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The comparative analysis of some Hungarian and Moldovan wines: The promise of protected geographical indication

E. Savchina[1]
e-mail: ec.savchina@gmail.com

A.-M. Borta[1]
e-mail: anna.maria.borta@gmail.com

L. Csige[2]
e-mail: csigelaszlo@unideb.hu

Z. Győri[1]
e-mail: gyori.zoltan@unideb.hu

J. Szepesi[1]
e-mail: szepesi@agr.unideb.hu

E. Máthé[1]
e-mail: endre.mathe@agr.unideb.hu

[1] University of Debrecen, Faculty of Agricultural, Food Sciences and Environmental Management, Institute of Nutrition, HU-4032 Debrecen, 138 Böszörményi St, Hungary
[2] University of Debrecen, Wine Academy of Mád, HU-3909, 37–39 Mád St, Hungary

Abstract. Hungary and Moldova are excelling in unique wines and alcoholic beverages that could qualify for the protected geographical indication (PGI) by emphasizing parameters attributable to the geographical area, production or processing methods. In this study, we have assessed some parameters of wine and brandy samples looking for specificities. The studied samples were of Moldovan and Hungarian Cabernet Sauvignon red wines, Hungarian Furmint white wines, and Moldovan wine distillate/brandy called Divin. The assessed samples were evaluated for: total polyphenol and flavonoid, ethanol, malic, citric, lactic, tartaric acids, reducing sugar, glycerol, carbon dioxide, total and free SO_2 content as well as for total acidity, volatile acidity, pH, and wine density.

Our results indicate that despite the relatively close geographical vicinity of Hungary and Moldova, the wines produced in the two countries have specific composition, antioxidant activity, and sensorial properties. Thus, the registration of such wines as PGI is clearly justified, and such a label itself does represent a competitive advantage worth promoting.

Keywords and phrases: wine quality, geographical indications, FTIR spectroscopy, Protected Designations of Origin (PDO)

1. Introduction

Historical features of Moldovan winemaking

Winemaking in the historical Moldavia has a rich past. In ancient times, the Dacians and the Getae, the two Scythian tribes, were engaged in agriculture, livestock husbandry, and winemaking. Around 50 BC, King Burebista issued a decree compelling the Dacians and the Getae to destroy vineyards, give up wine making and consumption. Until the Roman invasion of Dacia (106 AD), the order was in force for nearly 150 years. By introducing new grape types and farming practices and sharing their winemaking technology with the locals, the Romans in this area supported the growth of wine-grapes and wine production.

In the Middle Ages, when Moldavia comprised the entire territory from the Dniester to the Carpathians, the Moldavian princes – Matei Basarab, Negru Vodă, Ştefan cel Mare, and Mihai Viteazul – planted new vineyards, brought new varieties of wine-grapes and experienced workers from the Hungarian Kingdom. After the death of Ştefan cel Mare (1504), Moldavia was partly conquered by the Ottoman Empire, and table varieties of grapes were cultivated in the colonized areas. During the Russo–Turkish war of 1806–1812, the southern wine-producing region of Moldavia was destroyed (*Taran*, 2010).

After the annexation of the eastern side of Moldavia (also called Bessarabia) by the Russian Empire, the viticulture and wine production started to develop intensively in this part of Moldavia. In 1832, the first special school for viticulture and winemaking was established. During the period of 1880–1915, winemaking in Bessarabia entered a period of crisis caused by wine adulteration practices at large scale, which was aggravated by the appearance of phylloxerae in the vineyards (*Taran*, 2010). Following World War I, the eastern part of Moldavia, called Moldavian Democratic Republic, became part of the Soviet Union, while the western part of Moldavia remained an integrated part of Romania.

In the following, we will refer only to the grapes and wines of the eastern part of Moldavia (today called Republic of Moldova), where approx. 54 wineries were built and rebuilt by the 1960s. Due to the technological modernization of the wine enterprises in 1970–1985, new types of high-quality wines were obtained, which made the Soviet Moldova known in the USSR and abroad as an important wine-producing country. The decline of the Soviet Moldovan wine industry began in 1985 with the issuance of Gorbachev's decree on combating alcoholism in the USSR, which led to the destruction of 50% of the wine-grape plantations (*Taran*, 2010).

Nowadays, the wine sector in the Republic of Moldova is of a strategic importance for the entire economy (*Taran*, 2010). Moldova was the first post-Soviet republic to join the International Organization of Vine and Wine as a member state (OIV). The *Law on Vine and Wine* was enacted by the Parliament of the Republic of Moldova in 1994, and it was the first law on this issue in the CIS countries (no such law had existed before either in the USSR or in European winegrowing countries). This law pays particular attention to the process of wine production as well as other wine products with a designation of origin. In 2005, the Republic of Moldova was one of the top-ten wine exporters of the world. In March 2006, the Russian Federation issued a nearly two-year embargo on Moldovan wines, denying Moldovan winemakers from access to the Russian wine market. In September 2013, the same scenario occurred, but this time the consequences were less harmful as the Moldovan companies diversified their export routes to Belarus, Kazakhstan, Ukraine, the EU, and Asia. Due to the severe crises of 2006 and 2011, the Moldovan wine industry focused on the development of high-quality wines, market diversification, and industrial modernization (*Wine of Moldova*, 2021). The establishment of the National Office of Wine (2013) was a significant step forward for the public and private sectors in implementing changes to the wine legislation and the regulatory framework. Driven mostly by marketing considerations, serious efforts were made to generate a country-specific wine brand called *Wine of Moldova. A Legend Alive*, which was further substantiated by applying a strict quality control (*Wine of Moldova*, 2021).

