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Relationships between harvest time and wine composition in *Vitis vinifera* L. cv. Cabernet Sauvignon 2. Wine sensory properties and consumer preference

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A B S T R A C T

A series of five *Vitis vinifera* L. cv Cabernet Sauvignon wines were produced from sequentially-harvested grape parcels, with alcohol concentrations between 12% v/v and 15.5% v/v. A multidisciplinary approach, combining sensory analysis, consumer testing and detailed chemical analysis was used to better define the relationship between grape maturity, wine composition and sensory quality. The sensory attribute ratings for *dark fruit*, *hotness* and *viscosity* increased in wines produced from riper grapes, while the ratings for the attributes *red fruit* and *fresh green* decreased. Consumer testing of the wines revealed that the lowest-alcohol wines (12% v/v) were the least preferred and wines with ethanol concentration between 13% v/v and 15.5% v/v were equally liked by consumers. Partial least squares regression identified that many sensory attributes were strongly associated with the compositional data, providing evidence of wine chemical components which are important to wine sensory properties and consumer preferences, and which change as the grapes used for winemaking ripen.

1. Introduction

Vitis vinifera L. cv Cabernet Sauvignon wines have been described as presenting a ‘dichotomy of sensory attributes’ and are notably distinguished by the presence of both *vegetative* and *fruity* characteristics (Heymann & Noble, 1987; Preston et al., 2008). Generally it is accepted that the *vegetative* (or *green*) attributes can be dominant in Cabernet Sauvignon wines made from earlier-harvested grapes, while *fruity* attributes are often more intense in wines made from later-picked fruit, but published evidence for this is limited. There are surprisingly few sensory studies which have investigated harvest timing, and where the above-mentioned trend in wine sensory characteristics has been reported, it is not necessarily consistent across multiple seasons (Heymann et al., 2013). It is therefore of interest to determine whether a ripening-specific sensory profile for Cabernet Sauvignon can be described, and whether these wine sensory attributes are defined by changes in wine composition as the grapes ripen.

Vegetative flavours in certain red wines are thought to arise primarily from the potent grape-derived aroma compound isobutyl methoxypyrazine (IBMP) (Bindon, Varela, Kennedy, Holt, & Herderich, 2013a; de Boubee, Cumsille, Pons, & Dubourdieu, 2002; Ryona, Pan, & Sacks, 2009; Sala, Busto, Guasch, & Zamora, 2005). *Vegetative* or *green* flavour attributes can also be derived from C_6 volatiles such as hexanal, hexanol, (E)-2-hexenal and (Z)-3-hexen-1-ol (Escudero, Campo, Fariña, Cacho, & Ferreira, 2007; Kalua & Boss, 2009, 2010). These C_6 compounds can be present in the grape berry (Kalua & Boss, 2009, 2010), but primarily derive *de novo* from the degradation of polyunsaturated fatty acids via the lipoxygenase pathway when cell membranes are disrupted during crushing (Herraiz, Herraiz, Reglero, Martinalvarez, & Cabezudo, 1990; Joslin & Ough, 1978; Roufet, Bayonove, & Cordonnier, 1986). It has also been found that the compound dimethyl sulfide can give a *cooked vegetable* note to some red wines (San-Juan, Ferreira, Cacho, & Escudero, 2011). The contribution of C_6-derived compounds to *green*

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attributes in wines is poorly understood, and is further complicated, since the corresponding esters of C_6 alcohols are thought to contribute *fruity* notes (Forde, Cox, Williams, & Boss, 2011).

The concentration of IBMP is known to decline during grape ripening (de Boubee, Van Leeuwen, & Dubourdieu, 2000; Scheiner, Vanden Heuvel, Pan, & Sacks, 2012). However, a close correlation between IBMP concentration and *vegetative* or *green* characters is not always observed (Preston et al., 2008; Scheiner et al., 2012) and is likely due to interactions within the wine volatile matrix, so that other volatiles mask the effect on flavour and aroma. As already highlighted, it is also possible that the attribute is caused by the interaction of IBMP and C_6 aldehydes and alcohols (Escudero et al., 2007).

The suppression of vegetative characters by compounds giving *fruity* attributes has been reported (Hein, Ebeler, & Heymann, 2009; King, Osidacz, Curtin, Bastian, & Francis, 2011). The contribution of esters to fruity aroma attributes has been well demonstrated, and particularly, *red berry*, *raspberry-like* aroma has been indicated as being related to proportionally higher concentrations of the compounds ethyl butanoate, ethyl hexanoate, ethyl octanoate, and ethyl 3-hydroxybutanoate, while *black berry* characters may be conferred by ethyl propanoate, ethyl 2-methylpropanoate, and ethyl 2-methylbutanoate (Escudero et al., 2007; Pineau, Barbe, Van Leeuwen, & Dubourdieu, 2009). The enhancement of *fruity* attributes is also reported to be caused by synergistic interaction of esters with low concentrations of C_{13}-norisoprenoids and dimethyl sulfide (Escudero et al., 2007). A ripening-related decrease in both IBMP and C_6 volatiles was recently reported in a series of *Vitis vinifera* L. cv. Cabernet Sauvignon wines, with concomitant increases in volatile esters (Bindon, Varela, Kennedy, Holt, & Herderich, 2013b; Bindon et al., 2013a). To further explore the effects of harvest date and wine alcohol concentration, it was of interest to compare these observed trends in wine composition with the resulting sensory perception of the wines.

