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Physico-Chemical Analysis of Rosé Wines From Different Hungarian Wine Regions

Keywords: rosé wine; wine region; wine analysis; physico-chemical analysis

1. Summary

The aim of this research was to analyse the physico-chemical composition, nutritional impact, and health risk assessment of rosé wines originating from the Balatonboglár, Eger, and Villány wine regions of Hungary. The methods applied included potentiometric analysis for pH determination, UV/VIS spectrometry for total phenolic content (TPC) and flavonoid content (FC). Generally, Balatonboglár wines obtained the highest pH, TPC, and FC. Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) was used to determine the concentration of 12 elements (Ca, K, Mg, P, S, Al, B, Cu, Fe, Mn, Sr, Zn). Balatonboglár wines had the highest concentrations for K, Mg, Al, Mn, and Sr. Higher levels of Ca and B were measured in Eger wines, while Villány wines showed higher concentrations of P, S, Cu, Fe, and Zn. The same trend was observed in the case of the Nutrient Reference Value (NRV) contributions, as the element concentrations were considered. The risk assessment indicated that all wines posed no significant health risks.

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2. Introduction

A considerable rise in the consumption of rosé wines has been observed over the past 20 years (Leborgne et al., 2022). The production of rosé wines involves a shorter maceration duration of the grape solids in contrast to the traditional red winemaking method, resulting in a blush colour and fruity and floral features (Wang et al., 2016). However, in some cases, the grape juice appears significantly darker even without maceration of the grapes due to the extended warm periods in recent years.

The chemical substances present in the raw materials and acquired during the winemaking process significantly determine the sensory characteristics and quality of wines (Wang et al., 2016). Therefore, sensory and chemical evaluations are performed to analyse wine quality (Merkytė et al., 2020).

Hungary has an extensive wine production, featuring different types of wine manufactured across numerous wine regions (Varga et al., 2023). In 2023, the total wine production in Hungary was 2.9 million hectolitres, with the top producing wine regions including Kunság, Eger, Mátra, Tokaj, Villány, and Szekszárd (Hegyközségek Nemzeti Tanácsa, 2023).

Several studies confirmed grapes cultivated from the same vineyard possess comparable properties, even when different grape varieties or storage times are applied. Environmental pollution, agricultural techniques, climate change, grape variety, local conditions, and winemaking practices are among the factors that can modify the wine's elemental content (Gajek et al., 2021).

The objective of this study is to examine the physico-chemical characteristics of rosé wines produced in various wine regions across Hungary, namely Balatonboglár, Eger, and Villány. The study involves evaluating parameters in rosé wines, such as pH, total phenolic content, flavonoid content, elemental content, and their contribution to the nutrient reference values. Additionally, a risk assessment was conducted to evaluate potential risks to human health associated with the concentration of elements in the wine samples.

3. Materials and methods

3.1 Materials

Twelve rosé wines were obtained from local stores in the city of Debrecen, with four samples originating from each of the Hungarian wine regions: Balatonboglár, Eger, and Villány. **Table 1** presents some characteristics of the rosé wines.

Table 1: Characteristics of the rosé wine samples

Sample No.	Place of Origin	Type
B1	Balatonboglár	Dry
B2	Balatonboglár	Dry
B3	Balatonboglár	Dry
B4	Balatonboglár	Semi-sweet
E1	Eger	Dry
E2	Eger	Dry
E3	Eger	Dry
E4	Eger	Semi-dry
V1	Villány	Dry
V2	Villány	Dry
V3	Villány	Dry
V4	Villány	Dry

3.2 Determination of pH

The pH meter (FiveEasyTM FE20, Mettler-Toledo AG, Switzerland) was first calibrated using solutions with predetermined pH values (4 and 7). The pH electrode was immersed into a 40 mL wine sample in a test tube, and the pH values of the samples were measured.

