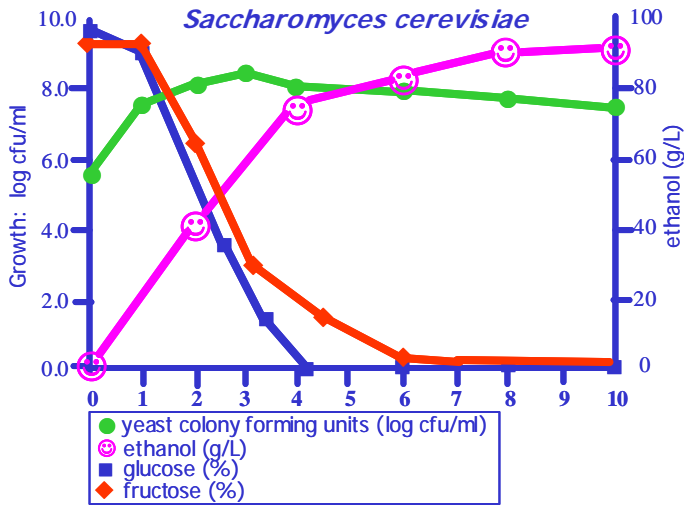
Pre-Fermentation Considerations—Juice or must may be stored in an air-tight vessel or be blanketed with carbon dioxide (say from dry ice) or other protective gas (e.g., argon) to guard against oxidation and microbial spoilage.

Alcoholic Fermentation (t₂)

General Discussion—Fermentation transforms sugars to ethyl alcohol (and carbon dioxide):




Colonization—Although a number of yeasts—"wild" or inoculated—can cause fermentation, the one most used is *Saccharomyces cerevisiae*.



For the 10-day time period shown above:^{vii}

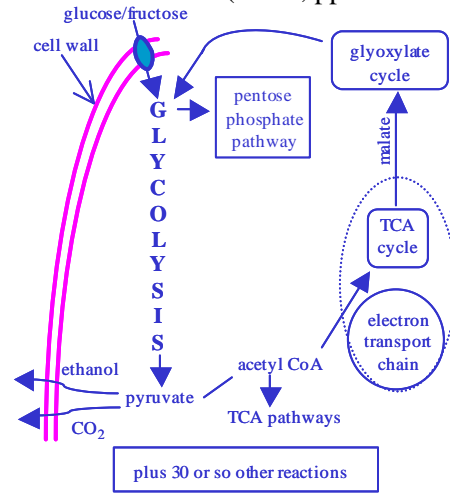
- **Colony forming units**—The population of yeast cells increases from about 10^4 - 10^6 cfu/ml to about 10^8 - 10^9 cfu/ml, holds more-or-less steady, and then declines. There are four phases: (a) lag, (b) growth to max cells, (c) stationary and (d) decline (or death).
- **Ethanol**—The alcohol content increases.
- **Glucose**—The glucose decreases (faster than the fructose) to zero (or so).
- **Fructose**—The fructose goes to zero (or so).

The Yeast Cell—Yeast cells are amazing. They grow by budding and, after a lag phase of a day or two, they grow exponentially to up to 2 billion per cubic centimeter (5 million or so in a single drop of juice).


 200,000,000-
 2,000,000,000
 cells per ml
 (or cc)

Each cell operates as a microscopic factory that converts glucose and fructose to ethyl alcohol and carbon dioxide via the glycolytic pathway (where the main reaction is glycolysis).

Major Pathways & Products—The glycolytic pathway and a few of the over 30 others—most generally promote cell grow among other things—are adumbrated below (PPW, pp. 126-176):



- **Pentose phosphate pathway**—Produces sugar phosphates needed for nucleic acid synthesis.
- **Glyoxylate cycle**—Pyruvate indirectly routed through this pathway near end of fermentation (suppressed by glucose).
- **Tricarboxylic acid (TCA) cycle**—Synthesizes needed metabolic intermediates and generates CO_2 and adenosine triphosphate (ATP) a vital form of energy (with no net change in redox balance).
- **Electron transport chain**—Converts a nicotinamide adenine dinucleotide (NADH) molecule into two or three ATP molecules.

Primary Fermentation—Unless "wild" yeasts are used for a "natural" fermentation, the juice or must is inoculated with a yeast (e.g., *Saccharomyces cerevisiae*). Both approaches rely on yeast cells that transform sugars to ethyl alcohol and carbon dioxide over a period that can last from a few days to a couple of weeks or longer. Nutrients (e.g., diammonium phosphate) are often added.

Press (Optional-Reds)—If extended maceration is not part of the red winemaking protocol, the red must is pressed off the skins after fermentation (or before fermentation is complete) with free-run wine often segregated from press-wine fractions.

