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PHYSICO-CHEMICAL CHARACTERISATION OF SLOVAK WINES

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ABSTRACT

The aim of the present study was characterisation of selected varieties of still wines produced in Slovak Republic in vintage year 2013 and one 2012. There were tested ten samples of nine varieties of wines originated from Malokarpatská "Lesser Carpathian" and Južnoslovenská "Southern Slovakia" wine regions of Slovak Republic, Dornfelder, Frankovka modrá, Svätovarinecké, Zweigeltrebe, Müller Thurgau, Veltlínské zelené, Rizling rýnsky, Rizling vlašský and Sauvignon wines. There were studied selected physico-chemical properties of tested wines as a total contents of anthocyanins and polyphenols by means of spectrophotometry, titratable acidity, density and chromatic characteristics. The highest content of anthocyanins (TAC) was found in red wine Frankovka modrá, 183 mg.L^{-1} and the lowest for sample rose wine St. Laurent 19 mg.L^{-1}. The content of total phenolic compounds as a gallic acid was in range 2833 to 1961 mg.L^{-1} for red wines, 1016 and 1013 mg.L^{-1} for rose wines, 1085 to 549 mg.L^{-1}for white wines. Total acidy was average 6.3 ±0.3 g.L^{-1} only for Ryzling rýnský, 8.2 g.L^{-1} and Sauvignon rose 8.0 g.L^{-1} and was expressed as the amount of tartaric acid. Quality of wines can be expressed by colour intensity too. Was evaluated and compared intensity of colour in wines by CIE Lab method and the total differences between red, rose and white wine ΔE* was calculated. The most differences was found for Svätovarinecké a Frankovka modrá (2.5) – red wines ("clearly perceptible") and 4.9 for Veltlýnské zelené and Müller Thurgau – white wine ("moderating effect").

Keywords: wine; analysis of wine; polyphenols; anthocyanins; spectrometry; CIELab

INTRODUCTION

Wine is one of the most drinking alcoholic beverages in the world with a benefitial influence both to the human health as well as to the countryside landscape architecture of the places of its production.

There are recognised six wine growing regions in Slovak Republic with about forty turfs regions, which are further divided into individual winery villages. According to the criteria of the European legislation Slovak vineyards are classified in Zone B, within which individual municipality's areas ascribed to the B1, B2 and B3 categories. Category B1 represents the areas with the best lodges and microclimate conditions of the cultivation of grapes. To B2 category includes vineyards lying in a climate less warm regions. In both categories turfs are lying mostly on the mountines slopes. B3 type wine yards lie in areas of less appropriate sun exposure and microclimate. These vineyards are located mainly in the plains areas, where they are harmed by cold winters and spring frosts. Within main six winery regions of Slovakia which include the winery regions of Limbach, Južnoslovenská, Stredoslovenská, Nitrianska, and Východoslovenská and region Tokaj **(Hronský, 2001; Stevenson, 2011)**.

The antioxidation activity is one of the most valuable properties of wine. It is assumed, that the phenolic content in wines is the most probably responsible for its antioxidant activity **(Staško et al., 2008)**.

The polyphenolic composition of the wine depends on the grape variety, vineyard location, cultivation system, climate, soil types, vine cultivation practices, harvesting time, production process (pressing, winemaking method, skin-contact maceration period, etc.) and aging. These compounds are grouped into several families according to their chemical structure: hydroxycinnamic acids, hydroxybenzoic acids, flavanols, flavonols, etc. **(Rodríguez-Delgado, González-Hernández, Conde-González, & Pérez-Trujillo, 2002)**. Phenolic compounds, which are responsible for the colour of wines are transferred from the skin and seeds of grapes and diffused into the must and wine during the maceration stage. The bright red colour of young wines is mainly due to free anthocyanins, self-association, and the copigmentation of anthocyanins with other phenols present in these wines such as flavanols, flavonols and hydroxycinnamic acids. Colour is one of the main parameters of the quality of wines, especially for red ones. The colour provides information about defects, the type, and the conservation of wines during storage. It has an important influence also on the overall acceptability by consumers. In majority of wineries, the routine analysis of the colour of wines is rutinelly performed to control and evaluate the wine quality. The CIELab method is one of the most widely used and has been applied by several authors to determine the chromatic characteristics of different wines and to study their evolution **(OIV, 1990; (Pérez-Magariño & González-Sanjosé, 2003a)**. Tristimulus colorimetry, through calculation of the ΔE^*_{ab} parameter (difference in colour), among others, allows the interpretation of copigmentation at the visual level **(García-Marino, Escudero-Gilete, Heredia, Escribano-Bailón, & Rivas-Gonzalo, 2013; Trouillas, 2016)**.

