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QUALITY OF FINE WINES: PHYSICOCHEMICAL AND COLORIMETRIC PARAMETERS IN STORAGE

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ABSTRACT: The storage time performs a large role in the changes occurring in wines. Thus, the goal of this work was to analyze both physicochemical and colorimetric parameters of red and white wines produced in Brazil. Eight commercial Brazilian fine wines were analyzed. All samples showed an increase of volatile acidity and decreased phenol content. There was an increase of pH in most samples and in the case of red wines, a decrease of anthocyanins. Browning occurred in red wines with red tint darker and less color saturation. White wines lost brightness, color saturation and green component, but continued classified as “pale yellow”. Significant changes, especially in pH, volatile acidity, total phenol, anthocyanins and color difference were observed after four years of storage. It is suggested that some parameters not so frequently used to evaluate the quality of wine, such as phenol compounds, anthocyanins and color difference should also be used in addition to parameters already used as Brazilian standard regulations for the attachment of identity and quality of fine wines.

Palavras-chave: White wine. Red wine. Color. Conservation. Chemical composition.

QUALIDADE DE VINHOS FINOS: PARÂMETROS FÍSICO-QUÍMICOS E COLORIMÉTRICOS NO ARMAZENAMENTO

RESUMO: O tempo de armazenamento desempenha um grande papel nas mudanças que ocorrem em vinhos. Assim, o objetivo deste trabalho foi analisar os parâmetros físico-químicos e colorimétricos de vinhos tintos e brancos produzidos no Brasil. Oito marcas comerciais de vinhos finos brasileiros foram analisadas. Todas as amostras mostraram aumento da acidez volátil e decréscimo do conteúdo fenólico. Houve aumento de pH na maioria das amostras e no caso dos vinhos tintos, um decréscimo de antocianinas. Houve escurecimento nos vinhos tintos com tonalidade vermelha mais escura e menor saturação da cor. Os vinhos brancos perderam brilho, saturação da cor e componente verde, mas continuaram sob a classificação de “amarelo pálido”. Alterações significativas, especialmente quanto ao pH, acidez volátil, fenóis totais, antocianinas e diferença total de cor, foram observadas após 4 anos de estocagem. Sugere-se que alguns parâmetros não tão frequentemente utilizados para avaliar a qualidade do vinho, tais como compostos fenólicos totais, antocianinas e diferença total de cor, deveriam ser também utilizados além dos parâmetros da Instrução Normativa Brasileira para fixação de padrão de identidade e qualidade de vinhos finos).

Keywords: Vinho branco. Vinho tinto. Cor. Conservação. Composição química.

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INTRODUCTION

During storage, it is known that the wine undergoes several reactions that imply major changes in its physicochemical and colorimetric, which can directly affect their quality. Works cited by Kallithraka et al. (2009) indicate that the storage bottle can provide improvements in the quality of red wine but white wine can contribute to technological defects.

The various factors related to storage conditions often affect the composition of wine and, therefore, seek some publications describe or assess the specific effects of these factors in the physicochemical properties of wine (GÓMEZ-PLAZA et al., 2000; FERREIRA et al., 2002; RECAMALES et al., 2006; CHUNG et al., 2008; HERNANZ et al., 2009). One of the main physical and chemical parameters affecting the quality of wine is phenol compounds, since they are related to astringency, bitterness and color. Most of the colorimetric changes of red wines is time-dependent (RECAMALES et al., 2006) and anthocyanins are among the phenols that contribute most to the color of this wine, but little is known about the chemical nature of the color of white wine (JACKSON, 2008).

Few scientific studies have been conducted to verify the changes which occurred during storage of Brazilian fine wines. Thus, the purpose of this study was to assess the degree of impact that the storage time can have on the physical and chemical characteristics of fine wines and colorimetric storage under common commercial conditions.

