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Difference of physico-chemical properties of red wines in polyethylenterephtalate and bag in box packaging

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ABSTRACT

Studies have shown that the type of packaging can affect the quality and physico-chemical features of foods stored over a longer period of time. Important physico-chemical characteristics of wines that can change over a storage period are alcoholic strength, the amount of acidity or sulfur dioxide, relative density of wines or total dry extract. The aim of this paper was to determine and compare the physico-chemical properties of red wines (Cabernet sauvignon, Frankovka, Merlot and Pinot noir), stored over a period of one year in two different types of packaging (polyethylene terephthalate and bag-in-box). Relative density of wine, total dry extract, alcoholic strength, total acidity content, volatile acidity content, free and total sulfur dioxide content were determined after 3, 6 and 12 months of storage. The results showed that total and free sulfur dioxide content decreased over time in all wines. Volatile acidity and total acidity content increased over time. Alcoholic strength and total dry extract remained mostly stable. Relative density of wine decreased with time. There were no observed differences of these parameters in wines packed in polyethylene terephthalate and bag-in-box containers. Statistical multiple regression confirmed latter assertion.

Introduction

Red wines are a complex liquid mainly constituted of water, ethanol and some bioactive molecules (Karbowiak et al., 2009). Wine quality can be assessed based on physico-chemical parameters such as alcoholic strength, amount of total acidity, volatile acidity, total dry extract, specific gravity and free and total sulfur dioxide (SO_2) (Kojić and Jakobek, 2019). Also, wine quality can be affected by shelf life. Packaging and storage time are very important factors that can significantly affect the physico-chemical properties of wine and wine quality (Kojić and Jakobek, 2021), considering they can extend or shorten the shelf life of wine (Stávek et al., 2012). A basic role in maintaining the quality of wine during storage is closely linked to packaging which gives protection from external influences. Nowadays, glass packaging is still preferred for wine storage (Ghidossi et al., 2012). It is easy to recycle and is characterized by high gas and vapour impermeability (Mentana et al., 2009). The added value of the glass bottle is the possibility of use for all types of wine due to the possibility of a much longer storage time compared to other alternative packaging (Ferrara and De Feo, 2020). Although, glass is considered more sustainable than plastic or multilayer packaging (Boesen et al., 2019), the wine industry strives to make packaging lighter and more flexible, while glass bottles are fragile and heavy (Gomes et al., 2019). That is why wines are now packaged in other packaging materials like polymeric materials, including polyethylene terephthalate (PET) bottles and multilayer packaging, such as bag-in-box (B&B) type containers (Robertson, 2012; Revi et al., 2014). B&B packaging consists of a bag (single or multilayer) with polyethylene or polyethylene metallized laminate, and an outer box or a container, most often low density polyethylene. For example, PET bottles can be an advantage in the wine

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industry, because, due to their lightness and strength, they can reduce the impact on the environment and transportation costs, even more than a glass bottle (Schmid and Welle, 2020). For wines that are consumed quickly, B&B packaging allows better preservation of the level of wine quality after opening. Hence, the added value of B&B packaging is the possibility of extending the shelf life of wine during consumption (Ferrara and De Feo, 2020). Besides, in some countries, alternative wine packaging solutions are highly valued by consumers because of their better price (Chrysochou et al., 2012) compared to glass. Temperature is probably the most important parameter during wine storage. The wine is usually stored in cellar conditions at a temperature of 10 to 15 °C (Butzke et al., 2012). Lower temperatures (e.g. <10 °C) reduce the risk of wine spoilage, but at the same time increase the time for wine to mature (Scrimgeour et al., 2015). On the other hand, during storage or transport, wines are exposed to higher and fluctuating temperatures that can be detrimental to the physical and chemical stability of the wine (Robinson et al., 2010; Cejudo-Bastante et al., 2013). Except temperature, the type of packaging can affect changes in wine composition during storage (Fu et al., 2009; Ghidossi et al., 2012). Namely, it has been shown in some papers that a glass bottle is better for storing wine than a PET bottle (Mentana et al., 2009) or a B&B (Ghidossi et al., 2012). A significant contribution to this manuscript can be found in approach of statistical multiple regression through time changes as a main effect or in interaction with the type of packaging, which provide answers related to changes in physico-chemical properties of wine in examined packaging.