The aim of this study is to evaluate variety of wines from different Slovak regions by selected physico-chemical and analytical methods.

MATERIAL AND METHODS

Sites characteristics

Malokarpatská (Lesser Carpathian) winery region

Lesser Carpathian wineyards are extended in the fields in coherent tracts on the slopes of the Little Carpathians from Bratislava towards Pezinok and further to the Horné Orešany. A region with the largest area of vineyards made from 12 wine-growing areas with land of 120 wine-growing villages. Altitude vineyard is ranging between 145 to 260 meters above sea level. Atmospheric rainfall for the year reaches 670 millimeters, and the average air temperature in the vegetation period is approximately about 16.8 °C. Soils are framed, soft and weaker retain water.

Južnoslovenská (Southern Slovak) winery region

South Slovak area represents a predominantly lowland plains with an average altitude of 140 m above sea level. The area is divided into 8-growing sub-regions and 114 winery villages. This region is the hottest winery region of Slovakia. Rainfall do not exceed 325 mm and the highest average air temperatures reaches 16.9 °C, thereby enabling to produce fine wines with the expression.

Nitranská winery region

This region is stretches over the southern, south-west and south-eastern slopes of the mountains of Tríbeč. The zone consists of nine winery sub-regions (159 winery villages) that start at the watershed scale. Mean rainfall is 333 mm and the average altitude 150 m above sea level, soils are medium-heavy and well-dependent.

Stredoslovenská winery region

In this area, the 7-growing sub-regions and 107 winery villages are located. Region is not coherent, it forms a rather different winery tracts, which extends on the southern slopes of Krupinska hills. The average air temperature is an about 16.2°C, and the precipitation of approximately 362 mm. Soils are nutritious and moderately heavy.

Východoslovenská winery region

Eastern Slovak winery areas are formed from four winery sub-regions and 89 winery villages, which are located on moderate slopes of mountains Vihorlat edge in Eastern Slovak lowland. The area is geologically diverse, and the climate is warm and moderately humid, with dry sites with colder winters. Average rainfall in this area is 373 mm. The temperature is on average around 16.6 °C.

Winery region Tokaj

Tokaj region is the smallest winery area of Slovakia, with an area of about 900 hectares. The area lies at the southern and often steep slopes in the southeastern part of Zemplín hills. For this area there are typical warm and slightly dry summers, having an average air temperature through vegetation about 16.8 °C and 336 mm rainfall. The soil is rocky gravel up and sandy with a higher content skeleton **(Hronský, 2001)**.

Experimental wine varieties characteristic

Ryzlik rýnský (Riesling)

It is originally a German variety, grown mainly in the northern winery regions. These include the highest-quality varieties of wine, characterized by a linden bouquet. Riesling cloth collecting reaches ripeness in the second decade of October, when favorable weather and a later harvest achieves outstanding quality. Wine of this variety is high quality of aromatic acids with harmony and with typical varieties characters. Synonym: Riesling, Hocheimer, White Riesling.

Ryzlik vlašský (Riesling Italico)

Tassel of this variety is smaller with a characteristic side-tagged shape. It requires a longer growing season and is resistant to winter and the spring frost. A harvest ripeness achieved also in the second decade of October. It is a most reliable variety, which has musts with a sugar content of 15° NM can be prepared in very high quality wines, which are characterized by slightly increased acidity, often with subtle varieties bouquet and odor resembling bitter almonds. Synonyms: Vlasak, Riesling Italico, Welschriesling, Graševina and other.