MATERIALS AND METHODS

Samples of wine

Eight commercial Brazilian fine table reds and white wines (*Vitis vinifera*) were analyzed. Wines (2006 vintage) were from the regions of "San Francisco Valley" (Juazeiro, BA and Petrolina, PE) and the "Serra Gaúcha" (Bento Gonçalves, RS). A total of 24 bottles was used and the lot number of bottles of the same brand was identical. The samples of red wine were identified as follows: A_r (Cabernet Sauvignon/Shiraz), B_r (Cabernet Sauvignon/Shiraz), C_r (Cabernet Sauvignon) and D_r (Merlot). On the other hand, the white wine samples were identified as: A_w (Moscatel), B_w (Moscatel), C_w (Moscatel) and D_w (Chenin Blanc/Moscato Canelli).

All analytic determinations were performed without storage and after 4 years storage. During storage, the samples were placed according to label recommendations (horizontally in the dark, in a dry place and the red wine samples at temperature of 20 ºC and the white wine samples at temperature of 10 ºC).

The results of physicochemical and colorimetric analysis before and after 4 years of storage of samples were compared using the Wilcoxon T test by GraphPad Instat®, v.3.10.

Physicochemical determinations

The parameters determined were relative density (20 ºC), alcohol content, pH, Titratable Acidity (TTA), Volatile Acidity (VA), Fixed Acidity (FA), Total Dry Extract (TDE); total sulfur dioxide (TSD) and total residual sugars (TRS) (AOAC, 1995).

The total phenol compounds (TPC) were extracted by adapting the methodology developed by Webb et al. (2001). About 20 mL sample was added an equal volume of ethyl acetate and incubated in the dark for 48 hours. The organic phase was collected, the solvent was removed by evaporation and the residue dissolved in methanol/chloroform 1:1 (extract). The accuracy of extraction was evaluated in terms of percentage of recovery from the addition of gallic acid (Sigma Aldrich, St. Louis, USA) as an analytical standard (82.94 to 100.85 %). After extraction, the quantification of the TPC was performed by the method described by Singleton and Rossi (1965). Results were expressed as mg gallic acid equivalent per liter of wine.

Anthocyanins of red wine samples were determined according to Lee et al. (2005). The results were expressed as mEq L^{-1} of monomeric anthocyanins cyanidin-3-glucoside. UV-Visible spectrophotometer (Tecnal, model Femto 800XI, Piracicaba, Brazil) was used in the analysis of anthocyanins and TPC.

Instrumental analysis of color

For the color analysis, the samples were conditioned in cuvettes (10 mL), and the readings made using a colorimeter (Konica Minolta, model CR 400, Tokyo, Japan) with a CIE D65 illuminant and standard CIE 2° observer, after calibration with white porcelain plate (CR-A43). The color space adopted for the interpretation of results was the CIELAB, where the coordinates L*, a*, b*, C* and h were measured. The color difference (ΔE*) observed before and after storage was calculated according to Gómez-Míguez et al. (2007) and the results expressed in CIELAB units.

RESULTS AND DISCUSSION

There was no significant difference in density after storage in the samples of red wines (Table 1). Therefore, changes in the density of white wines are in agreement with the changes also observed in the content of TRS (Table 2). There was no significant difference in the degree of alcohol in all samples.

For pH, almost all red wines showed a significant increase in their scores, except for the sample C_r (Cabernet Sauvignon) that retains its value after 4 years (3.86) near the initial pH (3.89). The same thing happened to white wines, except for the sample C_w (Muscatel), which also kept its final pH value (3.50) near the initial pH (3.52). According to Jackson (2008), there is usually an increase in pH of the wine during its aging, which is related to their biological instability, because microbial growth is favored in less acidic wines. The low pH produced by wine acids has a beneficial antimicrobial effect. Most bacteria do not grow at low pH values. A pH range of between 3.1 and 3.4 is suitable for most white wines, and between 3.3 and 3.6 for most red wines.

Table 1 • Evaluation of physicochemical parameters of red wines samples in storage.

