EFFECT OF GRAPE BERRY QUALITY ON WINE QUALITY

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Abstract

Wine quality is very important in the wine business. The quality of the grape berries is one of the factors in controlling wine quality. The aim of this study was to find the effect of the grape berry quality in relation to the quality of the produced wine. An experiment was carried out in a humid subtropical climate site in the southwest of China (Xichang district, Sichuan province). A 15-year-old vine variety, Cabernet Sauvignon, was planted from root cuttings in 1998 with spacing of 1.25 × 2.00 m in a north-south direction. Five different total soluble solid levels of grape berries (14°Brix, 16°Brix, 18°Brix, 20°Brix, and 22°Brix) were picked and their wines were made in 2013. It was found that the wine made from the 22°Brix grapes had the best quality but the chaptalization process also helped the 18°Brix and 20°Brix grapes to have the same quality in terms of alcohol content, volatile acidity, reducing sugar, and wine color but not in terms of total acidity and pH.

Keywords: Chaptalization, fermentation, must, *Vitis vinifera*

Introduction

Grape berry maturity can be a critical factor in determining wine quality. The importance of picking the fruit at the optimum maturity has led to rational vineyard sampling and improved harvesting of wine grapes. It has always been recognized that wine quality is related to the quality of the fruit. All works stress the picking of mold-free or insect-free grapes for wine. Controlled experiments have shown that most molds, beyond a small percentage of fruit infections, can cause off-tastes and aromas. Acetic acid provides one means of detecting mold in grapes, by indicating the activity of yeast and bacteria on the broken grapes (Ough, 1980). Grapes need full sunlight and high temperatures to ripen, so vines should be planted on southern slopes, on the south side of windbreaks, or on the south sides of buildings. Northern slopes and low ground should be avoided since these will be cooler throughout the growing season and delay the ripening of the fruit. It is important to choose deep, well-drained soils to avoid standing water in the spring and to encourage early growth (Hoover and Hemstad, 2000). Plants are able to use sunlight to make sugar from carbon dioxide and water through the process of photosynthesis (Vine *et al*., 1999). Berry ripening is, therefore, tightly coordinated with seed development.

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During veraison, water, sugars, and nitrogen compounds are transported to the berry via the phloem. Sucrose is hydrolyzed to glucose and fructose in the berry (Lang and During, 1991). The berry flavor and aroma compounds are synthesized within the berry. The sugar content increases during ripening and is, therefore, a function of the berry age. Simple sugars such as sucrose, fructose, and glucose are measured in terms of the percentage of total soluble solids (TSS) which is also relatively easy to assess; this adds to the value of TSS as an index of ripeness. However, the sugar:acidity ratio is quite variable across different varieties and growing conditions, especially in a humid subtropical climate, and these kinds of universal rules of thumb may be of little general predictive value for wine quality, especially if indiscriminately applied (Boulton *et al*., 1996).

Total acidity (TA) and pH are of great importance for grape juice and wine stability, and both parameters are commonly used as indicators of quality (De La Hera-Orts *et al*., 2005). Tartaric acid and malic acid, which represent 90% of the acids in wine grapes, are secondary products related to sugar metabolism and are synthesized primarily in the grapes and also in leaves. The tartaric acid and malic acid ranges vary with maturity, variety, site, climate, and vintage. During ripening, the TA decreases and the pH increases. Wine grapes from warmer sites or warmer seasons have lower TA and higher pH than wine grapes from cooler sites or cooler seasons. Wines with a low to moderate pH also tend to have crisper, fruitier flavors and tend to age better than wines with a higher pH level (Watson, 2003).

Therefore, the objective of this study was to investigate the ripeness of the grape berries in relation to making a different wine style and quality in a humid sub-tropical climate area.

Materials and Methods

Materials

Microorganisms

The Enoferm BDX (*Saccharomyces cerevisiae*) yeast strain was collected for use in this study. The BDX strain was obtained from Lallemand Inc., Montreal, Canada (LALVIN®). The Viniflora® oenos malolactic bacteria strain (*Oenococcus oeni*) was obtained from Chr. Hansen Holding A/S, Hørsholm, Denmark.

