GRAPE MATURITY

Section 2.

Measuring Vineyard Variation

A number of studies have reviewed the factors impacting vineyard variation (Rankine et al., 1962; Smart and Robinson, 1991; Trought, 1996; Trought and Tannock, 1996). Prior to fruit sampling, one needs to gain some appreciation of the variation within each vineyard block.

Several techniques can be used to quantify the level of dispersion around a population mean, including range, mean deviation, sum of squares, variance, standard deviation, and the coefficient of variation. Expressed as a percentage, the coefficient of variation (CV) is a unitless measure of the sample variability, relative to the sample mean:

$$\text{coefficient of variation (CV)} = \frac{\text{standard deviation (s)}}{\text{mean (x)}} \times 100$$

A sequential comparison of CVs can reveal both the source of variation and the points of re-synchronization in the berry's developmental cycle (Gray 2006).

Vineyard Variation Management

Zonal management and zonal harvest are appropriate techniques where the grape grower has ready access to the necessary technology. Perhaps the best approach to help minimize vine variation is site selection. Variation may be minimized by choosing a site with limited variation in soil, topography, aspect, and extreme weather events.

Cluster variation may be managed by applying viticultural best-practices or a viticultural Hazard Analysis and Critical Control Points (HACCP) plan to promote uniform bud burst, shoot growth, flowering, cluster exposure, and berry development (Coombe and Iland, 2004).

The specifics of berry-to-berry variation are not well understood. Factors that may contribute include variations in cluster architecture, the role of vascular function in berry growth and development, the relationship between seed development and berry development, and the relative importance of cell division and cell expansion throughout the entire developmental cycle (Gray, 2006).

Fruit Maturity Gauges

Maturity evaluation should be viewed in the context of stylistic goals. If the fruit does not contain desirable aroma/flavor, color, and tannin characteristics, these features will likely not be optimized in the resultant wine. If a clear descriptive analysis of the quality target exists, the time of harvest can aid in meeting those goals. Maturity evaluations usually involve several to many of the following (Zoecklein et al., 1999):

- aroma/flavor, and intensity of aroma/flavor
- grape skin tannins and tannin extractability
- stem lignification or “ripeness”
- seed numbers per berry
- seed “ripeness” or tannin extractability
- sugar per berry
- red fruit color
- °Brix
- acidity
- pH
- berry softness
- berry size/weight
- berry shrivel
- potential for further ripening, general fruit condition

Maturity variables often change with time. It is not completely understood how each of the above relate to one another, and the importance of their individual or collective values as predictors of wine quality. The time to harvest is *prior* to deterioration of desirable fruit characters or components.

However, the factors that control the loss of berry aroma/flavor compounds, for example, and when degradation may be initiated, is not well understood. As such, a chemical marker of the onset of fruit aroma/flavor deterioration would be ideal as a maturity gauge (Bisson, 2001).

Berry Size/Weight

There is evidence suggesting that smaller berries may yield richer must, in terms of color intensity and tannin composition. However, Matthews and Kriedemann (2006) reported that the cause of berry size is more important in determining must composition and wine sensory properties than berry size *per se*. They suggested that how the change in size came about is important, making a distinction between environmental factors versus biological processes that underlie variation in reproductive development.

For example, smaller berry size in red varieties, such as Cabernet franc, commonly yields a richer must if berry size is reduced by environmental factors such as deficient irrigation. By contrast, Shiraz berries that are smaller for developmental reasons, and have fewer seeds, do not necessarily produce musts that are richer (Walker et al., 2005). High yield reduces the weight of individual fruit, but generally causes lower, rather than higher, concentrations of solutes (Bravdo et al., 1985). Increased light exposure increases both berry size and solute concentration (Dokoozlian and Kliewer, 1996).

Additionally, the timing of water deficits prior to véraison often, but not always, increases Brix. The question remains whether that is solely the consequence of a reduction in berry size. Knowledge of berry size may allow for adjustments in wine processing methodologies such as cap management, *saignée*, etc., to reach stylistic goals.

