The concept of berry sugar loading

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Sugar loading – Introduction

Sugar loading can be defined as the evolution of the quantity of sugar per berry, expressed as mg per berry, from véraison onwards. Véraison corresponds with the onset of fruit maturation. In the grapevine, this fruit maturation starts with an abrupt softening of the berry (within 24 hours). This softening goes hand-in-hand with sugars being actively introduced into the berry (sucrose rapidly hydrolysed into hexoses: glucose and fructose). In red and black cultivars, véraison is characterised, after softening, by skin colouring as a result of the biosynthesis of anthocyanins.

The evolution of sugar loading in grape berries gives an indication of the ripening process from a new perspective and is a novel approach to identifying practical indicators for obtaining particular styles of grapes and wine. Sugar loading may also provide information on ripening kinetics and enables the principal phases of ripening to be distinguished (McCarthy & Coombe, 1999; Wang *et al*., 2003a & b; Hunter & Deloire, 2005). Furthermore, this information provides a greater understanding of how grape quality develops in the vineyard.

Sugar loading calculation

Phloem sugar transport, principally to the flesh cells, has been characterised in studies on plant-to-berry sugar loading, and phloem sugar unloading, notably by the peripheral vascular system of the berry (Ollat & Gaudillère, 1996; Fillon, 1997; Hunter & Ruffner, 2001; Wang *et al*., 2003a). Phloem sugar unloading into cell vacuoles occurs mainly via an apoplastic mechanism, which requires the intervention of hexose transporters (Agoerges *et al*., 1995; Terrier *et al*., 2005). From the above-mentioned studies, it can be concluded that sugar loading into the berry, coupled with the dynamics of sugar concentration changes, may be considered a useful indicator of grape quality. It takes into account the evolution of the sugar level per berry (mg per berry) and therefore enables the kinetics of sugar concentration changes to be monitored.

Kinetic monitoring of the quantity of sugar per berry may be considered as a method of measuring the plant's physiological functioning (Hunter & Deloire, 2005; Deloire *et al*., 2004; Wang *et al*., 2003b; Carbonneau & Deloire, 2001; Carbonneau *et al*., 1998) and in particular, photosynthesis, which is a reliable indirect indicator of temperatures to which the vine is subjected under given conditions over a specific time period and grapevine water status.

Active sugar loading is calculated on the basis of berry volume (or berry fresh mass) and sugar concentration (McCarthy & Coombe, 1999; Brenon *et al*., 2005; Hunter & Deloire, 2005).

Example of sugar loading calculation

For a berry with a ripeness level of 25 °brix:

1. Convert 25 °brix to in probable alcohol:
   - 25 x 0.59 = 14.75° in probable alcohol, where 0.59 is the coefficient used for yeast activity to convert brix in probable alcohol (this coefficient as to be adapted to the probable alcohol level).
2. Determine mg of sugar per ml probable alcohol:
   To obtain 1° probable alcohol, 17 g/L of sugar is required.
   - 14.75° x 17 g/L = 250.75 g/L, which is equivalent to 250 mg of sugar per ml (in this example).
3. Calculate quantity of sugar per berry:
   In addition to measuring °brix, the volume of a berry (or berry fresh mass thereof) should also be measured so that the quantity of sugar per berry can be calculated. Approximately 50 berries should be used to determine berry fresh mass so that the single berry fresh mass is an average of a berry population.
   - 250 mg x volume of a berry (or the berry fresh mass thereof, because for many varieties there is a linear correlation between berry volume and fresh mass).

It should be taken into consideration that this calculation is only an approximation of sugar loading into berries. This is due to a number of reasons; among others seed volume, sugar distribution between skin and pulp. Despite the calculation being an approximation, with associated shortcomings, it nevertheless is a useful indicator and the use thereof is becoming increasingly more common.

Profiles of sugar loading

It is possible to distinguish three principal sugar loading profiles:

1. Continual and rapid loading

This type of sugar loading occurs from véraison and is related to the active functioning of carbon production sources (leaves) which supply plant sinks (berries, secondary shoots etc.) during their growth phases. It is therefore often associated with significant vegetative growth and greater berry volume. Phenolic maturity is not affected. This type of loading is often considered beneficial for the production of rosé, fresh fruit red wines, or pleasant aromatic white wines.