Grape Berries

The berries were obtained from vines which were planted in Moon Valley Vineyard in a humid subtropical climate located in the Southwest of the People's Republic of China (Xichang district, Sichuan province at 27 ºN, 102 ºE and 1650 meters elevation above mean sea level). The berries were harvested in August, 2013 with different sugar contents (14°Brix, 16°Brix, 18°Brix, 20°Brix, and 22°Brix).

Methods

Must Preparation

To produce the must, 5 kg of berries were destemmed and crushed with a small destemmer and crusher. The must was transferred to PET 5-L vessels and treated with 45 mg/L of sulfur dioxide. Several total soluble solid (°Brix) berries were measured and adjusted up to 22°Brix (Ough and Amarine, 1998).

Starter Preparation

The active dry yeast was rehydrated at an amount of 200 mg/L in warm water (37ºC) for 30 min, according to the manufacturer's specifications, and then it was inoculated into the must.

Alcoholic Fermentation

After inoculation, as mentioned above, the must was fermented under a controlled temperature at 25ºC and stirred twice a day. Fermentation was finished in about 7-9 days or until the sugar was reduced to 0ºBrix.

Malolactic Fermentation

Malolactic fermentation with *Oenococcus oeni* (Viniflora® oenos) in dried powder form was employed after the alcoholic fermentation had finished. The reducing sugar remained at lower than 4 g/L. The inoculation at the initial step was 2 ppm. The malolactic fermentation progress was checked by paper chromatography to determine the malic acid and lactic acid (Iland *et al*., 2000).

Chemical Analysis

Determination of the total soluble solid in the must and wine

The TSS was measured using a hand refractometer (Ough and Amarine, 1998).

Determination of the pH in the must and wine

The pH was determinated on a portion of clarified grape juice or clear wine with a pH meter. The temperatures of the must and wine were the same as those of the standard buffers used in the calibration step (Iland *et al*., 2000).

Determination of the total acidity in the must and wine

The total acidity was analyzed by the titration technique with 0.1 M NaOH and phenolphthalein was used as the indicator, and a pH meter was used to observe the end point at pH 8.2 (Ough and Amarine, 1998).

Determination of the volatile acidity in the must and wine

The volatile acidity (VA) analysis was carried out on a degassed (by a vacuum system) sample of the wine. The distillation method and titration technique were used for analysis of the acetic acid (Iland *et al*., 2000).

Determination of the alcohol in the wine

The alcohol was recovered by distillation. The specific gravity of the distillate was determined with a hydrometer. The hydrometer was calibrated with the appropriate correction. The correct reading of the alcohol's strength was expressed as % (v/v) at 20°C (Iland *et al*., 2000).

Determination of the reducing sugar in the wine

Determination of the reducing sugar followed the method of Lane and Eynon (Iland *et al*., 2000).

Determination of the free sulfur dioxide and total sulfur dioxide

Determination of the free sulfur dioxide and total sulfur dioxide was done by the aspiration method (Iland *et al*., 2000).

Determination of the total red pigment and phenolic compound

The Total red pigment and phenolic compound were measured with a spectrophotometer at 420 nm and 520 nm (Iland *et al*., 2000).

Wine color density = $A_{520} + A_{420}$

Wine color hue = A_{420}/A_{520}

Total red pigments (absorbance units) = $A^{HCl}{}_{520}$

Total phenolics (absorbance units) = $A^{HCl}{}_{280} - 4$

Sensory Evaluation

The wines were subjected to sensory evaluation by 10 experienced panellists at 25°C. The wines were compared using paired comparison scoring testing to determine whether there were 3 repetitions of each treatment in a random order (Wanapu *et al*., 2012). The ranking method was used in order to determine the quality difference between the tested wines. The panellists were trained to evaluate the individual characteristics of the wines and to define the characteristic aroma descriptors used in sensory analysis. Each sample of wine was judged for intensity of appearance, aroma, taste, aftertaste, and overall impression using the Modified Davis 20-point cardinal scale based on the original data quality checks developed at Purdue University (Vine *et al*., 1999). Questionnaires and water for mouth rinsing between each tasting were provided. The panellists were asked to read through the questionnaires, and the meaning of each attribute was explained to the panellists to avoid any misinterpretation.