3.3 Determination of total phenolic content (TPC)

The TPC of the wine samples was measured using the Folin-Ciocalteu method (Singleton et al., 1999). For the sample preparation, 1.0 mL of the sample was extracted and mixed with methanol:distilled water (MeOH:DW) solution (80:20 ratio) (Sigma-Aldrich Chemie GmbH, Steinheim, Germany), and then filtered (Grade 292;

Ahlstrom Munksjö, Helsinki, Finland). Folin-Ciocalteu reagent (VWR International, S.A.S., France) and sodium carbonate (Scharlab, S.L., Spain) were added and the solution was stored in a dark place for 2 hours. Gallic acid stock solution (Alfa Aesar GmbH & Co. KG, Karlsruhe, Germany) was used for the preparation of calibration standard solutions.

The TPC was determined using a UV-VIS spectrophotometer (Evolution 300 LC, Thermo Electron Corporation, England) at a wavelength of 760 nm. The results were presented as milligrams of gallic acid equivalent per 100 ml of sample (mg GAE 100 mL^{-1}).

3.4 Determination of flavonoid content (FC)

For the sample preparation, 1.0 mL of the sample was mixed with MeOH:DW solution (80:20 ratio) (Sigma-Aldrich Chemie GmbH, Steinheim, Germany), and then filtered (Grade 292; Ahlstrom Munksjö, Helsinki, Finland). Distilled water, 5% sodium nitrite (Scharlab, S.L., Spain), 10% aluminium chloride (VWR International, S.A.S., France), and sodium hydroxide (Sigma-Aldrich Chemie GmbH, Steinheim, Germany) reagents were added. Calibration standard solutions were prepared using catechin stock solution (VWR International, S.A.S., France) (Kim et al., 2003).

The FC was measured using a UV-VIS spectrophotometer (Evolution 300 LC, Thermo Electron Corporation, England) at a wavelength of 510 nm. The results were presented as milligrams of catechin equivalent per 100 mL of sample (mg CE 100 mL^{-1}).

3.5 Determination of element content

To analyse the element content of the samples, a wet digestion procedure was conducted using nitric acid and hydrogen peroxide, both purchased from VWR International Ltd. (USA). Ultrapure water (Synergy UV Water Purification System, Millipore, S.A.S., France) was used for dilution, and qualitative filter paper (Grade 388; Ahlstrom Munksjö, Helsinki, Finland) was used for filtration (Kovács et al., 1996). The determination was performed using ICP-OES (iCAP 6300, Thermo Scientific, Cambridge, UK). The elements analysed were Ca, K, Mg, P, S, Al, B, Cu, Fe, Mn, Sr, and Zn. The monitored wavelengths are shown in **Table 2**. The limit of detection (LoD) for each element was set at 100 µg L^{-1}.

Table 2: Applied wavelengths

Elements	Wavelengths [nm]	Elements	Wavelengths [nm]
Ca	317.933	B	249.772
K	766.490	Cu	324.752
Mg	279.077	Fe	238.204
P	213.617	Mn	257.610
S	182.563	Sr	460.733
Al	396.153	Zn	213.857

3.6 Risk Assessment

The risk value was calculated using Eq. (1):

$$Risk\ value = \frac{PTDI\ or\ RfD \times body\ weight}{C \times V}$$

where: PTDI or RfD is the provisional tolerable daily intake or reference dose (mg $kgbw^{-1}$) (**Table 3**); body weights are 30 kg, 60 kg, and 90 kg (kgbw); C is the element concentration (mg L^{-1}); and V is the average consumption (0.2 L).

Table 3: Tolerable daily intakes (mg $kgbw^{-1}$) for examined elements

Elements	Tolerable intake or reference dose [mg $kgbw^{-1}$]	Literature
Aluminium	PTDI = 0.29	WHO, 2011
Iron	PTDI = 0.8	WHO, 1983
Boron	RfD = 0.2	IRIS, 2024a
Copper	RfD = 0.5	IRIS, 2024b
Manganese	RfD = 0.14	IRIS, 2024c
Strontium	RfD = 0.6	IRIS, 2024d
Zinc	RfD = 0.3	IRIS, 2024e

If the calculated risk value is less than 1, the consumption of the wine (200 mL) poses a significant risk to human health.