Besides wines, Divin is a Moldovan brandy made of wines. It is produced in accordance with its own specifications and under the supervision of the Association of Authorities and Producers. Divin is obtained by the double distillation of grapes such as Aligote, Chardonnay, Fetească Albă, Rhein Riesling, and Rkatsiteli, while the obtained wine spirit is aged for at least 3 years in oak barrels. The name Divin literally comes from the Romanian phrase "din vin", which means "from wine", and it also has the meaning of divine. Divin stands out by its hue with brownish to amber shades, balanced and soft taste with floral notes, which later develop into fine aromas of chocolate (*ADBPM*, 2012).

Regarding Moldovan grape production, there are four Moldovan grape-growing areas as follows: Valul lui Traian, Ştefan Vodă, Codru, and Divin, all having Moldovan-protected geographical indications (PGI) similar to the European Union type of regulations. The wine areas are defined by the *Law on Wine and Vineyards* of the Republic of Moldova and the Order of *Delimitation of Wine-Growing Geographical Areas for the Production of Wines with a Protected Geographical Indication* issued by the Ministry of Agriculture and Food Industry.

Red grape varieties largely cultivated in the Republic of Moldova are Cabernet Sauvignon, Cabernet Franc, Gammay Freaux, Malbec, Merlot, Pinot Gris, Pinot Noir, Saperavi, and Syrah, while the most relevant white grape varieties are Aligote, Bianca, Chardonnay, Hibernal, Muscat Frontignan, Muscat Ottonel, Müller Turgau, Pinot Blanc, Rhein Riesling, Riton, Rkatsiteli, Sauvignon, Traminer roze, and Ugni Blanc. The locally cultivated red grape varieties such as Pervomaiski, Codrinski, Fetească Neagră, and Rară Neagră and the white grape varieties such as Fetească Albă, Fetească Regală, Perveneț Magaracea, Suholimanski Belîi, Alb de Onițcani, Floricica, Legenda, Luminița, Muscat de Ialoveni, and Viorica (*Wine of Moldova*, 2021) are also relevant for winemaking.

Besides the large number of cultivated grape varieties, it can be expected that the uniqueness of the geographical conditions would further strengthen the character of Moldovan wines. Some of the most relevant features of the Moldovan wines and regions related to the current study are shown in *tables 1* and *2.* The climate of the Codru wine-growing area is influenced by the Western European oceanic climate (Marine West Coast) and the East European Continental climate (Humid Continental) (*WADGR „Codru"*, 2017). The climate of the Ştefan Vodă region is determined mainly by the Black Sea (*AWPPGI "Ştefan Vodă"*, 2017), while the climate of the Valul lui Traian zone is affected by both the Black Sea and the Mediterranean climate (*WUDGR "Valul lui Traian"*, 2019). The delimited Divin area is again influenced by two geographical factors, namely the Carpathian Mountains and the Black Sea (*ADBPM*, 2012).

Taken together, it is impressive to notice the improvements of the Republic of Moldova regarding the quality of its own wines that have been recognized by numerous awards at major international wine competitions such as the Decanter World Wine Awards, Mundus Vini, Concours Mondial du Bruxelles, International Wine Challenge, and others (*Wine of Moldova*, 2021).

Historical features of Hungarian wine making

In historical terms, wine production and consumption was present on the territory of Hungary throughout the centuries, and the specific connotations of the different wine types are still present in the Hungarian cuisine and eating habits. Winemaking in Hungary dates back to Roman times, and by the 5th century AD, extensive vineyards are reported in Pannonia (*Bede*, 2016). The ancient Hungarians settling down in the Carpathian Basin introduced Inner Asian and Caucasian traditions into winemaking, while during the Middle Ages, abbeys of the Catholic Church continued the diversification of cultivated grapes and wine varieties. During the Austro-Hungarian period, winemaking was intensified, and several wine varieties emerged mainly related to local grape varieties. However, during the 1870s, grape phylloxerae spread following the Danube river route, first to Upper and Lower Austria and Burgenland and then to Czech, Slovakian, and Hungarian regions, affecting dramatically the grape and wine production (*Tello et al.*, 2019). After the "Great phylloxera attack", more emphasis was put on creating new resistant grape varieties by using own-rooted local *V. vinifera* varieties grafted onto partially resistant American *non-vinifera Vitis* spp. or hybrids used as rootstocks (*This et al.*, 2006).

The cultivated red grape varieties in Hungary are the Kékfrankos, Cabernet Franc, Cabernet Sauvignon, Merlot, Nero, Pinot Noir, and Syrah. The most popular white grape varieties cultivated in Hungary are Chardonnay, Italian Riesling, Sauvignon, Muscat Blanc, Pinot Blanc, Pinot Gris, and Bianca. Local red grape varieties are Kadarka, Kékfrankos, Kékoportó, and Zweigelt, while the locally cultivated white grape varieties are Ottonel muskotály and Tramini. Indigenous Hungarian red wine-grapes are, e.g. Bíborkadarka, Csókaszőlő, Rubintos, and Turán, while Cserszegi fűszeres, Furmint, Hárslevelű, Irsai Olivér, Kövérszőlő, Zengő, and Zenit are based on local white grape-wine varieties (*TWRAC*, 2014; *ABUWR*, 2016; *EBWRAC*, 2017; *BWRAC*, 2018).

