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Grape (*Vitis vinifera*) compositional data spanning ten successive vintages in the context of abiotic growing parameters

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ABSTRACT

Information about changes in grape berry composition (e.g. total anthocyanins, total soluble solids and pH) in the context of the main growing parameters said to be changing with climate change (e.g. temperature, rainfall) is limited. This information is necessary in order to predict wine composition in possible future climate change scenarios as well as to help us to understand the adaptability of new varieties, new viticultural regions or winemaking practices. The aims of this study were to look at grape berry composition results of ten successive vintages in the context of temperature, rainfall and CO_2 emissions. Results of this study confirmed observations and anecdotal evidence that warm viticultural regions tend to produce grapes with lower total anthocyanins (in average 0.9 mg g^{-1}) compared with cool regions. However, some growing regions and seasons may have sub-optimal temperatures for anthocyanin production and may improve with climate change related temperature rises. Although the results presented here are from observations, we believe that these data can be utilised and incorporated to climate change modelling systems, in order to better understand and define the effect of climate change on the environmental and economical sustainability of the wine production in Australia.

1. Introduction

Several publications relate the effect of changes in temperature, rainfall and CO_2 emissions to understanding dynamics of photosynthesis, biomass production and crop yield that can be used to forecast climate changes and their impact on food production and sustainability (Porter and Semenov, 2005; Slingo et al., 2005; Erda et al., 2005; Ziska and Bunce, 2007; Challinor et al., 2009; Goncalves et al., 2009). In addition, the quality of food agriculture based products is also expected to be affected by global climate changes. For example, crop quality is thought to be multi-component, complex and affected by plant growth, assimilate partitioning and storage, pre- and post harvest events, as well as changes in nutritional, technological and environmental factors (Porter and Semenov, 2005; Slingo et al., 2005; Erda et al., 2005; Challinor et al., 2009; Goncalves et al., 2009). In this scenario crop physiologists will increasingly need to take into account the interest of growers and winemakers by studying, quantifying and modelling changes not only in yield but also in composition/quality of different varieties in response to changes in temperature, water availability, gas emissions, among others (Porter and Semenov, 2005; Slingo et al., 2005; Erda et al., 2005; Ziska and Bunce, 2007; Challinor et al., 2009; Goncalves et al., 2009).

The ability to objectively measure fruit quality is an important requirement to further enhance the Australian wine industry's reputation for the production of competitively priced, high quality wines and sustainable production (Kennedy, 2002; Francis et al., 2005). Objective quality measures will allow vineyard managers to target required quality levels and will allow rewards for quality, in terms of quality related grape payment systems (Kennedy, 2002), where large areas of new plantings coming on stream will apply a correction to the fruit supply and demand situation, placing further urgency on the requirement to determine quality levels (Francis et al., 2005). To assist in benchmarking of fruit composition, information sourced from surveys and historical data, can be an alternative in order to evaluate the potential quality of a given region or grape variety. Moreover, grape compositional data need to be considered in the context of climate change (e.g. temperature, rainfall and water availability, green house emissions, among others), in order to maintain sustainable viticultural production and need to be available for modelling the impact of future scenarios of climate change influencing grape and wine composition.

As it occurs with many other horticultural and agricultural products, the chemical composition of grapes depends on many factors, such as variety, climate (e.g. temperature, rainfall), degree of maturity, soil characteristics, water availability and vineyard

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management. The capacity of red grapes to produce wine depends on the chemical composition of precursors such as sugars, acids, and pigments, present in the grape (Iland and Gago, 2002; Glasdstones, 1992, 2004). It is well known that environmental factors such as temperature and water availability, can have a significant effect on nutrient concentration in several crops, including grapes, therefore there is a need to develop a database on grape composition that is both current and widely applicable.

The measurement of total soluble solids (TSS, °Brix) is a well-established parameter for basic grape quality assessment (Iland et al., 2000). Depending on variety, growing region and the style of wine to be made, fruit is required within certain maturity ranges. However, although fruit must achieve target ripeness to maximise quality, sugar maturity alone does not guarantee quality. This concept is supported by the empirical observation that for a given region and variety, fruit harvested early in the season tends to produce better quality wines that fruit achieving the same °Brix later in the season, therefore a second order of quality measurement is required (Kennedy, 2002; Francis et al., 2005). Two other important grape quality measures are total anthocyanins (colour) and pH (Francis et al., 2005; Kennedy, 2002). Good colour extraction is a quality that winemakers seek when making red wines and there is an objective evidence that wine quality does indeed positively correlate with colour (Herderich and Smith, 2005).