Parameters	Samples and storage period (n = 3)								Significance[a]
	No storage:				4 years storage:				
	Ar	Br	Cr	Dr	Ar	Br	Cr	Dr	
Relative density (20 °C)	0.9963±0.0001	0.9981±0.0003	0.9968±0.0001	0.9961±0.0005	0.9956±0.0002	0.9978±0.0001	0.9966±0.0005	0.9961±0.0002	ns
Alcoholic (% vol.)	13.17±0.21	12.80±0.20	12.93±0.58	12.93±0.12	13.63±0.06	12.83±0.12	12.93±0.15	12.33±0.06	ns
pH	3.78±0.01	3.83±0.00	3.89±0.01	3.71±0.01	3.93±0.01	3.89±0.01	3.86±0.01	3.87±0.01	**
Titratable acidity ($mEq\ L^{-1}$)	73.10±0.17	84.5±0.50	78.17±1.26	75.90±0.66	72.87±0.58	87.12±1.90	88.07±0.90	77.00±1.73	**
Volatile acidity ($mEq\ L^{-1}$)	9.72±0.40	12.69±0.14	9.26±0.28	7.93±0.03	11.59±0.20	15.44±0.59	10.75±0.14	9.74±0.08	***
Fixed acidity ($mEq\ L^{-1}$)	63.38±0.58	71.81±0.40	68.91±1.42	67.97±0.66	61.27±0.78	71.68±1.45	77.31±0.85	67.26±1.68	ns
Total dry extract ($g\ L^{-1}$)	34.67±0.92	38.37±0.12	35.17±1.59	33.60±1.18	33.93±0.58	37.40±0.17	34.97±1.10	31.77±0.68	*
Reduced dry extract ($g\ L^{-1}$)	30.07±1.14	29.05±0.32	28.83±1.53	27.75±1.29	29.98±0.84	30.33±0.12	29.21±1.02	26.15±0.65	ns
Total SO_2 ($g\ L^{-1}$)	0.03±0.00	0.04±0.04	0.04±0.00	0.07±0.00	0.01±0.00	0.03±0.01	0.02±0.01	0.04±0.00	*
Total residual sugar ($g\ L^{-1}$)	5.60±0.35	10.31±0.21	7.33±0.12	6.85±0.13	4.95±0.27	8.07±0.06	6.76±0.07	6.62±0.13	**
Total compounds phenol ($mg\ L^{-1}$)	1410.83±10.51	1798.70±12.64	1763.57±14.66	1542.93±23.09	1158.73±6.30	1220.54±12.59	1373.27±9.62	1336.91±18.89	***
Total anthocyanins ($mg\ L^{-1}$)	156.48±1.02	22.02±3.05	82.50±1.02	62.53±1.76	12.04±1.34	14.38±0.51	26.42±0.88	22.61±0.51	***

[a] ns, *, **, ***, **** = not significant, p<0.05, p<0.01, p<0.001 and p<0.10, respectively by Wilcoxon T test. L* (luminosity); a* (component green-red); b* (component blue--yellow); C* (chroma); h (hue angle); ΔE* (color difference); Samples: Ar (Cabernet Sauvignon/Shiraz, "Vale do São Francisco"); Br (Cabernet Sauvignon/Shiraz, "Vale do São Francisco"); Cr (Cabernet Sauvignon, "Serra Gaúcha"); Dr (Merlot, "Serra Gaúcha").

Source: Prepared by the author, 2014.

Table 2 • Evaluation of physicochemical parameters of white wines samples in storage.