Currently in Hungary, there are several grape varieties and cultivars, largely grouped into six wine regions as follows: (1) Észak-Dunántúl (North Transdanubia or Upper Pannonia) with subregions as Ászár-Neszmély, Etyek-Buda, Mór, Pannonhalma, and Sopron; (2) Lake Balaton, divided into subregions as Badacsony, Balatonfelvidék, Balatonfüred-Csopak, Dél-Balaton, Somló, and Zala; (3) Dél-Dunántúl (South Transdanubia or Pannonia) consisting of subregions as Pécs, Villány, Szekszárd, and Tolna; (4) Duna or Alföld with subregions as Csongrád, Hajós-Baja, and Kunság; (5) Észak-Magyarország (Northern Hungary or Upper Hungary) including sub-regions as Eger, Mátra, and Bükkalja; and (6): Tokaj (*Smyth*, 2016). Some of the most relevant features of the Hungarian wines and the corresponding regions related to the current study are shown in *tables 1* and *2*, and further details about the Hungarian wine regions can be found on the following webpage: https://winesofhungary.hu/wine-regions.

The aforementioned six Hungarian wine regions are associated with specific soil and climatic conditions, and together with local grape and wine varieties are attributable features that suggest the inclusion of such wines into the EU Protected Food Name (PFN) quality scheme. Four types of protected names were established under the EU PFN general rules, and they are the following: (1) Protected Designations of Origin (PDO); (2) Protected Geographical Indications (PGI); (3) Traditional Specialties Guaranteed (TSG), and (4) the so-called optional quality terms. By definition, the PDO and PGI foodstuffs look similar in terms of identity, as the product originates from a particular geographical area, which, associated with natural and human factors, conveys particular qualities to that product. The differences between the two above-mentioned PFN quality categories are related to the foodstuff manufacturing, so that in case of PDO the entire production should take place in the defined geographical area, while in the case of PGI only one of the production steps must take place in the defined area. It is worth mentioning that geographically defined manufacturing areas could be as large as a whole country in exceptional cases. The TSG quality category is attributed to foods obtained through traditional practices, including the ingredients, technology, and the food name. The PFN optional quality terms are intended to describe some specific features of a locally obtained foodstuff, with additional meaning in a European dimension.

Comparing wines to transform their specific features into competitive advantages

It has become a common fact that the wine offer is increasingly overwhelming across the markets of highly developed countries, yet wine producing still continues to grow. Therefore, new strategies and practices are needed to introduce and position wine brands on markets, while the health-conscious consumer category is looking for novel keynotes related to the beneficial effects of wine. Moreover, to promote the circular bioeconomy and sustainability, there is a stringent need for the promotion of local knowledge even in the case of foodstuffs like wine and nutrition. In the light of the above-mentioned considerations, efforts should be made to promote local wines made of locally grown grapes. Identifying the specific features of such wines made from local resources can bring about new knowledge that might confer competitive advantage on both local and global levels. The chemical analysis of Hungarian and Moldovan wines suggests the use of PDO, PGI, and TSG categories under the auspices of the EU Protected Food Name (PFN) quality scheme.

2. Materials and methods

Several wines from Hungary and Moldova together with two Divin brandies were included into the present study as they are considered top alcoholic beverages. The dry white wines were made from Furmint, while the dry red wines were obtained from Cabernet Sauvignon wine-grapes. Some features of the selected wine regions and study objects are shown in *tables 1* and *2*.

Table 1. Wine/wine brandy samples selected for the study

Product type	Code	Vintage year	Ethanol content	Origin (Wine region)
White dry Furmint wine	WW1	2017	14.5%	Tokaj
	WW2	2017	14.0%	Tokaj
	WW3	2017	13.5%	Tokaj
	WW4	2017	14.5%	Tokaj
	WW5	2017	13.5%	Tokaj

Product type	Code	Vintage year	Ethanol content	Origin (Wine region)
Red dry Cabernet Sauvignon wine	WR1	2018	15.0%	Lake Balaton
	WR2	2017	14.0%	Lake Balaton
	WR3	2018	12.0%	Upper Hungary
	WR4	2018	14.0%	South Transdanubia
	WR5	2017	13.5%	Ştefan Vodă
	WR6	2018	14.5%	Codru
	WR7	2017	14.5%	Valul lui Traian
Divin Brandy VSOP	D1		40.0%	Divin
	D2		40.0%	

Note: VSOP – Divin brandy aged for 5 years.

Table 2. Some characteristics of the selected wine regions from Hungary and Moldova

Characteristics	Wine regions							
	Divin	**Codru**	**Valul lui Traian**	**Ştefan Vodă**	**Lake Balaton**	**Upper Hun-gary**	**South T. danubia**	**Tokaj**
Vineyards' area (ha)		61,200	43,203	10,000	10,718	78,092	6,700	88,124
Elevation (m)	150–250	150–400	5–311	120–190	120–350	160–500	120–450	100–300
Annual precipitation (mm)	400–700	450–550	450–550	450–550	650	592.6	600–800	525
Yearly clear days	300–320	310–320	310–320	310–320	nd	nd	nd	nd
Yearly insolation hours	2,100–2,200	2,100–2,200	nd.	nd.	1,900	1,964	1,900	2,009
Sum of active temperatures (°C)	2,900–3,100	3,000–3,450	3,000–3,450	3,000–3,450	nd.	nd.	nd.	1,600–1,800
Average annual temperature (°C)	10–12	9.0–9.5	9.5–10.0	9.0–10.0	9.0–11.0	10.65	9.0–11.0	10.8
Soil types	Alfisol, brown earth soil, common Chernozems (typical, cambic), mostly well-aerated and light		Chernozems (typical, cambic), mostly well-aerated and light	Chernozems (typical, cambic), mostly heavy and rich	Clay washed brown earth soil, volcanic rhyolite tuff	Volcanic rhyolite tuff, dacite tuff and andesite brown earth soil and loess	Brown earth soil (luvisols)	Brown earth soil (luvisols) volcanic rhyolite tuff

Note: nd – non-determined.