Materials and methods

Samples

Four red wines (Cabernet sauvignon, Frankovka, Merlot and Pinot noir) were produced in Belje plus Ltd from grapes which were cultivated on the slopes of the Ban's hill, Baranya vineyard county. At the time of sampling, wines were not blended and clarification or filtration were not conducted. The wines were investigated just a few days after filling in PET and B&B packages as well as after 3, 6 and 12 months of storage. Samples were obtained directly from the winery. The wine samples were stored upright at a temperature of 15 to 18 °C in the dark at wine cellar of the Vupik plus Ltd during 12 months. At each time period, new packages were opened for the analysis. For examination, two different packages were used, bottles made from mono-layer polyethylene terephthalate (PET) and bag in box containers. All samples were treated in replicates.

Physico-chemical wine analysis

Physico-chemical analysis was performed in the wine laboratory of Vupik Ltd, whereby the following parameters were determined: relative density of wine, alcoholic strength, total dry extract, total acidity, volatile acidity, free and total SO_2. All analyses of the physico-chemical properties of wine were performed according to standard procedures of the International Organization of Vine and Wine (OIV, 2007). These methods were already described earlier (Kojić and Jakobek, 2019). Alcoholic strength in wine was determined by the distillation method based on the relative density of the distillate at 20 °C compared to the water of the same temperature. Total acidity (as tartaric acid) in wine was determined by the neutralization method with 0.1 M NaOH and bromothymol blue (indicator). Volatile acidity (as acetic acid) in wine was determined by the neutralization of the sample previously distilled into the water vapour stream with 0.1 M NaOH and phenolphthalein (indicator). Relative density was determined based on the specific gravity of the wine sample at 20 °C compared to the water at the same temperature. The total dry extract was determined densimetric from the remainder of the distillation according Eq. 1:

$$dr = dw - da + 1 \quad (1)$$

where, dr is relative density at 20 °C / 20 °C, dw is density of wine, da is density of the wine distillate. Free and total SO2 in wine was determined by iodometric method by Ripper.

Statistical analyses

All results of physico-chemical parameters from this study were analyzed with multiple regression analysis using Minitab software (Minitab LLC., State College, PA, USA). The main effects that show a statistical difference in the level of significance in their interactions ($P<0.001$) were selected: type of packaging, type of wine and storage time. A model with fitted values and standard errors (SE) was created for each measurement of wine characteristics.

Results and discussion

Physico-chemical properties

The results of the physico-chemical parameters of wine are shown in Table 1 and Figures 1 to 3. Wines had relative density in range for: Cabernet sauvignon

0.99215 – 0.99222, Frankovka 0.99355 – 0.99410, Merlot 0.99319 – 0.99336 and Pinot noir 0.99255 – 0.99282, respectively (Table 1). Relative density showed the decrease over a period of one year (Frankovka, Merlot, Pinot noir). The only exception was Cabernet sauvignon, where the relative density of wine increased slightly over time. It can be noticed that those observed differences were not high, only in fourth and fifth decimal point, which actually indicates similar values over time. Furthermore, there were no observed differences in relative density in wines packed in two different packagings.

Data for alcoholic strength in examined wines are shown in Table 1. Cabernet sauvignon had 13.85 – 13.96 % vol., Frankovka 13.20 –13.35 % vol., Merlot 13.05 – 13.12 % vol. and Pinot noir 13.47 – 13.57 % vol., respectively. Alcoholic strength was similar after one year of storage in all wines, and in both types of packaging. The results for the alcoholic strength are in accordance with the earlier study (Kojić and Jakobek, 2019).

