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Quality of *Cabernet Sauvignon* Wines Determined by the Variability of Climatic Attributes

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Abstract

Essential to understand the dynamics responsible for the quality of red wines, the objective of revealing the physico-chemical and climatologic relationships that determine the quality of *Cabernet Sauvignon* wines. The experiment was carried out in the municipality of Dom Pedrito, Rio Grande do Sul, Brazil, in the agricultural crop of 2016. The experiment was conducted in a randomized block design where the treatments corresponded to nine microvinifications arranged in three replicates. The concentration of total polyphenols in *Cabernet Sauvignon* red wines is associated with anthocyanins, indices of absorbances of 420 and 520, as well as total acidity. However, the tannins are directly proportional to the total acidity of the wine. Environmental conditions with high rainfall, minimum oscillations in thermal amplitude and incident solar radiation tend to increase the hydrogenionic potential and the absorbance indices of 420 (yellow) and 620 (bluish) red wines of *Cabernet Sauvignon*. The thermal amplitude was preponderant to elevate levels of anthocyanins in *Cabernet Sauvignon* wines.

Keywords: enology, grape production, physicochemical traits

1. Introduction

The climatic aspects can determine the physical and chemical parameters of the wine, being these essential for the sensorial quality and shelf life in front of the consumer market (Zocche et al., 2017). In this context, *Cabernet Sauvignon* wines presented differences among the physical and chemical parameters due to the peculiar characteristics of the producing regions and climatic conditions (Zocche et al., 2016a). Thus, total acidity, anthocyanins, pH, tannins and total polyphenols are determinant for sensory quality, maturation and aging of red wines (Flanzy, 2003; Zamora, 2003). The region of the Campanha Gaúcha is located in the south of the state of Rio Grande do Sul, Brazil, and stands out nationally due to its production of fine wines. Sinimbu (2015) reports that this region is responsible for a production of 31% of the total fine wines produced in Brazil. Among the cultivated varieties, *Cabernet Sauvignon* is a highlight that reveals great commercial appreciation and accounts for a high fraction of the wines produced in the region of Campanha Gaúcha, both elaborated for young wines and for aging. Research has defined that this variety is currently the most cultivated in the country (Giovannini, 2001; Zocche et al., 2016a, 2016b; Jacobs et al., 2016).

Cabernet Sauvignon has been subjected to detailed research in the Campanha region in the state of Rio Grande do Sul, Brazil, where Zocche et al. (2016a) and Jacobs (2016) measured the characteristics important for this variety and defined what would be the essential relations for the quality of the wine obtained. However, some criteria are relevant for the elaboration of quality wines, and it is necessary to understand the mechanisms that determine the physical and chemical parameters of these wines, evidencing the relationships and climatic attributes that can affect these parameters of importance. Research on *Cabernet Sauvignon* determined the influence of the peculiar characteristics of the growing environment on the physical and chemical characteristics of the grape (Barnuud et al., 2014).

Among the important traits, anthocyanins directly influence the color of red wines, where their concentration oscillates according to the variety cultivated and the environment where it is inserted. However, the phenolic composition and the concentrations of some attributes vary due to the cultural practices, managements, microclimate and genetic characteristics of the variety (Downey et al., 2006). These phenotypic characters of importance are linked to the sensorial quality of the wine, and the concentration of these can aid in the selection of which will be the procedure applied in the production of aging or young wine. The sensorial peculiarities of wine are dependent on the magnitudes of the pH that determines the stability and precipitation of anthocyanins, this attribute when elevated entails in the instability and reduction of the concentration of anthocyanins in the wines (Zocche et al., 2016a), in the same way, these can be influenced by air temperature and incident solar radiation intensity (Soubeyrand et al., 2014).

The pH of the wines determines the sensory quality and shelf life of the product obtained, influences the microbiological stability, the color of the red wines, causes microbiological and physicochemical changes in the wine produced (Rizzon & Miele, 2002). The color of wines is defined as one of the quality parameters for red wines. As a criterion, it is measured the absorbance spectra of 420, 520 and 620 nanometers to represent the shades and intensity referring to the colors yellow, red and blue.

The tannins influence the sensorial quality in red wines through body characteristics, tactile sensations, astringency, in contrast, their excess can lead to pejorative definitions (Zamora, 2003). The tannins act fundamentally on the stability of the anthocyanins of red wines, and these can prevent the precipitation and the loss of coloration through the connections among them. The proanthocyanidins present in grape are characterized as polymers consisting of flavanols that protect wine from oxidation, increase flavor complexity and color stability. The presence of tannins with anthocyanins is sought, but for this to occur it is necessary for both to exhibit adequate concentrations and to be efficiently linked so that anthocyanins remain stable over time (Cheynier, 2005).