The **FOSS WineScan SO_2** analyser was used to determine the wine- and brandy-specific chemical parameters. The system uses an FTIR interferometer to scan the entire infrared spectrum of the sample. Phosphoric acid is employed as a hydrolysing agent to liberate SO_2 gas from the wine sample, which is then scanned using an FTIR analyser (*FOSS*, 2019).

The **Folin–Ciocâlteu method** was applied to determine the total polyphenol content in wines and cognacs, as described by Pisoschi et al. (2016).

3. Results and discussion

Evaluation of the quality parameters of the studied wines' and brandies' distillate was conducted in order to identify specific traits that might lead to the definition of wine/wine distillate profiles with respect to the geographical location of vineyards, the used wine-grape varieties, and the manufacturing technologies.

The **phenolic compounds** are known to influence the wine's organoleptic properties such as colour, astringency, bitterness, flavour as well as antimicrobial properties (*Jackson*, 2020). It has been suggested that higher total phenolic content (TPC) is correlated with higher antioxidant activity (*Burns et al.*, 2000). Apart from caffeic, ferulic, and p-coumaric acids, the concentration of the rest of the phenolic compounds found in the wines declines over time (*Kallithraka et al.*, 2009), leading to TPC diminution. The relationship between the TPC and the vintage of wines is still an open question. All the analysed red wine samples (WR1-7) featured significantly higher TCP values as compared to the white wine samples (WW1-WW5) (for details, see *Table 3*). The brandy samples showed equally low levels of TCP as compared to the red wines, but the TPC values were almost similar to the white wine values.

Relying on reference literature, the TPC of young red wines is about 1,300 mg GAE/l on average, while for white wines is about 190–290 mg GAE/l (Jackson, 2020). Apart from WR1 and WR2 featuring relatively higher TPC values, the rest of the red wines showed TPC values specific for young wines. The WR1-2 was from the Lake Balaton region, having the same vintage year like all the other analysed red wine samples, which suggests the relevance of soil and climatic conditions with respect to TPC.

Jackson reported that increased pH and ethanol concentration positively affect the extraction of phenolic compounds (*Jackson*, 2020). This is confirmed only in red samples in this study. The pH decrease is known to affect wine colour, paling its blueness and shifting it to red. Thus, as white wines mostly contain colourless (leucoform) phenolics, the pH does not influence their extraction yield.

The increased amounts of TPC in Balaton wine samples are due to their geographical provenance, characterized by volcanic soils and intense solar UV radiation. It was demonstrated that such environmental factors create stressful growth conditions, forcing the plant to activate its natural defence (*Heras-Roger et al.*, 2017). In order to increase the TPC values of wines, producers are recommended to prolong the maturation stage, stick to traditional winemaking technology, which implies longer contact between skins and must and implicitly with the formed ethanol (*Fuhrman et al.*, 2001). At the same time, carbonic maceration, thermo-vinification procedures, or commercial pectolytic enzymes should be avoided (*Generalić-Mekinić et al.*, 2019; *Jackson*, 2020).

Speaking of Divin type of wine distillates, sample D1 showed an amount of TPC comparable to white wines, while sample D2 contained 2.2 times less polyphenols. As the main source of phenolic compounds in distilled spirits are wooden barrels, the observed relevant difference can be justified by the use of older barrels made of Hungarian oak on a par with French limousine oak that was used for sample D1. The seasoning and maturation of the wood, the heat treatment and size of the barrel, the cellar microclimate, and the technological operations used could also be among the influencing factors (*Canas*, 2017).

In order to continue the characterization of the studied wines/brandies, we decided to assess several parameters that are considered conventional markers used to describe wine products. Based on oenological considerations, great wines are described as fully balanced when their four fundamental traits, i.e. acidity, tannin content, alcohol strength, and sweetness, reach a sensation harmony that could be preserved by acidity, as the wines are aged. The importance of acidity cannot be underestimated from the consumers' point of view, so that many of them would prefer more sourness than sweetness. Interestingly, sweetness decreases the sensation of acidity, and consumers preferring sweet wines would be more appreciative of the sweetness sensation. Reaching the right combination of sourness and sweetness together with the proper alcohol content remains a permanent open question for wine manufacturers that they must face on yearly basis, and the challenges are enormous as several variables should be considered, while the cause-effect type of correlations remain largely elusive.

In the following, we will present the data of the current study referring to the analysed red and white wines' specific parameters affecting acidity.

Looking at the **citric acid** concentration, all the assessed white wines, with the exception of WW3, were showing higher values than the reference of 270 mg/l (*IARC*, 1988), which could be explained most likely by the grape varieties involved. In the case of red wines, citric acid values were reduced all the way from the WR1 to WR6. It is known that the addition of citric acid to wine as a stabilizer could prevent ferric haze and enhances acidity. It is possible that applying such a consideration could explain the higher concentration of citric acid in sample WR7.