Parameters	Samples and storage period (n = 3)								Significance[a]
	No storage:				4 years storage:				
	A_w	B_w	C_w	D_w	A_w	B_w	C_w	D_w	
Relative density (20 ºC)	1.0040±0.0002	1.0080±0.0001	0.9907±0.0007	0.9920±0.0001	1.0040±0.0002	1.0090±0.0001	0.9940±0.0001	0.9960±0.0001	**
Alcoholic (% vol.)	11.03±0.29	8.63±0.06	11.37±0.06	12.27±0.15	11.43±0.12	8.33±0.15	10.73±0.17	11.30±0.17	ns
pH	3.63±0.01	3.25±0.01	3.52±0.02	3.34±0.01	3.94±0.02	3.66±0.02	3.50±0.01	3.63±0.01	**
Titratable acidity (mEq L^{-1})	83.30±0.50	77.67±0.76	87.37±0.55	99.53±0.64	81.87±0.55	77.33±0.29	84.40±0.36	99.57±0.90	*
Volatile acidity (mEq L^{-1})	6.94±0.23	2.58±0.03	1.66±0.10	9.28±0.38	9.58±0.18	6.97±0.31	4.26±0.15	11.81±0.05	***
Fixed acidity (mEq L^{-1})	76.07±1.14	74.73±1.31	85.63±0.72	90.25±0.28	72.29±0.46	70.36±0.30	80.14±0.26	87.76±0.87	***
Total dry extract (g L^{-1})	48.73±0.90	51.20±0.00	13.90±0.00	20.93±0.29	49.47±0.72	53.00±1.33	22.07±0.58	27.17±0.70	**
Reduced dry extract (g L^{-1})	23.73±1.17	19.47±0.31	11.33±0.29	15.20±0.26	24.19±0.65	20.85±1.29	19.30±0.53	21.68±0.60	**
Total SO_2 (g L^{-1})	0.08±0.00	0.09±0.00	0.13±0.00	0.12±0.01	0.07±0.01	0.06±0.00	0.09±0.00	0.16±0.00	ns
Total residual sugar (g L^{-1})	26.00±0.69	32.73±0.31	3.57±0.29	6.40±0.35	26.28±0.07	33.15±0.05	3.77±0.18	6.48±0.47	*
Total compounds phenol (mg L^{-1})	548.42±20.68	523.58±16.40	369.63±4.81	278.73±1.82	368.42±19.10	239.33±19.44	175.09±15.85	153.27±1.83	***

[a] ns, *, **, ***, **** = not significant, $p<0.05$, $p<0.01$, $p<0.001$ and $p<0.10$, respectively by Wilcoxon T test. L* (luminosity); a* (component green-red); b* (component blue-yellow); C* (chroma); h (hue angle); ΔE* (color difference); Samples: Aw (Moscatel, "Vale do São Francisco"); Bw (Moscatel, "Vale do São Francisco"); Cw (Moscatel, "Vale do São Francisco"); Dw (Chenin Blanc/Moscato Canelli, "Vale do São Francisco").

Source: Prepared by the author, 2014.

It was also observed that after four years as both the white and red wines showed a significant increase in levels of volatile acidity, in which the highest average (15.44 mEq L^{-1}) was noted in the B_r sample (Cabernet Sauvignon/Shiraz). Moreover, both the white and red wines made by blends and elaborated on the "Vale do São Francisco" had the highest levels of volatile acidity in both periods (Tables 1 and 2). The increase in pH may have contributed to the elevation of volatile acidity in wines become more susceptible to a possible microbial growth. The acetic acid is one of the acids formed during fermentation, which is responsible for volatile acidity in wine. At normal levels in wine, acetic acid can be a desirable flavorant, adding to the complexity of taste and odor. It is more important, though, in the production of acetate esters that can give wine a fruity character. However, acetic acid progressively gives wine a sour taste and taints its fragrance. High levels of acetic acid are usually associated with contamination of grapes, juice, or wine with acetic acid bacteria (JACKSON, 2008).

Moreover, the pH is not greatly affected by the volatile acids or by total SO_2, because this is dissolved in the form of gas (DÍAZ et al., 2003). Since the non-volatile organic acids are represented by fixed acidity, it's possible to check a logically inverse relationship between pH and acidity fixed in all samples (Tables 1 and 2).