These characters are influenced by the processes of elaboration and climatic attributes, in this way, researches of Leão and Silva (2003) determined that the performance of the vines were based on the interaction genotypes x growing environments, and the air temperature and rainfall were essential for the phenolic maturation of the grapes, however, the thermal amplitude determined the physical and chemical characteristics of the wine (Kishino & Marur, 2007). Vines depend on climatic attributes for biosynthesis, translocation, degradation and accumulation of substances in the berries, and that these are transferable to wines and reflect on color, aroma, taste, body, acidity and structure (Zanus & Tonietto, 2012). In this context, it is essential to understand the dynamics responsible for the quality of red wines. Thus, this work had the objective of revealing the physico-chemical and climatologic relationships that determine the quality of *Cabernet Sauvignon* wines.

2. Material and Methods

The experiment was carried out in the municipality of Dom Pedrito, Rio Grande do Sul, Brazil, in the agricultural crop of 2016. The grapes were harvested from the *Cabernet Sauvignon* variety and from a commercial vineyard located at Latitude: 31°01′20.031″S and Longitude: 54°36′11.655″W, with a climate characterized as subtropical Cfa not very humid, with cold winter and mild summer, annual precipitation between 1200 and 1500 mm and average air temperature from 17 to 20 °C, the soil is classified as Vertic Planosol of medium to clayey texture (IBGE, 2017a, 2017b; Rossato, 2011). The vineyard is composed of seedlings from the clone R5 and rootstock SO4, conducted in a trellis driving system, with two double mobile wires, spacing 1.25 meters (m) between plants and 3 m between rows, pruning was performed in bilateral cordons in a vineyard of 2.5 hectares implanted since 1990.

The experiment was conducted in a randomized block design where the treatments corresponded to nine microvinifications arranged in three replicates. These were carried out in graduated glass bottles with a capacity of 20 liters. The grapes were harvested and stored in a cold chamber for 24 hours so that after, there could be performed manual destemming, addition of potassium metabisulphite at a dose of 100 mgL^{-1} and in the sequence, a dose of 300 mg L^{-1} of yeasts *Saccharomyces cerevisiae* (Maurivin® PDM).

After 30 days of the end of the alcoholic fermentation the physical-chemical characteristics were measured, being these: hydrogenionic potential (HIP): measured in pH units (Ribéreau-Gayon et al., 1976); titratable total acidity (TTA): obtained by titrating in meq L^{-1} (Amerine and Ough, 1976); volatile acidity (VTA): obtained by titrating in meq L^{-1} (Amerine and Ough, 1976); tannins (TAN): expressed in g L^{-1} (Ribéreau-Gayon & Stonestreet, 1965); anthocyanins (ANT): expressed in g L^{-1} (Ribéreau-Gayon & Stonestreet, 1965); color indices 420 (420): expressed in units (Ribéreau-Gayon & Stonestreet, 1965); color index 520 (520): expressed in units

(Ribéreau-Gayon & Stonestreet, 1965); color index 620 (620): expressed in units (Ribéreau-Gayon & Stonestreet, 1965); total polyphenols index (TPI): expressed in g L^{-1} (Ribéreau-Gayon & Stonestreet, 1965).

The data were submitted to analysis of variance at 5% of probability where the homogeneity of variances was verified by the Bartlet test (Ramalho et al., 2012) and normality by Shapiro-Wilk (1969). Significant characters were submitted to linear correlation in order to reveal the trend of linear association among the measured characters. Afterwards, the stepwise multiple regression was performed, where the pH, anthocyanins, color indexes of the absorbances of 420, 520 and 620, total polyphenols index, tannins and total acidity in wine were determined as dependent characters, on the other hand, meteorological variables such as air temperature range, minimum and maximum air temperature, incident solar radiation and rainfall were considered as independent or explanatory characters of the predictor model.

3. Results and Discussion

The minimum and maximum air temperatures, rainfall and incident solar radiation are considered climatic attributes essential for the growth and development of the vines. In this way, the vineyard is located in an area that reveals annual average air temperatures from 17 to 20 ºC and rainfall around 1200 to 1500 mm (Table 1). For the maturation of *Cabernet Sauvignon*, the minimum and maximum air temperatures required were above the average expected for the period of this study. On the other hand, rainfall levels were lower than the required by the crop. The mean physical-chemical parameters measured in the wine (Table 1) are outside the parameters required in the production of quality wine.

