THE EXPECTED IMPACT OF CLIMATE CHANGE ON GRAPE FLAVOR COMPONENTS – A REVIEW–

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ABSTRACT

Today, the vast majority of the scientific community admits the reality of climate change. Climate change in the Mediterranean region is associated with increased temperature and atmospheric dioxide and drought. Viticulture is one agricultural sector that has a very close association with climate because the production of fine wine is strongly related with the concept of ‘terroir’. The general composition, aroma and phenolic compounds that make up the flavor will be affected by this change. These important factors which strongly affects sensory characteristics of grapes and wines are playing a fundamental role in consumer preferences. The shift in climate and the resulting changes to weather patterns and carbon dioxide levels may cause shifts to grape chemistry and the resulting quality of wine. This study provide some examples of effects of climate change and growing conditions on grape and consequently wine quality characterstics expressed as flavors.

INTRODUCTION

Like all other agricultural products, grapes are sensitive to climate and short term weather conditions. The vine plant grows in a wide climatic range in the world while this area is limited for some special wine grapes. The most popular wine-growing areas are located between the 35th and the 50th parallels in the Northern Hemisphere, 30th and the 45th parallels in the Southern Hemisphere [1]. Any change in climate and local weather conditions will probably affect the wine industry, which has significant economic benefits for these regions. Considering that the small changes in seasonal,temperatures may create the difference between,a poor, good or perfect wine vintage year, it can be understand how important the consequences. There are some claims in the literature that the Premium wine production regions will shift towards the poles as a consequence of global warming [2]. Many of the zones considered to be perfect for the development of some vine species will lose their attribute and the regions that are more accurate to the poles will become more popular production zones. In recent years, many popular publications stated that the owners of wineries from the Champagne,region, which has a well-established settlement, are more interested in buying land from the Northern regions, especially from the UK [3]. According to Parker, De Cortazar-Atauri [4] with climate change sequential phenological development stages of vine (budding, flowering, falling and maturity) will shift earlier times than normal. In many regions around the world, the ripening period of grapes is likely to shift out of the ideal maturation range. For this reason, not only because of climate change but also because maturation becomes in the hotter terms of the year, grapes are grown in the higher temperatures. Higher temperatures than normal will over-ripen the fruit with low acidity (especially malic acid), high in sugar and cause a fruit formation in cooked flavors [5]. Wine produced from these grapes with higher sugar content will have higher alcohol than normal and this will change the aroma and mouth feel at the end. The wines obtained from grapes with a lower acidity level than normal will be both unstable microbiologically and unbalanced as flavor. Also acidity is important for the freshness of the wine [6, 7]. These estimates have already begun to take place. van Leeuwen and Darriet [1] has reported that the potential alcohol level has increased by 2%, the total acidity has decreased by 1 g of tartrae / L and the pH has increased by 0.2 units in the past 30 years. It should be noted that these results are not only related to temperature rise, but also to increased atmospheric carbon dioxide (CO_2), increased radiation and cultural processes applied to vine. Further research is needed on the effects of these factors on grape composition. So, climate change is associated to atmospheric CO_2 increases, enhanced temperatures, an increase in incoming radiations and scarce water availability, limiting seriously crop yield and quality, especially in the Mediterranean Area. Therefore, it is urgent to investigate and understand the effects of climate change scenarios. This study focuses on the effect of temperature, vine water status, UV-B radiation and increased atmospheric CO_2 on grape flavour components to understand the upcoming changes with climate change.

