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ANALYSIS OF THE POLYPHENOL CONTENTS OF TRADITIONAL METHOD SPARKLING WINES

Domonkos Frigyes Török

Correspondence Author: Domonkos Frigyes Török, **E-mail:** dtorok@digillic.com

| Abstract

Over the last decade, the global demand for sparkling wine has surged by 40%, with Hungary being a pivotal player in this industry due to its rich history in wine production. Given the rising health consciousness among consumers and the established health benefits associated with moderate wine consumption, understanding the polyphenolic composition of these wines has become imperative. In this study, a spectrum of analytical and sensory tests were performed on a variety of 2017 vintage traditional method sparkling wines to delineate their polyphenol content, which plays a crucial role in defining the wine's taste and potential health benefits. Through meticulous analysis covering parameters such as leucoanthocyanin, catechin, colour intensity, and total antioxidant capacity, alongside routine analyses examining factors such as alcohol content and pH level, we aimed to offer a granular understanding of the characteristics defining both domestic and foreign traditional method sparkling wines. Our data revealed a remarkable diversity in the world of sparkling wines, with Hungarian variants standing toe-to-toe in terms of quality with their foreign counterparts. We discerned significant variability in the phenol content across different samples, and identified a general trend of lower polyphenol content in sparkling wines compared to still wines. This study not only underscores the commendable quality of Hungarian sparkling wines but also accentuates the vital role of polyphenols, advocating for a deeper exploration into this aspect to cater to the health-conscious consumer market and facilitate the continued growth of the Hungarian sparkling wine industry in the booming global market.

| Keywords

Polyphenols, sparkling wines, traditional method, champagne

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Introduction

The global consumption of sparkling wine has experienced a 40% increase within the last decade. It has no wonder that a rising number of people in Hungary are interested in making sparkling wine. This sparkling wine is produced in many of the countries that are associated with the wine business, and it is one of the most profitable commodities in the food market. The (International Organisation of Vine and Wine, 2018) report shows that the rate of growth for sparkling wine surpasses that of still wines, and sparkling wines accounts for 20% of the wine product market. France, Italy, Spain, Germany, and Russia are the five top producers of sparkling wines worldwide, with a combined output of approximately 1.5 billion bottles, representing over 70% of total production.

Hungary, occupying the eleventh spot on this list, has a notable background in sparkling wines production. Prior to World War I, Hungary was the second largest sparkling wines producer in the world, producing eight million bottles annually. Today in Hungary, around twenty-two million bottles of sparkling wines are produced every year, most of which are tank method sparkling wines. Annually, twenty million bottles are sold, and it is pleasing to note a rise in value because increased people are seeking traditional bottle-fermented sparkling wines.

Sparkling wine has become symbolic of status for the younger generations. Adopting a healthy lifestyle is becoming more essential, and people are focusing on what they consume (Török, 2023). Many studies have showed that moderate consumption of wine is beneficial to health, due to polyphenolic compounds. Resveratrol is the most widely known for its potential to protect against heart disease and other vascular diseases. Increasingly, more research is being conducted into wine to acquire a clearer knowledge of the qualitative and quantitative makeup of polyphenolic compounds. During my research, I completed both analytical and sensory assessments of several traditionally fermented sparkling wines, concentrating on the polyphenol content.

In conclusion, the worldwide rise in sparkling wines consumption, Hungary's respected history in sparkling wines production, and the escalating knowledge of the health advantages of drinking wine in moderation all offer exciting potential for the Hungarian sparkling wines industry to develop and thrive.

Objective

The creation of sparkling wines is an intricate process that requires a multitude of elements that determine the taste and aroma of the final product. Recognising the aspects of sparkling wine is essential to creating top-notch items. My research had the purpose of bringing to light the composition of different traditional method sparkling wines, with an emphasis on polyphenolic compounds.

To accomplish this aim, I collected sparkling wines from the 2017 vintage, or having most of the base wine from the 2017 vintage. This standard provided the assurance that the samples came

from the same period, allowing me to compare the wines' components and establish if any resemblances exist. I included foreign sparkling wines in my research to distinguish between Hungarian and foreign sparkling wines.

Highlighting Hungary's history of producing sparkling wine is of paramount importance, yet it has been overlooked. During the time prior to World War I, Hungary was considered being one of the most substantial sparkling wines powers in the world, producing eight million bottles annually. Presently, Hungary occupies the eleventh place on the list of sparkling wines producers. My research was conducted to highlight the variety of sparkling wines and to draw attention to Hungary's renowned sparkling wine background.

My study was based on the analysis of sparkling wines from eight distinct wine regions, which displayed considerable variation. As a result, I expected major discrepancies in the components of the sparkling wines, making the comparative analytical and sensory assessments crucial. I conducted examinations for polyphenol content, catechin, leucoanthocyanin, and the overall antioxidant capacity.

Comprehending the components of sparkling wines are pivotal to bettering the manufacturing of high-grade goods. Polyphenols, such as resveratrol, have properties which are protective to health, thus making them a vital component in the manufacturing of sparkling wines. My research provided an in-depth assessment of multiple bottle-fermented sparkling wines through comparative analytical and sensory tests, with a focus on the differences between sparkling wines from Hungary and foreign countries, and to emphasise Hungary's sparkling wine history.

Literature review

Carbon dioxides present in sparkling wine or Champagne is created by secondary fermentation occurring in a contained space, either through the direct fermentation of must or the addition of sugar to wine (Eperjesi Imre, Kállay Miklós, Magyar Ildikó, 1998).

It is alleged that Dom Perignon, the cellar master of the Benedictine abbey, was the originator of sparkling wine, though it is currently known that wine with intentional carbonation was already being made in Carcassonne, Languedoc, prior to Dom Perignon. Cool climates with long maturing seasons are perfect for producing excellent sparkling wines.

The term Champagne has two interpretations: when used in French, it relates to sparkling wine, while the other interpretation alludes to a specific region in France, thus only applies to wines produced in that area.

The term "sparkling wine" includes three product categories: sparkling wine, quality sparkling wine, and fragrant quality sparkling wine.

According to Regulation 1234/2007/EC[1] of the Council of the European Union:

Sparkling wine is a product:

a) Obtained by first or second alcoholic fermentation of fresh grapes, grape must, or wine.

b) In which only carbon dioxide originating from the fermentation is released when the container is opened.
c) Which, when stored in closed containers at 20 degrees Celsius, has a pressure of not less than 3 bars because of the presence of dissolved carbon dioxide; and
d) Where in the total alcohol content of the cuvée intended for production shall not be less than 8.5% by volume.

The actual alcohol content of the finished sparkling wine, including any alcohol in the expedition liqueur that may have been added, must be at least 9.5% by volume.

Quality sparkling wine is a product:

a) Obtained by first or second alcoholic fermentation of fresh grapes, grape must, or wine.
b) In which only carbon dioxide originating from the fermentation is released when the container is opened.
c) Which, when stored in closed containers at 20 degrees Celsius, has a pressure of not less than 3.5 bars due to the presence of dissolved carbon dioxide; and
d) Wherein the total alcohol content of the cuvée intended for production shall be at least 9% by volume.

The actual alcohol content of the finished quality sparkling wine, including any alcohol in the expedition liqueur that may have been added, must be at least 10% by volume.

Quality aromatic sparkling wine is:

a) which is obtained only by making use, when constituting the cuvée, of grape must or grape must in fermentation which is derived from specific wine grape varieties
b) which has an excess pressure, due to carbon dioxide in solution, of not less than 3 bar when kept at a temperature of 20 Celsius in closed containers which has a minimum actual alcohol content of 6% by volume.
c) which has a total alcohol content of not less than 10% by volume.

There are four distinguishable sparkling wine production techniques, which share many common elements. I have described these common elements based on my thesis only for the traditional method of sparkling wine production.