Table 1 also showed results for total dry extract in wines. Data for total dry extract in the examined wines are shown as follows: Cabernet sauvignon 26.40 – 26.61 g/L, Frankovka 27.80 – 29.67 g/L, Merlot 26.80 – 27.00 g/L and Pinot noir 25.90 – 26.98 g/L, respectively. Total dry extract was similar after one year of storage in all wines and packagings. The exception was Frankovka where the decrease of total dry extract over time was observed.

The results for total acidity content in wines are shown in Table 1. Cabernet sauvignon had 5.10 – 5.22 g/L, Frankovka 5.40 – 5.66 g/L, Merlot 5.80 – 6.10 g/L and Pinot noir 5.00 – 5.10 g/L, respectively. Total acidity slightly increased over time (except is Pinot noir wine). In comparison of wines in two different packagings, there were no observed differences in the total acidity content. Volatile acidity is a very important indicator of wine quality. Figure 1 showed the results for volatile acidity in examined wines as follows: Cabernet sauvignon 0.50 – 0.71 g/L, Frankovka 0.40 – 0.55 g/L, Merlot 0.50 -0.68 g/L and Pinot noir 0.43 – 0.60 g/L, respectively. Their concentration after one year in all four wines increased (Figure 1). Volatile acidity was similar in two types of packaging, with slightly higher values in PET packaging.

Volatile acidity is a very important indicator of wine quality. Figure 1 showed the results for volatile acidity in examined wines as follows: Cabernet sauvignon 0.50 – 0.71 g/L, Frankovka 0.40 – 0.55 g/L, Merlot 0.50 -0.68 g/L and Pinot noir 0.43 – 0.60 g/L, respectively.

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Volatile acidity was similar in two types of packaging, with slightly higher values in PET packaging.

Table 1. Physico-chemical properties of wines during 12 months of storage at 15-18 °C

Time (months)	**Cabernet sauvignon**		**Frankovka**		**Merlot**		**Pinot noir**	
	PET	B&B	PET	B&B	PET	B&B	PET	B&B
Relative density of wine								
0	0.99215	0.99215	0.99407	0.99407	0.99336	0.99336	0.99280	0.99280
3	0.99220	0.99220	0.99410	0.99405	0.99335	0.99332	0.99275	0.99282
6	0.99220	0.99220	0.99380	0.99390	0.99320	0.99325	0.99255	0.99260
12	0.99222	0.99222	0.99355	0.99355	0.99319	0.99319	0.99257	0.99257
Alcoholic strength (% vol.)								
0	13.94	13.94	13.34	13.34	13.05	13.05	13.57	13.57
3	13.95	13.96	13.32	13.35	13.05	13.06	13.56	13.57
6	13.90	13.90	13.28	13.30	13.08	13.10	13.52	13.54
12	13.85	13.88	13.20	13.25	13.10	13.12	13.47	13.50
Total dry extract (g/L)								
0	26.54	26.54	29.67	29.67	26.97	26.97	26.98	26.98
3	26.59	26.61	29.40	29.55	27.00	27.00	26.89	26.85
6	26.54	26.54	29.67	29.67	26.97	26.97	26.98	26.98
12	26.40	26.45	27.80	27.93	26.80	26.85	25.90	25.98
Total acidity (g/L)								
0	5.10	5.10	5.40	5.40	5.80	5.80	5.00	5.00
3	5.11	5.11	5.42	5.44	5.82	5.88	5.05	5.03
6	5.16	5.14	5.50	5.45	5.90	5.90	5.10	5.05
12	5.22	5.17	5.66	5.62	6.10	6.00	5.02	5.00

