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Grapevine quality: A multiple choice issue

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A B S T R A C T

Over decades, the concept of grape quality has evolved emphasizing its multidisciplinary nature and that the same "desired quality" might correspond to even strikingly different compositional patterns. The review takes a long journey throughout the multiple factors impinging on grape quality, not excluding also sections devoted to table grapes. It starts with a through survey on the genetic factors influencing grape quality focusing on diversity in different compositional traits (sugar, organic acid, pH, phenolics and aromas) relating to cultivars and clones. Then, most recent knowledge about the effects of soil characteristics, nutrients, light, temperature and water availability, as standalone factors or in interaction, on grape quality are summarized. The more applied section of the review introduces the very much debated yield-quality relationship that, over years, is being interpreted with more flexibility and with greater consensus for an "optimal yield range" that within a given context can anyway reach the desired quality. The impact of the main summer pruning operations (leaf removal, shoot and cluster thinning, shoot trimming) is reviewed and special care taken to highlight most recent contributions with adjusted summer pruning developed to either adapt to climate change issues or to induce specific composition patterns. Review ends with a quick survey on methods nowadays available for fast, non-destructive grape composition assessment.

1. Introduction

Finding a shared definition of "quality" for wine grapes is still a formidable task simply because quality, being dependent upon individual wine taste, stylistic preferences, vintage variation and a number of other factors, is tremendously subjective. Based on a given final wine target, grape "quality" often reflects quite different "optimal maturity or ripening patterns" and "quality" can exist in every category of wine, from box and jug wines to the very expensive and exclusive premium wines.

Thus, optimal grape maturity would correspond to a strikingly different grape composition depending upon the wine styles (e.g. fresh white sparkling vs. aged reds) and its identification in time is the crucial decision. Total soluble solids (TSS) concentration is still the most used parameter to assess ripening and, in several cases, to tag grape prices. The validity of sugar level as an estimator of berry function is not under debate and recent findings have shown that, in cultivars such as Merlot (Bondada et al., 2017) and Chardonnay (Tillbrook and Tyerman, 2008) a level of 24–25 °Bx likely sets the threshold beyond which a further TSS increase is primarily due to berry dehydration or deterioration. Such threshold is indeed cultivar dependent though; in Shiraz berries attained maximum mass at about 20 °Bx and then started to shrink; conversely, cv. Muscat Gordo Blanco showed no phloem impedance until 27 °Bx (Coombe and McCarthy, 2000). Unfortunately, a TSS-derived good "maturity level" does not necessarily correspond to the best overall maturity and in some years the grapes will be ripe and have a distinct varietal character at 20 °Bx while another year they may still not have a ripe varietal character at 23 °Bx (Barnuud et al., 2014). The decoupling between technological maturity parameters (i.e. sugar, acids or their ratio), phenolic maturity (i.e. quantity and quality of all tannins and pigments) and aromatic ripeness (i.e. typical olfactory features reached without appearance of untypical ageing or excessive

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veggie-green aromas) is considered to be aggravated under a global warming scenario (Palliotti et al., 2014). In warm districts, it is quite common to face excessively fast sugaring while anthocyanins and flavors accumulation is still lagging behind. In more general terms, wine grape quality attributes in white cultivars should aim at the confluence between the desired sugar-to-acid ratio coupled with moderate must pH and clean varietal character; in reds non limiting sugar and anthocyanin pools have to merge with ideal texture of the grape tannins in the skin and the seeds.

Quality of table grape includes intrinsic (i.e. visual, mechanical, chemical, etc.) and extrinsic (i.e. price, country of origin, cultivar, production method, etc.) attributes. The consumer's perception of intrinsic attributes can be defined as 'acceptability'. As a consequence, the perception of quality may change in the marketing chain and among the types of consumers in the different countries. Therefore, sensory evaluation is a valid approach to measure consumer preference and satisfaction (Ma et al., 2016).

Appearance is one of the major factors the consumer uses to evaluate the quality of table grape, especially visual attributes such as berry size, shape and color (Ferrara et al., 2017) together with taste, aroma and texture. Consumers like large, seedless berries along with pleasant flavour and aroma (Costenaro da Silva et al., 2010). Seedlessness is a key factor for quality (Vargas et al., 2013) and young consumers prefer seedless varieties because the absence of the seeds makes the berry easier to chew, thus avoiding the astringency of the seeds or the spitting. Color (from pale green to nearly black) is a direct sensory characteristic making table grape more or less attractive. In addition to visual characteristics, physicochemical properties are involved in quality evaluation (Crisosto and Crisosto, 2002; Jayasena and Cameron, 2008). Texture of table grape berry includes several attributes such as hardness, elasticity, shape and sensations in the mouth during chewing (Rolle et al., 2012).

The sensory quality of table grapes depends primarily on TSS, TA, organic acid composition and the balance between these factors (Munoz-Robredo et al., 2011). TSS correlated to ripeness is one of the grape properties most likely to match consumer perceptions of berry quality and preference. Organic acids balance the mouth-feel sensation of quality of table grapes, but high acidity can negatively affect palatability. Table grapes are harvested after the berries reach minimum maturity requirements (TSS: TA ≥ 20:1 if the Brix level is greater than or equal to 12.5 and less than 14 °Bx, TSS:TA ≥ 18:1 if the Brix level is greater than or equal to 14 and less than 16 °Bx).