2. Slow sugar loading – inhibition of ripening

Low sugar content per berry, associated with a slow loading rate, can be considered to "blocked" ripening and this could be indicative of an imbalance in the vine. If major physiological problems, such as mineral deficiencies, viral diseases etc., are

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excluded, blocked ripening can often be related to excessive water deficit (Wang *et al*., 2003b) or to an excessive crop load in relation to the exposed leaf surface (Carbonneau & Deloire, 2001).

In all grape varieties, this type of situation is far from ideal in terms of the standard vinification practices in white and dry red wine production. Furthermore, in relation to red and black grapes, this situation may be associated with blocked technological and phenolic maturities. Ultimately, it may be necessary to adapt the fermentation procedure to this type of grape, with thermo vinification and short macerations with limited extraction being the preferred options.

3. Sugar loading presenting a plateau phase

Vines showing this tendency present a phase of active sugar loading in the berry (ripening), followed by a plateau representing a cessation of sugar loading and corresponding to maturity (Hunter & Deloire, 2005; Deloire *et al.*, 2005a & b). In some cases, there is a third phase corresponding to a possible decrease of the quantity of sugar per berry (over ripening). To date a probable explanation for the occurrence of this phase has not been identified.

Theoretical berry sugar loading curves (evolution of berry sugar content over time) are presented in Fig. 1. These curves are based on data obtained over five years using at least 20 different grape varieties in mainly France, Spain, Argentina, Chile and recently in South Africa.

The implications of this curve in terms of defining the finished wine is important: depending on whether grapes are harvested in the early, mid or later stages of the plateau phase, the wine

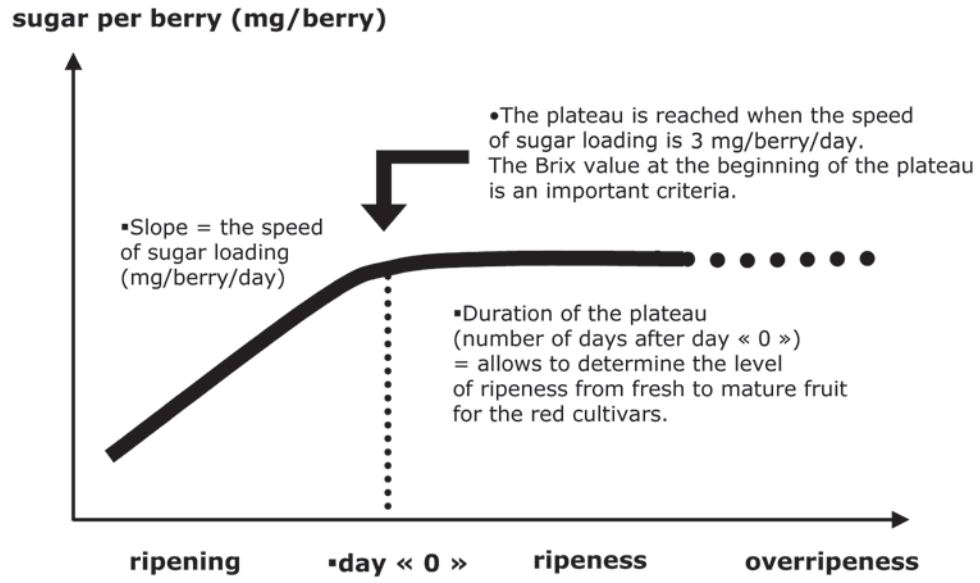

FIGURE 1. Berry sugar loading concept. This theoretical curve is based on data obtained over five years using at least 20 different grape varieties in different countries, principally France, Spain, Argentina and Chile. This curve has been recently calibrated for some South African viticulture areas and cultivars (in collaboration with Distell).