Sugar Evaluation

Methods of Expressing Sugar Concentration. Sugar is usually expressed as °Brix, °Baume, total soluble solids concentration (TSS) or by specific gravity. °Brix, named after the German scientist Adolf Brix, is defined as grams of soluble solids per 100 g of solution. It is a measure of all soluble solids, including pigments, acids, glycerol, and sugar.

Generally, the fermentable sugar concentration of grape must accounts for 90 to 95% of the total soluble solids. Therefore, determination of °Brix provides only an approximate measurement of sugar concentration. The vast majority of grape sugar consists of the two monosaccharides, glucose and fructose. The ratio of these two is dependent upon the variety and the extent of fruit maturity, with glucose dominating during early berry development. Overripe fruit has a low glucose to fructose ratio, which can have implications with regard to fermentation completion (Zoecklein et al., 1999).

Baumé, often used in Europe and Australia, named for the French pharmacist Antoine Baumé, is a measure of the sugar concentration of fruit and the potential alcohol that can be achieved by complete fermentation. Thus, °Brix and °Baumé naturally relate to each other: 1.0°Baumé is equivalent to 1.8°Brix.

Grapes with a 13°Baumé, if fermented completely, would produce a wine with about 13% (v/v) alcohol. °Brix, or its equivalents, is commonly used for the estimation of potential alcohol, important for stylistic winemaking and as a method for grower compensation.

A number of studies have shown a correlation between sugar accumulation and grape berry aroma/flavor compounds, however, the strength of the association depends on a number of variables (Robinson and Davies, 2000). The synthesis of many grape aroma/flavor compounds requires energy, but the factors leading to cessation of synthesis have not been well defined.

In cold to cool heat summation regions, °Brix is generally more strongly correlated to aroma/flavor than in warmer regions (Jackson and Lombard, 1993). Strauss et al. (1987) demonstrated that one group of aroma/flavor compounds, norisoprenoids, are strongly correlated to grape sugar.

Norisoprenoids, 13-carbon terpenoids, are derived from the degradation of carotenoids, and are associated with descriptors such as grassy, tobacco, smoky, kerosene, tea, and honey (Strauss et al., 1987). The norisoprenoids appear to be more stable than the compounds associated with fruity aroma notes.

Thus, while sugar can indicate general maturity level, it is not a clear estimation of aroma/flavor. It is commonly found that higher quality wines from a particular variety within a region are made from grapes that reach their targeted soluble solids earlier.

Potential for Further Ripening; Hang Time. A typical sugar profile during ripening shows an initial rapid accumulation, but at some point during development, the vine ceases transport of sugar to the fruit. Further increases in sugar concentration are due to dehydration.

°Brix, berry aroma/flavor, and phenol maturity are not always strongly correlated. This has resulted in extended fruit "hang time" to allow for desirable changes in secondary metabolites. The results may include the loss of fruit weight, increases in °Brix and, thus, elevated levels of potential wine alcohol.

Figure 5. Relationship Between °Brix and Berry Weight at Different Sampling Dates

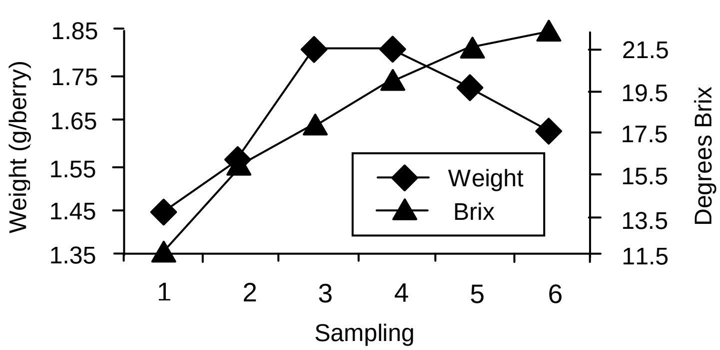

Figure 5 illustrates the relationship between berry weight and °Brix at several sampling dates. As maturation continues, berry weight increases, then declines. This decline frequently occurs prior to harvest. °Brix can increase in late stages of maturity, either due to the production of sugar by the plant, or to dehydration of the berry.

Berry Shrivel and Weight. Grape maturation can be evaluated by assessing physical properties of the berry, such as weight, firmness, and deformability. Berry softening is due to changes in composition of cell walls of the fruit, particularly due to pectin and xyloglucan depolymerization, which accompanies arrest of xylem flow to the fruit (Rogiers et al., 2006).

