"Extended" winegrape ripening

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"Hang time" or extended ripening of winegrapes has been a controversial issue in the wine industry for the last few years in California. It has been the topic of numerous articles in trade publications, the focus of several industry meetings, and the subject of heated debates. During the 2005 growing season it was the focus of numerous research projects (Table I).

Extended winegrape ripening is the practice of allowing fruit (usually red wine grapes) to remain on the vine beyond conventional harvest times. During extended ripening, soluble solids increase above traditional levels of 23° to 25° Brix.

Extension of the ripening period has become more prevalent in recent years. This California trend parallels a similar trend in Australia.[11] The practice is driven by wineries in pursuit of softer, rounder tannins, a preponderance of ripe fruit flavors, an absence of vegetative flavors, and the perception that longer residence time on the vine is the best or only means to these ends.

There are several difficulties associated with extended ripening and therein lies the controversy. For grape growers it means increased risk of fruit damage and disease. More importantly, fruit yields usually decline during extended ripening and, correspondingly, so does a grower's income.

Difficulties, however, are not limited to the vineyard. High sugar musts are prone to stuck fermentations and higher volatile acidity.[43] Higher alcohol wines are subject to higher taxes. High alcohol can be mitigated, but not without complications. Addition of water, prior to fermentation, creates potential perception issues with wine consumers, while blending and de-alcoholization increase production costs and additional wine quality risks.

As sometimes happens in the wine business, practice precedes full knowledge. Until recently there have been no research projects specifically addressing extended winegrape ripening and, given its complexity, recent research can be expected to only scratch the surface.

In January 2005, the California Association of Winegrape Growers (CAWG) conducted a literature search and review focused on extended winegrape ripening.[12] They were able to glean some information from a few of sources that included the general horticulture literature, varietal surveys that included one or more early ripening varieties, studies that barely extended beyond conventional ripeness, and that followed only a single parameter to high sugar levels.

Below a is summary of our current knowledge of extended ripening based on the CAWG effort and preliminary findings from recent research. We will begin with some definitions.

Definitions

Maturation — the developmental processes in which fruit changes from the immature to the mature state with viable seeds.[21,30,50]

Mature — the state of fruit at the end of maturation.[50]

Ripening — the alteration of mature fruit from an unfavorable to a favorable condition with respect to firmness, texture, color, flavor, and aroma.[50] Ripening is a senescence process controlled by hormones.[30]

Ripe — the optimum developmental state or chemical and physical condition for the intended enological use of the fruit.[3,10,50,52]

Overripe — too ripe, the physical and chemical condition of fruit after the optimum for the intended enological use.[10,50,52]

Maturity, ripeness, and overripeness

There is an important distinction between mature fruit and ripe fruit. Fruit maturity is an objective state distinguished by seed viability, while ripeness is a subjective state dependent on the intended use or wine style. Therefore, ripeness is at the discretion of winemakers and, by appearances, so is overripeness. Overripe fruit, however, has some defining physical and

Table I. 2005 Extended winegrape ripening research projects

Researcher	Region	Crush Dist.	Variety	Number of Trials	Trial Location
Mark Battany	Central Coast	8	Cab. Sauv.	1	San Luis Obispo
Mark Battany	Central Coast	8	Merlot	1	San Luis Obispo
Mark Battany	Central Coast	8	Syrah	1	San Luis Obispo
Keith Patterson	Central Coast	8	Pinot Noir	1	San Luis Obispo
Erica Lundquist	North Coast	2	Cab. Sauv.	1	Lake
Rhonda Smith	North Coast	3	Merlot	3	Sonoma
Ed Weber	North Coast	4	Cab. Sauv.	5	Napa
Paul Verdegaal	Northern Interior	11	Cab. Sauv.	1	San Joaquin
Paul Verdegaal	Northern Interior	11	Merlot	1	San Joaquin
Paul Verdegaal	Northern Interior	11	Syrah	1	San Joaquin
Terry Prichard	Northern Interior	11	Syrah	1	Sacramento
Donna Hirschfelt	Sierra Foothills	10	Zinfandel	1	Amador
Sanliang Gu & Bob Wample	South S. J. V.	13	Cab. Sauv.	1	Fresno
Sanliang Gu & Bob Wample	South S. J. V.	13	Merlot	2	Madera, Kern
Sanliang Gu & Bob Wample	South S. J. V.	13	Syrah	3	Fresno, Madera, Kern
			TOTAL FIELD TRIALS	24	

Table II. Yield loss per unit soluble solids in several studies[1]