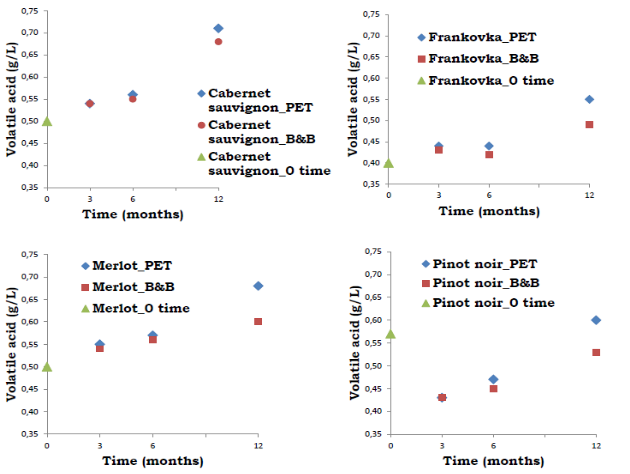

Figure 1. Volatile acidity amount in Cabernet sauvignon, Frankovka, Merlot and Pinot noir wines in PET and B&B packaging during storage of 12 months

It is very important to quantify the amount of sulfur, since sulfur is the active ingredient that protects wine (Kojić, 2019). Figures 2 and 3 represented values for free and total sulfur content in examined wines as shown: Cabernet sauvignon 9.2 – 31.8 mg/L (free SO_2) and 31 – 72.08 mg/L (total SO_2), Frankovka 8.80 – 28.10 mg/L (free SO_2) and 29 – 64.02 mg/L (total SO_2), Merlot 8.30 – 29.06 mg/L (free SO_2) and 30 – 88.42 mg/L (total SO_2) as well as Pinot noir 9.10 – 32.44 mg/L (free SO_2) and 29.6 – 102.14 mg/L (total SO_2), respectively. Free and total SO_2 content (Figures 2 and 3) decreased over time in all wines. The decrease was the highest in the first three months of storage.

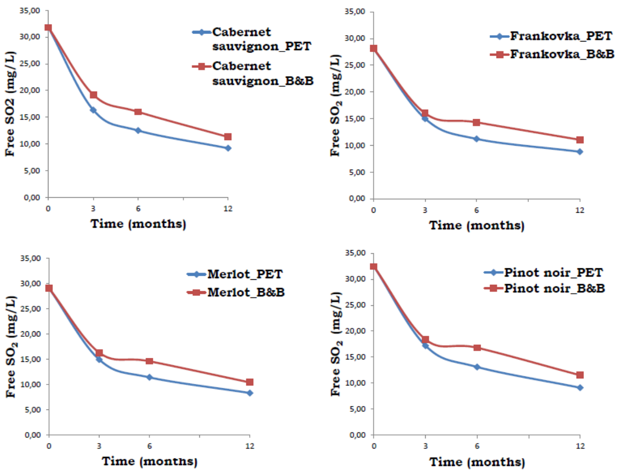

Figure 2. Free SO_2 amount in Cabernet sauvignon, Frankovka, Merlot and Pinot noir wines in PET and B&B packaging during storage of 12 months

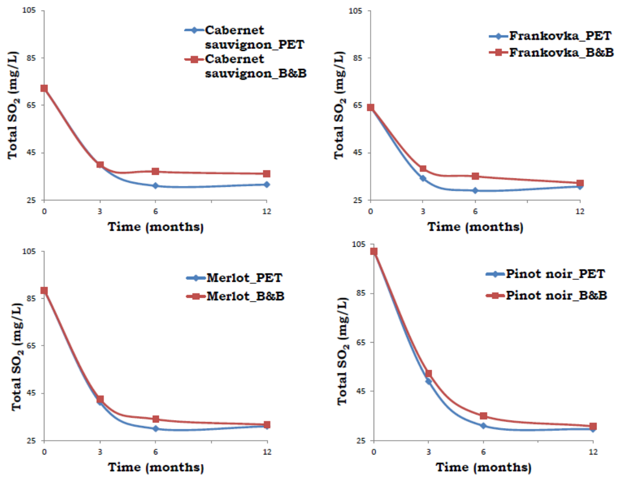

Figure 3. Total SO_2 amount in Cabernet sauvignon, Frankovka, Merlot and Pinot noir wines in PET and B&B packaging during storage of 12 months

In comparison of both types of packaging, there were no observed difference. All measured physico-chemical parameters are in accordance with the results of the earlier study (Kojić and Jakobek, 2019) as well as with the data from literature (Dimkou et al., 2011; Ghidossi et al., 2012).