L-malic and **L-lactic acid** content is an important quality parameter of wines and is related to malolactic fermentation, decreasing the fixed acidity in wine together with the formation of volatile acids and esters that greatly influence the wine “bouquet”. The L-malic acid is essential for determining grape ripeness, and it gives sourness and stability to the finished wine (*Volschenk et al.*, 2006). L-lactic acid is a by-product of malolactic fermentation, rather than an indigenous acid found in grapes, and it is considered ideal for controlling secondary fermentation (*Virdis et al.*, 2021; *Volschenk et al.*, 2006).

Regarding the assessed red wines, samples WR2, WR4, WR5, and WR6 had the highest lactic acid values, all associated with non-detectable malic acid levels. Higher levels of malic acid in association with lower levels of lactic acid were detected in WR1, WR3, and WR7, probably indicating that the malolactic fermentation was not fully completed. As expected in the case of white wines, high levels of malic acid with reduced levels of lactic acid were observed, indicating that the malolactic fermentation does not play an important role in “bouquet” formation. However, WW3 represents an exception among the analysed white wines, so that it shows reduced malic acid and greatly increased lactic acid levels, indicating that malic and lactic acid content could be used for “bouquet” profiling even in the case of Tokaj white wines.

Tartaric acid has a great impact on the pH, general stability, and sensory qualities of wines (*Volschenk et al.*, 2006). With the exception of WR3, the other Hungarian red wines had lower tartaric acid content as compared to the Moldovan samples, which could be due to the differences in soil type, as tartaric acid concentration is highly dependent on the potassium content of soil (Robinson, 2006). The tartaric acid content of the assessed Tokaj white wines is not surprising since the Tokaj region, with its volcanic origin soil, is rich in potassium (*O’Geen et al.*, 2008). However, tartaric acid is also a grape-specific acid, and its concentration could also be highly influenced by the grape variety, so the relevance of cultivated grapes remains to be clarified with respect to the observed tartaric acid values exceeding the internationally accepted average level of ~2,120 mg/l (*IARC*, 1988).

Volatile acidity is another important quality parameter indicating microbial activity during fermentation (*Nyknen* & *Suomalainen*, 1983), and its normal range falls between 0.3 and 0.7 g/L (*Tsakiris et al.*, 2014), though the EU legal limit is about 1.2 g/L of acetic acid. It has been observed that volatile acidity exceeding 0.8 g/L acetic acid could confer unpleasant acidic taste and vinegar aroma to wine. With the exception of WR1 (0.8 g/L acetic acid), all the other wines included in the present study have normal volatile acidity.

Wine-specific **total acidity** (TA) indicates the concentration of acids present in wine, and its normal values range between 3.6 and 5.5 g/L, expressed as sulphuric acid (*Jackson*, 2020). With the exception of WR7, the red wines’ specific values indicate normal TA, while the white wines’ TA values exceed the upper limit of the normal range.

Usually, all wines have an acidic **pH** ranging between 2.5 and 4.5. Wine-specific pH level indicates the intensity of acidic taste. As expected, all the analysed white wines fall into the pH range of 3.1–3.3, which is a characteristic of sweet and light-bodied white wines. The studied red wines showed a wider pH spectrum (3.4 – 3.8), suggesting that the red wines situated closer to pH = 3.5 could be regarded as of normal category, while those that reach pH = 3.8 would fall into the low-acid red wine type. The assessed brandies had a higher pH than all analysed wines, but this does not pose any problem for the stability because their high ethanol content will prevent microbial deterioration.

In order to explain the acidity-specific parameters of wines, numerous factors could come into play, but in the present situation we can also think of the influence of climate. All the assessed white wines were from the Tokaj region and were based on the Furmint grapevine, while the studied red wines were obtained using Cabernet Sauvignon grapevine produced in different Hungarian and Moldovan wine regions. The relatively low values and narrower pH spectrum of Tokaj wines could be associated with either cooler night-time temperatures or a shorter wine-grape growing season (see *Table 2*). It is believed that cool nights and cold weather stop the grapes from losing their acidity, but the scientific confirmation of such a presumption is still awaiting further proof. Some genomic studies indicate that temperature might desynchronize the sugar and organic acid metabolism in ripening wine-grape fruits, as shown by transcriptome analysis (*Rienth et al.*, 2016), but such studies should comprise more wines and regions.

Talking about wine-grapes, they contain fermentable sugars such as glucose, fructose, and sucrose and pentose as a non-fermentable sugar. Based on their reducing ability, the above-mentioned sugars can be included into (i) the reducing (glucose, fructose, pentose) and (ii) the non-reducing (sucrose) sugar categories.

In wines, some **reducing sugars** remain after fermentation, and their quantity may rise during oak barrel aging. If the reducing sugar content is higher than 1.5 g/L, the wine's ability to resist spoiling could be affected, and wine stewards can perceive sweetness at a value of 2 g/L (*Jackson*, 2020). All studied red wines had the reducing sugar concentration exceeding 2 g/L. Interestingly, WR1 and WR7 scored higher values than 4 g/L reducing sugar concentration, which is most probably due to some technological reasons. The reducing sugar content of the analysed white wine samples falls between 1 and 1.7 g/L, with the exception of WW2, were a value of 3.7 g/L was detected. Our data cannot be considered of absolute relevance since the applied FTIR assay does not detect pentose and other non-sugar reducing compounds (*Wilkes et al.*, 2019). No reducing sugars were found in the analysed Divin brandies, though sucrose-derived caramel colorant (E150) is used to set the colour of the product.