Variety	Battany[2]	Dokoozlian[3]	Gu & Wample	Hirschfelt	La Rosa & Nielson	Lundquist	Prichard, et. al.	Richardson & Anthony	Verdegaal	Weber
Cab. Sauv.	6.7	0.8 to 3.0	4.3 & 5.5			0.0			3.5 to 16	0.0 to 6.9
Merlot	5.1	0.6 to 3.0	0.3 & 4.2						18 to 29[3]	
Syrah	3.6	1.1 to 1.8	2.5 & 3.3				6.0 to 6.5	3.1 to 5.2	1.1 to 8.7	
Zinfandel				32[5]						
Grenache					3.9 to 11					

1 References: 2, 5, 13, 15, 23, 27, 32, 33, 42, 46, 49
2 Based on berry weights
3 Combination of two years data (2004 & 2005). Peak yield occurred at ≈ 22º Brix
4 Sugar accumulation stalled, increasing only 1º Brix over 37 days, while yields continued to decline
5 Entire loss occurred during the final 10 days of the experiment while there was negligible change in soluble solids, pH, and TA

chemical attributes to be discussed later in this report.

Overripeness is seldom an issue for cool climates and short growing seasons where grapes often struggle to attain ripeness.[18] Even in California, extended ripening is not possible in all seasons or for all varieties within a given growing region.[2,27,46,49]

Yield loss during extended ripening

Maximum yield generally occurs between 20º and 22º Brix, but may vary depending on vineyard location and variety.[5,9,26] Berries shrivel and lose weight during extended ripening (Figure I).[7,10,14] Weight loss is mainly due to water lost through transpiration, but likely involves reduced inflow through the vascular tissues of the cluster stems.[14,35]

Weight loss is highly variable and can be substantial (Table II). Prevailing weather conditions during extended ripening and crop load appear to affect the rate and extent of yield loss.[15] Yield loss varies with variety,[5,13,46] and within a given variety and region by vineyard location.[49] Vineyard design factors, such as vine spacing, training, and trellising also effect yield loss during extended ripening.[46]

Perhaps the most precise and practical means for dealing with yield losses associated with extended ripening are the water additions required to decrease high soluble solids to conventional levels.

Progressive Viticulture has developed a yield loss model based on cluster weight partitioning and a U.S. Depart of Agriculture table of Brix and specific gravity values. The model may be used for hand-harvested or machine-harvested grapes.

For example, the water addition required to decrease a hand-harvested, 28º Brix grape must to 23.5º Brix is equivalent to ½-ton per acre for an initial yield of 4.4 tons per acre.

There is some evidence that yield loss may be mitigated, at least in part, without affecting fruit flavor and aroma by soil moisture management.[5,13,46] The success of mitigation, however, appears to depend on irrigation timing and amount of water applied.[32]

Effect of extended ripening on fruit condition and chemistry

Grapes that become overripe during extended ripening have some clearly discernable physical characteristics. They tend to shrivel as they lose water. In addition, there is a loss of firmness and very soft texture that is the result of tissue senescence and breakdown.[10,30,50,52] These conditions make overripe fruit more susceptible to mechanical damage and infection by pathogens.[10,19,26,50,52]

Desiccation during extended grape ripening has a concentrating effect on most soluble compounds, while metabolism consumes others, causing their decline. Both of these affects are evident for sugars, which are by far the most plentiful solutes in grape berries. Soluble solids, which is mainly a measure of sugars, continues to increase during extended ripening, even though their synthesis is believed to have ceased.[4,7,10,14]

However, the increase is almost entirely due to fructose, because glucose levels decline in overripe fruit.[7,14] The ratio of glucose to fructose, which was greater than 1.0 during maturation and near 1.0 at ripeness, becomes less than 1.0 during overripening.[14]

Titratable acidity, which dramatically decreases after veraison, decreases at a moderate rate during extended ripening presumably due to berry desiccation.[7,14,27,32]

With the loss in acidity there is a corresponding increase in fruit pH. The decrease in acidity is almost entirely due to loss of malic acid, because the tartaric acid level remains stable.[7,14] The loss in acidity during extended ripening is of less magnitude than the increase in sugars, causing a rise in the ratio of sugar to acid.