It can be concluded that the most important physico-chemical parameters in the examined wines changed over one year of storage time (relative density of wine decreased, total acidity and volatile acidity increased, free and total SO_2 decreased). But there were no observed differences in those parameters in two different packages.

Statistical analyses

To confirm obtained results, a statistical multiple regression analysis was applied. This allowed us to create fitted values of physico-chemical parameters with their standard deviations (Table 2) and to see possible statistically significant differences (Table 3). The statistical regression confirmed the observed differences. Namely, it was shown that the change in relative density of wine over time, alcoholic strength in Merlot wine over time, total dry extract in Frankovka wine over time, total acidity over time, volatile acidity over time, free and total SO_2 over time, are statistically significantly different. Furthermore, there were no statistically significant differences in physico-chemical parameters in wines packed in two different types of packaging.

Table 2. Fited values of physico-chemical parameters and their standard errors (SE) obtained by using multiple regression and two variable interactions

Time	Cabernet sauvignon		Frankovka		Merlot		Pinot noir	
(months)	PET	B&B	PET	B&B	PET	B&B	PET	B&B
				Relative density of wine				
0	0.992192 (0.000019)	0.992192 (0.000019)	0.994132 (0.000029)	0.994132 (0.000029)	0.993357 (0.000029)	0.993357 (0.000029)	0.992795 (0.000029)	0.992795 (0.000029)
3	0.992192 (0.000019)	0.992192 (0.000019)	0.993992 (0.000021)	0.993992 (0.000021)	0.993312 (0.000021)	0.993312 (0.000021)	0.992731 (0.000021)	0.992731 (0.000021)
6	0.992192 (0.000019)	0.992192 (0.000019)	0.993851 (0.000019)	0.993851 (0.000019)	0.993266 (0.000019)	0.993266 (0.000019)	0.992666 (0.000019)	0.992666 (0.000019)
12	0.992192 (0.000019)	0.992192 (0.000019)	0.993570 (0.000034)	0.993570 (0.000034)	0.993175 (0.000034)	0.993175 (0.000034)	0.992538 (0.000034)	0.992538 (0.000034)
				Alcoholic strength (% vol.)				
0	13.9555 (0.0083)	13.9555 (0.0083)	13.3245 (0.0058)	13.3245 (0.0058)	13.0642 (0.0089)	13.0642 (0.0089)	13.5848 (0.0083)	13.5848 (0.0083)
3	13.9324 (0.0072)	13.9324 (0.0072)	13.3013 (0.0047)	13.3013 (0.0047)	13.0750 (0.0067)	13.0750 (0.0067)	13.5616 (0.0069)	13.5616 (0.0069)
6	13.9092 (0.0069)	13.9092 (0.0069)	13.2782 (0.0051)	13.2782 (0.0051)	13.0857 (0.0067)	13.0857 (0.0067)	13.5385 (0.0064)	13.5385 (0.0064)
12	13.8629 (0.0091)	13.8629 (0.0091)	13.2319 (0.0085)	13.2319 (0.0085)	13.1072 (0.0124)	13.1072 (0.0124)	13.4922 (0.0083)	13.4922 (0.0083)