The **ethanol** content of the analysed wines and distillates was also determined (see *Table 3*), and for wines it ranged between 12.12 and 14.62%, while for distillates it was at about 42%. When compared, no obvious differences were observed between red and white wines. The ethanol content of wines contributes to their stability, but through its antimicrobial property – further strengthened with some polyphenols and proper pH – it could have bacteriocidal and/or bacteriostatic effects on human pathogens such as *Helicobacter pylori, Salmonella enterica* serovar *Enteritidis*, and *Escherichia coli* (*Jackson*, 2020; *Boban et al.*, 2010; *Ruggiero et al.,* 2007). However, it remains an open question whether the ethanol content of wines might have harmful effects on the microbiota of human gut. Nevertheless, some experimental data indicate that polyphenols and ethanol can influence gut microbiota and some inflammatory markers (*Queipo-Ortuño et al.*, 2012). When several alcoholic beverages were investigated in three independent cohort studies, it turned out that moderate red wine consumption was associated with an increased gut microbiota α-diversity (*Le Roy et al.*, 2020). White wines showed a lesser but relevant positive association with α-diversity, while no associations were observed with other alcohol categories. Interestingly, these gut-microbiota-related effects were attributed to the wine polyphenols (*Nash et al.*, 2018).

Another alcohol found in wine is the **glycerol**, which in normal condition is produced by *Saccharomyces cerevisiae*, *Candida pulcherrima* during fermentation, and it is produced in concentrations ranging between 2 and 36 g/L *(Nykänen* & *Suomalainen*, 1983). Higher glycerol concentrations (26 g/L and above) increase wine viscosity (*Jackson*, 2020) and are rot indicators (*Restani et al.*, 2007). Clearly, there is no indication of putrefaction since all the analysed red wines showed values ranging between 7.2 and 10 g/L, the white wines were between 7 and 9 g/L, and the wine distillates had a glycerol content of 3.4–4 g/L. When the glycerol concentration exceeds 13 g/L, the sweeter taste sensation increases (*Jackson*, 2020), but this was certainly not the case of any of the analysed wines (see *Table 3*). Our data is in good agreement with the known facts that usually red wines have a greater glycerol content in comparison to white wines. The studied brandy samples contained traces of glycerol, most probably due to the distillation process (*Sarvarova et al.*, 2011).

The **sulphur dioxide** (E220) content evaluation was also included into the present study to provide further conclusions regarding wine quality. SO_2 is added to the wine to prevent undesired residual fermentation activities, for the inhibition of the oxidative processes, and to avoid spoilage (*Jackson*, 2020). Usually, three chemical forms of SO_2 are distinguished in wines: the total (TSD), the free (FSD), and the bound forms. FSD accounts for the preservative effects of SO_2, and the bound SO_2 arises from the reaction of bisulphite and other wine components. Both bound SO_2 and FSD count towards TSD, which is regulated in most wine-producing countries.

In our experiments, samples WR5 and WR7 indicate low FSD, which may jeopardize safety during storage (see *Table 3*).