Sauvignon

Sauvignon ripening in early October. The wine is characterized by a spicy flavor and an intense aroma of black blackcurrant, stinging nettle or peaches, which is influenced by soil conditions and year. Synonyms: Sauvignon Blanc, Fumé Blanc, Punechon and other.

Müller Thurgau

Müller Thurgau is more fertile than Riesling and was created by crossing Riesling and Silvaner varieties in Switzerland. Wines of this variety are finely aromatic with low acid content and exhibit flowery bouquet with quality fruity character. Harvest ripeness is reached at the end of September. It requires a soil rich in nutrients and humidity with higher calcium content. For these wines, it is recommended its earlier consumption, because the longer maturing bouquet with expressiveness and quality decreases. Synonyms: Mueller Thurgau, Rivaner, Riesling Sylvaner.

Veltlínské zelené (Green veltliener)

Green Veltliener is the second most widely produced variety in Slovakia. Matures in mid-October at a sufficient ripeness it gives a very gentle, pleasant wine with an intense bouquet. The taste is depending on the soil and position. It shall enter character linden honey, bitter almonds or spices. Synonyms: Gruner Veltliner, Muskateller.

Frankovka modrá (Lemberger)

Lemberger ripening in the second decade of October. Well it's doing on moderate slopes with a south exposure. It is characterized by ruby red color, delicate flavor and cinnamon typical astringents taste, with fullness and balanced acidity. It is recommended to be picked up at the latest available time, because of a higher bouquet character of the wine. Synonyms: Limberger, Lemberger, Blaufränkisch, Starosvětské.

Svätovavrinecké (St. Laurent)

This is a variety typical for northern winery regions. A harvest ripeness is reached at the end of September, it is easy to land at any location and it prefers colder climate. It belongs to varieties which give a typical red wine with intense color, pleasant bitterness and a high content of tannins. By maturation and aging their character is softening and wines ecome softer and harmonic. Synonyms: Saint Laurent, Laurenztraube.

Zweigeltrebe

It is widely grown variety that cloth collecting ripeness is reached in early October, provides wines rich of dyes having a violet shade and often is this variety applied in the production of rose wines of fine fruity taste. Synonyms: Zweigelt, Rotburger.

Dornfelder

Dornfelder is one of the major German red varieties. This variety is resistant to diseases and rot, matures relatively early and achieves a greater production of wines with rich color, better taste and tannins. Variety Dornfelder is registered in Czech Republic since 2004. However, it is not yet registered in Slovak Republic.

Chemicals

Gallic acid, Folin-Ciocalteau reagent, Tartaric acid were purchased from Sigma Aldrich (USA).

Methods

UV-VIS spectrophotometric measurements were realiazed on UV/VIS - SERIE CE 1000 CECIL (Germany) and Chroma characteristic on HunterLab UltraScan PRO (USA). For potenciometric titration there was used pH meter Mettler Toledo (Switzerland).

Analytical methods

Analytical methods are essential tools for wine quality control and authentication. The "chromatic characteristics" of a wine are its luminosity and chromaticity. Luminosity depends on transmittance and varies inversely with the intensity of colour of the wine. Chromaticity depends on dominant wavelength (distinguishing the shade) and purity.

Conventionally, for the sake of convenience, the chromatic characteristics of red and rosé wines are described by the intensity of colour and shade, in keeping with the procedure adopted as the working method. Clarity (L* – lightness), red/green colour component (a*), and blue/yellow colour component (b*); and by its derived magnitudes: chroma, saturation (C*), hue angle (h_{ab}*) and chromacity [(a*, b*) or (C*, h_{ab}*)]. In other words, this CIELab colour or space system is based on a sequential or continuous Cartesian representation of 3 orthogonal axes: L*, a* and b* Coordinate L* represents clarity (L* = 0 black and L* = 100 colourless), a* green/red colour component (a* >0 red, a* <0 green) and b* blue/yellow colour component (b* >0 yellow, b* <0 blue) **(OIV, 1990; Zmeškal et. al., 2002)**.

$$C*_{ab} = \sqrt{(a*)^2 + (b*)^2} \quad (1)$$

$$h_{ab}* = \tan^{-1}(b*/a*) \quad (2)$$

Color differences between two wines (ΔE_{ab}*) can be calculated by equation (3):

Table 1 Studied samples of red wine.