Traditional method sparkling wine production (Champagne method)

Sparkling wine needs to be handled delicately from the start of the harvest. Hence, those who endeavour to make premium sparkling wine only pick small harvest boxes manually to prevent berry damage. The harvest is performed either during morning or evening hours when the temperature is lower to reduce oxidation. (R. Gil-Munoz, E. Gómez-Plaza, A. Martínez, J.M. López-Roca, 1999) found that fewer polyphenols are dissolved into the must when the grapes are cooler. The pressing process is conducted delicately, using primarily free-run juice, and avoiding any bits of grape that could cause a bitter flavour. Most presses today feature a sparkling wine program

that employs a maximum of 1.4 bar and slowly increases in pressure. Champagne producers prefer the large-diameter hydraulic vertical presses from the Coquard manufacturer, as they are known for their gentle nature. The most prevalent pressing system is whole cluster, as it yields a must with a low polyphenol content, since polyphenols can cause a darker hue later, and iron content can be a major hazard, as it can spark the oxidation of polyphenols (Eperjesi Imre, Kállay Miklós, Magyar Ildikó, 1998). The traditional juice yield ratio is still followed when producing Champagne: One hundred liters of must are derived from one hundred and fifty kilograms of grapes. Incorporating sulphur dioxide into the grapes may depend on the grapes' well-being, chemical composition, the temperature of the must, and the winemakers' intention to have malolactic fermentation occur. Skin contact is usually not part of the process, apart from the production of rosé sparkling wine, where the colour can be got through contact with the skin. Once pressed, the must is cooled to enable the larger particles to settle. The divided components of the colour must be extracted through racking after settling. Enzymes that fail pectin are sometimes employed for must clarification. Certain individuals are fining the must prior to fermentation, which alters the taste profile. According to (Hardy, 1989), it is common to use 50 g/hL of bentonite or casein for this purpose.

Primary fermentation

The lower the number of insoluble solid particles and the colder the fermentation process, the higher the quality of the product and the better it keeps the aromas (Williams, Ough, & Berg, 1978). To maintain the fresh character of the wine, it is recommended the fermentation temperature should be between 12-18 Celsius. The carbon dioxide generated during fermentation is trapped in the bottle, creating bubbles. Yeast autolysis during aging contributes to the flavour complexity of the final product. Or they use sulphur dioxide because it is simple and, even in lesser amounts, it inhibits lactic acid bacteria. Citric acid hydrolysis occurs at 18-20 degrees Celsius and takes twice as long as primary fermentation, which means it can take from four to six weeks. The Oenococcus oeni bacterium reduces the citric acid, and as a result, the sparkling wines loses its acidic, fresh, fruity feel, but becomes more elegant and can be aged longer. Finished base wines are often blended to achieve consistent quality.

Stabilisation

The main purpose of filtration is to ensure that the bottled fermentation process begins with no other yeast present. Different yeasts are employed for both fermentations, to avoid the outcome being too one-dimensional. The other reason is to inhibit malolactic fermentation, as there is a risk that malolactic fermentation will occur during the bottled fermentation, which reduces citric acid, increases lactic acid and pH, and can also lead to fermentation defects. Therefore, sterile filtration is usually used before bottling. Tartaric stabilisation can be achieved by cold treatment

or the use of protective colloids. Cold stabilization can be done by natural or artificial cooling and can be combined with additions. During the process, the wine is cooled to a near freezing point and stored under these conditions for a few days. With protective colloid tartaric stabilisation, carboxymethyl cellulose (CMC) or metatartaric acid is used. Protein stability can be easily achieved by settling or by heating. General clarifying agents such as gelatine and/or bentonite are recommended for settling.

Liqueur de tirage

The element known as liqueur de tirage is put into the cuvée to induce secondary fermentation. Upon incorporation into the base wine, the second fermentation is started. This usually occurs in the bottle, typically with crown caps. Liqueur de tirage is a blend of sugar and yeast and may contain nutrients if necessary. The sugar content must be adjusted to around 24 g/l, which will generate a pressure of 6 bar during fermentation. High-grade sugar beets or cane sugar can be used, occasionally concentrated grape juice.

Bottle fermentation and aging

The base wine and the liqueur de tirage are combined in the bottle, where the second fermentation occurs. Fermentation occurs at 10-16 degrees Celsius and starts about 2-3 weeks after bottling, lasting for two weeks or even several months depending on the temperature. During this time, the yeast cells consume all the sugar and CO2 is produced. Since the sugar is depleted and the yeast has nothing left to consume, the cells die and fail into their constituents. It is important that the bottle is placed horizontally because this way it will be airtight, and because it will have a large surface area in contact with the lees. After the second fermentation, the wine is aged on the lees for a period, which gives the wine more complexity and depth. The wine is then gradually turned upside down until it stands on its neck, so that the lees collect in the bottle's neck. The next step is to remove the lees from a process called disgorgement.

After the fermentation is complete, aging begins on the lees. Aging takes several months or even years, during which the yeast, which has completed its job, binds to the acids and dry matter in the sparkling wines and slowly dies. Its enzymes start an autolytic breakdown process, which causes the yeast cells to fail and enrich the sparkling wines with aromas. Autolysis can take up to 10 years, depending on pH, alcohol, and temperature. Better sparkling wines can only be released to the market after at least 36 months of aging, such as Champagne.

Disgorgement

When the winemaker decides that the sparkling wines has aged enough in the bottle, the process of disgorgement begins. It is more difficult to remove the lees from young sparkling wines. Auxiliary materials, which are also used during clarification (e.g., bentonite), are used for

disgorging to expedite the process. Disgorging can be done traditionally or with modern technology. In traditional technique, the shaken bottles are placed on riddling racks, slanted head-down at a 30 or 45-degree angle. The bottles are rotated one-eighth of a turn several times a day with a special wrist movement, causing

Figure 1. Riddling racks

the lees to slide down gradually and eventually settle at the bottle's neck. This takes about 3-4 weeks, and the process may be repeated several times.

In modern technique, this work is done with a gyropalette, which rotates and shakes the bottles automatically according to a program. Modern technology is much faster and more efficient. Today's modern gyropalettes can complete the process in a few days.

When the sediment settles at the bottle's neck, the neck is placed in a freezing solution containing a -20-24 Celsius saltwater solution, and the lees freeze into an ice plug in 5-10 minutes. The frozen lees in the bottle's neck are removed by removing the crown cap, and the pressure of the sparkling wines ejects the ice plug. This can be done either by hand or with a machine. Losing sparkling wines during this process is approximately 2%.

During disgorgement, the wine is cooled to 4-10 degrees Celsius to minimise the loss of carbon dioxide during the process. Disgorged sparkling wines ages faster than undisgorged sparkling wines.

Expedition liquor

Expedition liquor is a product added to sparkling wines to achieve a specific flavour. After disgorging, the expedition liquor is placed in the bottle and it does not receive a cork cap, but a special agglomerated cork and wire cage. The expedition liquor is used to adjust the sugar content

corresponding to the sweetness category showed on the label. It can contain sucrose, grape must, grape concentrate, ascorbic acid, which is effective against oxidation, and sulphur dioxide. Another effect of the expedition liquor is that it can decrease the alcohol content by 0.1-0.4%. Before distribution, the bottles undergo further aging in a light-protected location in a horizontal position. As it ages, the foam's stability is increased. The sparkling wines is ready to be consumed!

Transvasement method

This is a sparkling wines production method that involves filtering. Compared to the Traditional method, the difference is that the lees deposited on the bottle wall are removed from the sparkling wine by filtration. The filling wine is placed in one and a half-litre bottle, where secondary fermentation and aging occur. After this, the contents of the bottles are collected in a refrigerated, pressure-resistant tank. The tanks are previously charged with carbon dioxide. The expedition liquor is added here and left to rest for a few days, then the lees are settled and removed by filtration. Afterward, it is cooled to -5 degrees Celsius to become tartar-stabilised, then sterilised by filtering through diatomaceous earth and filter sheets. Since it is kept at low temperatures and does not encounter much oxygen during transfer, the free carbon dioxide content does not change significantly. This process has numerous advantages, such as being a cheaper process since it requires much less labour. The other significant advantage is that it is a much faster process.

Charmat method

Since the traditional method is costly and slow, a technology has been developed in which secondary fermentation occurs in refrigerated or heated tanks. The base wine is poured into a refrigerated tank, then the tirage liquor (with yeast) with the sugar content is added to reach the desired carbonation level. The temperature is kept at 20-25 degrees Celsius, and when the pressure reaches 5-6 bar, the fermentation is stopped by transferring the wine to a refrigerated tank and adding sulphur dioxide. Then, it is filtered, and the expedition liquor is added. It is kept at -5 degrees Celsius for a week, then -4 degrees Celsius to become tartar stabilised. Finally, it is passed through a sterile filter, then bottled using a counter-pressure filling machine (Eperjesi Imre, Kállay Miklós, Magyar Ildikó, 1998). Counterpressure is used during the operations.

