VITIS VINIFERA FACING CLIMATE CHANGE

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Introduction

The entire wine industry production could roughly be separated into two major parts which are grapevine cultivation and winemaking, whereas the influence of climate change is more directly related to processes in the vineyard and grape production. On the other hand, even though winemaking can be directly affected by climate change (i.e. higher energy consumption for cooling systems during harvest period) it is mostly indirectly influenced through the usage of grapes which are nowadays cultivated in hotter and drier climate in certain wine regions. Therefore, to closely understand the impact of climate change on wine industry it is required to determine links between the major berry compounds (sugars, organic acids, aromatic and phenolic compounds) and weather factors.

Phenology stages

Vitis vinifera undergoes diverse physiological and morphological changes during the vegetative and reproductive cycles. The grapevine reproductive process is separated by dormancy period, and divided into four main phenological stages: bud break, inflorescence, véraison and maturity. The length and timing of each individual stage and reproduction cycle as a whole is defined by climatic and non-climatic factors. The most abundant climate factor is air temperature (Malheiro et al., 2013) and certain temperature derived factors, such as thermal accumulation (Urhausen et al., 2011). In fact, this was concluded by many studies which reported that increase of air temperature induced earlier occurrence of grape maturity in Italy, France, Germany, Slovakia (Jones et al., 2005a) etc. While other climatic factors such as precipitation and sunshine duration are definitely not irrelevant, however, often have a lesser influence on phenological stages timing (Jones et al., 2005a; Tomasi et al., 2011; Urhausen et al., 2011). It is noteworthy that higher air temperature and thermal accumulation is not ultimately leading to advance in harvest timing (Jones et al., 2005a), indicating that plant reproductive cycles are rather complex. A practical issue arising from hastening grape maturation could be production of “unbalanced wines”. Faster pace of phenological phases could cause earlier occurrence of grape technological maturity (optimum ratio between total soluble solids content and acidity), while aroma precursors and phenolic compounds may remain undeveloped. On the other hand, if grape growers leave grapes to hang on plants and wait for development of aroma and phenolic compounds, acidity values may reach a level below optimum.

Sugars

Grapevine synthesizes carbohydrates (sugars) during the process of photosynthesis, a natural source of energy required for plant development, which rapid accumulation in grape berries is initiated at véraison. The rate of sugar accumulation in berries is greatly influenced by weather conditions, thus climate change could be relevant as well. In particular, elevated air temperature and atmospheric CO_2 concentration (up to 30°C and 800 ppm CO_2, respectively) (Greer and Weedon, 2012; Long et al., 2004) may accelerate photosynthesis and sugar accumulation. This is due to preferential synthesis path of carbohydrates comparing to the synthesis path of secondary metabolites, such as anthocyanins (Martínez-Lüscher et al., 2016). In fact, influence of air temperature on berry total soluble solids content (TSSC) was studied in the Lower Franconia (Germany), whereas during the period from 1950 to 2010 grape TSSC at harvest period increased by 2.4 °Oe/decade (Bock et al., 2011). However, it is not a "thumb rule" that warmer conditions during the relatively long period (few decades) will cause higher TSSC at harvest period. Jones and Davis (2000) reported the lack of TSSC increase in cv. Cabernet Sauvignon and cv. Merlot grapes in the Bordeaux (France), even if higher temperatures were detected during the 28-year period (1970–1997). Besides temperature, moderate water stress may also hasten sugars accumulation in grape berries as a result of inhibiting lateral shoot growth allowing transportation of carbohydrates to berries (Coombe, 1989).