There was an increase in levels of titratable acidity in all samples of red wine, except for the sample A_r that remained its initial and final values close (Table 1). This increase can be justified by the increase of volatile acidity. Although the sample A_r has shown an increase of volatile acidity, the decrease of fixed acidity caused by the higher pH value contributed to the decrease in titratable acidity. The role of acids in maintaining a low pH is crucial to the color stability of red wines. As the pH rises, anthocyanins lose their red color and turn bluish. Acidity also affects ionization of phenolic compounds. The ionized (phenolate) state is more readily oxidized than its nonionized form. Accordingly, wines of high pH (3.9) are very susceptible to oxidization and loss of their young color (JACKSON, 2008) and consequently there is a loss in flavor and in quality. As for white wines, there was a decrease in titratable acidity, except for the sample D_w which also maintained its initial and final close (Table 2). Possibly, the elevated levels of volatile acidity were not enough to cause a significant increase in levels of titratable acidity of these samples.

Decrease in titratable acidity of wine was also observed by Chung et al. (2008), mainly between 9 and 18 months of storage. It was found that the sample composite by blend Chenin Blanc/Muscat Canelli presented the highest mean titratable acidity before and after storage (Table 2).

There was a significant increase in the content of TRS in the samples of white wines (Table 2). This increase could be derived from phenol compounds, as Alamo et al., (2000) report that the increased content of monosaccharides in wine is related to the degradation of flavonoid glycosides. The samples of red wines, however, showed significant reduction of this parameter and this agrees with the results of Alamo et al. (2000) and Chung et al. (2008) who found reductions in glucose levels up to 5 months and after 9 months of storage, respectively.

As the pH and the volatile acidity, total SO_2 is also related to the health of wines. Significant reductions were observed in red wine samples after storage. This fact may have occurred possibly due to the volatility of this compound. Because of its function as processing aids, it is likely that lower levels of SO_2 could facilitate possible microbial proliferation.

In all samples there was a significant reduction on the TPC (Tables 1 and 2), which was expected due to the phenomenon of oxidation and polymerization over time. Ferreira et al. (2002) cite that the rate of auto-oxidation of phenol compounds in wine may be nine times higher at pH 4 than at pH 3 for some compounds. The decrease observed in the TPC red wine samples ranged from 13.35 % (sample D_r) to 32.14 % (sample B_r), while losses in the white samples ranged between 32.82 % (sample A_w) and 54.30 % (Sample B_w).

Although there was reduction in the concentration of TPC from the wine samples, there is the possibility of maintaining their antioxidant activity, as observed by Zafrilla et al. (2003) and Kallithraka et al. (2009). The synergistic effect of other bioactive compounds such as tannins, vitamins and trace elements, as well as unchanged number of -OH groups (responsible for antioxidant activity) after condensation reactions were identified as the main factors contributing to this fact.

With respect to anthocyanins, there was also significant decrease in all samples of red wines (Table 1). The greatest reduction was noted in the A_r with 92.31 % loss, which may indicate serious changes in its coloration. Zafrilla et al. (2003) also reported declines of up to 91 % at concentrations of anthocyanins in different types of red wines. The free monomeric forms of these pigments can undergo oxidation, or condensation polymerization among themselves or with other phenols (catechins and epicatechins) as suggested by Gómez-Plaza et al. (2000).

As for the colorimetric parameters, it was observed that the sample A_r had their values of L*, b*, C* and h increased (Table 3), indicating bleaching of this sample. Recamales et al. (2006) claim that the increase in the values of C* is one of the characteristic changes in wine during storage. The sample A_r also showed a significant reduction of the component associated with red (a*) at 0.94 %. According to Bernardo (2005), red wines tend to bleaching and loss of bright red color as they age.

Table 3 • Evaluation of physicochemical parameters of red wines samples in storage.