Asti method

Here, the must is fermented into sparkling wine using a method like the Charmat method. It is usually made from aromatic grape varieties. The tirage liqueur is not used in this technology. Fermentation occurs slowly at low temperatures, and if it accelerates, it is stopped. Then, the wine goes through a filtering process several times and is cleared using tartaric acid gelatine until the nitrogen and yeast have been extracted. The base wine, containing 5-7% alcohol and 80-120 g/l

of sugar, is kept stable because of its low nitrogen content. The second fermentation occurs in the tank. Fermentation starts at 18-20 degrees Celsius but is continuously slowed down by reducing the temperature. When it reaches a pressure of 5 bar, it is cooled down to a near freezing point and clarified again. It is stabilised by cold treatment, then sterile filtered to prevent further fermentation. The result is a drink with an alcohol volume percentage of 6-9%, which contains approximately 80 g/l of sugar.

Wine's sensory attributes and health benefits are significantly influenced by its chemical makeup, which includes a rich array of components such as alcohols, sugars, organic acids, and notably, polyphenols. This manuscript reviews polyphenols, a critical group of compounds in winemaking, discussing their benefits, physiological effects, and the roles they play in crafting a wine's character.

Composition of musts and wines' polyphenols

Polyphenols are vital in winemaking, contributing positively by offering a pleasant sourness and velvety texture to the wines, and endowing red wines with their distinctive colour through anthocyanins. However, they have a downside; oxidation can cause browning and other unwanted precipitations (Kállay, Borászati Kémia, 2010), while also introducing astringent and bitter tastes.

The concentration of polyphenols in grapes exhibits a dynamic pattern during ripening, initially increasing and then decreasing (James Harbertson, James Kennedy, Doug Adams, 2002). This concentration is subject to various factors including grape variety, vintage, ripening, and harvest timing.

Polyphenols are typically classified into three groups, as defined by (V L Singleton, P Esau, 1969): tannins, flavonoids, and non-flavonoid compounds, each offering distinct contributions to the wine's final profile.

Non-Flavonoid Phenolics

Predominantly found in the pulp and skin of grape berries, non-flavonoid phenols include compounds such as hydroxybenzoic and hydroxycinnamic acids and their derivatives, alongside resveratrol, a powerhouse with benefits ranging from protecting cardiovascular systems to showcasing antiviral properties. The grape processing technology, involving variables such as maceration time and temperature, greatly influences their quantity in musts and wines. These phenols play a pivotal role in crafting a wine's flavour and taste, often offering a less astringent note (Ibern-Gómez, és mtsai., 2000).

Flavonoids

Found in both white and red grape skins, stems, and seeds, flavonoids are vital in determining a wine's taste and colour attributes. They are primarily composed of catechins and leucoanthocyanin, and their concentration can influence a wine's bitter and astringent taste notes.

Tannins

Despite being less researched, tannins are complex biomolecules with a variety in their structure and influence on wine's profile. Influenced by numerous factors including climate and ripening stage, they possess characteristic astringent and bitter tastes, with a role in protein precipitation.

The Role of Polyphenols in Sparkling Wines

In the context of sparkling wines, maintaining a low polyphenol content is essential to prevent technological risks associated with oxidation and polymerization. Strategies such as early harvest and minimized skin contact are employed to keep polyphenol content low, ensuring the production of quality sparkling wines (Zoecklein, 2002).

Polyphenols, present in an array of compounds such as resveratrol, anthocyanins, and tannins, play an integral role in defining a wine's character, dictating its sensory attributes and health benefits. Understanding the intricate dynamics of polyphenols is central to mastering winemaking, offering insights into how to optimize the process to produce wines that are not just delightful to the senses but beneficial to health. Future research avenues could focus on a deeper understanding of tannins and strategic approaches to balance polyphenols in sparkling wine production to achieve desired sensory attributes while maintaining health benefits.

Method of Analysis

In the analytical examination of sparkling wines, various parameters were measured to obtain a more comprehensive picture of the differences between the different sparkling wines. The characteristics examined, and their corresponding methods and measurement techniques are:

- Actual alcohol - by distillation
- Titratable acidity - by acid-base titration
- Volatile acidity content - according to MSZ 9473-87
- Reducing sugar - Rebelein method
- pH measurement with a combined glass electrode
- Determination of total polyphenol content using Folin-Ciocalteu reagent, calibrated to gallus acid, according to MSZ-9474-80
- Determination of Leucoanthocyanin content by spectrophotometry after heating with a mixture of sulfuric acid-butanol containing ferrous sulphate, according to the modified method of Flanzy (1970)
- Determination of catechin content in alcohol-diluted wine by reaction with vanillinin sulfuric acid, spectrophotometrically at 500 nm (Tanner, Brunner, 1979, modified)
- TAC - RANDOX test
- Colour intensity - according to MSZ 14849:1979

Location of Analysis

The analysis was conducted at the Department of Enology (Hungary, 1118 Budapest, Ménesi street 45.), except for the Champagne samples. Their analysis was conducted at the Sofralab laboratory (79 avenue A.A. Thévenet, 51530 Magenta, France), and only the actual alcohol, titrate-able acid content, volatile acidity, pH, and total polyphenol content were examined.

Sensory Evaluation

The sensory evaluation took place at the Department of Enology. Five judges evaluated the different sparkling wines based on the hundred-point OIV evaluation method (OIV 332A 2009), which is a fully accepted evaluation method for wine quality in Hungary. All participants were employees of the Department of Winemaking. The judges blindly scored the different sparkling wines. A temperature-controlled and bright space was the tasting room. The sparkling wines were pre-cooled to 10 degrees Celsius.

Results

I present the results of the analytical examination in separate diagrams for better visualisation. During the measurements, we examined ten different parameters, thus we can obtain a more complex picture.