Wine	Labelling	Production year	Type	Locality
Dornfelder	DR	2013	quality	Južnoslovenská
Frankovka modrá	FR	2013	late harvest	Malokarpatská
Svätovavrinecké	SV	2013	late harvest	Malokarpatská

Table 2 Studied samples of rose wine.

Wine	Labelling	Production year	Type	Locality
Svätovavrinecké	SVR	2013	late harvest	Malokarpatská
Zweigeltrebe	ZW	2013	late harvest	Južnoslovenská

Table 3 Studied samples of white wine.

Wine	Labelling	Production year	Type	locality
Müller Thurgau	MT	2013	late harvest	Malokarpatská
Veltlínske zelené	VZ	2013	grape selection	Malokarpatská
Rizling Rýnsky	RR	2013	late harvest	Malokarpatská
Rizling Vlašský	RV	2013	grape selection	Malokarpatská
Sauvignon	SG	2012	berries selection	Malokarpatská

$$\Delta E_{ab}* = [(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2]^{1/2} \quad (3)$$

The Chroma and hue values were determined by the procedure reported by **(Wang et al., 2015)**. After adjusted the pH of the tested samples to 3.6, the samples were filtered through a 0.45 mm membrane, and then, used deionized water as the blank control, the absorbance values at wavelengths of 420 nm, 520 nm and 620 nm were measured in triplicate by a UV-VIS Cecil spectrophotometer.

The Chroma value was the sum of the absorbance values at 620 nm, 520 nm and 420 nm, and the hue value was the ratio of the absorbance values at 420 nm and 520 nm.

$$I_{10\,mm} = A_{420} + A_{520} + A_{620} \quad (4)$$

The shade O is conventionally given by eq. (5):

$$O = A_{420}/A_{520} \quad (5)$$

The total anthocyanins content (TAC) was estimated by spectrophotometric measurements **(Hosu, Cristea and Cimpoiu, 2014)**.

One sample 1 mL wine and 49 mL 1 mol.L^{-1} HCl was stirred and after 60 min was measured in 10 mm cuvette at wavelength 520 nm, second sample 1.3 mL wine and fresh 20% bisulfide potassium ($K_2S_2O_5$) aqueous solution was measured after 1 minute at 520 nm. Sample absorbance was determined at 520 nm by a blank solution. The differences between the absorbance values of sample prepared without potassium bisulfide and the absorbance value of sample prepared with potassium bisulfide were calculated. The anthocyanin content was express in mg.L^{-1} of wine and was calculated by eq. (6):

$$x = 20 * [50 * A_{520}\,(HCl) - 5/3 * A_{520}\,(SO_2)] \quad (6)$$

where x is content of anthocyanin in mg.L^{-1} and A_{520} is absorbance at 520 nm **(Balík 2010)**.

The total phenolic content (TPC) was determined according to the Folin-Ciocalteu colorimetric method **(Folin & Ciocalteu, 1927; Staško et al., 2008; Bajčan et al. 2016)**. Absorbance was measured at 760 nm. Results were expressed as mg.L^{-1} Gallic acid equivalents (GAE). Gallic acid standard solutions were prepared at a concentration ranging from 0 to 1000 mg.L^{-1} **(Sun et al., 2017)**. For this assay, 1.0 mL of Folin–Ciocalteu reagent (0.2 mol.L^{-1}) was added to1.0 mL of wine appropriately diluted with distilled water to ensure the absorbance was in the range of 0.20 – 0.80. The reaction was allowed to react for 5 minutes and then, 5 mL of 20% solution of Na_2CO_3 was added. Samples were incubated at the room temperature in dark place for 120 min, and the absorbance was measured at 760 nm. All measurements were performed in triplicate. A standard curve was obtained using 0 – 1000 mg Gallic acid.L^{-1} and was used to calculate the total phenolic content of wines. Gallic acid (mg GAE.L^{-1}) was used because it is a more stable and pharmacologically active antioxidant, quantitatively equivalent to most phenolic and gives consistent and reproducible results **(Wu et al., 2016)**.