The hydrogenionic potential (HIP) was above the ideal defined for the production of wines. In this way, high magnitudes can result in instability in color, microbiological and red wine tonality. However, it is important to note that the magnitude of pH is determinant for the expression of anthocyanins, and their increase may result in oxidized shades, whereas their decrease results in red tones in the wine (Castañeda-Ovando et al., 2009; Heras-Roger, 2016). Several factors are related to pH magnitude, such as total acidity, potassium concentration and the proportions of tartaric and malic acids (Conde et al., 2007). The titratable total acidity (TTA) obtained was higher than the values recommended for the production of red wine, high magnitudes did not favor the pH reduction, this requires that detailed studies be elaborated to understand the dynamics of the acids contained in the wine during the processes of elaboration. The volatile acidity (VTA) evidenced that its magnitude is within the criteria established as optimal for the elaboration and conservation of red wines. Researches define that this character is a physical-chemical parameter measured throughout the process of wine elaboration, and the alcoholic fermentation occurs within the limits from 4 to 6 meq L^{-1} of volatile acidity (Ribérau-Gayon et al., 2003).

Table 1. Means of meteorological indices and physico-chemical parameters of *Cabernet Sauvignon* wines, in the municipality of Dom Pedrito, RS, crop 2016

Variable	Means
Maximum temperature (°C)	30.269
Minimum temperature (°C)	20.126
Radiation (kJ/m²)	1874
Precipitation (mm)	2.043
Amplitude (°C)	10.143
pH	3.880
Total acidity (meq L^{-1})	131.611
Volatile acidity (meq L^{-1})	4.757
Tannins (g L^{-1})	1.287
Anthocyanins (mg L^{-1})	308.116
DO 420	0.275
DO 520	0.385
DO 620	0.071
Tonality (420/520)	0.741
TPI (g L^{-1})	34.122

The tannins were lower than the desired magnitude of 2 g L^{-1}, these limits define the elaboration of quality wines (Zamora, 2003). Tannins are responsible for tactile sensations such as astringency, bitterness and structure of wine (Flanzy, 2003; Zamora, 2003). Anthocyanins (ANT) were lower than the desired amount of 400 mg L^{-1} (Zamora, 2003). The concentration of anthocyanins and the pH that define wine quality are dependent on the intrinsic genetic characteristics of the genotype used and the growing environment (Castañeda-Ovando et al., 2009; Zocche, 2016a). Regarding the characters related to the color of the wine (absorbance indexes of 420, 520 and 620 nanometers), it was observed that the wine tonality was close to 1.0 indicating the great evidence of the yellow color present in the wine, that is due to the expression of the wines reddish-brown tonalities. Research has shown that *Cabernet Sauvignon* wines produced in Campanha resulted in similar tonalities (Zocche et al., 2016a). These effects were derived from the dynamics expressed by the magnitude of the pH and oxidation processes of the wine (Castañeda-Ovando et al., 2009). The total polyphenols were less than 40 g L^{-1}, which was defined as adequate in the elaboration of red wine (Zamora, 2003). For the production of quality wines, the pH, total acidity, anthocyanins, tannins, and total polyphenols are important for phenolic maturation and adequate wine aging (Flanzy, 2003; Zamora, 2003).

The characters hydrogenionic potential (HIP), titratable total acidity (TTA), volatile acidity (VTA), tannins (TAN), anthocyanins (ANT), color indices 420 (420), color index 520 (520), color index 620 (620) and total polyphenols index (TPI) revealed significance at 5% of probability by the t test, in this way, all the characters were submitted to linear correlation analysis in order to identify the tendency of association among the characters of interest (Table 2), together, it was correlated the climatic attributes maximum air temperature (MXT), minimum air temperature (MNT), incident solar radiation (RAD), rainfall precipitation (PRE) and air temperature range (RAN). There were performed 78 linear associations, and only 15 of these relations were significant at 5% of probability by the t-test.