				Total dry extract (g/L)				
0	26.526 (0.115)	26.526 (0.115)	29.953 (0.178)	29.953 (0.178)	26.817 (0.081)	26.817 (0.081)	26.817 (0.081)	26.817 (0.081)
3	26.526 (0.115)	26.526 (0.115)	29.506 (0.129)	29.506 (0.129)	26.817 (0.081)	26.817 (0.081)	26.817 (0.081)	26.817 (0.081)
6	26.526 (0.115)	26.526 (0.115)	29.058 (0.117)	29.058 (0.117)	26.817 (0.081)	26.817 (0.081)	26.817 (0.081)	26.817 (0.081)
12	26.526 (0.115)	26.526 (0.115)	28.163 (0.209)	28.163 (0.209)	26.817 (0.081)	26.817 (0.081)	26.817 (0.081)	26.817 (0.081)
				Total acidity (g/L)				
0	5.1388 (0.0130)	5.1388 (0.0130)	5.4559 (0.0089)	5.4559 (0.0089)	5.8451 (0.0134)	5.8451 (0.0134)	5.0264 (0.0125)	5.0264 (0.0125)
3	5.1388 (0.0130)	5.1388 (0.0130)	5.5094 (0.0119)	5.5094 (0.0119)	5.9118 (0.0129)	5.9118 (0.0129)	5.0264 (0.0125)	5.0264 (0.0125)
6	5.1388 (0.0130)	5.1388 (0.0130)	5.6164 (0.0230)	5.6164 (0.0230)	6.0453 (0.0235)	6.0453 (0.0235)	5.0264 (0.0125)	5.0264 (0.0125)
12	5.1388 (0.0130)	5.4024 (0.0103)	5.4024 (0.0103)	5.7783 (0.0182)	5.7783 (0.0182)	5.0264 (0.0125)	5.0264 (0.0125)	5.0264 (0.0125)
				Volatile acidity (g/L)				
0	0.4819 (0.0107)	0.4819 (0.0107)	0.4819 (0.0107)	0.4819 (0.0107)	0.4819 (0.0107)	0.4819 (0.0107)	0.4819 (0.0107)	0.4819 (0.0107)
3	0.5322 (0.0106)	0.5322 (0.0106)	0.4819 (0.0107)	0.4819 (0.0107)	0.5229 (0.0106)	0.5229 (0.0106)	0.4819 (0.0107)	0.4819 (0.0107)
6	0.5825 (0.0160)	0.5825 (0.0160)	0.4819 (0.0107)	0.4819 (0.0107)	0.5640 (0.0160)	0.5640 (0.0160)	0.4819 (0.0107)	0.4819 (0.0107)
12	0.6832 (0.0315)	0.6832 (0.0315)	0.4819 (0.0107)	0.4819 (0.0107)	0.6460 (0.0315)	0.6460 (0.0315)	0.4819 (0.0107)	0.4819 (0.0107)
				Free SO_2 (mg/L)				
0	30.350 (0.503)	30.350 (0.503)	30.350 (0.503)	30.350 (0.503)	30.350 (0.503)	30.350 (0.503)	30.350 (0.503)	30.350 (0.503)
3	16.120 (0.478)	16.939 (0.478)	15.807 (0.478)	16.626 (0.478)	15.727 (0.478)	16.546 (0.478)	16.198 (0.478)	17.017 (0.478)
6	13.679 (0.532)	15.318 (0.532)	13.052 (0.532)	14.690 (0.532)	12.893 (0.532)	14.531 (0.532)	13.835 (0.532)	15.473 (0.532)
12	8.798 (1.002)	12.074 (1.002)	7.542 (1.002)	10.819 (1.002)	7.224 (1.002)	10.501 (1.002)	9.108 (1.002)	12.384 (1.002)
				Total SO_2 (mg/L)				
0	81.71 (2.37)	81.71 (2.37)	71.23 (3.20)	71.23 (3.20)	78.66 (3.20)	78.66 (3.20)	95.24 (3.58)	95.24 (3.58)
3	39.19 (1.65)	39.19 (1.65)	28.71 (2.37)	28.71 (2.37)	36.14 (2.37)	36.14 (2.37)	46.45 (2.65)	46.45 (2.65)
6	39.19 (1.65)	39.19 (1.65)	28.71 (2.37)	28.71 (2.37)	36.14 (2.37)	36.14 (2.37)	40.19 (2.40)	40.19 (2.40)
12	39.19 (1.65)	39.19 (1.65)	28.71 (2.37)	28.71 (2.37)	36.14 (2.37)	36.14 (2.37)	27.67 (4.31)	27.67 (4.31)