Development of actual alcohol

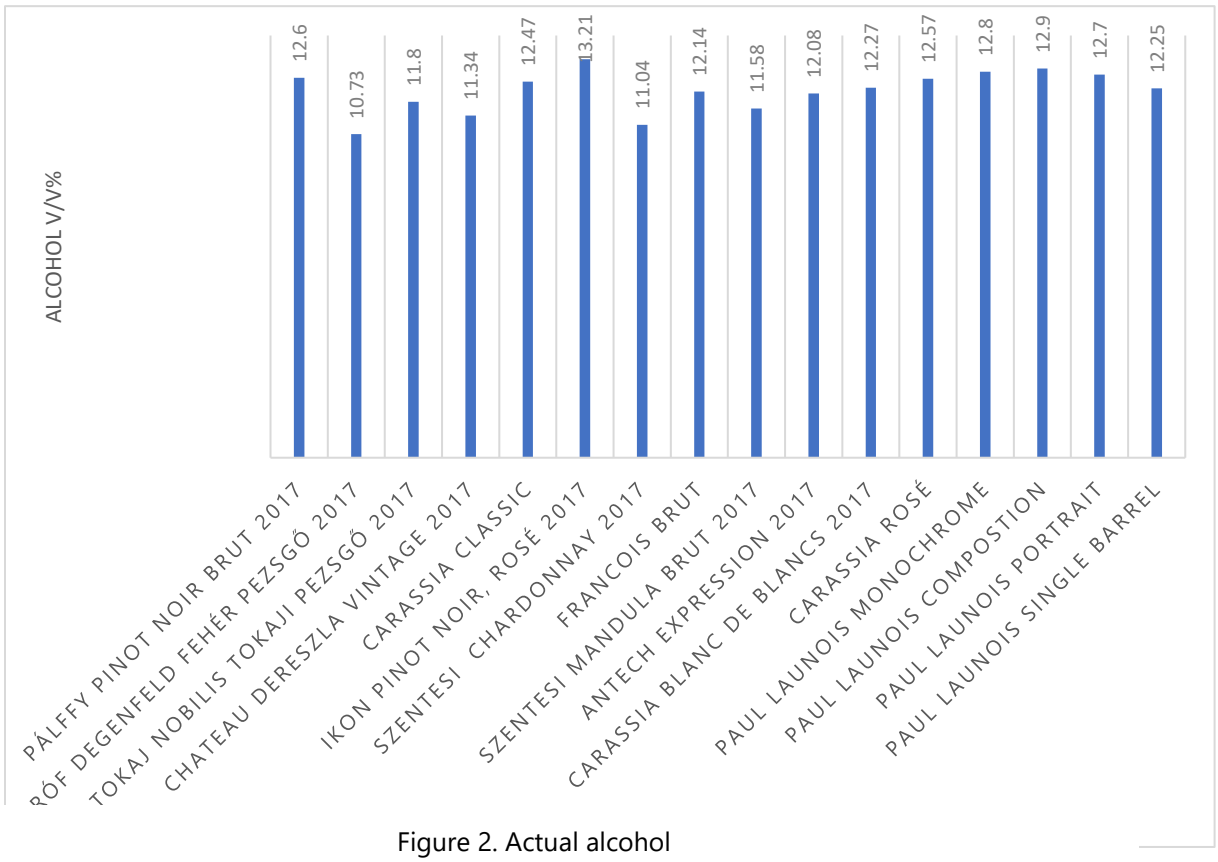

Figure 2. Actual alcohol

The alcohol contents of the examined sparkling wines range from 10.73 to 13.21% v/v. There was no significant difference among most samples. The lowest alcohol content was found in the Gróf Degenfeld white sparkling wine 2017, while the highest was in the Ikon Pinot Noir Rosé 2017. Sparkling wine's alcohol content is determined by the ripeness of the grapes. The 2017 vintage was outstanding in Tokaj, and the grapes were harvested in early September. Therefore, it is unclear to me why the alcohol content is so low. The alcohol content is primarily determined by the sugar content of the must, but it also depends on the yeast strain used. The new trend in Champagne is to aim for an alcohol content of 12.5-13% v/v because alcohol above this level has an aggressive effect, while below it loses complexity. All samples exceed the minimum required alcohol content of 8.5%. Alcohol is a natural preservative and protective agent. The typical alcohol content of sparkling wine is 12.5%, while the average alcohol content here is 12.16%.

Development of titratable acidity

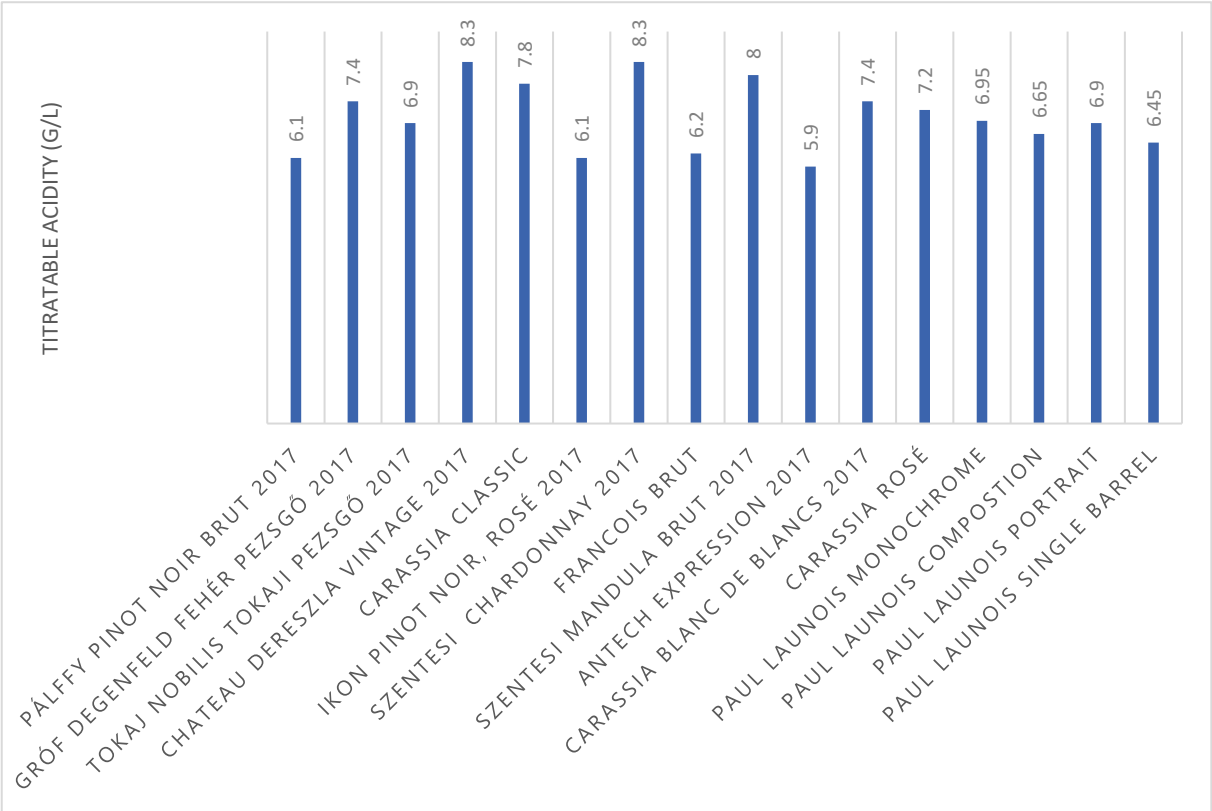

Figure 3. Titratable acidity (g/l)

During the period investigated, the amount of titratable acidity in the sparkling wines ranged from 5.9 to 8.3 g/L. The Antech Expression 2017 had the lowest value, while the Chateau Dereszla 2017 and Szentesi Mandula Brut 2017 had the highest. The Antech was made in a much warmer climate in southern France, which easily explains why it is lower than the others. There is a marked distinction between Hungarian sparkling wines, which may be attributed to the variety and region of production. It is interesting to note that historically, high acidity has always been associated with Champagne, however, that is no longer the case.