Effect of temperature

As it is a well-known fact that sugar accumulation rises with temperature, but grape acidity, mainly the malic acid content, decreases in high temperature [7, 8]. Aroma is one of the most important factors determining consumer preferance, especially in wine. The main result of the rise in average temperature during grape ripening is the limitation of the characteristic aromas of grapes and wines [9]. It is known that a well known many White grape wines like Gewürztraminer, Sauvignon Blanc, Riesling develops more favorable aroma in cool climates (special varietal aroma compound groups; isoprenoids and pyrazines)[10]. Other aromatic white wines like Muscats have dominantly monoterpenes. Sun light is essential for accumulation of monoterpenes, which may release fruity, floral or spicy aromas. According to the study of Belancic, Agosin [11] at the same sugar concentrations, higher temperatures lowered the monoterpene levels in white aromatic grape varietals consequently leading to reduce aromatic intensity. Also, warm temperatures have been associated with more 1,1,6-trimethyl-1,2-dihydronaphthalene (TDN) formation, which is known with overly strong kerosene-petrol notes to Riesling, as well as other C13 norisoprenoids [12]. There can be find some contrasting results in terpinol family. For example, it is claimed that Linalol content in berries is reduced at high temperatures, but no negative effect is reported on geraniol content [1]. Massoia lactone (5,6- dihydro- 6-pentyl -2(2H)-pyranone) is the typical aroma of figs- coconuts and it may be found in wines produced from over-ripe fruits. According to Pons, Lavigne [13] in warm vintages massoia lactone amounts in Pomerol wines were higher. Another characteristic aroma compound group is Methoxypyrazines for Cabernet Sauvignon and Sauvignon Blanc cultivars with bell-pepper aromas (vegetal-herbaceous) in a certain concentration. But it is reported that high temperatures lowers Methoxypyrazine concentrations especially 2-methoxy-3-isobutylpyrazine (IBMP) amount [14]. IBMP can be found charactristicly in Carmenère, Merlot wines. It is also reported that Rotundone amount which is responsable characteristic peppery aroma in Syrah wines is decreased with temperature [15]. As an off-flavor o-Aminoacetophenone is famous aroma compound with its acacia blossom, mothball-like or varnish aroma. This off-flavor which is known as untypical or atypical ageing is being related with temperatures increase [16]. With high grape sugar levels, higher temperatures can cause cooked flavors on grapes like higher amount of furanon (sugar, caramel flavors) and lactone compounds which makes a really important flavor change [9]. From the phenolic compounds anthocyanins, are known as negatively affected with temperature rise [7, 17].

Effect of drough

It is not very clear to understand the change in rainfall patterns but most of the wine growing regions will be faced with a uncertain degree of drought [18]. Thus, more or less, all areas will experience reduced yields. If the drough is in a moderate level, quality may be affected positively [19], with reducing berry size, and enhancing skin phenolics in grapes [20]. For a certain level drough can be increase grape anthocyanin and tannin concentration. But when the drough become severe, the quality may be affected negatively, which can decrease photosynthesis, damage leaves and consequently stuck grape ripening [1]. Similar result were also reported for volatile thiole precusors. According to des Gachons, Leeuwen [21] and Schüttler, Gruber [22] volatile thiole precursors can be increased by a certain water deficit but if the stress is too high, volatile thiole precursor production is reported as reduced. In the study of Schüttler, Gruber [22] monoterpenes, were reported as not affected by vine water status. According to Koundouras, Marinos [23] under water deficit conditions the amount of C13-norisoprenoids is increased. Excessive water stress also can lead to higher the concantration of IBMP in grapes which negatively affect the acceptability of wines. As it is already mentioned above, IBMP is responsable from green pepper, vegetal-herbaceous smells [9]. According to Pons, Allamy [9] in dry vintages Sauvignon blanc grapes have increased flavane-3-ols and decreased glutathione levels in Bordeaux. Glutathione known with its anti oxidative properties and it has a positive effect on the aging potential of white wines.