Acids

The most abundant organic acids in grape berries are tartaric and malic acid (over 90% of total berry acids) (Ford, 2012) which are synthetized in early stages of berry development. Even though there are certain indications that L-tartaric acid could undergo degradation process when grapes are exposed to high day temperatures (40°C) and night temperatures (30°C) during several days (Ford, 2012), once it is synthetized L-tartaric acid is generally considered as stable and its concentration in grapes independent of weather conditions. On the other hand, content of L-malic acid changes as berry ripening advances due to respiration and degradation processes (Lakso and Kliewer, 1975). Degradation of L-malic acid is strongly regulated by temperature, whereas temperature higher than 35°C have detrimental effect on malic acid content in berries (and wine total acidity afterwards) due to inactivation of synthetic enzymes (Lakso and Kliewer, 1975). The negative impact of high temperatures on must acidity was reported in Luxembourg, whereas from 1965 to 2005 decrease of must acidity was detected for cv. Riesling (~0.1 g/L) (Urhausen et al., 2011).

Aromatic compounds and aroma precursors

Wine is considered as a product very rich in aromas and may contain up to several hundred of aromatic compounds. Part of these compounds is released from grape aroma precursors via chemical and biochemical reactions during winemaking process. The grapevine aroma precursors are mainly present in their non-volatile form while volatile form occurs rarely (Darriet et al., 2012). The synthesis and accumulation of grape aromatic precursors take place in berries and for certain compounds (e.g. 3-Isobutyl-2-methoxypyrazine; IBMP) starts with fruit set, peaks prior to véraison and degrade as ripening advance (Ryona et al., 2008). Similarly as for sugars and organic acids, weather factors and climate change have a relevant impact on final concentration of aromatic precursors in grape berries. In particular, IBMP responsible for “bell pepper” sensation and present in several red grape varieties decompose at higher amount during warm vintages (Allen and Lacey, 1993). Furthermore, concentration of rotundone which contributes to “black pepper” sensation and it is present in cv. Syrah is negatively correlated to higher temperatures in bunch zone (Zhang et al., 2015). Excessive berry temperatures are also linked with lower concentration of terpenols (i.e. linanol, nerol, geraniol etc.) in certain muscat grape varieties (Belancic et al., 1997). Furthermore, a recent study reported that lower water availability during dry years may also induce reduction of certain aromatic precursors in grapes, suggesting the significance of diverse weather factors on its final concentration (Vršič et al., 2014).

Phenolic compounds

The biosynthesis of all phenol compounds starts with production of phenylalanine amino acid, which is afterwards used by grapevines for a synthesis of phenolic compounds via phenylpropanoid, flavonoid and stilbenes pathways (Sparvoli et al., 1994). Phenolic compounds are not different from other major groups of components naturally occurring in grape, and its concentration is affected by climatic factors and climate change. In particular, water stress resulted in increase of stilbene accumulation in cv. Cabernet Sauvignon berries (Deluc et al., 2011). The concentration of anthocyanins in berries which are responsible for colour of red wines, could be lower during excessively warm vintages due to inhibition of anthocyanin synthesis and degradation of existing anthocyanins. Furthermore, concentration of skin proanthocyanidins in cv. Merlot is also strongly related to heat accumulation, whereas both excessively lower and higher temperature reduces proanthocyanidins content in grape skin (Cohen et al., 2008).

Conclusion

As aforementioned, there are clear relations between climate factors and grape quality parameters, suggesting that climate change is affecting grape cultivation, thus, also the entire wine industry. It is important to understand that climate change should not be considered as an exclusively negative phenomenon. In fact, a study reported that warming in Rhone valley (Germany), Mosel valley (Germany) and Burgundy (France) caused increase of wine ratings for certain red and white varieties (Jones et al., 2005b). Furthermore, the negative impact of climate change on wine industry could be partly mitigated by utilization of diverse adaptation strategies. For example, berry sugar and organic acids content at harvest period could be reduced and increased, respectively, performing late winter pruning (Frioni et al., 2016); excessive alcohol in wines could be removed by using non-*Saccharomyces cerevisiae* species with lower ethanol yield (Orlic et al., 2007) or nanofiltration (García-Martín et al., 2010). However, we should keep in our minds that not even the most sophisticated scientific technologies would be able to “save wines” if mankind continues to pollute the environment as it is nowadays case.

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