Table 3. The analysed wine/Divin brandy parameters

Parameter	**Wine/Distillate Sample ID**													
	WR1	**WR2**	**WR3**	**WR4**	**WR5**	**WR6**	**WR7**	**WW1**	**WW2**	**WW3**	**WW4**	**WW5**	**D1**	**D2**
TPC, mg GAE/L	1892.24 ±6.52	1743.58 ±11.75	1158.38 ±8.62	1515.90 ±11.29	1203.54 ±3.26	1434.99 ±3.26	1295.75 ±5.65	194.26 ±1.63	179.24 ±1.84	167.89 ±5.40	187.48 ±1.63	194.82 ±4.39	180.51 ±5.08	82.02 ±1.00
Ethanol, % vol.	14.62 ±0.01	13.95 ±0.00	12.12 ±0.01	13.95 ±0.00	13.59 ±0.00	14.37 ±0.01	14.53 ±0.02	14.39 ±0.01	13.79 ±0.01	13.32 ±0.01	14.38 ±0.02	13.24 ±0.02	42.12 ±0.04	42.05 ±0.04
pH	3.86 ±0.00	3.79 ±0.00	3.43 ±0.00	3.69 ±0.00	3.60 ±0.00	3.75 ±0.00	3.56 ±0.00	3.13 ±0.00	3.16 ±0.00	3.35 ±0.01	3.25 ±0.00	3.13 ±0.00	3.59 ±0.00	3.49 ±0.00
Total acidity, g/L	5.30 ±0.01	4.80 ±0.01	5.20 ±0.01	5.00 ±0.02	5.20 ±0.01	5.10 ±0.00	6.50 ±0.02	6.50 ±0.01	6.50 ±0.00	5.80 ±0.00	6.50 ±0.01	6.70 ±0.02	0.50 ±0.00	0.60 ±0.00
Volatile acidity, g/L	0.80 ±0.00	0.70 ±0.01	0.50 ±0.00	0.70 ±0.01	0.70 ±0.00	0.70 ±0.00	0.70 ±0.01	0.50 ±0.00	0.30 ±0.00	0.70 ±0.00	0.40 ±0.00	0.50 ±0.00		
Malic acid, g/L	0.50 ±0.01	0.00 ±0.02	0.30 ±0.00	0.00 ±0.01	0.00 ±0.02	0.00 ±0.01	1.30 ±0.03	1.00 ±0.00	1.50 ±0.00	0.10 ±0.00	1.70 ±0.00	1.50 ±0.00		
Citric acid, g/L	0.180 ±0.009	0.080 ±0.002	0.160 ±0.006	0.130 ±0.002	0.110 ±0.004	0.100 ±0.002	0.240 ±0.000	0.280 ±0.000	0.340 ±0.004	0.220 ±0.002	0.340 ±0.006	0.310 ±0.001		
Lactic acid, g/L	1.00 ±0.01	1.80 ±0.01	1.20 ±0.02	1.50 ±0.05	1.40 ±0.00	1.50 ±0.01	0.50 ±0.01	0.80 ±0.01	0.70 ±0.02	1.80 ±0.04	0.60 ±0.02	0.60 ±0.01		
Tartaric acid, g/L	1.70 ±0.02	1.50 ±0.02	2.00 ±0.01	1.50 ±0.03	2.20 ±0.04	1.80 ±0.00	2.10 ±0.01	2.80 ±0.00	2.60 ±0.03	2.30 ±0.01	2.40 ±0.03	2.60 ±0.02	0.50 ±0.04	0.80 ±0.09
Reducing sugar, g/L	4.20 ±0.22	2.00 ±0.03	2.30 ±0.04	3.60 ±0.17	3.50 ±0.02	3.00 ±0.10	4.90 ±0.07	1.20 ±0.04	3.70 ±0.02	1.70 ±0.02	1.70 ±0.11	1.00 ±0.01		
Glycerol, g/L	10.00 ±0.01	8.20 ±0.09	7.20 ±0.01	8.70 ±0.05	8.30 ±0.07	8.90 ±0.02	10.0 ±0.00	7.50 ±0.03	7.30 ±0.01	9.00 ±0.00	7.60 ±0.02	7.00 ±0.01	3.40 ±0.04	4.00 ±0.02
Density, g/cm³	0.9960 ±0.0001	0.9935 ±0.0000	0.9935 ±0.0000	0.9936 ±0.0000	0.9933 ±0.0000	0.9934 ±0.0000	0.9947 ±0.0000	0.9886 ±0.0000	0.9903 ±0.0000	0.9906 ±0.0000	0.9893 ±0.0000	0.9899 ±0.0000	0.9709 ±0.0000	0.9702 ±0.0000
CO_2, mg/L	199.37 ±0.11	735.62 ±3.35	466.36 ±3.07	453.7 ±3.09	478.8 ±2.48	384.03 ±2.12	259.26 ±0.69	430.90 ±9.32	1004.04 ±6.91	246.37 ±0.43	704.31 ±4.46	550.40 ±1.00	230.05 ±0.99	226.91 ±0.27
Total SO_2, mg/L	92.0 ±1.0	48.0 ±0.0	81.0 ±2.0	65.0 ±1.0	34.0 ±1.0	73.0 ±0.0	59.0 ±0.0	347.5 ±17.4	80.0 ±4.0	89.0 ±4.5	44.0 ±2.2	65.0 ±3.3		
Free SO_2, mg/L	7.6 ±0.07	5.9 ±0.08	8.3 ±0.15	10.4 ±0.06	0.7 ±0.39	6.2 ±0.10	1.6 ±0.33	212.3 ±10.62	24.0 ±1.20	11.0 ±0.55	7.0 ±0.35	15.0 ±0.75		

In sample WR2, with the lowest level of reducing sugars among the tested red wines, it seems likely that the production of a substantial amount of bound SO_2 was prevented, minimizing the requirement for additional SO_2 during processing. Samples WR1 and WR4 had the highest FSD values, while the white wines, with the exception of WW1, had FSD values between 7 and 24 mg/L. The assessed brandies did not reveal the presence of any SO_2, which complies with the international trends and food safety regulations.

Carbon dioxide (E290) is a by-product of fermentation that exerts a stabilizing-preservative effect, antioxidant activity, and brings a fizzy taste to wines (*Easton*, 2009). Winemaking technologies deal with CO_2 in multiple ways, so that it can be intentionally kept in the wine, gradually removed while the wine is getting processed, or removed intentionally by sparging, while during force carbonation the CO_2 can be intentionally introduced into wine. It is also important to notice the sensory impact of dissolved CO_2 in wine, so it can boost the perception of freshness and acidity together with bitterness and astringency, decreasing sweetness. It should be pinpointed that wines usually contain between 0.4 and 1.0 g/L of CO_2, and, regularly, white wines show higher CO_2 levels than red ones to accentuate their acidity. The assessed red wines had their CO_2 content varying between 0.19 and 0.73 g/L, while in the case of the white wines, the CO_2 concentration seemed to vary at a much larger range: 0.24–1 g/L (see *Table 3*). Samples WR2, WW2, and WW4 contain considerably greater levels of CO_2, allowing winemakers to lower the total sulphur dioxide addition. These samples are likely to have a more acidic taste. On the other hand, WR1 featured the lowest CO_2 level, and it will be regarded as "flat" by wine stewards. As expected, the analysed brandies exhibited the lowest CO_2 levels due to the distillation process.

Finally, it should be mentioned that the assessment of water content, or more specifically the **density** of wines and wine distillates, offers general but important data on the quality of alcoholic beverages. In normal conditions, wine densities above the water-specific value (~1 g/cm^3 depending on the ambient temperature) indicate an increased sugar and/or acid content, while lower wine density values suggest increased ethanol content. Statistically, consumers would rate wines with a lower density (elevated ethanol level) as being of higher quality (*Miadad*, 2015). All the assessed red and white wines had their density values integrated into the 0.98–0.99 g/cm^3 interval, while the Divin brandy densities were about 0.97 g/cm^3 (see *Table 3*).