Table 3. The results of the multiple regression with the selected strongly significant (P<0.001) main effects and interactions for all physico-chemical parameters in wine

Term	Coefficient	Standard error of coefficient	P-Value
PHYSICO-CHEMICAL PROPERTIES OF WINE			
		Relative density of wine	
Constant	0.993119	0.000013	0.000
FrankovkaTime	**-0.000047**	**0.000004**	**0.000**
MerlotTime	**-0.000015**	**0.000004**	**0.001**
PinotTime	**-0.000021**	**0.000004**	**0.000**
Merlot *vs* Pinot	0.000562	0.000041	0.000
Cabernet *vs* others	-0.001236	0.000025	0.000
Frankovka *vs* MerlotplusPinot	0.001056	0.000035	0.000
		Alcoholic strength (% vol.)	
Constant	13.4823	0.0054	0.000
Merlot *vs* Pinot	-0.5206	0.0128	0.000
Cabernet *vs* others	0.63102	0.00844	0.000
Time	**-0.007717**	**0.000872**	**0.000**
MerlotTime	**0.01130**	**0.00157**	**0.000**
		Total dry extract (g/L)	
Constant	27.5283	0.0668	0.000
Cabernet *vs* others	-1.336	0.140	0.000
Frankovka *vs* MerlotplusPinot	3.136	0.196	0.000
FrankovkaTime	**-0.1491**	**0.0259**	**0.000**
		Total acidity (g/L)	
Constant	5.33645	0.00839	0.000
FrankovkaTime	**0.01783**	**0.00221**	**0.000**
MerlotTime	**0.02225**	**0.00277**	**0.000**
Merlot *vs* Pinot	0.7519	0.0234	0.000
Cabernet *vs* others	-0.2636	0.0166	0.000
		Volatile acidity (g/L)	
Constant	0.4819	0.0107	0.000
CabernetTime	**0.01677**	**0.00286**	**0.000**
MerlotTime	**0.01368**	**0.00286**	**0.000**
		Free SO_2 (mg/L)	
Constant	20.919	0.503	0.000
CabernetTime	**-0.677**	**0.100**	**0.000**
FrankovkaTime	**-0.782**	**0.100**	**0.000**
MerlotTime	**-0.808**	**0.100**	**0.000**
PinotTime	**-0.651**	**0.100**	**0.000**
Time0 *vs* others	**11.789**	**0.795**	**0.000**
PET:B&B:Time	**-0.2730**	**0.0731**	**0.001**
		Total SO_2 (mg/L)	
Constant	47.69	1.41	0.000
PinotTime	**-2.087**	**0.533**	**0.001**
Merlot *vs* Pinot	-16.57	4.36	0.001
Frankovka *vs* MerlotplusPinot	-15.72	3.22	0.000
Time0 *vs* others	**42.52**	**2.89**	**0.000**

Main effect orthogonal contrasts (vs) are built from differences of multiples of indicators and interaction terms (marked with **:**) are built from products of them. Terms are shown in bold when they correspond to time changes as a main effect or in interaction with the type of packaging

.

Conclusions

Results showed that some physico-chemical parameters changed during storage, regardless of the type of packaging. So, total and free sulfur dioxide content decreased over time in all wines, and volatile acidity content increased during storage. On the other hand, alcoholic strength, total dry extract and total acidity content remained mostly stable, as well as relative density of wine. Statistical analyses showed there were no observed significant differences in physico-chemical parameters in wines packed in polyethylene terephthalate and bag-in-box. Based on our results, although the statistical differences were negligible, it is evident that bag-in-box packaging was more able to withstand changes during storage time, since free and total sulfur dioxide content were higher, and content of volatile acidity as a very important indicator of wine quality smaller, compared to polyethyleneterphthalate.

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