Data Analysis and Hypothesis Testing

Significant differences among the wines and their variability were assessed by analysis of variance (ANOVA) and the least significant difference (LSD). The statistical package IBM® SPSS® Statistics for Mac release 20.0.0 from IBM Corp was used. Duncan's Multiple Range Test (DMRT) was used to separate the means ($p \leq 0.05$) when the ANOVA test results were significant.

Result and Discussion

Size and Weight of the Grape Berries

The results of the grape berry size and

berry weight are shown in Table 1. The berry sizes and weights increased from veraison to maturity. The availability of water led to greater increases in the berry weight. The berry sizes and weights were significantly different among the treatments. Kok *et al.* (2013) found that the berry size was broadly accepted as a factor determining wine grape quality. In wine grape growing, there is demand for not only small berries and clusters but also abundant grape must. The increase was very fast during the first days of Stage III (defined as the period of time from veraison to maturity). It has been widely recognized that berry size is an important factor determining wine grape quality, and berries do not grow by 'pumping' water into a vessel (the berry) of flavor solutes (Matthews and Nuzzo, 2007).

Total Acidity and pH of the Grape Berries

The TA and pH values are shown in Figure 1. At the time of harvest, the TA levels were very similar for all the grapes. As the TA decreased during ripening, the pH values increased. A small change in the pH reflects large changes in the TA. This finding agrees with Esteban *et al.* (2002) who observed that the pH increased linearly with berry ripening while the TA decreased exponentially. At the beginning, when the TA was high, a decrease in the TA did not bring about a substantial change in the pH; as ripening advanced, the variation in the pH became larger. However, the pH values found in the must at maturity were high. The decrease in the TA during ripening is normally attributed to falling concentrations of malic acid because tartaric acid is considered to be unaffected (Calo *et al.*, 1997).

Color Analysis of the Grape Berries

The color of the berry is very important for wine quality. Table 2 shows the evolution of anthocyanins and phenolics during ripening.

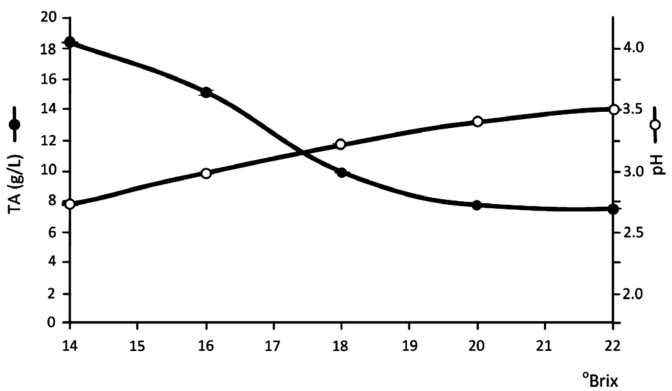

Figure 1. Total acidity and pH analyses of various grape berries' qualities: 14°Brix, 16°Brix, 18°Brix, 20°Brix, and 22°Brix

Table 1. Physical analysis of various grape berries quality

TSS (°Brix)	Size (mm)	Weight per berry (g)	Fifty berry weight (g)
14	11.73[a]	1.18[a]	60.49[a]
16	12.00[b]	1.25[b]	60.77[ab]
18	12.33[c]	1.30[c]	61.23[b]
20	12.43[c]	1.32[c]	61.40[bc]
22	12.57[c]	1.33[c]	61.63[c]

In a column each treatment means followed by a common letter are not significantly different at the 5% level by DMRT

A higher concentration of anthocyanins was found in the riper grape berries (22°Brix) that had color/berry at 0.880 mg of anthocyanins/ berry and total phenolics/berry at 0.660 a.u., while the less ripe grape berries (14°Brix) were obviously lower in color/berry and total phenolics. Coombe *et al*. (1987) reported that the sugars in ripe berries were present at high concentrations in the flesh, and are not localized in the skin. Gonzáles-San *et al*. (1991) found that the anthocyanins accumulate in the grape berry beginning with veraison, and correlate with sugar accumulation. Anthocyanin concentrations reach a maximum at full maturity, but are broken down if the grapes become overripe (Ribéreau-Gayon *et al*., 1998).