The aroma perceived during berry chewing is a quality factor of great importance as a result of the volatile composition of each cultivar (Ruiz-García et al., 2014). Muscat aroma is greatly appreciated in grapes destined for fresh consumption and is directly related to monoterpenes, such as linalool, rose oxide, citral, geraniol, nerol and citronellol (Fenoll et al., 2009).

Table grapes are a major source of health promoting bioactive compounds (Baiano and Terracone, 2012; Lutz et al., 2011). Colored grapes are the most active because of their richness in phenolic compounds with multiple biological effects and potential health benefits (Carrieri et al., 2013; Guerrero et al., 2009).

The quality of table grapes tends to deteriorate (either on vine or in storage) and this is one of the foremost problems faced by the stakeholders. It is well known that one of the major postharvest problems of table grape is its susceptibility to grey mold which can limit the shelf life during storage and retail marketing (Romanazzi et al., 2012). Fungal decay would affect appearance characteristics, firmness and weight loss of clusters during cold storage. Since sulfur dioxide fumigation used to preserve quality and extend shelf life of table grapes has negative effects on food safety and the environment, different products such as chitosan, salicylic acid, etc., can be used to reduce decay incidence and improve grape quality (TSS, phenolic compounds, sensory attributes) and shelf life (resistance to Botrytis cinerea) during cold storage (Shen and Yang, 2017). From a storage point of view, berry shattering, decay and stem browning are some of the most important factors limiting the quality and marketability of table grapes (Cantín et al., 2007).

2. Genetic factors influencing grape quality

A large diversity of grape cultivars is used in the wine industry with distinct characteristics in berry traits, such as berry size, color, flavors, and aromas (Pelsy, 2010; This et al., 2006). Such a wide range of cultivars is largely a result of sexual crossing (natural or introduced by breeders) and natural mutation (This et al., 2006). In addition to cultivars, different clones of the same cultivar may also bring further diversity to grape quality (Pelsy, 2010). This diversity is important not only for providing different wines but also for furnishing opportunities to adapt to the future climate change conditions (Duchêne, 2016) and for enabling the identification of genes controlling quality traits in grapevine (Pelsy, 2010).

2.1. Diversity of sugars among cultivars and clones

Sugar composition and concentration vary with cultivars and clones in grape berry. In most wine grapes (*Vitis vinifera* cultivars), berry starts, at the onset of ripening, to accumulate roughly equal amounts of glucose and fructose, with very low levels of sucrose. However, *V. labrusca* and *Muscadinia rotundifolia* varieties and interspecific hybrids can also accumulate non-negligible amount of sucrose (Liu et al., 2006). Sugar concentration, measured as TSS, varies from 13.7–31.5 °Bx between different cultivars (Kliewer, 1965, Kliewer, 1967a; Kliewer, 1967b; Liu et al., 2006). Moreover, sugar content can vary as much as 23 g/L (~1.4% in potential alcohol) among 10 clones of Cabernet franc (Van Leeuwen et al., 2012), or 2.0–2.5 °Bx (~1.0–1.2% in potential alcohol) among 15 clones of Aglianico and 21 of Muscat of Alexandria (De Lorenzis et al., 2017). Almost 90% of table grape cultivars (*Vitis vinifera* and hybrids *V. labruscana* × *V. vinifera*) are hexose accumulators, which means fructose, glucose, and trace amounts of sucrose (Shiraishi et al., 2010).

The sugar concentration at maturity is a result of various processes, including sugar supply from the leaves, loading via phloem, metabolism in cells, transport into vacuole for storage (Lecourieux et al., 2014), and water dilution effect (Dai et al., 2016; Sadras et al., 2008). The complex nature of the sugar concentration hampers the identification of its genetic markers. Several quantitative trait loci (QTLs) have been recently reported at ten linkage groups (LG1, 2, 3, 4, 7, 9, 11, 14, 17 and 18) (Chen et al., 2015), at LG2 (Houel et al., 2015), or at LG1 and LG6 (Yang et al., 2016) in different mapping progenies. These QTLs had minor effects and were not stable among growing conditions. Interestingly, Duchêne et al. (2012) showed that the variability in sugar concentration was strongly reduced after considering the differences in leaf-to-fruit ratio and dates of véraison within a progeny and argued that suitable pre-processing of the phenotypic data is necessary for detecting genetic markers that are involved in sugar metabolisms and/or transport. One option might be to couple sugar accumulation profile with eco-physiological models to dissect complex traits into more stable and environmental-independent processes, in order to facilitate genetic assisted breeding (Prudent et al., 2011).

2.2. Diversity of organic acids among cultivars and clones

Acidity is one of the main characteristics of wines, driving their sensory properties, chemical and microbiological stability as well as ageing potential. Grape acidity can be assessed by titratable acidity or pH. However, the pH better reflects the content of the grapes in organic acids, mainly malic and tartaric acids, and in cations, mainly potassium (K^+). Indeed, K^+ partly neutralizes organic acids: the higher the concentrations, the higher the pH. The genotypes used, both for scions and rootstock varieties, play a major role in the final acidity of wines, with