Table 2. Pearson correlation between meteorological variables and physicochemical arameters of Dom Pedrito *Cabernet Sauvignon* wine, RS, 2016 crop

	TPI	HIP	TTA	TAN	ANT	420	520	620	MXT	MNT	RAD	PRE	RAN
TPI	1.00	-0.76*	0.70*	0.56	0.83**	0.83**	0.88**	0.61	0.44	0.44	0.18	0.18	0.33
HIP		1.00	-0.97**	-0.60	-0.96**	-0.39	-0.59	-0.06	-0.14	-0.09	-0.36	0.01	-0.39
TTA			1.00	0.69*	0.94**	0.54	0.71*	0.10	0.07	-0.01	0.21	-0.04	0.30
TAN				1.00	0.69*	0.35	0.43	0.16	0.15	0.18	-0.16	-0.35	0.23
ANT					1.00	0.54	0.71*	0.23	0.08	0.05	0.18	-0.05	0.41
420						1.00	0.96**	0.94**	0.29	0.31	-0.27	0.32	0.26
520							1.00	0.83**	0.24	0.21	-0.17	0.31	0.36
620								1.00	0.23	0.27	-0.45	0.33	0.14
MXT									1.00	0.95**	0.53	0.27	-0.17
MNT										1.00	0.44	0.11	-0.12
RAD											1.00	0.18	-0.04
PRE												1.0	0.41
RAN													1.00

Note. **, * Significant at 1 and 5% of probability by t test.

TPI: total polyphenols index; HIP: hydrogenionic potential; TTA: titratable total acidity; TAN: tannins; ANT: anthocyanins; MXT: maximum air temperature; MNT: minimum air temperature; RAD: radiation; PRE: precipitation; RAN: air temperature range.

N: 36 experimental samples.

The hydrogenionic potential (HIP) showed an inverse association with total polyphenols (TPI), anthocyanins (ANT) and total acidity (TTA). In this context, the reduction of the hydrogenionic potential of the wine results in an increase in the concentration of total polyphenols and changes in the concentration of anthocyanins, stability in wine coloring, as well as greater evidence of tartaric and malic acids, essential components for the total acidity of the wine (Ribéreau-Gayon, 2003).

Total acidity (TTA) was positively associated with anthocyanins (ANT), tannins (TAN) and total polyphenols (TPI). Therefore, the concentration of extracted anthocyanins, total tannins and polyphenols may be associated

with the total acidity (TTA) of the wine. Acidic media may contribute to the expression and extraction of these compounds from the berry by disrupting the film cells. Total acidity was positively associated with the color index 520 (520) character, in this way, it is evident that the anthocyanins were determinants for the red color expression in wines, since they potentiate the presence of flavilium cation in the A + form (Zamora, 2003).

Total polyphenols (TPI) were associated with anthocyanins (ANT) and color index 520 (520). This dynamics occurred due to the anthocyanins composing the scope of the total polyphenols (TPI) and being closely related to the red coloration of the wine. There was a positive correlation between the concentration of tannins (ANT) and anthocyanins (ANT) present in wine, in this way, the synthesis and extraction of anthocyanins occurs through the film of the berries, which enable them to obtain anthocyanins and extract tannins during the winemaking processes.

The color index of 420 (420) was positively associated with total polyphenols (TPI) and color indices 520 (520) and 620 (620). Thus, the increase of the colorimetric fraction of red (520) and blue (620) results in the direct increase of the yellow fraction (420), this occurs due to the oxidative processes occurring on darker spectra (520 and 620), physical-chemical changes and changes in pH magnitude. In this way, it is sought to potentiate the absorbance spectra (520 and 620) to result in increased hue, as well as to improve the color quality of red wines. Through the linear correlations it was not possible to identify any significant linear association between the climatic attributes and those focused on the quality of the wine, of these conditions, it is assumed that a multivariate dynamics should be considered for the explicability of each character that confers quality to the wine.

A predictor model was established through Stepwise multiple regression for each wine quality character, under these conditions the characters pH, anthocyanins, color indices were measured at the absorbances of 420, 520 and 620, total polyphenols index, tannins and total acidity being considered as dependent, in contrast, the air temperature range, minimum and maximum air temperature, incident solar radiation and rainfall were considered as explanatory for the predictor model (Table 3). The predictive models showed a coefficient of determination (R^2) intermediate to high values of 0.41 and 0.89, which gave high accuracy of the predictive model of wine quality determined by the climatologic attributes.