Chemistry Analysis of the Wines

The total acidity of the wines was significantly different (Table 3). Young berries with 14°Brix had a higher TA and lower pH. The sugar content in the berries at harvest influenced the must TSS values, and this in turn is directly related to the alcohol content of the wine, principally in the form of ethanol. It was found from this research that alcohol contents were not significantly different because, before fermenting, all treatments were chaptalized up to 22°Brix. Peynaud (1984) found that sugar additions of up to +2% (2 g per 100 mL or 20 g/L) are normally allowed, and up to 4% may be used in very difficult vintages. To raise the alcohol level by 1% by volume, about 17 g/L of sugar needs to be added to white juice and about 20 g/L to red must. Greater additions are necessary for red wine to compensate for the evaporation of alcohol during warmer red fermentations. The VA was comprised of acids formed by spoilage bacteria (Vine *et al*., 1999). The VA found in the wines included mainly acetic acid and, to a lesser extent, other acids such as butyric, formic, and propionic. The concentrate of acetic acid formed during fermentation is

Table 2. Color and phenolic content analysis of various grape berries quality; color / berry (mg of anthocyanins / berry), color/berry weight (mg anthocyanins / g berry), total phenolics / berry (absorbance units / berry) and total phenolics / berry weight (absorbance units per g berry)

TSS (°Brix)	Color / berry	Color / berry weight	Total phenolics / berry	Total phenolics / berry weight
14	0.813[a]	0.667[a]	0.480[a]	0.390[a]
16	0.833[ab]	0.690[ab]	0.513[b]	0.423[b]
18	0.857[b]	0.707[b]	0.577[c]	0.477[c]
20	0.873[bc]	0.713[b]	0.633[d]	0.520[d]
22	0.880[c]	0.713[b]	0.660[e]	0.533[d]

In a column each treatment means followed by a common letter are not significantly different at the 5% level by DMRT

Table 3. Chemistry analysis of wine from various TSS concentrations; total acidity (TA as g/L tartaric acid), pH, alcohol content, volatile acidity (VA as g/L acetic acid), and reducing sugar

TSS (°Brix)	TA (g/L)	pH	Alcohol content (%v/v)	VA (g/L)	Reducing sugar (g/L)
14	11.30[e]	3.13[a]	12.47[a]	0.55[c]	2.78[c]
16	10.43[d]	3.20[b]	12.47[a]	0.43[b]	2.63[b]
18	9.13[c]	3.35[c]	12.50[a]	0.33[a]	2.48[a]
20	7.47[b]	3.45[d]	12.50[a]	0.31[a]	2.40[a]
22	6.63[a]	3.51[e]	12.53[a]	0.31[a]	2.39[a]

In a column each treatment means followed by a common letter are not significantly different at the 5% level by DMRT

usually less than 0.5 g/L (Iland *et al*., 2000). The VA had significant differences and the 14°Brix had higher VA than other treatments. Reducing sugar is a fermentable sugar and decreases with the increasing period of fermentation. Reducing sugar is the most important sugar for fermentation as it is easy to metabolize by yeast (Singh *et al*., 2013). The value for the concentrate of reducing sugars at the end of fermentation is about 2 g/L or less (Iland *et al*., 2000). Reducing sugar was significantly different when the grape berries were at 14°Brix and there was higher reducing sugar after fermentation.

Color Analysis of the Wines

It was shown in Table 4 that the higher concentration of sugar in the grape berries gave a higher color in the wine. This study showed that the grape berries at 14°Brix gave a lower value in the total red pigment, total phenolics, wine color density, and wine color hue than any of the other treatments. The total red pigment of the grape berries at 18°Brix was not significantly different from the grape berries at 22°Brix. The berries were ripe at maturity and gave wines which were higher in total red pigment and total phenolic. A higher concentration of sugar in the grape berries produced a higher level in the wine color density and wine color hue. Oberholster *et al*. (2010) found that the wine color or color density (A420 nm + A520 nm) correlated with the anthocyanin concentration (mg/g berry). This finding indicated that differences in grape composition and color were visible in the subsequent wines. There was a strong relationship between the Brix value and the general quality of the grape extracts which subsequently affected the character of the wines. The anthocyanin concentration (mg/g berry) and wine hue were also correlated.