4. Conclusions

The characterization of alcoholic beverages and in particular of wines and wine distillates is of particular interest for both those involved in such businesses and the gourmet consumers. The competition on the wine market is fierce, and we are often facing adulteration and misguidance. The effort to make wine business safe and trustworthy is becoming an imperative, and defining validated methods to describe the specific features of wine/wine distillates are increasingly needed (*Palade & Popa*, 2014). Analytical chemistry has been called into action, and the methodology is steadily improving, while a great deal of data continues to emerge (*González-Centeno et al.*, 2015). Despite all the accomplishments, the relevant conclusions regarding wine/brandy authenticity are still missing, though some promising results, by combining advanced analytical chemistry and statistics, look rather promising (*Hu et al.*, 2019). On the other hand, sommeliers have come to the fore, and they are considered knowledgeable wine professionals having a formal training regarding all aspects of wine service, wine and food matching, and wine ageing. It is interesting that at the crossroads of food chemistry coupled with microbiology and wine manufacturing together with marketing, the concept of oenology has emerged as the science of wine and winemaking, with a lot of subjectivism. However, oenology is not completely separable from viticulture, which is the science addressing the cultivation and harvesting of grapes.

By now, wine specialists and enthusiasts all have agreed that in order to define the profile of a certain wine, all relevant measurable parameters of the assessed wine should be included into the evaluation. The history of wine should indicate the geographical conditions specific to a particular wine region, the wine-grape variety, the annual specificity of the chemical composition of the wine-grape(s), the applied wine manufacturing technology, the obtained wine parameters that will be monitored throughout the ageing process, together with the appreciations of sommeliers and consumers.

Taken all together, the presented data on the chemical parameters of several Hungarian and Moldovan red and white wines, including some Moldovan wine distillates too, clearly demonstrate the efficiency of the applied FTIR methodology. According to the current national and international standards, the assessed wines/ wine distillates can be considered of high quality. It was our aim to perform a comparative chemical assessment, hoping that some specific features of the analysed wines might be revealed (see *Table 4*). It seems obvious that the total polyphenol content (TPC) of red wines is significantly higher as compared to white wines or wine distillates. It is our opinion that the polyphenols and other phytonutrients of the wines should be more carefully assessed both qualitatively and quantitatively as they might hold relevant information for the wine-specific features, including both traceability and authenticity. In a recent study by Kalló and collaborators (2021), several compounds with antiviral, anti-inflammatory, and anticancer activity were identified in wines from the Tokaj region, using high-resolution mass spectrometry, statistics, and bioinformatics. It is noteworthy that the qualitative and quantitative chemical analysis of the phytonutrient profile including TPC could be an influential tool for the definition of wine specificity.

Table 4. The relative comparison of some representative wine parameters

Product type	Code	TPC	Total acidity (g/L)	Malic acid (g/L)	Lactic acid (g/L)	Tartaric acid (g/L)	Reducing sugar (g/L)	Glycerol (g/L)	CO_2 (g/L)	Origin (Wine region)
White dry Furmint wine	WW1		6.5–6.7	0.5–1.7	0.6–1.8	2.3–2.8	1–3.7	7–9	0.2 –1	Tokaj
	WW2									
	WW3	↓↓↓								
	WW4									
	WW5									
Red dry Cabernet Sauvignon wine	WR1	↑↑↑	5–6.5	0.0–1.3	0.5–1.8	1.5–2.2	2–4.9	7.2 –10	0.2–0.7	Lake Balaton
	WR2	↑↑↑								Lake Balaton
	WR3	↑								Upper Hungary
	WR4	↑↑								South Transdanubia
	WR5	↑								Ştefan Vodă
	WR6	↑↑								Codru
	WR7	↑								Valul lui Traian
Divin VSOP	D1	↓↓↓	0.5–0.6	0	0	0.5–0.8	0	3.4–4	0.2	Divin
	D2	↓↓↓								

Note: The arrows refer to relative values. The upward arrows show increased while the downward decreased values. VSOP – aged for 5 years.

Our results indicate that Tokaj white wines have relatively higher total acidity levels as compared to all the red wines, which could be due to the wine-grape variety and the geographical conditions together with the applied grape cultivation and wine manufacturing technologies. Looking at malic acid content, again, Tokaj white wines surpass Cabernet Sauvignon red wines, and the observed variation range could indicate grapevine, geographical, and/or technological specificities. No malic acid was found in the Moldovan Divin brandy type of wine distillates. The lactic acid content does seem to vary in the same value interval for all analysed wines, while it is not detectable in Divin. Tartaric acid reaches higher values in the case of Tokaj wines, while Cabernet Sauvignon red wines showed lower values and wider variation intervals. Divin distillates did contain some reduced levels of tartaric acid. The reducing sugar content of Tokaj wines seems to be lower than in the case of the assessed red wines. The glycerol content of all studied wines looks similar, though the values for the Tokaj wines fall into a narrower interval as compared to the red wines. A lower amount of glycerol was detected in the Divin wine distillates. In the case of Tokaj wines, the level of CO_2 varied across a larger interval as compared to the red wines, and almost identical levels were visible in the case of the Moldovan wine distillates.

The present study offers clues about the relevance of wine chemistry with respect to the definition of wine specificity. Our data also suggest that after conceiving a general study plan, statistically significant amount of data should be collected on each wine parameter. The fact that the Tokaj wines are showing distinguishable features from the analysed red wines, together with the narrower variation ranges of red wine variables, plead for considering other factors than just the wine-grape variety in the context of plausible explanations. Again, we can conclude that the local climatic, soil, and anthropogenic factors all influence the characteristics of wines, even if they are made of the same grape variety. Therefore, the concept of protected geographical indication should be promoted and further substantiated through scientific proofs for specificity.

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