3.7 Contribution to nutrient reference value (NRV)

The calculation of contributions to the NRVs was performed using Eq. (2):

$$Contribution\ (\%) = \frac{C \times V \times 100}{NRV}$$

where: C is the element concentration (mg L^{-1}); V is the average consumption (0.2 L); and NRVs are the following: 2000 mg for K; 800 mg for Ca; 700 mg for P; 375 mg for Mg; 14 mg for Fe; 10 mg for Zn; 1 mg for Cu; and 2 mg for Mn (Regulation 1169/2011/EU).

4. Results and evaluation

4.1 Physico-chemical composition

The pH values of the wine samples are summarised in Table 4. Tartaric acid, one of the acids found in wines, essentially impacts the wine's pH and organoleptic characteristics (Tôrres et al., 2011). The highest and lowest pH values were measured in E3 and E1, respectively. The results align with the research conducted by other authors (Leborgne et al., 2022; Gajek et al., 2021).

Table 4: pH values of the analysed rosé wines (mean ± standard deviation).

Sample No.	pH
B1	3.22 ± 0.01
B2	3.24 ± 0.01
B3	3.10 ± 0.01
B4	3.25 ± 0.00
E1	2.94 ± 0.01
E2	3.10 ± 0.01
E3	3.29 ± 0.00
E4	3.06 ± 0.00
V1	3.21 ± 0.00
V2	3.23 ± 0.01
V3	3.19 ± 0.01
V4	3.04 ± 0.01

Figure 1 shows the TPC of the wine samples. Wine and grape juices have the ability to protect against oxidation due to the presence of polyphenolic compounds (Pasvanka et al., 2019). Only five samples (B1, B2, B4, E2, E3) align with the results cited in other literature (Baron et al., 2017). Generally, our results were higher than those reported in the study of wines from Romanian grape cultivars (Banc et al., 2020).

The FC of the wine samples are shown in **Figure 2**. Lower results compared to our wine samples were noted in other studies (Leborgne et al., 2022; Banc et al., 2020; Baron et al., 2017). Moreover, the B3, E4, and V2 samples contained both the highest TPC and FC within their respective regions.

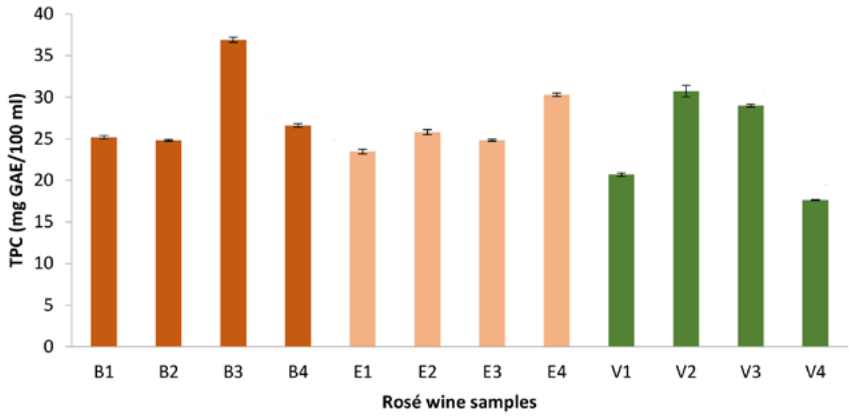

Figure 1. Total phenolic contents of the analysed rosé wines.
Error bars represent the standard deviations.

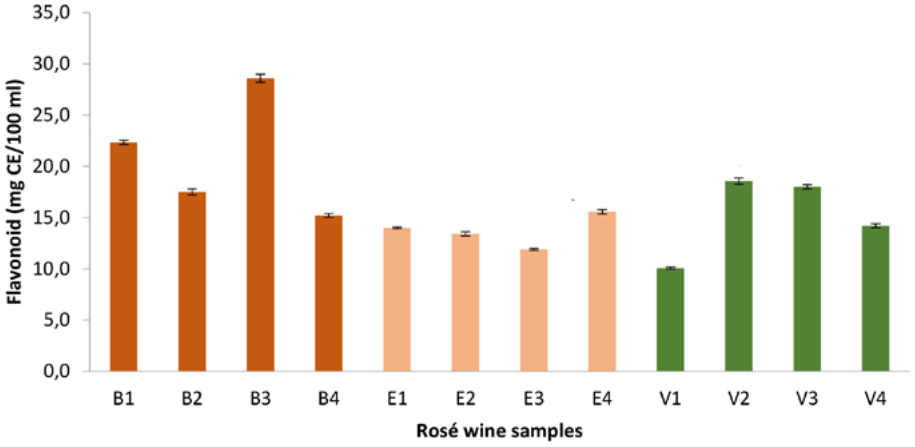

Figure 2. Flavonoid contents of the analysed rosé wines.