Table 3. Step wise predicted model for qualitative parameters of *Cabernet Sauvignon* wines from Dom Pedrito, RS, crop 2016

	Predicted model	**R^2**
HIP	4.18861 – 0.00013200·RAD + 0.00848·PRE – 0.10125·AMP	0,61
ANT	261.83100 + 44.58166·AMP	0.41
DO 420	-0.05845 + 0.01923·TMN – 0.00008683·RAD + 0.00497·PRE	0,66
DO 520	-0.12428 + 0.02827·TMX – 0.00015179·RAD + 0.1434·AMP	0.61
DO 620	0.03293 + 0.00445·TMX – 0.00004171·RAD + 0.00146·PRE	0.79
TPI	2.98972 + 1.17003·TMN + 2.45465·AMP	0.59
TAN	3.9487 + 0.50807·TMX – 0.57767·TMN – 0.00060873·RAD – 0.12663·PRE + 0.70871·AMP	0.89
TTA	85.13047 + 6.99842·TMX – 7.73215·TMN + 0.03124·RAD – 4.26697·PRE	0.48

Note. HIP: hydrogenionic potential; ANT: anthocyanins; TPI: total polyphenols index; TAN: tannins; TTA: titratable total acidity; RAD: radiation; PRE: precipitation; MNT: minimum air temperature; MXT: maximum air temperature; RAN: air temperature range.

The predictive model for the hydrogenionic potential (HIP) was determined by the reduction of the thermal amplitude and photosynthetically active radiation, in contrast to an increase in rainfall (Table 3). The increase of the pH of the wine occurs when the plants are cultivated in environments with high precipitation, in the same way, they reveal smaller intencities of incident radiation with minimum oscillations of the air temperature. Research has shown that the increase in pH was due to the higher concentration of malic acid in the berries, water supply to plants and availability of nutrients mainly of potassium (Kliewer, 1967; Johson & Nagel, 1976). Anthocyanins (ANT) are influenced by a higher thermal amplitude gradient of the air, these results are confirmed by Ubalde (2010), who determined the synthesis of anthocyanins in *Cabernet Sauvignon*, being higher in harvests or seasons of the year when the air temperature range was higher. The air amplitude corresponds to the interval between the maximum and minimum thermal temperatures, which are closely related

to the synthesis of the anthocyanins, therefore it is defined that air temperatures above 35 °C decrease the accumulation of anthocyanins in the berries (Cheng et al., 2014).

The absorbance index for color 420 (420) represents the yellow tones and the index of 620 (620) represents the bluish tones in wines, these characters were represented by a predictor model determined by the increment of rainfall, minimum temperature to 420 (420) and maximum temperature for 620 (620), in contrast, less emphasis on incident solar radiation. Due to this, wines that show yellowish and blue tones can be obtained when minimum and maximum air temperatures and high accumulated precipitation are obtained, however the solar radiation on the canopy is reduced. The 520 (520) index was determined by increasing the maximum air temperature and the thermal amplitude, with reduction of incident solar radiation, this character is shown to be directly dependent on higher air temperatures. Researches define that the absorbance indices in wines are directly influenced by the climatological attributes (Ubalde, 2010).

Total polyphenols (TPI) were determined by raising the minimum air temperature and thermal amplitude. *Cabernet Sauvignon* red wines are directly influenced by climatological attributes (Ubalde, 2010). The concentration of tannins (TAN) in wine was defined by maximum air temperatures and higher thermal amplitudes, in contrast, lower effects of incident solar radiation and rainfall. Research has shown that the phenolic compounds of the wine are determined by the enzymatic activity of the phenylalanine ammonia-lyase (PAL), which is dependent on the quality and light intensity, as well as on the incident radiation balance (Dias et al., 2015).

The total acidity (TTA) was determined by the increase of the maximum air temperature, incident solar radiation, however, smaller effects are obtained through minimum air temperature and rainfall. This dynamics can influence the photosynthetic process and absorption of nutrients by the grapevine, mainly absorption and translocation of potassium characterized with a macronutrient determining to the magnitude of the total acidity. These predictive models made it possible to understand the climatic attributes determining the characteristics of the *Cabernet Sauvignon* red wines. The understanding of this dynamics allows to increase the biological explanation about the elaboration of red wines in the region of Campanha, Rio Grande do Sul.

4. Conclusion

The concentration of total polyphenols in *Cabernet Sauvignon* red wines is associated with anthocyanins, indices of absorbances of 420 and 520, as well as total acidity. However, the tannins are directly proportional to the total acidity of the wine.Environmental conditions with high rainfall, minimum oscillations in thermal amplitude and incident solar radiation tend to increase the hydrogenionic potential and the absorbance indices of 420 (yellow) and 620 (bluish) red wines of *Cabernet Sauvignon*.The thermal amplitude was preponderant to elevate levels of anthocyanins in *Cabernet Sauvignon* wines.

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