Berry shrivel is an important attribute impacting yield and, frequently, wine style. Shrivel is particularly notable in some varieties such as Shiraz, where shrinkage begins in warm regions at about 80 to 90 days post-flowering (McCarthy, 2001).

The decline in berry weight is more closely related to the time from flowering than to °Brix. Symptoms include loss of berry turgidity and wrinkling of the skin. The rate of berry shrinkage varies as a result of region, season, and/or climatic conditions, and among vines within blocks (Rogiers et al., 2006).

Between the maximum berry weight and time of harvest, there can be substantial decline in weight. Research indicates that the maximum rate of production of aroma/flavor compounds occurs at about the time the berry stops importing water from the phloem, or shortly thereafter. Therefore, maximum aroma/flavor occurs sometime after the berry reaches maximum weight in most instances, suggesting the importance of this as a stylistic winemaking tool.

In one study, McCarthy and Coombe (2001) determined optimum harvest weight for maximum secondary metabolite concentration in an Australian Syrah to be

1.2 g per berry. The incidence of berry shrivel and degree of shrivel is used as a maturity gauge for some varieties.

Brix-to-Alcohol Ratio. Producing balanced, harmonious wines is an important industry goal. Balance refers to the relative concentrations of volatile and structural/textural components. Making wine in a warm growing region or vineyard site may pose a challenge with regard to avoiding excessive alcohol concentration, where increased “hang time” can result in alcohol levels that negatively impact wine balance.

Theoretically, a given weight of fermentable sugar will yield 51.1% alcohol by weight. The actual alcohol yield is generally different from the theoretical. In the past, winemakers used the conversion factor of 0.55 multiplied by the °Brix to estimate the potential alcohol produced in a dry wine.

However, the actual conversion rate can vary from 0.54 to 0.62, or higher. These differences are the result of several factors listed below. For example, softening of grapes occurs from véraison to harvest as a result of changes in pectin polysaccharides. Increases in deformability occur with increases in the water-soluble polysaccharide concentration, which can increase the non-sugar soluble solids concentration, caused by the following:

- variety
- season
- maturity level/soluble solids
- fermentation temperature
- open vs. “closed” fermentors

Sugar per Berry. The °Brix of grape must accounts for 90 - 95% of the fermentable sugars. However, this measurement is a ratio (wt/wt) of sugar to water, and may change due to physiological conditions in the fruit.

A potential problem encountered in °Brix, °Baumé, or any soluble solids measures used as a fruit maturity index, occurs with changes in fruit weight. Over time, soluble solids readings may show no change, but in fact there may be substantial changes in the fruit weight, either increases or decreases (Table 2).

Table 2. Determination of Sugar per Berry

Changes in Sugar/berry	**Changes in berry weight**		
	Decreases	**No Change**	**Increases**
Increases	Maturation & dehydration	Maturation	(a) Major increase: maturation & dilution (b) Minor increase: maturation
No change	Dehydration	No change	Dilution
Decreases	Dehydration & sugar export	Sugar export	Sugar export & dilution

Source: Long (1984)

Sugar accumulation may cease due to unfavorable environmental conditions, such as very high or low vineyard temperatures, but resume once conditions have changed. It is important to be able to distinguish transient effects from the permanent cessation of transport of photosynthates. Once phloem transport has ended, any further increases in °Brix will be due to loss of water, not continued synthesis and translocation of sugar.

Assessing changes in berry weight, and noting the point at which average berry weight starts to decrease, while °Brix increases, can indicate the onset of dehydration. However, this can be difficult to monitor where fruit maturity is not uniform across clusters or berries.

The concept of sugar per berry utilizes a soluble solids evaluation, such as °Brix, and takes into account the weight of a berry sample. For example, if data were taken from the same vineyard at 5-day intervals and the soluble solids (°Brix) of both sample dates measured 22°Brix, it might be concluded that there had been no change in fruit maturity.

However, sugar per berry calculations could lead to a different conclusion if there were changes in berry weight (Table 2). Sugar per berry calculations yield considerably more information than that available by evaluation of °Brix measurements alone.