GRAPE MATURITY

<u>Learning Outcomes:</u> *After reviewing this chapter, the reader will understand the importance and complexity of grape maturity evaluations. The changes occurring in berry development, factors impacting berry chemistry, and practice issues such as sample collection and processing, are discussed.*

Chapter Outline

- **Grape Quality**
- **Environmental Factors Influencing Grape Maturation**
- **Vineyard Factors Impacting Maturation**
- **Fruit Sampling**
- **Asynchronous Ripening**
- **Measuring Vineyard Variation**
- **Fruit Maturity Gauges**
- **pH and Acidity**
- **Berry Sensory Analysis (BSA)**
- **Non-Conventional Maturity Evaluation Tools**
- **Grape Sample Processing**

Section 1.

Grape Quality

Virginia wines, and the grapes used to produce them, are highly differentiated products influenced by a wide array of factors including variety, growing season, soil, vineyard management, and winemaking characteristics. High quality wines, regardless of how they are defined, are the result of the confluence of important attributes, including grape quality.

Virginia grape quality is impacted by 1) maturity, purity, and condition, 2) aroma/flavor and phenolic characteristics, and 3) harvesting methods, transportation, and processing protocols. For the most part, each of these is best evaluated not in isolation, but in combination, to define optimum grape quality for a particular wine type and style.

There are three stages of berry development following flowering: green berry; arrest of green berry development, and pause before the onset of ripening; and fruit ripening or *véraison* (Jackson and Lombard, 1993) (Figure 1).

Figure 1. Stages of Grape Maturation

Stages of berry development

Flowering → *Stage I* Green berry growth → *Stage II* Arrest of green growth → *Stage III* Véraison

Stages of véraison

Stage I Sugar/water accumulation → *Stage II* Arrest of phloem transport → *Stage III* Dehydration → *Stage IV* Raisining

(Arrest of berry flavorant synthesis)

(Deterioration of berry flavorants)

Véraison can be divided into stages based upon berry metabolism and transport of substances to the vine (Figure 1; Bisson, 2001). It is not well understood if synthesis is controlled by hormonal signals in the vine, or in the fruit independent of other vine influences (Robinson and Davies, 2000). Both changes in phloem transport and the onset of berry dehydration influence fruit composition (Matthews et al., 1990).

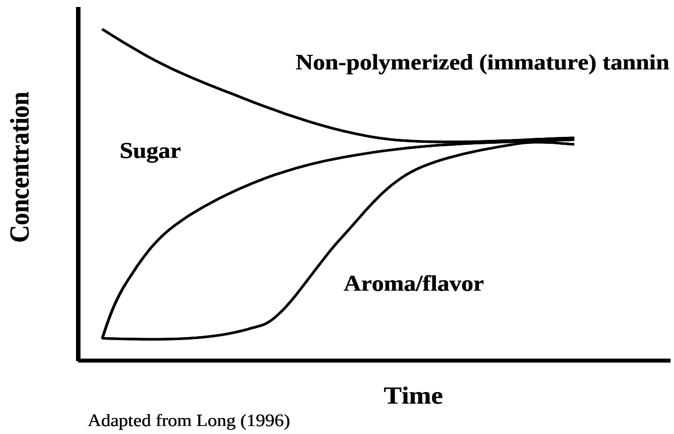
In Virginia's climate, overall, the berry approximately doubles in size between véraison and harvest (Conde et al., 2007). As a result, many of the solutes accumulated in the fruit during the first period of development have their concentration substantially reduced.

However, some compounds are reduced on a per-berry basis, not simply due to dilution. For example, malic acid, which is metabolized and used as an energy source during the ripening phase, is substantially decreased relative to tartaric acid, whose concentration usually remains almost constant after véraison.

Tannins also decline considerably on a per-berry basis after véraison. Some aromatic compounds, including several of the methoxypyrazine compounds, decline after véraison.

Fruit maturity influences wine style, and most winemakers understand that timing of grape harvest determines the maximum wine potential thereafter. High quality wine, regardless of how it is defined, is the result of the confluence of important fruit attributes, including the development of fruit-derived aroma/flavor components, desirable color, and desirable tannins. Ideally, these coincide with primary metabolites, such as optimum soluble solids concentration (Figure 2). In reality, grape maturity indices seldom align; if they did, maturity evaluations would be an easy task.

Figure 2. Stylized Grape Maturation



Environmental Factors Influencing Grape Maturation

The following is adapted from Gladstones (1992). High temperatures (35/30°C day/night) during stage 1 of berry development cause irreversibly smaller berries. Because the skins contain a high concentration of so-called luxury or secondary metabolites, a change in the surface-to-volume ratio is highly important.