Development of volatile acidity

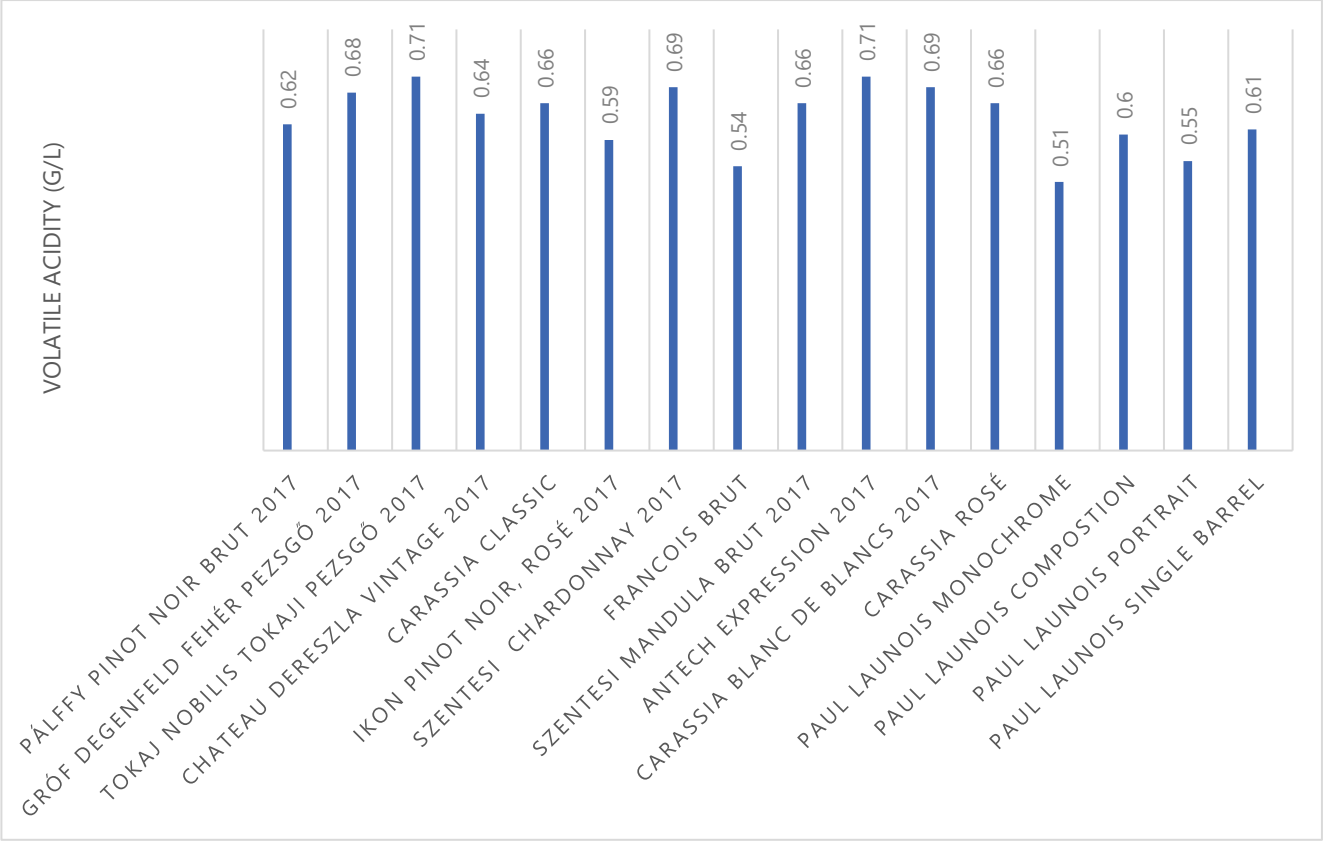

Figure 4. Volatile acidity (g/l)

There were no significant differences in volatile acidity, with measured values ranging from 0.51-0.71 g/l. The lowest value was found in the Paul Launois Monochrome champagne, but the other three champagnes also belonged to the group of sparkling wines with lower volatile acidity. All sparkling wines comply with the maximum allowable limit for volatile acidity set by the authorities.

Development of reducing sugar content

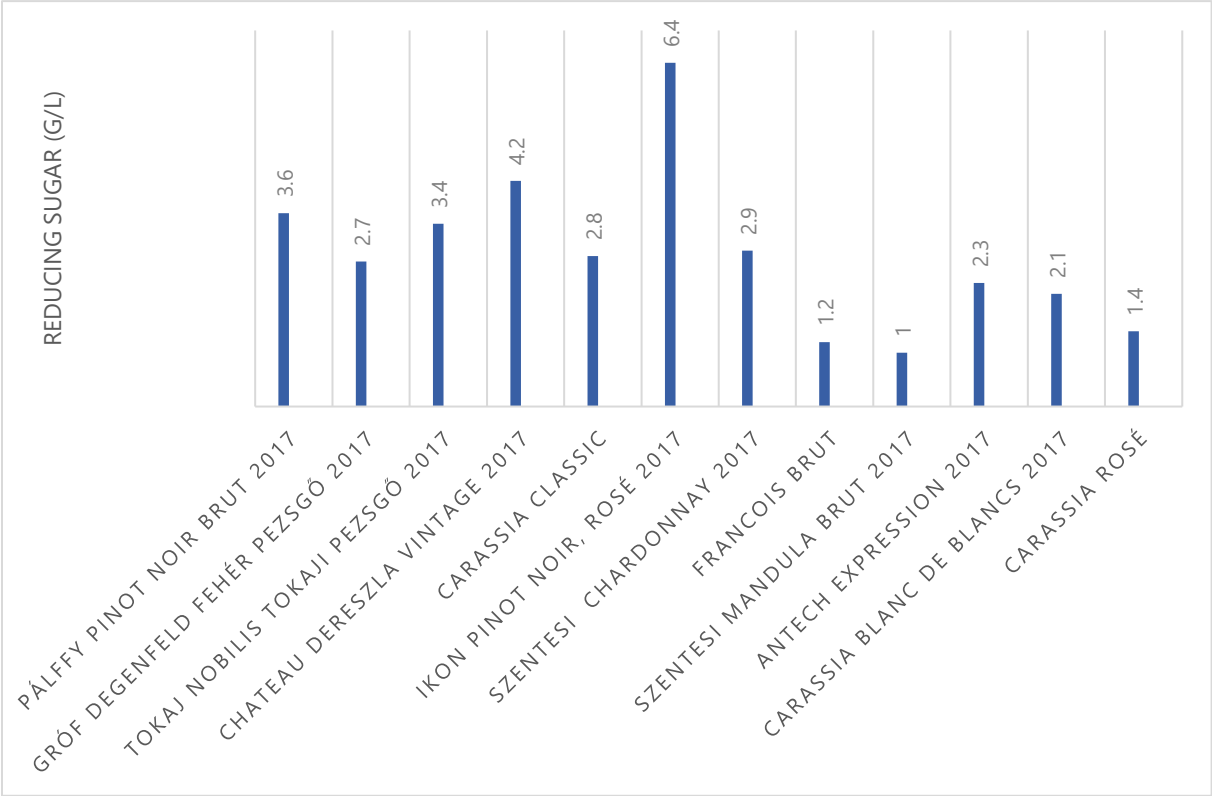

Figure 5. Reducing sugar (g/l)

The role of reducing sugars in the taste of wine is significant; above 2-3 g/l, their taste is noticeable during sensory evaluation, and they affect the sensory properties of wine, especially its acidity (Kállay, Borászati Kémia, 2010). Yeasts cannot convert all sugars into alcohol, so some remain. The significant part of reducing sugars is fructose. The highest value was observed in the Ikon Pinot Noir Rosé, which is 6.4 g/l. As this champagne is also associated with high alcohol, they must have worked with high sugar content must, and the high alcohol inhibited fermentation, leaving a high amount of reducing sugar.

Development of pH value

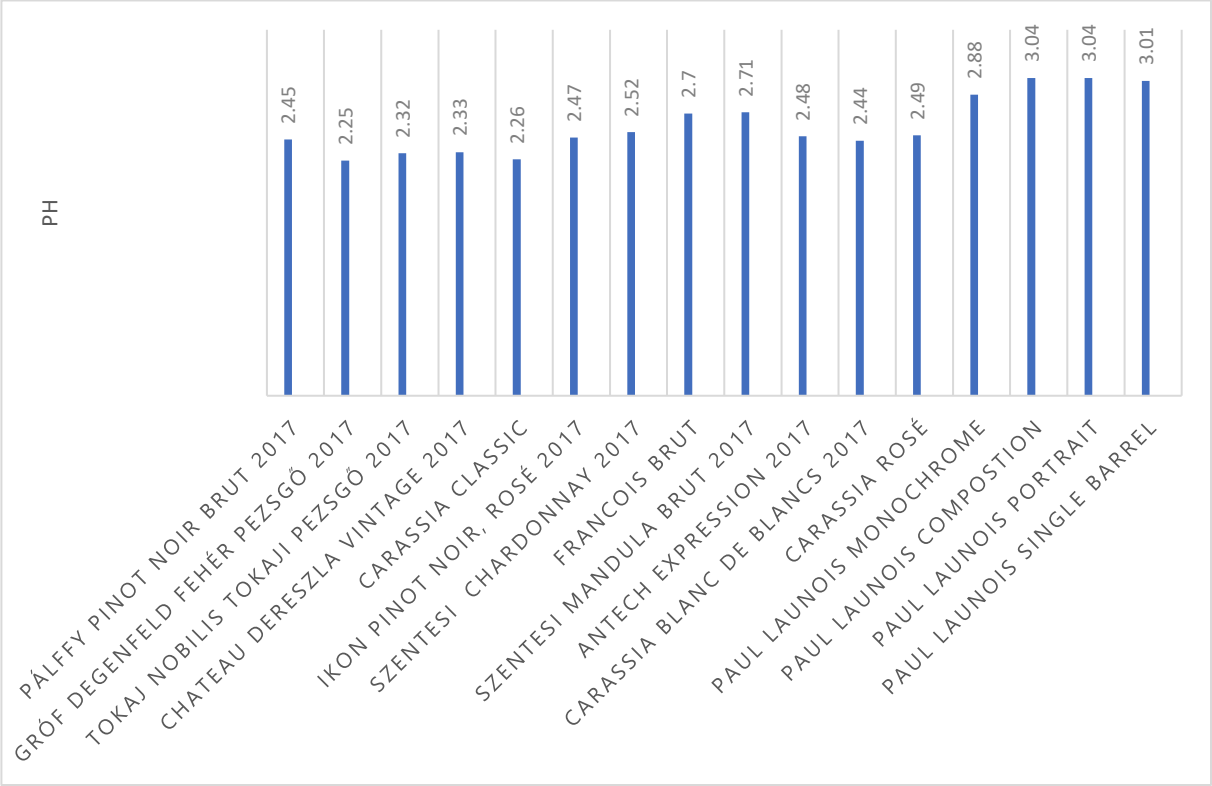

Figure 6. pH

The pH value is defined as the negative logarithm of the concentration of H+ ions, serving as a useful indicator of the strength of acids. Wine's pH level is determined by its tartaric acid content. The pH values of the samples in this study ranged from 2.25 to 3.04. It is noteworthy that the Champagnes exhibited higher pH values than the other samples. Although no significant differences were observed among the other samples, a low pH range can hinder the biological breakdown of malic acid by malolactic bacteria because of unsuitable environmental conditions, such as high alcohol and high acid content, presence of sulphur dioxide, and nutrient deficiency. The most well-known malolactic bacterium, Oenococcus oeni, has a lower growth limit at around a pH value of 3.0. Therefore, the pH value is a crucial parameter to monitor in wine production.