The total acidity of the wine is the sum of its titratable acidities when it is titrated to pH 7 against a standard alkaline solution 0.1 M NaOH with the potentiometric detection of the end point. Carbon dioxide is not included in the total acidity. The total acidity expressed in grams of tartaric acid per litter and is given by eq. (7):

$$x = a * f * 0,75 \quad (7)$$

where x is total tartaric acid in g.L^{-1}, a is assumption of 0.1 M NaOH to pH 7, f is a factor of 0.1 M NaOH **(OIV, 1990)**.

All measurements were done at least in two replicates, each measurement was repeated at least 5×. Data were analysed using one way analysis of variance (ANOVA) method (Microsoft Excel, USA). These analysis allowed to detect the significance of the effect of fat content addition as well as of type of the fat used on contact angles of wetting results. For all tested samples combinations the observed differences were of high statistical significance ($p \leq 0.05$).

RESULTS AND DISCUSSION

The highest content of total polyphenolic compounds as gallic acid was determined for Saint Laurent red wine, vintage 2013 Late Harvest, where the concentration of polyphenols was 2832.78 mg.L^{-1}. The somewhat lower concentration was determined for wine Lemberger blue

Table 4 Results of tested wines analytical measurements.

Labelling	TPC (GAE) (mg.L^{-1})	TAC (mg.L^{-1})	Total acidity (g.L^{-1})	Density (g.cm^{-3})	$I_{10\,mm}$	O
DR	1960.56 ±22.23	176 ±5	6.5 ±0.1	0.9915	8.291	0.74
FR	2557.78 ±38.25	183 ±8	6.0 ±0.2	0.9907	8.323	0.73
SV	2832.78 ±35.33	114 ±4	6.2 ±0.1	0.9934	8.003	0.80
SVR	1013.33 ±15.28	19 ±1	8.0 ±0.2	0.9928	0.544	1.13
ZW	1016.11 ±24.56	43 ±2	6.7 ±0.1	0.9929	0.801	1.06
MT	549.44 ±10.96		6.0 ±0.1	0.9887		
VZ	732.78 ±13.54		6.0 ±0.1	0.9898		
RR	1085.56 ±16.73		8.2 ±0.2	0.9994		
RV	577.22 ±8.15		7.0 ±0.2	0.9882		
SG	952.22 ±10. 57		6.3 ±0,1	1.0111		

Note: Results expressed as the mean value ±standard deviation (n = 3). Significant differences (Anova, p <0.05) between samples.

(2013, late harvest) and 2557.78 mg.L^{-1}. Conversely, the lowest concentration, 549.44 mg.L^{-1} showed a sample of white wine Müller Thurgau (2013) in the Table 4. However, even this amount is still higher than reported **(Jackson, 2008)**, where the concentration of total polyphenols in red wines were ranging between 955 – 1300 mg.L^{-1} and in white wines were ranging from 190 to 290 mg.L^{-1}. This concentration is similar to that of found by us for set rosé (SVR and ZW), but significantly lower than that of red wines monitored within this study (DR, FR and SV). Obtaind results are comparable with data reported by **(Balík 2010)**, where the ranges of polyphenols content in Moravian wines were ranged between 1580 – 1912 mg.L^{-1} for wine Dornfelder, 1334 – 1756 mg.L^{-1} in Lemberger blue (Frankovka) and 1455 to 2512 mg.L^{-1} at St. Laurent. These results were similar, as observed in another study, of red wines originating from different regions of Macedonia. In this study, the authors disclosed the resulting value in the range of 1394 to 3097 mg.L^{-1} **(Ivanova-Petropulos et al., 2015)** and the contents of polyphenols ranging between 1585 – 4203 mg.L^{-1} for red wines was reported in another study originating from the city of Mendoza in western Argentina **(Fanzone et al., 2012)** for Cabernet Sauvignon from Slovak was values 1838 to 2636 mg.L^{-1} **(Bajčan et al. 2016)**.