An optimum mean ripening temperature for grapes is about 20°C or slightly higher. This temperature is a little below the mean temperature of around 23-25°C at which grapevines reach their greatest rate of photosynthesis and growth.

Below that temperature, growth rate is limited more by the rates of biochemical processes other than photosynthesis. As such, a surplus of sugars can accumulate which is available to be stored or transported to the fruit, or to be used to produce luxury products not essential for plant growth, such as anthocyanins (blue to red pigments) and aroma/flavor compounds.

As the temperature increases above the optimum, the demand for sugar due to rapidly accelerating respiration, combined with no further increase in the rate of photosynthesis, leaves a smaller amount of sugar for growth and luxury products. This is why anthocyanins disappear at high growing temperatures.

Phenol production is the result of enzymatic activity in the plant. The maximum rate of pigment synthesis depends on a good supply of sugar as the basic chemical substrate and energy source, together with favorable intermediate temperatures for maximum enzyme activity.

Kliewer and Torres (1972) studied the effects of day/night temperature range on grape anthocyanins. They found a strong positive correlation between minimal temperature differences, and anthocyanin development and concentration.

Anthocyanin concentration in the skin is influenced by sun exposure, as are non-colored phenols. For example, flavonol concentration can be increased by a factor of 20 or more, due to solar exposure (Price et al., 1997). The increase in total phenols as a result of solar exposure is an important issue in defining the optimum degree of selective fruit zone leaf removal in a warm climate, such as Virginia's.

What are the effects of short-term temperature spikes on grape aroma/flavor? It may not be realistic to rely too heavily upon the maximum and minimum temperatures to describe the thermal characteristics of a region or site. As suggested by Happ (1999), if the movement of temperature between the daily maximum and minimum exhibited the properties of a straight line, the mean would provide the average temperature experience. However, the true average lies away from the mean.

The rise in a temperature curve is asymmetrical, and changes with cloud cover, wind, etc. The optimum temperature for enzymatic reactions which govern aroma/flavor development and retention is about 22°C. Therefore, it has been suggested that the periodic difference between the temperature experienced throughout the day (for example, every twenty minutes) and 22°C, is the true measure of site climate. An issue may be the consistency of temperature during the entire day, for the final 28 days before harvest.

Happ (1999) has calculated a heat load index, which takes into account that a temperature rise does not necessarily have a linear effect on aroma/flavor. For example, a temperature increase to 25°C does not have the same impact on aroma/flavor as a rise to 35°C.

Vineyard Factors Impacting Maturation

A significant volume of research has advanced our understanding of how various viticultural variables and practices, including fruit maturity, crop level, crop exposure (Bergqvist et al., 2001; Zoecklein et al., 1998), leaf area to crop ratio (Kliewer and Dokoozlian, 2005), shoot density, and training systems (Reynolds et al., 1996) affect grape composition and maturation.

It is commonly found that higher quality wines from a particular variety within a designated region are made from fruit that reach their targeted maturity earlier. Those that do not are either out of balance, young vines, or are not optimally managed with respect to cropping level, irrigation, pruning, and/or canopy management. Important features impacting fruit maturation include the following:

- fruit temperature
- humidity
- rainfall
- site characteristics, including soil type and sun exposure
- soil moisture, irrigation management, deficit irrigation
- variety/clone
- training and trellising systems
- row orientation

- canopy management
- rootstock
- yield components: kg fruit per vine, clusters per vine, clusters per shoot, berries per cluster, berry weight

Table 1 shows how viticultural and environmental factors affect grape composition variables.

Table 1. Grape Variables Impacted by Viticulture and the Environment

Quality variable	Soil nutrition	Canopy	Irrigation	Pests and disease
Sugar	Nitrogen excess Potassium	Leaf & fruit exposure Crop load Pruning Summer pruning Crop removal Plant growth regulators	Irrigation RDI[a] PRD[b]	Powdery mildew Viruses
Color	Nitrogen excess Potassium	Shading Crop removal	RDI Irrigation	*Botrytis* Viruses
Berry size	Nitrogen excess	Pruning Crop removal Plant growth regulators	Irrigation RDI	
pH	Nitrogen excess Potassium	Shading Crop load	Irrigation	
Titratable acidity	Nitrogen excess	Shading Crop load	Irrigation	
Contaminants (including MOG, and pests and diseases)	Nitrogen excess Excess chloride	Canopy ventilation Bunch exposure Shading Pruning Crop removal	Saline water	Pests & diseases Chemical residues *Botrytis* Powdery mildew Downy mildew Pests Harvest

Source: Krstic *et al*. (2003). Legend: [a]RDI = Regulated deficit irrigation; [b]PRD = Partial rootzone drying.