Development of total polyphenol content

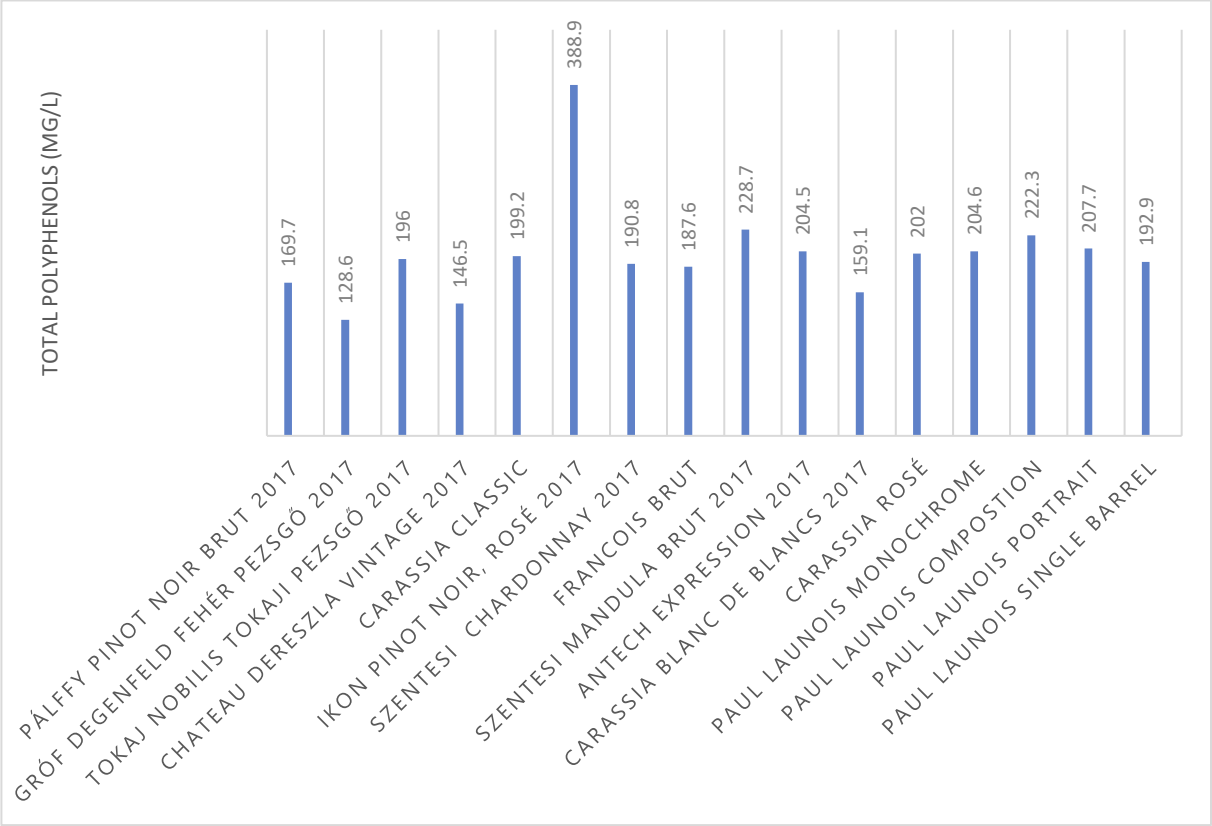

Figure 7. Total polyphenols (mg/l)

The measured polyphenol content in the studied sparkling wines ranged from 128.6 to 388.9 mg/l, with the highest value found in the Ikon Pinot Noir Rosé 2017 and the lowest in the Gróf Degenfeld white sparkling wine. The Szentesi Mandula Brut 2017 had the highest measured polyphenol content among the white sparkling wines, with a value of 228.7 mg/l. Most of the samples had polyphenol content between 190-200 mg/l, which is in line with the values reported in the literature (Chamkha, Cathala, Cheynier, & Douillard, 2003). However, the Ikon Pinot Noir Rosé had almost double the reported values, showing a potentially unique wine.

Rosé sparkling wines have higher polyphenol content than white sparkling wines. However, the low polyphenol content in sparkling wines can also be attributed to the gentle pressing, short maceration times, and extended aging, which can cause the characteristic reactions of polyphenolic compounds, such as polymerisation and oxidation.

Flavonoid phenols (Leucoanthocyanidin and Catechin)

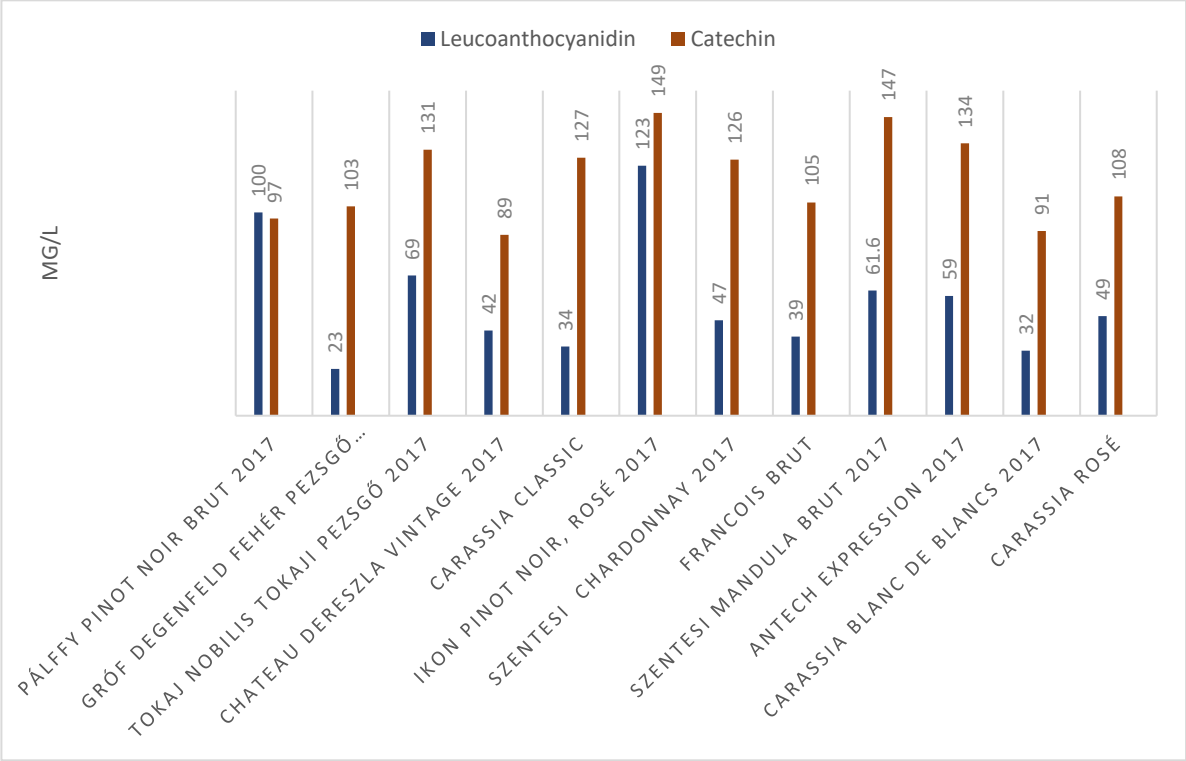

Figure 8. Amount of flavonoid phenolics (mg/l)

According to the research by (V L Singleton, P Esau, 1969), flavonoids can be the cause of browning tendency and other sensory changes. The quantity of Leucoanthocyanin was measured between 23 and 123 mg/l. Not surprisingly, the highest amount was found in the Ikon Rosé, followed by Pálffy Pinot Noir with a value of 100 mg/l. The values of Catechin are between 91 and 149 mg/l. The catechin values are higher than the leucoanthocyanidin values, except for Pálffy sparkling wine. Compared to the values of normal white still wines described in the literature, these values are several times higher. Flavonoids, including leucoanthocyanin and catechin, are natural compounds present in wine that contribute to its colour, taste, and health benefits. However, elevated levels of flavonoids can also lead to browning and other sensory changes in wine.