Sensory Analysis

Chen *et al*. (2013) found that sensory evaluation by tasters was commonly used in evaluating the grape wine sensory quality. During the evaluation, tasters grade several indexes of the grape wines after tasting them. Based on the summation of the indexes, the quality of grape wines was finally evaluated. The results of the 20-point cardinal scale of paired comparison scoring test was converted to percentages which showed differences in all parameters between the young grape berries (14°Brix and 16°Brix) and higher ripeness grape berries (18°Brix, 20°Brix, and 22°Brix) in taste, color, and aftertaste among the treatment wines (Figure 2). However, the wines made from 18°Brix, 20°Brix, and 22°Brix berries were not significantly different in appearance, aroma, taste, aftertaste, and overall character. The experienced wine tasters were more influenced by color (Pangborn *et al*., 1963). Oberholster *et al*. (2010) found that wines made during the highest grape color peak were not significantly different from the wines on either side of the maturity period. This indicated that grapes could have been harvested earlier at lower sugar concentrations. However, this does not mean that other sensory criteria did not

Table 4. Color and phenolic content analysis of wine from various TSS concentrations; total red pigment (a.u.), total phenolics (a.u.), wine density, and color hue

Treatment	Total red pigment (a.u.)	Total phenolics (a.u.)	Wine color density	Wine color hue
14 °Brix	6.070[a]	18.830[a]	2.760[a]	0.660[a]
16 °Brix	8.200[b]	19.700[b]	3.833[b]	0.727[a]
18 °Brix	9.033[c]	21.467[c]	4.250[c]	0.903[b]
20 °Brix	9.133[c]	21.633[c]	4.460[c]	0.927[b]
22 °Brix	9.233c[c]	28.200[d]	5.283[d]	0.933[b]

In a column each treatment means followed by a common letter are not significantly different at the 5% level by DMRT

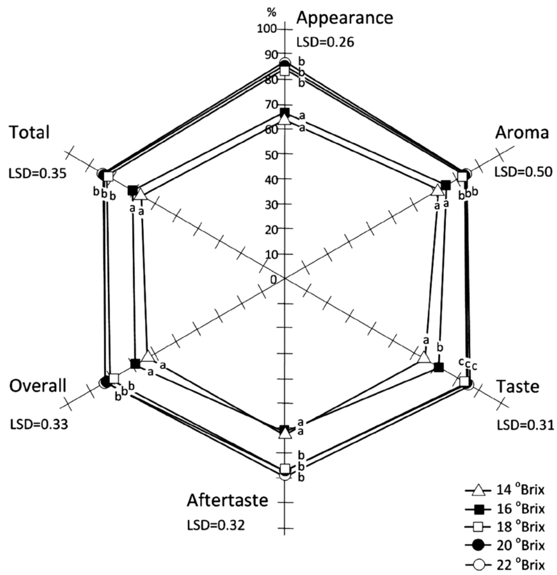

Figure 2. Sensory scores of wines from various grape berries' qualities. The LSD value is the mean least significant difference among wines. The percentage of mean in each sensory parameter followed by the same letters is not significantly different (P>0.05)

change significantly.

Conclusions

Quality might be defined as those attributes of the grape that make it attractive or pleasant to drink as wine. The absolute concentrations of sugar and acids, as well as their ratio, play an important role in the flavor of wine. Phenolics determine color qualtity in nearly all wines and they are a major factor in the flavor in red wines. Aroma compounds that are important in wine flavor arise from both the fruit and as a product of fermentation. The higher ripe maturity of grape berries that had TSS of 22°Brix gave wine with a high density in color, low TA, low VA, and low reducing sugar. The less ripe berries containing TSS of 14°Brix gave results with high TA, VA, and reducing sugar that made wine of lower quality. However, the berries that had TSS more than 18°Brix gave an acceptable wine quality but the chaptalization method must be used to increase the TSS to a desirable sugar level of the must. Finally, the quality of the grape berries directly affected the wine quality and this could be used as the index to predict the quality of wine. A range of parameters could effectively differentiate between the grapes and the wine on the basis of ripeness. The parameters that could improve wine quality in a humid subtropical climate over seasonal and climatic variance will be investigated further.

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