The total content of anthocyanins (TAC) in red and rosé wines were obtained by fitting the measured absorbance values of wine with the addition $K_2S_2O_5$ and wines with the addition of HCl into the equation (6). Measured values of the content of anthocyanins given in mg.L^{-1}, are shown in Table 4. The highest content of anthocyanins, was found in samples of red wine Lemberger blue, where the total content of 183 mg.L^{-1} antocyanins was found. The lowest content found was 19 mg.L^{-1} for the sample rose wine St. Laurent. Similar values were measured by **(Fanzone et al., 2012)**, which together with colleagues measured for red wines originated from the city of Mendoza (Argentina), ranged from 177.6 to 587.2 mg.L^{-1}of total anthocyanins. Measured values of anthocyanins were significantly lower, because the content of anthocyanin was lower with aging. Anthocyanin concentration decrease due to the reaction with other phenols, enzymatic reactions by the production of quinoas via coupled oxidation reactions and/or condensation between quinines and/or non-enzymatic reactions by production of polymers from anthocyanin monomers **(Figueiredo-González et al., 2014)**.

In the case of rose wines and for wine St. Laurent 50 mg.L^{-1}of anthocyanins was found and for Zweigeltrebe of 64 mg.L^{-1}. Observed results in this study were lower in comparison to the results of 321 – 941 mg.L^{-1} found in the study **(Ivanova-Petropulos et al., 2015; Balík 2010)**.

Titration acidity was expressed as the amount of tartaric acid was for each wine under study ranging from 6.0 to 8.2 g.L^{-1}. The highest titratable acidity was found for the

Table 5 Measured L* a* b*, saturation (C*) and hue angel (H*) for variety of origin wines under study.

Labelling	*L**	*a**	*b**	*C**	h_{ab}*
DR	15.42	45.46	25.58	52.16	29.36
FR	16.53	46.50	27.26	53.89	30.38
SV	15.16	45.66	25.29	52.19	28.98
SVR	85.64	11.82	10.61	15.88	41.91
ZW	81.50	17.55	15.17	23.20	40.84
MT	95.67	-0.69	4.25	4.30	-80.77
VZ	94.28	-0.77	8.93	8.96	-85.07
RR	95.06	-1.22	8.07	8.16	-81.40
RV	95.84	-0.88	4.08	4.17	-77.83
SG	95.13	-0.92	6.42	6.48	-81.84

Table 6 Color differences of red and rose wines (ΔE*) between the samples of red wines (red colour), rose wines (pink colour) and the differences between red and rose wines (pink colour).

Labelling	DR	FR	SV	SVR	ZW
DR	-				
FR	2.3	-			
SV	0.4	2.5	-		
SVR	79.3	79.1	79.5	-	
ZW	72.5	72.1	72.8	8.4	-

Table 7 Colour differences of white and rose wines (ΔE*) between the samples of white wines (yellow colour), rose wines (pink colour) and the differences between white and rose wines (pink colour).