Error bars represent the standard deviations.

4.2 Element content and contribution to NRV

The origin of wine can be traced from its mineral composition, as the mineral elements present in the soil are taken up by the vine roots and subsequently stored within the grape skins, seeds, and cellular walls. As the grapes are processed, these minerals are transferred into the wine (Norocel and Gutt, 2017). Regular and moderate consumption of wines can provide key minerals such as K, Ca, Mg, Fe, Cu, Mn, and Zn, yet excessive intake may pose health risks (Sass-Kiss et al., 2008). Additionally, elements including Ca, K, Mg, and Na aid in regulating yeast cellular metabolism, ensuring optimal pH levels and ionic balance, while minor elements such as Cu, Fe, Mn, and Zn, along with certain trace elements, contribute significantly to yeast activity (Rossi et al., 2022).

Table 5 shows the concentrations of the macro elements in the wine samples. Potassium was the most abundant element present in the samples. Our results for Ca, S, and P align with other authors' (Gajek et al., 2021; Ivanova-Petropulos et al., 2013). Higher and lower concentrations of Mg and K, respectively, were also noted (Gajek et al., 2021) compared to those in our samples. The V2 sample obtained the highest concentrations for Ca, K, P, and S, whereas the V4 sample had the lowest concentrations for Ca, Mg, P, and S. The highest Mg concentration was measured in the B4 sample.

Table 5: Concentrations (mg L^{-1}) of the macro elements in the analysed rosé wines

Wine origin	Statistics	Ca	K	Mg	P	S
Balatonboglár (n=4)	Mean ± SD	55.8 ± 7.8	553 ± 30	51.1 ± 6.9	96.8 ± 11	156 ± 26
	Range	49.3-64.6	532-596	42.5-57.0	82.5-107	129-191
Eger (n=4)	Mean ± SD	56.2 ± 7.9	420 ± 193	41.0 ± 5.8	103 ± 20	129 ± 16
	Range	46.7-63.3	230-677	36.0-47.6	83.0-129	110-143
Villány (n=4)	Mean ± SD	49.1 ± 22	499 ± 145	32.3 ± 13	134 ± 43	156 ± 95
	Range	22.7-76.1	383-695	13.0-41.9	71.1-169	76.1-293

Table 6 presents the concentrations of the micro elements in the wine samples. Boron was the most abundant micro element, while copper had the lowest concentration. The concentrations of Cu and Mn were in good agreement with other studies (Gajek et al., 2021; Iwegbue, 2014). Lower Al and Zn concentrations and higher B, Fe, and Sr concentrations were reported in other published works (Gajek et al., 2021; Caridi et al., 2019; Papunidze et al., 2019; Ivanova-Petropulos et al., 2013; Perez-Trujillo, 2002).

Table 6: Concentrations (mg L^{-1}) of the micro elements in the analysed rosé wines

Wine origin	Statistics	Al	B	Cu	Fe	Mn	Sr	Zn
Balatonboglár (n=4)	Mean ± SD	3.22 ± 1.00	2.77 ± 0.64	0.177 ± 0.035	1.35 ± 0.48	1.05 ± 0.25	0.383 ± 0.051	0.594 ± 0.14
	Range	2.23-4.61	3.29-1.95	0.145-0.220	0.927-2.03	0.855-1.41	0.310-0.420	0.453-0.767

Wine origin	Statistics	Al	B	Cu	Fe	Mn	Sr	Zn
Eger (n=4)	Mean ± SD	2.67 ± 0.20	3.32 ± 0.30	0.140 ± 0.022	1.21 ± 0.80	0.865 ± 0.25	0.378 ± 0.022	0.572 ± 0.15
	Range	2.96-2.54	2.90-3.59	0.116-0.165	0.637-2.39	0.676-1.23	0.347-0.395	0.432-0.762
Villány (n=4)	Mean ± SD	2.86 ± 0.17	2.87 ± 0.51	0.228 ± 0.192	1.51 ± 0.30	0.636 ± 0.31	0.284 ± 0.090	0.906 ± 0.47
	Range	3.04-2.70	2.38-3.50	0.127-0.515	1.13-1.79	0.292-0.947	0.182-0.399	0.615-1.61