Further to changes in volatile compounds, grape ripening certainly confers changes to non-volatile wine composition, affecting major components such as sugars and acid concentration, as well as secondary metabolites such as anthocyanins and tannins. In our previous report (Bindon et al., 2013a) wine made from later-harvested grapes was characterised by higher concentrations of glycerol and yeast-derived mannoprotein, but had lower grape-derived polysaccharides. These changes might be expected to contribute to wine in-mouth sensory properties, with polysaccharide concentration having been shown to exert effects on the perception of *astringency* and *bitterness* (Vidal et al., 2004a). Furthermore, Cabernet Sauvignon wine made from later-harvested grapes (Bindon et al., 2013a) was shown to be characterised by higher skin tannin concentrations, notably with a reduction in the relative contribution of grape seed tannin, resulting in a higher proportion of grape skin-derived tannin and mean degree of polymerisation (mDP). In addition, anthocyanin concentration in wine was enhanced by ripeness, and as such, wine colour density and polymeric (tannin-bound) colour increased. Similar observations in terms of phenolic composition have recently been reported for sequentially-harvested Cabernet Franc wines, with later-harvested wines having a higher tannin concentration and proportion of epigallocatechin, but not a higher mDP (Cadot, Caille, Samson, Barbeau, & Cheynier, 2012). For the sensory attributes determined by descriptive analysis in the Cabernet Franc study, later harvest date was associated most strongly with higher perceived *colour intensity*, *bitterness* and *astringency*.

The question as to whether a target 'optimal grape ripeness' for a given grape variety can be defined is important in commercial winemaking practice. This is because decisions around the timing of harvest are aimed at maximising positive attributes in the wine, minimising negative attributes, and optimising resources during the season. For Cabernet Sauvignon, *green* characters in wine aroma or flavour are generally considered negatively by wine producers. The commonly-held belief that delaying harvest date can reduce *green* grape-derived component IBMP is one of the factors which contribute to a trend toward higher alcohol content in Cabernet Sauvignon, through an increase in total soluble solids in the grapes. In addition, market demands for strongly fruit-flavoured, intensely coloured wines, with desirable textural attributes, has also resulted in extended ripening periods for grapes. The evidence that delaying harvest can significantly affect these attributes is limited, and for the most part anecdotal. In fact, for warm wine-growing regions, which generally have lower grape colour, and a shorter ripening phase, this practice may result only in higher alcohol concentration without a significant increase in desirable compounds (Cozzolino, Cynkar, Dambergs, Gishen, & Smith, 2010). The added pressure of compressed growing seasons, warming climatic conditions, and water deficits associated with climate change may compound the current world-wide industry trends toward wines with higher alcohol content (Webb et al., 2012). A pertinent question, therefore, is whether the sensory attributes of wine made from grapes of different ripeness levels support the practice of delayed harvest. Perhaps even more important, is whether consumers in fact prefer the sensory attributes associated with late-harvest, higher alcohol wines.

In order to address these questions, the aim of the current study was to determine the effect of harvest stage on the sensory attributes of wine, and how the sensory attributes relate to detailed wine compositional data, previously reported (Bindon et al., 2013a, 2013b), and liking scores of consumers. The ultimate objective was to better define optimal grape ripeness in Cabernet Sauvignon.

2. Materials and methods

2.1. Wine production and analysis

Experimental conditions outlining the production of triplicate *Vitis vinifera* L. cv. Cabernet Sauvignon wines have been reported previously (Bindon et al., 2013a). Briefly, grape samples were obtained from a commercial vineyard in the Langhorne Creek region of South Australia, Australia at five different stages of ripeness (H1–H5), in 2010. Harvest dates were on the 16th (H1) and 23rd February (H2), and on the 2nd (H3), 10th (H4) and 17th (H5) March. Grape batches of triplicate 50 kg were crushed and destemmed with the addition of 50 mg/L SO_2. The pH of the musts were adjusted to a target of 3.2 using tartaric acid. Total assimilable nitrogen was adjusted to 250 mg/L with diammonium phosphate (DAP). Yeast (*Saccharomyces cerevisiae* PDM, Maurivin, Sydney, Australia) was inoculated at 200 mg/kg, and fermentation was carried out on the skins for 7 days in a temperature-controlled room at 15 °C, and plunged 20 times, twice daily. Thereafter, the ferments were drained and pressed and fermentation was completed to <1 g/L glucose and fructose. Following racking off gross lees, 60 mg/L SO_2 was added, the wines were acid-adjusted to pH 3.5 with tartaric acid, cold-stabilised, and thereafter racked off fining lees. The final SO_2 level was adjusted to a total of 80 mg/L, since no malolactic fermentation was performed. Wines were filtered through a 0.8 μm membrane, bottled under screw-cap and stored at 12–15 °C until chemical and sensory analysis, approximately 10 months after bottling. Analysis of wine composition was performed as reported previously (Bindon et al., 2013a).

2.2. Sensory descriptive analysis

The sensory analysis was conducted in February–March 2011. A panel of twelve assessors (four male, eight female) was convened