Labelling	MT	VZ	RR	RV	SG	SVR	ZW
MT	-						
VZ	4.9	-					
RR	3.9	1.2	-				
RV	0.3	5.1	4.1	-			
SG	2.2	2.7	1.7	2.4	-		
SVR	17.2	15.4	16.3	17.5	16.4	-	
ZW	25.5	23.2	24.2	25.9	24.6	8.4	-

sample of white wine Ryzlik rýnský (production year 2013, Late harvest) and rose St. Laurent. For wine St. Laurent red and rose, which was originated from the same grapes from the same winemaker, we can see the difference in titratable acidity. This difference is the production technology applied, where for St. Laurent red there was produced malic-lactic fermentation resulting in decreased acidity. The final concentration of titratable acidity measured for red wines within this work were similar to the results published in study of Ivanova-Petropulos et al. **(Ivanova-Petropulos et al., 2015)**. They found titratable acidity of 5.5 to 7.9 $g.L^{-1}$. Also reported by authors **(Fanzone et al., 2012)**, there were obtained similar results ranging between 4.4 to 6.8 $g.L^{-1}$ titratable acidity for studied red wine.

Color intensity *I* and hue *O* of red wine were obtained by calculation from the measure absorbance at the wavelengths of 420, 520 and 620 nm, according to equations (4) to (5) and results are shown in Table 4.

The brightest sample of studied red wines, with a value of L* = 16.53% was Lemberger blue. Overall the red wine of clarity did not significantly differ. The color of red wines is relative to the CIELab diagram, and it is located within a dark red and blue regions. For rosé wines the higher brightness was found for wine St. Laurent (L* = 85.64%) and sample Zweigeltrebe had a more intense colour to orange and pink (Table 5).

The brightest of white wines tested was Rizling Walnut (L* = 95.84 %). The color of all the white wines was in the colour space green and yellow. For comparison we included the value of color parameters from work package, where was in the evaluation of red wines, the brightness value L* ranged between 1.51 to 15.16%, coordinates a* = 19 to 52.31 and the coordinates b* = 2.61 to 25.33 for wine Dornfelder. For wine Lemberger blue represents values: L* = 15.40% to 23.94%; a* = 53.68 to 60.96; b* = 25.68 to 38.32 and for the wine St. Laurent: L* = 2.73 to 18.16%; a* = 29.88 to 55.73; b* = 4.58 to 28.16. Obtained values were not differing significantly each other. In Table 6 are shown the total color differences between the different wines (ΔE*) as calculated according to equation (3).

Table 6 shows that the lowest color difference 0.4 was found between the samples of wine St. Laurent red wine and Dornfelder. The differences were "very weak" **(Zmeškal, Čeppan and Dzik, 2002)**. In general, the eye is able to discriminate two colours when ΔE* ≥1 **(Gonnet, 2001)**. Between samples Dornfelder and Lemberger blue (2.3) and also St. Laurent red wine and Lemberger (2.5) submission was already a "clearly perceptible" differences. Between the samples of pink and red wines were very high differences which we designated as "disturbing". Of interest was "significant" difference observed between rose wine samples, St. Laurent rose and Zweigeltrebe (8.4). Average colour differences between two red wines was found to be 1.7. These results are similar to those obtained by other authors **(Pérez-Magariño and González-Sanjosé, 2003b)**.

The colour difference observed for tested white wines was about 0.3 (Müller Thurgau and Riesling). Among these samples, the difference was "very weak". "Weak" contrast dyes were compared with samples of Grüner Veltliner and Riesling (1.2). Additionaly, Sauvignon and the other four samples of white wine, were "clearly perceptible" difference. "Medium" color difference was observed between the samples of wine Green Veltliner - Riesling walnut (5.1) and VZ – Müller Thurgau (4.9). Similarly, it was also in detecting the colour difference Riesling – Müller Thurgau (3.9) and RR – Rizling walnut (4.1). The differences between the white and rosé wine samples were as in the previous case, the high (interference), but significantly lower as compared with red rose wines.

CONCLUSIONS

There were measured basic physico-chemical and colour characteristics of the variety of wines produced in Slovak Republic in this study. It was found, that the quality of wines is a complex property of several physico-chemical properties in their mutual synergistic combination. That is why, individual factors affected by the human physiological perception sensitivity are determining overall wine quality perception. There was found, that the interpretation of the components of ΔE*ab – lightness, chroma, and especially hue differences, as the expression of qualitative observable change is very important for determination of wine quality.

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