Total Antioxidant Capacity

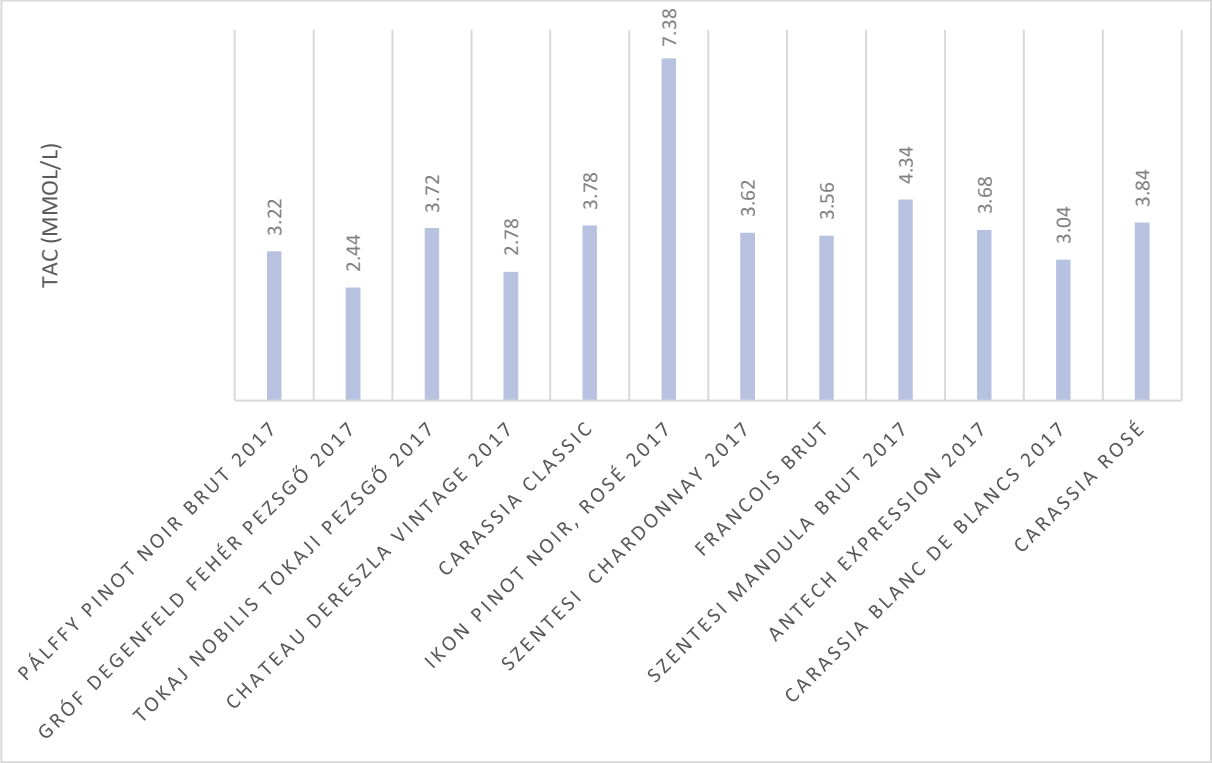

Figure 9. Total Antioxidant Capacit (mmol/L)

The antioxidant properties of sparkling wines are guaranteed by polyphenolic compounds (Kállay & Nyitrainé Sárdy, Borok és borászati termékek illetve polifenolokkal jellemezhető italok (gyümölcslevek, üdítőitalok, sör) antioxidáns kapacitásának mérése, 2008). The higher the value of total antioxidant capacity, the more antioxidants are present that can stop oxidation. Antioxidants are molecules that can significantly reduce the number of free radicals (Kalt, Forney, Martin, & Prior, 1999). The values ranged from 2.44 to 7.38 mmol/L. Once again, Ikon Pinot Noir Rosé came out on top with a measured value close to twice the average.

Development of color intensity

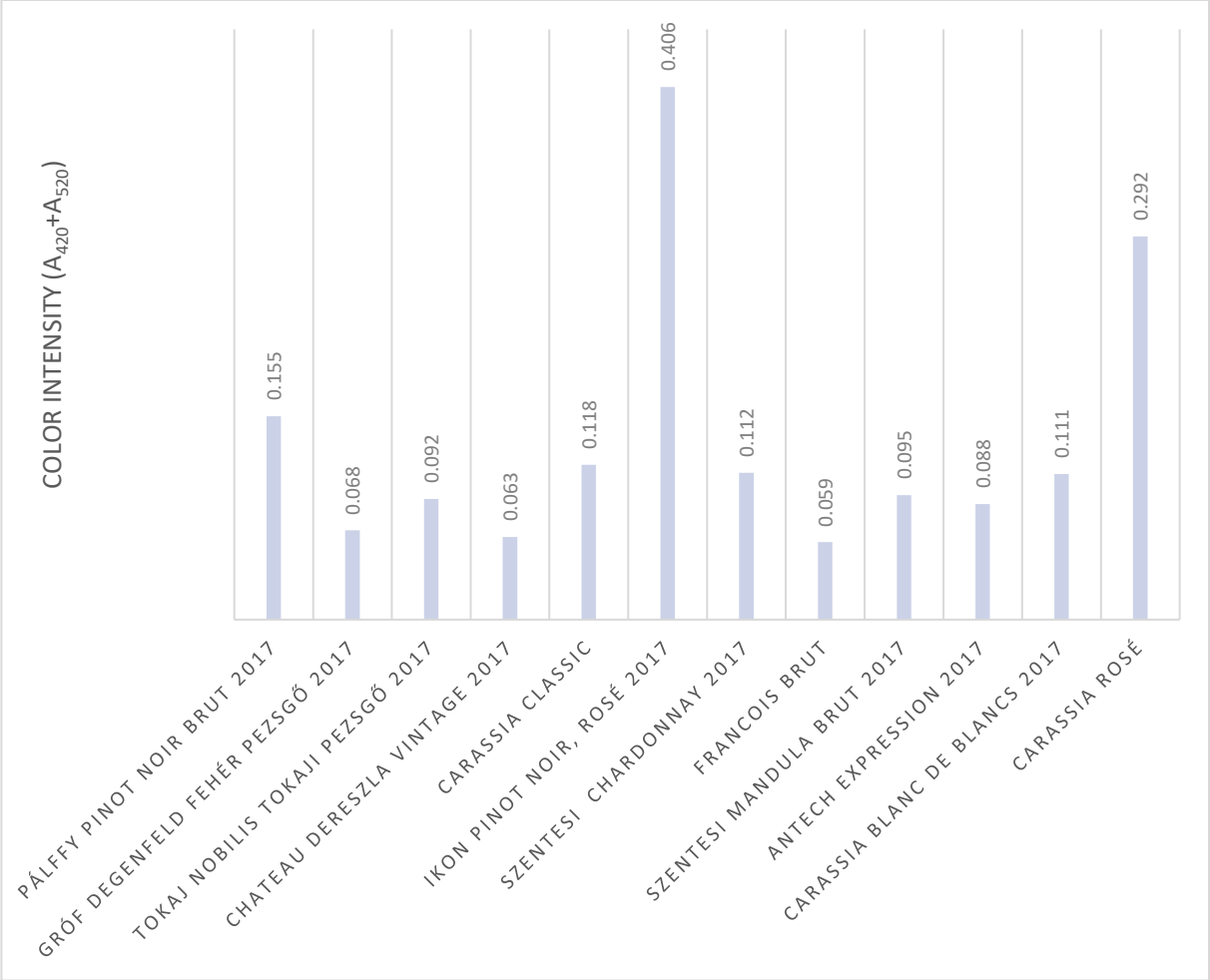

Figure 10. Colour intensity

During the examination of colour intensity, brown-coloured compounds are measured: the higher the value, the higher the quantity of brown-coloured compounds. Since adding sulphur blocks browning and oxidation, it is not surprising that the measured values are low as these are ready-made products on the market, and they have received the amount of sulphur. There is a direct relationship between the colour intensity and the anthocyanin content of sparkling wines. The colour intensity of rosé wines is significantly higher, so it is not surprising that Ikon Pinot Noir Rosé and Carassia Rosé produced the highest value. Based on the measured value of 0.406 for Ikon Pinot Noir Rosé, one can infer over-oxidation. In white sparkling wines, the values ranged from 0.059 to 0.155.