Samples and storage period n = 3	L*	a*	b*	C*	h	ΔE*
No storage:						
A_r	26.29±0.12	35.00±0.09	13.33±0.12	37.46±0.12	20.84±0.12	-
B_r	32.03±0.27	33.62±0.05	20.89±0.22	39.59±0.16	31.86±0.24	-
C_r	32.73±0.19	36.13±0.08	19.77±0.24	41.17±0.18	28.63±0.25	-
D_r	35.63±0.17	35.50±0.02	22.03±0.05	41.80±0.01	31.83±0.07	-
4 years storage:						
A_r	29.66±0.06	34.67±0.09	17.62±0.16	38.89±0.15	26.93±0.15	5.47±0.01
B_r	29.76±0.08	33.81±0.17	17.58±0.19	38.11±0.23	27.48±0.13	4.02±0.53
C_r	31.68±0.14	36.80±0.20	18.35±0.25	41.12±0.30	26.50±0.18	1.87±0.08
D_r	32.95±0.09	36.29±0.13	20.05±0.14	41.46±0.17	28.93±0.12	3.43±0.17
Significance[a]	ns	****	ns	ns	ns	-

[a] ns, *, **, ***, **** = not significant, p<0.05, p<0.01, p<0.001 and p<0.10, respectively by Wilcoxon T test. L* (luminosity); a* (component green-red); b* (component blue-yellow); C* (chroma); h (hue angle); ΔE* (color difference); Samples: Ar (Cabernet Sauvignon/Shiraz, "Vale do São Francisco"); Br (Cabernet Sauvignon/Shiraz, "Vale do São Francisco"); Cr (Cabernet Sauvignon, "Serra Gaúcha"); Dr (Merlot, "Serra Gaúcha").

Source: Prepared by the author, 2014.

The remaining red samples showed a colorimetric behavior similar to each other, with a reduction of L*, b*, C* and h elevation of a*. This indicates that the samples darkened over time, with a smaller proportion of yellow component, the lower color saturation and hue to a darker red. The red color of red wines occurs primarily by the proportion of anthocyanins in the state *flavylium*. This proportion depends on the pH and content of free SO_2. As the pH increases with the aging of wine, the color density and proportion of anthocyanins in the state *flavylium* decline quickly, and provide the hydrolysis of these pigments (JACKSON, 2008). The results obtained by Tsanova-Savova et al. (2002) show that the proportion of red color produced by anthocyanins cations *flavylium* free or bound decreased with the progress of polymerization during aging and storage of their samples of red wines of different varietals, including Cabernet Sauvignon and Merlot.

Moreover, in samples of white wines (Table 4) decreased brightness over time, loss of components associated with the colors green and yellow and less color saturation. The loss of the green component (-a*) is related to the aging process of the drink, as Bernardo (2005) states the shade represents greenish white wines (too young).

Table 4 • Evaluation of physicochemical parameters of white wines samples in storage.

Samples and storage period n = 3	L*	a*	b*	C*	h	ΔE*
No storage:						
A_w	80.23±0.02	-2.70±0.01	11.22±0.02	11.54±0.02	103.52±0.03	-
B_w	79.22±0.01	-2.01±0.00	11.62±0.02	11.81±0.01	99.80±0.02	-
C_w	80.18±0.17	-1.48±0.01	5.16±0.01	5.37±0.02	106.02±0.06	-
D_w	80.76±0.01	-1.90±0.01	7.05±0.01	7.30±0.01	105.13±0.03	-
4 years storage:						
A_w	75.79±0.18	-2.62±0.02	10.90±0.14	11.21±0.13	103.44±0.06	4.45±0.20
B_w	78.42±0.02	-1.56±0.01	11.12±0.01	11.22±0.01	98.01±0.03	1.05±0.01
C_w	80.08±0.25	-1.28±0.01	4.27±0.09	4.46±0.08	106.65±0.44	0.98±0.04
D_w	80.30±0.01	-1.06±0.01	3.14±0.01	3.31±0.01	108.75±0.09	4.03±0.01
Significance[a]	**	***	***	***	ns	-