Flavor and aroma development in grape berries appear to be environmentally-regulated (light and heat) by enzyme activity and unrelated to changes in sugars and acids. Vegetative flavors and aromas degrade slowly after veraison and, depending on weather and vineyard factors, may or may not be present during extended ripening depending on climate and vineyard conditions.[4]

Floral aromas appear to reach a maximum at ripeness and decline during extended ripening.[10,14] Jammy, prune, date, and raisin are the flavors typically associated with extremely ripe fruit.[3] These dried fruit flavors evolve after the typical ripe fruit flavors.[3,36]

General fruit development trends during ripening and overripening are presented in Table III.

Extended ripening and fruit quality

There are many and varied opinions regarding the impact of extended ripening on grape and wine quality.[6,8,9,16,24,25,33,34,40,41,45] In contrast, pertinent research is scant. Intensified ethanol aromas, bitterness, viscosity, and black pepper and berry flavors were the main influences of overripeness in Zinfandel wine.[31]

Shortened post-harvest periods

An extended ripening period takes time away from the post-harvest period. During the post-harvest period, vines continue to convert sunlight into carbohydrates and a large percentage of these carbohydrates are stored in the permanent woody vine tissues for use during the following growing season.

A portion of the mineral nutrients taken up from the soil after harvest is also stored for subsequent use. Some winegrape growers have been concerned that shortened post-harvest periods may lead to a decline in vine health and fruit production.

Available evidence indicates that post-harvest periods are not essential. First, during the growing season there is a net gain of carbohydrates in the roots of normally cropped vines long before the onset of extended ripening.[28,29,30,47,51] Second, carbohydrate storage in buds and canes appears the same for normally-harvested vines and unharvested vines.[48] Finally, commercial viticulture has been sustained in regions that regularly have little or no post-harvest period.[20,38]

Post-harvest periods do, however, allow for storage of additional carbohydrate reserves.[39,51] The additional storage allows vines to draw upon both currant assimilates and reserves for fruit development during the growing season, providing the basis for larger yields of ripe grapes.[17,22]

Table III. Changes in grape berries during maturation, ripening, and overripening

	During Ripening		During Extended Ripening (overripeness/senescence)	
	Trend	References	Trend	References
Biomass	↗	Mullins, et. al. (1992), Winkler, et. al. (1974)		
Fresh weight	↗	Coombe (1992), Christensen, et. al. (1995), Jensen, et. al. (undated a), Jensen, et. al. (undated b), Singleton (1966), Winkler, et. al. (1974)	↘	Bisson (2001), Coombe & McCarthy (1999), Kennedy, et. al. (2000a), Kennedy (2004a), Jensen, et. al. (undated a), La Rosa & Nielson (1956)
Water	↗	Coombe (1975), Coombe (1992), Hamilton & Coombe (1992), Winkler, et. al. (1974)	↘	Coombe (1975), Galet (2000), Hamilton & Coombe (1992)
Dry weight	↗	Coombe (1992), Mullins, et. al. (1992), Williams (1987)		
Soluble constituents	↗	Coombe (1975), Coombe & McCarthy (2000)	↗	Coombe (1975)
Soluble solids	↗	Coombe (1975), Jackson & Lombard (1993), Kliewer (1965b), Pirie & Mullins (1977), Singleton (1966), Westwood (1993), Winkler, et. al. (1974)	↗	Coombe (1973)
Must density or specific gravity	↗	Galet (2000)	↗	Galet (2000)
Physiological Changes				
Sensitivity to ethylene	↗	Westwood (1993)		
Chlorophyll	↘	Hamilton & Coombe (1992), Mullins, et. al. (1992), Westwood (1993), Uhlig & Clingeleffer (1995)		
Photosynthesis rate	➘	Mullins, et. al. (1992)		
Respiration rate	➘	Geisler & Radler (1963), Mullins, et. al. (1992), Westwood (1993)	➚	Inoescu (1968)
Osmotic potential	↘	Mullins, et. al. (1992)		
Cell expansion	↗	Mullins, et. al. (1992), Winkler, et. al. (1974)		
Cell division	→	Harris (1968), Mullins, et. al. (1992)		
Cell wall integrity	↘	Mullins, et. al. (1992)		
Xylem tissue functionality	↘	Creasy, et. al. (1993), Mullins, et. al. (1992), Kennedy (2002), Lakso, et. al. (1995)		
Invertase activity	↗	Mullins, et. al. (1992)		
Seed maturation	→ (completed at maturity)	Kennedy (2002)		

Post-harvest periods are important to grapevines compromised by pests, diseases, disorders, deficiencies, and stresses, which may alter the production of carbohydrates and their partitioning within grapevines.[30,37,51] This includes vines that were inadvertently subjected to severe water stress as a part of a deficit irrigation schedule. Post-harvest periods are critical to vines with large crops or limited leaf area.[1,17]

Conclusions

Fruit is ripe when winemakers feel it is suitable for the wine style they want to make and, in recent years, suitability has often come later than usual in the growing season. As a result, wine is increasingly made from fruit which can be considered overripe due to the following characteristics: soft texture, high soluble solids, glucose to fructose ratios less than 1.0, low titratable acidity, high pH, low ratios of malate to tartrate, very high sugar to acid ratio, diminished floral characters, and the presence of dried fruit characters. Other compositional features of overripe fruit have yet to be adequately characterized.