Fruit Sampling

Fruit sampling in Virginia is usually begun sometime after berries have reached full véraison. Regardless of maturity gauges utilized, an important and universal concern is accurate vineyard sampling. Fruit sampling methodologies have been extensively reviewed (Rankine et al., 1962; Roessler and Amerine, 1963; Jordan and Crosser, 1983; Kasimatis and Vilas, 1985; Wolpert and Howell, 1984).

There are two basic choices in fruit sampling: cluster sampling or berry sampling. With cluster sampling, a further choice can be made of gathering clusters from throughout the vineyard, or using one or more targeted vines. If berry sampling is to be employed, two samples of 100 berries each can give accuracy to 1.0°Brix, and five samples of 100 berries each can give accuracy to 0.5°Brix. Using cluster sampling, ten clusters can be accurate to 1.0°Brix (Jordan and Croser, 1983; Kasimatis and Vilas, 1985).

It should be noted that there is a general tendency, when examining a cluster prior to berry sampling, to select the most mature berries. Therefore, berry sampling should involve locating the fruit zone, and sampling without examining the clusters or berries. If this does not occur, berry samples will frequently be about 2°Brix higher than the true value.

About 90% of the variation in berry sampling comes from variation in the position of the cluster on the vine, and the degree of sun exposure (Trought, 1996). The vineyard must be sampled based on the degree of fruit exposure (Jordan and Croser, 1983).

Fruit Yield Components

Many components contribute to grapevine yield (May, 1972). These include the following:

- vines per acre/vines per ha
- shoots per vine/shoots per meter
- clusters per shoot
- clusters per vine
- cluster weight
- berries per cluster
- berry weight
- fruit weight per vine

An over-cropped vine is one that has a large crop with insufficient, healthy active leaves; it cannot produce enough sugar to maintain all clusters for desirable ripening, and it fails to produce grapes with sufficient aroma/flavor and/or desirable phenolic compounds. Yield can impact the rate of fruit maturation (Winkler, 1965; Zoecklein et al., 1996). Variation in some of the above-listed components of yield can contribute to variation in the yield at harvest, although the grapevine itself is capable of self-regulation (Clingeleffer, 1983) and yield component compensation (Freeman et al., 1979; Smart et al., 1982).

While many yield components cannot be controlled directly, vineyard managers do have the capacity to manipulate some variables in the vineyard. Pruning regulates node number per vine and budburst. Carbohydrate reserves can be modified to influence bud fruitfulness and fruit set (Smith and Holzapfel, 2003). Grapevine canopies can be managed to enhance budburst, bud fruitfulness, and berry growth (Baldwin, 1964; Buttrose, 1974; Smart and Robinson, 1991; Smart, 1992).

The earlier the estimation of average berry weights, the more time the winemaker has to evaluate the crop load, make adjustments, and plan for the season. There is a relationship between berry weight at véraison and berry weight at maturity.

For Syrah, McCarthy (1997) determined that relationship to be the following: $y = 1.35x + 0.53$, where y = the berry weight at 23°Brix, and x = the berry weight at about 5°Brix.

This relationship will differ by cultivar and site, but can be determined by collecting véraison and harvest samples for several seasons. Accurate estimations of yield from precision viticulture techniques, with mapping using GPS systems, optical remote sensing, and other tools, may soon be available.

Asynchronous Ripening

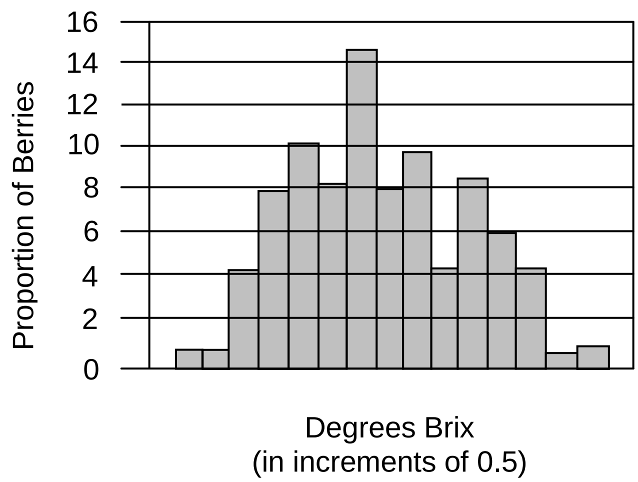
Variation is an inherent part of biological systems. Variation in the vineyard occurs among berries, bunches, and vines. The wine industry presumes that variation has a negative impact on crop level, fruit composition, and wine quality, although few studies have been conducted to substantiate this assumption (Gray, 2006).