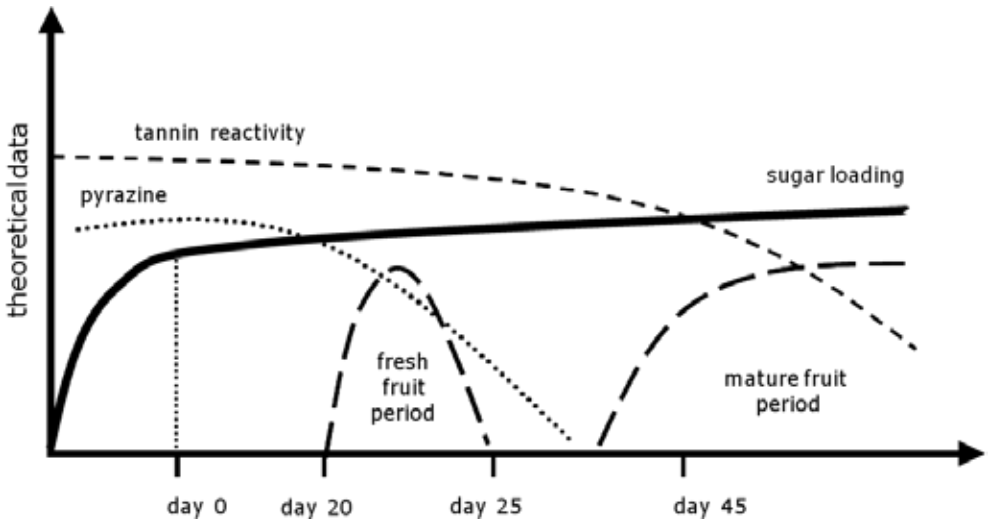

FIGURE 2. The Berry Aromatic Sequence (B.A.S.): Sugar loading and style of wine. Example of relationships between the berry sugar loading curve and the possible related style of wine, for Cabernet-Sauvignon. After "day 0", three successive main periods have been determined: a fresh fruit period, a "neutral" period and a mature fruit period. In terms of harvesting dates, these periods have been determined according to the number of days after "day 0", which corresponds to the sugar loading "plateau", and not directly to a calendar date. This introduces the concept of a "physiological clock".

will be characterised by fresh fruit, neutral-spicy or mature fruit flavours, respectively.

The concept of Berry Aromatic Sequence (B.A.S.)

The above curve demonstrates that selecting a harvesting date according to the quantity of sugar per berry in conjunction with other indicators (titratable acidity, malic and tartaric acids, pH, berry volume, berry tasting, tannins, anthocyanins, etc.) enables different styles of wine to be produced. Hence, for a balanced red wine, complete ripeness will be achieved between one and five weeks after the cessation of sugar loading (Fig. 2). Once the plateau phase of berry sugar loading has been reached, the evolution of ripening will depend on other factors such as cultivar, bunch microclimate, the leaf/fruit balance, the ratio of primary to secondary shoots and the climate mainly during berry ripening (maximum temperature, night-time coolness, sea-breeze, wind-speed, late season rains, and various factors which are quantifiable) (Bonnardot *et al*., 2005; Carey, 2001; Hunter & Bonnardot, 2002).

It should be noted that the plateau phase in sugar loading may be reached at different sugar concentrations (brix), depending on the cultivar and environmental conditions. A red cultivar, with a very high sugar concentration (brix) when the maturity plateau is reached, will not always be desirable for the production of certain types and/or styles of wine (Deloire *et al*., 2008).

Monitoring ripening with various indicators, coupled with appropriate analytical data measurements such as berry fresh mass or volume, brix, sugar loading, evolution of titrable acidity, malic acid tartaric acid, pH, colour evolution, anthocyanins, tannins, berry tasting, etc.) enable decision-makers to determine the optimum harvesting date, a major consideration in determining grape quality. Such monitoring provides a greater understanding of vine morphological and physiological parameters during ripening and therefore vineyard practices can be adapted to production objectives. There are, in most vineyards, several potential optimal harvesting dates and optimal ripening levels according to the desired style of wine. The wine is therefore created in the vineyard!

As the world becomes more technologically advanced, more advanced technology is being developed to monitor berry ripening. This technology is rapidly being adopted by large estates and co-operatives to enhance their marketing edge.

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