The concentrations of micro elements in the samples varied significantly across wine regions. The B4 sample obtained the highest concentrations for Al, Mn, and Sr. The E4 sample had the highest B and Fe concentrations. The highest concentrations of Cu and Zn were measured in the V3 and V2 samples, respectively. All samples were below the maximum acceptable limit for Zn (5 mg L^{-1}) and Cu (1 mg L^{-1}) (OIV, 2019).

The NRV contributions of the wine samples are summarised in **Table 7**. The order of the NRV contributions is as follows: Mn>K>Cu>P>Mg>Fe>Zn>Ca. The manganese contents of the wine samples provide the highest mean contribution (8.50%) to the NRVs. The consumption of wine significantly contributes to the recommended daily intake of manganese (Pour Nikfardjam et al., 2012). The Balatonboglár region showed the highest contributions to Ca, K, Mn, and Mg intakes, while the highest contributions to daily P, Fe, Zn, and Cu intakes were measured in the Villány region.

Table 7: NRV contributions (%) of the analysed rosé wines

Sample No.	Ca	K	Mg	P	Cu	Fe	Mn	Zn
B1	1.23	5.32	2.27	2.75	3.04	1.76	9.14	1.06
B2	1.23	5.53	3.01	2.36	2.90	1.32	10.2	1.53
B3	1.62	5.96	2.59	2.89	3.81	1.73	8.55	0.91
B4	1.50	5.33	3.04	3.06	4.39	2.90	14.1	1.26
E1	1.58	2.30	2.35	2.37	2.99	1.18	7.58	0.96
E2	1.17	3.29	1.94	2.73	2.31	0.91	6.76	0.86
E3	1.32	6.77	1.92	3.69	3.30	1.43	12.3	1.23
E4	1.55	4.43	2.54	3.03	2.60	3.41	7.99	1.52
V1	1.33	3.83	2.23	4.17	2.59	1.61	8.47	1.41
V2	1.90	6.95	2.12	4.83	2.53	2.55	9.47	3.22
V3	1.11	5.24	1.85	4.24	10.30	2.44	4.60	1.23
V4	0.57	3.96	0.69	2.03	2.80	2.04	2.92	1.38

4.3 Risk Assessment

The calculated risk values for all wine samples were higher than 1. Therefore, the consumption of our samples in an amount of 200 mL is unlikely to present significant health risks and is deemed safe for human consumption. Daily consumption of at least 250 mL of wine over an extended period poses a higher health risk if the wine contains increased metal concentrations or foreign materials. Conversely, moderate consumption can still offer health advantages (Tariba, 2011). The E4 sample had the lowest risk value in terms of boron content; therefore, 1.67 L of this sample would have to be consumed per day by an individual with 30 kg body weight to reach the risk value of 1.

5. Conclusions

Among all rosé wines, Balatonboglár wines have lower acidity and higher total phenolic and flavonoid contents. The element concentrations decrease in the following order: K>S>P>Ca>Mg>B>Al>Fe>Mn>Zn>Sr>Cu. Balatonboglár samples recorded the highest mean K, Mg, S, Al, Mn, and Sr concentrations. The highest Ca and B concentrations were observed in the Eger wines, whereas higher concentrations of P, S, Cu, Fe, and Zn were detected in the Villány wines. These results emphasise the distinctive qualities and individual attributes of the wines originating from the included Hungarian wine regions. All wine samples were deemed safe for human consumption in the quantity considered by the risk assessment. Furthermore, a 200 mL glass of the rosé wines can contribute a considerable amount to the daily intake of manganese and potassium.

Further studies should investigate additional Hungarian wine regions and additional parameters, including alcohol content, pesticide residues, toxic elements, and organoleptic properties, for a more comprehensive assessment of the quality and safety of rosé wines in Hungary.

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