We know that wines made from partially desiccated grapes are more costly and risky to produce. We also know that continued production of such wine calls for a realignment of business agreements between producers and processors to fairly partition these costs and risks. What we need are measures of cost and risk that are agreeable to both parties. Compensation based on a water addition model calibrated for grape musts is one possibility.

Economically-viable production techniques that avoid or mitigate the costs and risks of extended ripening fruit are probably the best long-term solution for all parties. Such technology requires a deeper, more thorough understanding of grape growth and development than we now possess.

Soil moisture management during ripening appears to be the most promising avenue for mitigating yield loss, but what we truly need are vineyard designs and management practices that produce desirable tannins, flavors and aromas before the onset of overripening. ■

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Table III (continued)

	During Ripening		During Extended Ripening (overripeness/senescence)	
	Trend	References	Trend	References
PHYSICAL ATTRIBUTES				
Volume	↗	Coombe (1992), Coombe (2001), Coombe & McCarthy (2000), Hamilton & Coombe (1992), Kennedy (2002), Winkler, et. al. (1974)	↘	Du Plessis (1984), Rogiers, et. al. (2004)
Firmness	↘	Mullins, et. al. (1992), Westwood (1993)		
Softness (texture)	↗	Coombe (1992), Coombe & Phillips (1980), Hamilton & Coombe (1992), Mullins, et. al. (1992), Winkler, et. al. (1974)	↗	Winkler, et. al. (1974)
Deformability	↗	Coombe (1992), Coombe & Phillips (1980)		
Turgidity	→ (at low levels)	Thomas, et. al. (2004)	↘	Galet (2000), Hamilton & Coombe (1992)
Adhesion to pedicel	↘	Mitchell (1979)		
Resistance to powdery mildew	↗	Chellemi & Marois (1992)		
Resistance to other pathogens	↘	Jensen, et. al. (unpublished a), Jensen, et. al. (unpublished b), Winkler, et. al. (1974)	↘	Winkler, et. al. (1974)
Resistance to mechanical injuries	↘	Winkler, et. al. (1974)	↘	Winkler, et. al. (1974)
CARBOHYDRATES	↗	**MULLINS, ET. AL. (1992)**		
Sugars	↗	Coombe (2001), Coombe & McCarthy (2000), Hamilton & Coombe (1992), Mullins, et. al. (1992), Westwood (1993), Winkler, et. al. (1974)	↗ (due to dehydration)	Bisson (2001), Coombe (1975), Galet (2000), Hamilton & Coombe (1992)
Sucrose	↗	Coombe (1992), Westwood (1993)		
Glucose	↗	Coombe (1975), Coombe (1992), Esteban, et. al. (1999), Galet (2000), Kennedy (2002), Lacey, et. al. (1991), Westwood (1993)	↘	Amerine & Thoukis (1958), Coombe (1975), Galet (2000), Hamilton & Coombe (1992), Kliewer (1965b), Webb & Coombe (1999)
Fructose	↗	Coombe (1975), Coombe (1992), Esteban, et. al. (1999), Galet (2000), Kennedy (2002), Lacey, et. al. (1991), Westwood (1993)	↗	Amerine & Thoukis (1958), Coombe (1975), Galet (2000), Hamilton & Coombe (1992), Kliewer (1965b), Webb & Coombe (1999)
Glucose/Fructose	→	Coombe (1975), Hamilton & Coombe (1992), Kliewer (1965b), Winkler, et. al. (1974)	↘	Coombe (1975), Hamilton & Coombe (1992), Kliewer (1965b), Winkler, et. al. (1974)
Pectins	↗	Coombe (1999), Galet (2000), Silacci & Morrison (1990), Westwood (1993)	↗	Galet (2000)

Table III (continued)