[a] ns, *, **, ***, **** = not significant, p<0.05, p<0.01, p<0.001 and p<0.10, respectively by Wilcoxon T test. L* (luminosity); a* (component green-red); b* (component blue-yellow); C* (chroma); h (hue angle); ΔE* (color difference); Samples: Aw (Moscatel, "Vale do São Francisco"); Bw (Moscatel, "Vale do São Francisco"); Cw (Moscatel, "Vale do São Francisco"); Dw (Chenin Blanc/Moscato Canelli, "Vale do São Francisco").

Source: Prepared by the author, 2014.

The main compounds responsible for the color of white wine are catechins and hydroxicinamates, which are initially colorless, but can be oxidized products of yellow or brown (HARBERTSON and SPAYDE, 2006). Thus, it is possible that the increased intensity of yellow (b*) observed in samples A_w and B_w is due to its higher phenol content than the higher levels of TRS, even after storage. Recamales et al. (2006) observed a decrease in the levels of catechin during storage of white wines, where one year after this compound was undetectable. Considering that the catechins have strong influence on the color of these wines, possibly the loss of yellow component of the samples of the current study occurred because of the fall in the levels of catechins.

Furthermore, the area between the angles 90º and 120º of the color hue (h) belongs to medium yellow with a slight tendency to green. Combining this area of the color hue with low values of chroma (C*) and light intensity close to 100 % the final color gets classified as "pale yellow" (RECAMALES et al., 2006). Thus, despite the changes experienced in colorimetric parameters, samples of white wines of this study also belonged to the category "pale yellow" after storage. The largest reduction in color saturation (C*) were noted in the D_w composed of more than one grape variety. The ΔE* checks whether these colorimetric changes can be detected by the human eye. Through its results, Martínez et al., (2001) considered that the value around 3.0 CIELAB units could be considered a preliminary estimate of the acceptable tolerance for detecting the difference between two colors by the human eye. Tables 3 and 4 show that the samples A_r, B_r, D_r, D_w and A_w had ΔE*>3.0 CIELAB units, i.e. the total difference in color between the two periods was evaluated as visually perceptible.

However, Pérez-Magariño and González-Sanjosé (2003) reported that when the judges observe the wine through a wine glass, the color discrimination ability decreases corresponding to a ΔE* of up to 5.0 CIELAB units. Even so, the sample A_r had ΔE* above this limit.

CONCLUSIONS

Significant changes, especially in pH, volatile acidity, total phenol, anthocyanins and color difference were observed at the end of four years of storage. The content of total phenolic compounds and anthocyanins can be directly related to the color of the wine and this is of the main quality parameters observed by the consumer. The measure of color difference by a colorimeter could be adopted for monitoring the chemical changes which occur during the storage of wine. As this is a quick and simple analysis, using the color difference for this purpose would reduce the use of glassware, chemicals and organic solvents, reducing the environmental impact and the time optimization.

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REFERENCES

ALAMO, M. et al. Red wine aging in oak barrels: evolution of the monosaccharides content. *Food Chemistry*, Madrid, v. 71, n. 2, p. 189-193, November, 2000.

AOAC. *Official Methods of Association of Official Analytical Chemists*. 16th ed. Arlington: Association of Official Analytical Chemists, 1995.

BERNARDO, E. *Savoir goûter le vin: par le meilleur sommelier du monde.* Paris: Plon, 2005. 205p.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. Portaria nº 229 de 25 de outubro de 1988. *Aprovar as normas referentes a "complementação dos padrões de identidade e qualidade do vinho".* Disponível em: <http://www.agricultura.gov.br/>. Acesso em: 9 jun. 2015.

CHUNG, H-J. et al. Effect of vibration and storage on some physico-chemical properties of a commercial red wine. *Journal of Food Composition and Analysis*, Seoul, v. 21, n. 8, p. 655-659, December, 2008.