Effect of Increased Radiation (UVB)

The changing rates of UV-B radiation is linked to the changes in the ozone layer of the World. In particularly UV-B radiation level (280–320 nm) rise is more or less 1–2% per decade, but it may reach 8% per decade at higher altitudes [24]. The literature is not enough for radiation effect on grapes because it is generally hard to seperate the effect of high temperatures. It is reported that vine photosynthesis increases with light intensity until one-third of maximal radiation and then levels off when water is not a limiting factor [25]. In the study of Spayd, Tarara [26] anthocyanin levels in grape skins increases with light but decreases by high temperature. According to literature rised UV-B radiation may be advantageous in red wine production because it enhances color, flavonol, and tannin synthesis in red grapes, but also can produce off-flavors in white grapes, like o-Acetoaminophenone and 1,1,6-trimethyl-1,2-dihydronaphthalene (TDN - the compound which is responsible from atypical aging) [1]. In a correlation with other C-13 norisoprenoids, ß-damascenone is reported as impaired with higher radiations [12]. In relation with grape aroma, main effects may seen in the composition of phenolic compounds, which play a significant role as photoprotective pigments in vines, and as antioxidants, color, aroma and mouthfeel relevant compounds in wines [27].

Effect of the rise in CO_2

According to Schultz [28], a rise in CO_2 with a lift in temperature and a change in relative humidity can increase biomass, increase sugar accumulation (thus alcohol potential), and decrease acidity. All these factors completely can change the grape aroma and flavor. According to Tate [2] the increase in atmospheric CO_2 level will lead faster growth, higher sugar concentrations and a thicker skin development (and consequently higher tannin concentration). Studies carried out by Bindi, Fibbi [29] and [30] with 20 year-old Sangiovese grapevines in 1996 and 1997 found that atmospheric CO_2 levels elevated from current values of 370–550 mmol/mol air increased biomass by 40–50% as total biomass and dry fruit weight. A more recent study presented by Goncalves, Falco [31] who studied Touriga Franca in field grown open top boxes with and without CO_2 fumigation couldn't find any negative effect on the quality of grapes and red wine. The rise in CO_2 did not significantly affect C6 alcohols, citronellol, carbonyl compounds, and damascenone concentrations. Obviously, more studies in closed systems which CO_2 levels changed will be needed to understand the possible effects of this variable.

Indirect effects of climate change

Some other consequences of climate change, there is a risk of submersion of some of the world's most important wine regions depending on the rising sea level (Bordeaux, Portugal, some regions of New Zealand, Australia's Swan Region and California's Carneros Apellation). Again, depending on the rising sea level in these regions, the growth of grapevines can be affected due to the increased salinity in groundwater [2]. Increased grape and wine salinity is a phenomenon also associated with several semi-arid and arid regions relying on irrigation, such as parts of Australia and Argentina. Salinity derived attributes, such as ‘‘brackish”, ‘‘seawater like”, ‘‘soapy” are considered negatively and have been correlated with high wine concentrations of Na, K and Cl [27, 32]. Climate change has favored increased incidence of forest and bushfires [33]. It is already being a problem as smoke taints in wines with the attributes dirty, burnt or ash mostly in Australia [34]. A study by Kennison, Wilkinson [35] revealed guaiacol, 4-methylguaiacol, 4-ethylguaiacol, 4-ethylphenol, eugenol, and furfural in the headspace of wine made from grapes that had been exposed to straw derived smoke. At the end, as another consequence of climate change is rising air temperature and humidity-induced vine pests and the increase in diseases caused by these harms can be added (WineTech, 2013).

CONCLUSION

In this study, it is tried to explain the effects of climate change on grape flavor components. Climate change is a major challenge for viticulture in the coming decades. Till now, wine and grape quality has increased with decreased yields in most wine growing regions because of temperature rises and moderate water deficits. If this tendency continues, quality may be suffered in the near future. To sum up, with climate change, grapes will contain more sugar and less organic acids, which results in higher pH. With this earlier ripened high sugar contained grapes, wines will have higher alcohol levels which will lead to lacking freshness and aromatic complexity, generally in wines. Both red and white important grape wines typical aroma levels will be lower and the risk of atypical aging in white wines will be higher than now. Growers need to adapt their strategies to continue the production of premium wines at economically acceptable yields in a warmer and dryer climate. Against global warming, every person must consider reducing their "carbon footprint" by reducing carbon usage. Clearly, more studies which can link more than one factors will be required to clarify the possible effects of climate change on grape flavor components.

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