Fermentation Considerations—Yeast selection and fermentation temperatures—whites at about $15^\circ\text{C}/59^\circ\text{F}$; reds in the $24\text{-}27^\circ\text{C}/75\text{-}81^\circ\text{F}$ range (WS, pp. 325-326)^{viii}—represent crucial decisions.

Post-Fermentation (t₃)

General Discussion—Again, the steps after alcoholic fermentation are optional. Time period t₃ can vary from zero to several weeks for extended maceration (or even months for malolactic fermentation). Many reds and some whites are put through MLF that can take from days to months to complete. In addition, extended maceration can take place. Pressing of the red wine off the skins can take place following alcoholic fermentation or extended maceration.

Malolactic Fermentation (Optional)—Many reds (and some whites) can be inoculated with *Leuconostoc oenos*—the ML bacteria—just after alcoholic fermentation has been started or, more commonly, after it has finished. MLF reduces acidity and vegetal notes and accentuates fruit flavors and buttery diacetyl (WS, pp. 330-342).

Cold Stabilization (Optional-Whites)—White wines are usually subjected to cold stabilization—say for five days at -5 °C/21 °F—to precipitate out potassium bitartrate (undesirable to have in bottle) with the stabilized wine racked of and bottled (often with pre-bottling filtering or fining).

Extended Maceration (Optional-Reds)—Some high quality wines are left on the skins after alcoholic fermentation. The 1999 Robert Mondavi Winery Oakville Cabernet Sauvignon was subjected to 38 days of skin contact "to naturally soften the grape tannins and develop varietal character" (according to the winemaker notes).

Press (Optional-Reds)—Reds not pressed at the end of (or during) alcoholic fermentation are pressed off the skins after extended maceration.

Impacts on Quality

General Discussion—Many factors having an effect on wine quality have been introduced above. Time, temperature, and oxidation and spoilage are important during t₁, t₂, and t₃. Yeast selection is crucial to alcoholic fermentation.

Time—Time: (a) increases the extraction of phenolics through contact of juice, must, and wine with skins, seeds, and stems and (b) increases risk of potential oxidation and spoilage. Whites can spend considerable time in alcoholic fermentation and MLF (*sans skins et al*). Reds can spend considerable time in all three time periods.

Temperature—Increased temperature equates to increased extraction of phenolics. Accordingly, lower temperatures are maintained for whites for all time periods. Somewhat higher temperatures are maintained for reds except for alcoholic fermentation where high temperatures are common: some favor a hot and fast fermentation followed by extended maceration to soften tannins while others favor a slow "native" yeast fermentation that allows several days of alcohol-free soaking to reduce harsh tannins.

Oxidation & Spoilage—Exposure to air is minimized, especially for whites. SO₂ is usually added after fermentation with free sulfur levels maintained at about 30 ppm to minimize risks.

Yeast & Nutrients—Commercial yeasts come in many forms that favor many wine styles. The addition of nutrients (e.g., DAP) must also be handled with care. See referenced web sites:^{ix}

Potential Contributions

Winemaking Step	Wine Components						
	A	A	F	F	B	S	B
	P	R	L	I	O	T	A
Potential contribution of step to component:	P	O	A	N	D	R	L
Strong	E	M	V	I	Y	U	A
Moderate	R	A	O	S		C	N
Weak	A		R	H		T	A
	N					U	N
	C					R	C
	E					E	E
Cold soak (R)	S	M	M	W	M	M	W
Alcoholic Fermentation	S	S	S	M	M	S	M
Press (R)	S	M	M	M	M	S	M
Malolactic fermentation	W	M	M	W	W	W	W
Extended Maceration (R)	S	M	M	M	M	M	M
Cold stabilization (W)	S	W	W	W	W	W	W

Note: R = Reds, W = Whites

- ⁱ See "Toward Quality Wine" paper at: www.shilohestate.com/
- ⁱⁱ Emil Peynaud, *Knowing and Making Wine (KMW)*, John Wiley & Sons (1981)
- ⁱⁱⁱ Jancis Robinson, ed., *Oxford Companion to Wine (OCW)*, Oxford University Press (1994)
- ^{iv} Bruce Zoecklein, et al, *Wine Analysis and Production (WAP)*, Aspen Publishers (1999)
- ^v Roger B. Boulton, et al, *Principals and Practices of Winemaking (PPW)*, Aspen Publishers (1998)
- ^{vi} Marian W. Baldy, *The University Wine Course (UWC)*, Wine Appreciation Guild (1997)
- ^{vii} VWT *Wine Chemistry and Microbiology*, Napa Valley College (Spring 2001)
- ^{viii} Ron S. Jackson, *Wine Science (WS)*, Academic Press (2nd Edition, 2000)
- ^{ix} See: www.thewinelab.com, www.vinquiry.com, www.scottlab.com for information on yeasts, nutrients.