Two components of berry-to-berry variation are significant in grape and wine production: size and berry composition. In extreme cases, this is referred to as “hen and chicken” or *millerandage* (Winkler, 1965).

Variation in berry size affects vineyard yield and wine quality. High levels of variation in the early post-flowering period suggest that variation originated prior to berry set. Such variation most likely results from asynchronous cell division in the floral primordium at budburst. Decreasing levels of variation may indicate points of re-synchronization in the berry growth cycle: the more synchronized the event, the lower the variation.

A crop with asynchronous clusters or berries has a mixture of developmental stages, resulting in berries with optimal qualities diluted by berries which may be inferior. This can be seen in a frequency distribution, with berry numbers plotted against °Brix (Figure 3).

Figure 3. Proportion of Berries at Different °Brix at Harvest



Source: Long (1986)

Even before differences arise from processing, it is generally not true that two vineyards or vineyard blocks with the same °Brix values will give similar wines. A juice at 22°Brix might be composed of a narrow distribution of a few berries at 20° and a few at 24°Brix, with the majority nearer to 22°.

However, there may be a much wider distribution, with berries below 18° and greater than 24°. Because °Brix is a distribution average, juices with similar °Brix values can produce quite different wines, due to variations in aroma/flavor and phenol compounds.

Vine-to-vine variability of visually-uniform vines (below), expressed as percentage of the coefficient of variation, was reported by Gray (2006), indicating the inherent nature of vineyard variability. While soluble solids concentrations may be fairly uniform, with a coefficient of variation usually less than ten percent, the variance can be much greater if the fruit is not uniform across clusters, or if the cluster microenvironment is variable among vines:

- Brix 4 to 5%
- pH 3 to 4%
- titratable acidity 10 to 12%
- berry weight 6 to 20%
- color 13 to 18%

Vine to Vine Variation. Many variables can be measured at the vine level, including soil characteristics, carbohydrate reserves, bud fruitfulness, percent budburst, inflorescence primordia number, node number, shoot number, and cluster number.

The inherent variation among individual vines can have a greater impact on yield than external influences such as soil variability, or drainage and fertility irregularities (Strickland et al., 1932). Variation in soluble solids concentrations, titratable acidity, and cluster weight between vines can be much greater than within vines (Rankine et al., 1962).

Spatial analysis techniques and global positioning systems (GPS) have aided our understanding of yield components. Aerial vineyard images, using satellite or aircraft, can be used to calculate a normalized different vegetation index (NDVI) for each vine. These maps can be used to visualize differences in vine vigor or relative biomass on a vineyard scale (Hall et al., 2002).

Variation among Clusters. Differences in cluster size are commonplace in most vineyards. Since yield forecasting and maturity-testing procedures may rely on cluster sampling, differences in cluster size can be a major source of error.

Stratified cluster and berry sampling programs have been devised to overcome some of these problems, but seasonal, varietal, and site-specific considerations confound general sampling protocols (Kasimatis and Vilas, 1985; Wolpert and Howell, 1984). The variables that contribute to variation among bunches include inflorescence primordia size, flower number, fruit set, berry number, cluster weight, and cluster position.

Variation among Berries. Variation among berries is poorly understood. A typical berry follows a double-sigmoid growth curve during its post-flowering development, but two berries in the same cluster may follow quite different paths (Matthews et al., 1987). The divergence of the growth curves becomes apparent shortly after flowering, and the timing of this divergence is responsible for the extent of the difference between the two berries at harvest.

Uneven berry development and its impact on wine quality is largely undocumented. Two studies (Trought, 1996; Trought and Tannock, 1996) determined the extent of variation in the size (weight and volume) and composition (°Brix) of berries within clusters of Chardonnay, Cabernet Sauvignon, and Pinot noir. Seed weight, berry volume, and vascular development of the pedicel were correlated. The variables that contribute to variation between berries include berry size, berry composition, seed number, seed size, and berry position.

Relative maturity dates of the important components of a red berry (skin, pulp, seeds, and cap stem) are shown in Figure 4. Given that all parts enter the fermentor in red wine production, the control of stylistic winemaking may be negatively influenced if component parts of the fruit are not at the optimal physiological maturity at harvest.

Figure 4. Relative Grape Maturation