DÍAZ, C. et al. Conventional enological parameters of bottled wines from the Canary Islands (Spain). *Journal of Food Composition and Analysis*, Santa Cruz de Tenerife, v. 16, n. 1, p. 49-56, February, 2003.

FERREIRA, A.C.S. et al. Kinetics of oxidative degradation of White wines and how they affected by selected technological parameters. *Journal of Agricultural and Food Chemistry*, Porto, v. 50, n. 21, p. 5919-5924, September, 2002.

GÓMEZ-MÍGUEZ, M.; VICARIO, I.M.; HEREDIA, F.J. Assessment of colour and aroma in White wines vinifications: effects of grape maturity and soil type. *Journal of Food Engineering*, Seville, v. 79, n. 3, p. 758-764, April, 2007.

GÓMEZ-PLAZA, E. et al. Color and phenolic compounds of a Young red wine. Influence of wine-making techniques, storage temperature, and length of storage time**.** *Journal of Agricultural and Food Chemistry*, Murcia, v. 48, n. 3, p. 736-741, February, 2000.

HARBERTSON, J.F.; SPAYD, S. Measuring phenolics in the winery. *American Journal of Enology and Viticulture*, [s.l.], v. 57, n. 3, p. 280-288, September, 2006.

HERNANZ, D. et al. Effect of storage on the phenolic content, volatile composition and colour of white wines from the varieties Zalema and Colombard. *Food Chemistry*, Seville, v. 113, n. 2, p. 530-537, March, 2009.

JACKSON, R.S. *Wine science:* principles and applications. 3rd ed. San Diego: Elsevier Academic Press, 2008. 776 p.

KALLITHRAKA, S.; SALACHA, M.I.; TZOUROU, I. Changes in phenolic composition and antioxidant activity of White wine during bottle storage: accelerated browning test versus bottle storage. *Food Chemistry*, Athens, v. 113, n. 2, p. 500-505, March, 2009.

LEE, J.; DURST R.W.; WROLSTAD, R. Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: collaborative study. *Journal of AOAC International*, Parma, v. 88, n. 5, p. 1269-1278, September-October, 2005.

MARTÍNEZ, J.A. et al. Note. Visual and instrumental color evaluation in red wines. *Food Science and Technology International*, Granada, v. 7, n. 5, p. 439-444, May, 2001.

PÉREZ-MAGARIÑO, S.; GONZÁLEZ-SANJOSÉ, M.L. Application of absorbance values used in wineries for estimating CIELAB parameters in red wines. *Food Chemistry*, Burgos, v. 81, n. 2, p. 301-306, May, 2003.

RECAMALES, A.F.et al. The effect of time and storage conditions on the phenolic composition and colour of white wine. *Food Research International*, Huelva, v. 39, n. 2, p. 220-229, March, 2006.

SINGLETON, V. L.; ROSSI, J. A. Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid reagents. *American Journal of Enology and Viticulture*, [s.l.] v. 16, n. 3, p. 144-158, January, 1965.

TSANOVA-SAVOVA, S.; DIMOV, S.; RIBAROVA, F. Anthocyanins and color variables of Bulgarian aged red wines. *Journal of Food Composition and Analysis*, Sofia, v. 15, n. 6, p. 647-654, December, 2002.

WEBB, G.A. et al. Isolation and *trans*-resveratrol analysis in Brazilian red wine by ^{1}H-nuclear magnetic resonance. In: WEBB, G.A.; BELTON, B.S.; GIL, A.M.; DELGADILLO. *Magnetic resonance in food science: a view to the future.* Cambridge: Royal Society of Chemistry, 2001. pp. 136-141.

ZAFRILLA, P.et al. Changes during storage in conventional and ecological wine: phenolic content and antioxidant activity. *Journal of Agricultural and Food Chemistry*, Murcia, v. 51, n. 16, p. 4694-4700, July, 2003.