	During Ripening		During Extended Ripening (overripeness/senescence)	
	Trend	References	Trend	References
Acids	↘	Coombe (1975), Coombe (2001), Galet (2000), Hamilton & Coombe (1992), Kliewer (1965a), Winkler, et. al. (1974)	↘	Kliewer (1965a), La Rosa & Nielson (1956), Winkler, et. al. (1974)
Titratable acidity	↘	Coombe (1975), Hamilton & Coombe (1992), Jackson & Lombard (1993), Kennedy (2004a), Mullins, et. al. (1992), Westwood (1993)	↗	Kennedy (2004a)
Tartrate	↘ & →	Coombe (1975), Esteban, et. al. (1999), Hamilton & Coombe (1992), Iland & Coombe (1988), Kliewer (1965a), Lacey, et. al. (1991)	→ or ↘	Coombe (1975), Kliewer (1965a)
Malate	↘	Coombe (1975), Galet (2000), Hamilton & Coombe (1992), Iland & Coombe (1988), Jackson & Lombard (1993), Mullins, et. al. (1992)	↘	Kliewer (1965a), Iland & Coombe (1988)
Tartrate/Malate	↘ & ↗	Kliewer (1965a)	↗	Kliewer (1965a)
Citric	→ or ↗	Esteban, et. al. (1999), Galet (2000)		
pH	↗	Iland & Coombe (1988), Jackson & Lombard (1993), Kennedy (2004a), Mullins, et. al. (1992), Singleton (1966), Winkler, et. al. (1974)	↗	Coombe (1975), Hamilton & Coombe (1992)
Lipids				
Terpeniods (in floral varieties)	↗	Coombe (1992), Jackson & Lombard (1993), Kennedy (2002), Marais & van Wyk (1986), Reynolds, et. al. (1995), Williams (?)	↘ or ↗ (terpene type & form dependent)	Gunata, et. al. (1985), Hirano, et. al. (1998)
Carotenoids	↘	Uhlig & Clingeleffer (1995)		

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Table III (continued)

	During Ripening		During Extended Ripening (overripeness/senescence)	
	Trend	References	Trend	References
PHENOLICS				
Total	↗	Coombe (1992), Hamilton & Coombe (1992), Keller & Hrazdina (1998), Pirie & Mullins (1977), Singleton (1966), Valero, et. al. (1989)		
Non-flavonoids				
Flavonoids				
Polymerization of skin proanthocyanidin	↗	Kennedy, et. al. (2002)		
Tannins	↘ or → (seed or skin, respectively)	Harbertson, et. al. (2002), Kennedy, et. al. (2000a), Kennedy, et. al. (2000b), Kennedy (2002), Mateus (2001), Winkler, et. al. (1974)		
Tannin softness	↗	Kennedy (2004b)	↗	Kennedy (2004b)
Flavonols	↗	Keller & Hrazdina (1998), Kennedy, et. al. (2002)	↘ (trend suggested by results)	Keller & Hrazdina (1998)
Anthocyanins (red varieties)	↗	Galet (2000), Keller & Hrazdina (1998), Kennedy (2004a), Mullins, et. al. (1992), Pirie & Mullins (1977), Webb, et. al. (1999), Westwood (1993)	↘ (maximum before shrivel)	Kennedy (2004a), Singleton & Esau (1969)
Methoxypyrazines	↘	Allen, et. al. (2000), Galet (2000), Hashizume & Samuta (1999), Kennedy (2002), Lacey, et. al. (1991), Marais (1994), Winter (2004)		
GLYCOSIDES (BOUND AROMA COMPOUNDS)	↗	**GALET (2000), LOMBARD & JACKSON (1993)**		
SENSORY ATTRIBUTES (grapes & wines [Noble & Shannon])	↗	Du Plessis (1975), Du Plessis (1984)	↘	Du Plessis (1975), Du Plessis (1984)
Aroma intensity	↗	Coombe (1992), Mullins, et. al. (1992), Kennedy (2002), Winkler, et. al. (1974)	→ except ethanol increased)	Coombe (1992), Noble & Shannon (1987)
Flavor intensity	↗	Coombe (2001), Coombe & McCarthy (2000), Kennedy (2002)	→ (except berry & black pepper up)	Noble & Shannon (1987)
bitterness	↗	Noble & Shannon (1987)	↗	Noble & Shannon (1987)
viscosity	→	Noble & Shannon (1987)	↗	Noble & Shannon (1987)
Wine scores	↗	Du Plessis & Van Rooyen (1982), Du Plessis (1984), Ough & Alley (1970)	↘	Du Plessis & Van Rooyen (1982), Du Plessis (1984), Ough & Alley (1970)