Historical data on end-use (i.e. the type of wine the fruit ultimately produces) is a useful way of targeting particular patches of fruit. However, with an end-use grading system, it is difficult to objectively assess fruit at the point of delivery. Determining end-use category after vinification requires fruit to be processed as separate parcels and is, to a degree, dependent on the wine making process. Observations that can be made in the vineyard (e.g. crop load, fruit exposure, berry size, leaf area/fruit ratio, and cane development) may be useful for the segregation of vineyards but are no guarantee of ultimate quality and are difficult to apply at a point of delivery.

Information about changes in total anthocyanins, total soluble solids and pH and their relationship with the main indicators of climate change is limited. This information is necessary in order to predict wine composition in possible future climate change scenario as well as to help to understand adaptability of new varieties, new viticultural regions and winemaking practices in a sustainable wine production.

The aims of this study were to describe the results of ten successive vintages, in multiple Australian regions and assess the compositional variation in the context of abiotic parameters such as temperature, rainfall and CO_2 emissions.

2. Materials and methods

2.1. Samples and sample preparation

Samples of red grapes (*Vitis vinifera* L.) were sourced from commercially grown grape cultivars of Cabernet Sauvignon ($n = 1197$), Shiraz ($n = 1341$), Grenache ($n = 73$) and Merlot ($n = 413$) during ten consecutives vintages (1999–2008) and fourteen Australian growing regions (from South Australia, Victoria, New South Wales and Western Australia), spanning a diversity of climates and soil types (Table 1). The wine regions in this study are defined according to those established by the Australian Wine and Brandy Corporation (2008) (http://www.wineaustralia.com/australia).

Samples were collected at harvest maturity (between 18 and 25.2 °Brix) (Iland et al., 2000) as whole berries and stored frozen (−18 °C) for up to six months before analysis. Frozen samples were always thawed overnight at 4 °C prior to homogenization. Samples were homogenised cold (<10 °C) and analysed on the day of homogenization following procedures reported elsewhere (Cynkar et al., 2004).

2.2. Chemical analysis

The determination of total anthocyanins (colour, mg g^{-1}) concentration, total soluble solids (TSS, °Brix) and pH were performed in duplicate according to the method described elsewhere (Iland et al., 2000; Cynkar et al., 2004).

2.3. Statistical analysis

Mean, standard deviation (SD) and range were calculated using JMP software (version 5.0; SAS Institute Inc., USA). Average growing season temperature (°C) and rainfall (mm) series for the decade were sourced from the Australian Bureau of Meteorology, Annual Australian Climate statements consulted in July 2009 (http://www.bom.gov.au/). The average growing season temperatures method used in this study is similar to those used and described by Jones et al. (2005) and Hall and Jones (2009). Mean January temperatures (MJT) were used to define cool, warm or hot regions as proposed by Dry and Smart (1992). These authors define regions with MJT from 23 to 24.9 °C such as Sunraysia, Riverland and Swan Valley; with MJT from 21 to 22.9 °C such as Adelaide Plains, Barossa, Clare and Hunter Valley; with MJT from 19 to 20.9 °C such as Langhorne Creek, Coonawarra and Padthaway.

Total CO_2 emissions data (mean value and increment) were obtained from the National Greenhouse Gas Inventory

Table 1
Distribution of samples per region, indicating coordinates and mean January temperature.

	Viticultural regions	Coordinates	Mean January temperature (°C)	Viticultural areas	N
South Australia	Adelaide Hills	34°50′S	19.1	Cool	109
	Barossa Valley	34°29′S	21.4	Warm	508
	Coonawarra	37°18′S	19.6	Cool	365
	Langhorne Creek	35°15′S	19.9	Cool	191
	McLaren Vale	34°14′S	21.7	Warm	314
	Padthaway	36°37′S	20.4	Cool	408
	Riverland	34°10′S, 140°45′E	24.6	Hot	463
New South Wales	Hunter Valley	32°50′S	22.7	Hot	23
Victoria	King Valley	36°20′S	20.8–22	Warm	55
	Sunraysia		23–24.9	Hot	68
	Wrattonbully				91
Western Australia	Margaret River	33°57′S	20.4	Cool	30
	Frankland				60
Other regions	n/a	n/a	n/a	n/a	342

N = number of samples, n/a: not applicable, different regions were included. MJT and viticultural areas as defined by Dry and Smart (1992).