Sensory examination

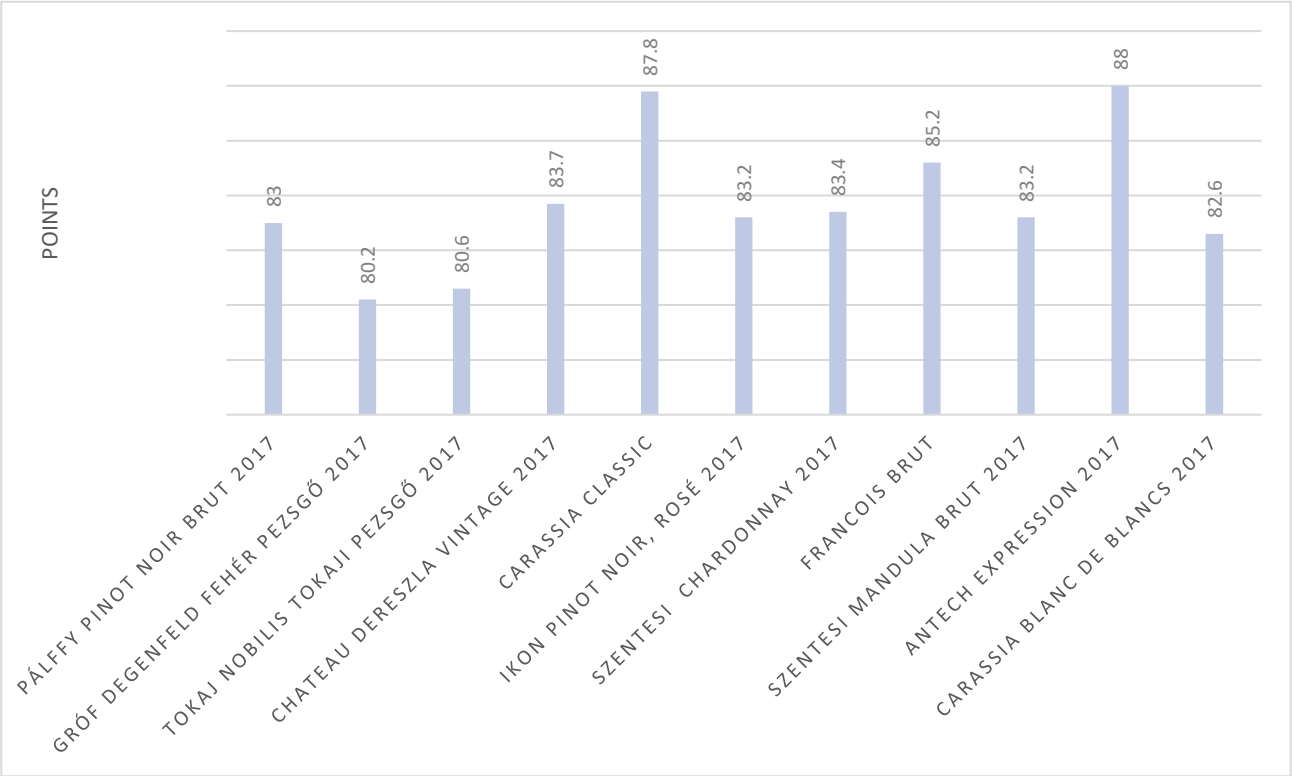

Figure 11. The combined averaged results of sensory evaluation

The Carassia Rosé was not included in the chart and will not be considered, as it had a corked bottle.

Overall, foreign sparkling wines performed well in the sensory evaluation. The Antech Expression 2017 was the favourite among the judges, closely followed by the Carassia Classic. The Carassia Classic was also the most divisive, with the largest spread of scores.

It is interesting that we often associate high acidity with sparkling wine, but the winner of the blind tasting had the lowest acidity.

During the evaluation, the Gróf Degenfeld White Sparkling Wine 2017 and the Tokaj Nobilis Tokaji Sparkling Wine 2017 received the lowest scores. Both are made from Furmint grapes in the Tokaj region. Despite the increasing number of bottle-fermented sparkling wines in Tokaj, it is unclear from the sensory evaluation whether the variety or the region caused the below-average results.

Conclusions

It is not viable to make a definitive conclusion regarding the origin of a sparkling wine based on its polyphenol composition, no matter if it is from a particular country or wine region. Through analytical evaluation, it has been showed that Hungarian sparkling wines are equal to or surpass the quality of foreign sparkling wines in both an analytical and sensory evaluation. Despite polyphenols having a considerable effect on taste perception, I could not find a relationship between the number of polyphenols in the sparkling wines and the quality of the wine.

Rosé sparkling wines contain more polyphenols than white sparkling wines, but do not have the same levels as rosé still wines. Although sparkling wines have lower levels of polyphenols with positive physiological properties than still wines, we primarily drink them for pleasure and enjoyment, not for the health benefits it provides.

It is essential to keep in mind that the polyphenol composition is only one of the various elements that help to the intricate nature of sparkling wines. Grape variety, winemaking technique, and aging process all have a considerable influence on the flavour and excellence of a sparkling wine, besides other aspects.

Summary

During our work, I conducted analytical and sensory tests on different bottle-fermented sparkling wines. We performed detailed analytical testing, including all polyphenol content, leucoanthocyanin, catechin, colour intensity, and total antioxidant capacity, besides routine analysis. In routine analysis, we measured actual alcohol content, titratable acidity, pH, volatile acidity, and reducing sugar to get a more complex picture. We paid special attention to the polyphenol content because this is a significant group responsible for the oxidation-related changes in wines and sparkling wines and can significantly affect the taste of sparkling wines. Another reason is that the scientific research of polyphenolic compounds has come to the fore because of their well-known favourable physiological effects, and it is essential for conscious sparkling wine consumers to consume healthy products, so it is necessary to better understand the amount and quality of polyphenols in sparkling wines. All sparkling wines are from 2017, and

we sought answers to how similar or different domestic and foreign bottle-fermented sparkling wines are. The analytical and sensory tests confirmed that the world of sparkling wines is remarkably diverse. Based on my research, Hungarian sparkling wines are of comparable quality to foreign sparkling wines. Regarding the results of routine analysis, most of them meet the requirements described in the literature. There was a significant difference in flavonoid phenol content. Leucoanthocyanin was measurable between 23 and 123 mg/L, while there was slightly less variation in catechin values, ranging from 91 to 149 mg/L. Catechin values exceeded leucoanthocyanin values, except for the Pálffy Pinot Noir Brut 2017. All polyphenol content varied between 128.6 and 388.9 mg/L. Sparkling wines have fewer polyphenols than still wines. The remarkably high value was measurable in the case of the Ikon Pinot Noir rosé, except for this sample, the measured data corresponds to the average.

We conducted an in-depth analysis of various bottle-fermented sparkling wines using both analytical and sensory evaluations. By analysing various polyphenolic compounds, we could acquire a comprehensive understanding of the quality and characteristics of these wines. We placed particular emphasis on the polyphenol content because of its significant impact on the taste and health benefits of sparkling wines. Our purpose was to analyse domestic and foreign bottle-fermented sparkling wines to understand what was similar and different between them. We discovered that the realm of sparkling wines is incredibly wide-ranging, with different polyphenol amounts, flavour, and other attributes. Our research confirmed that Hungarian sparkling wines are of high quality and are comparable to foreign sparkling wines. Our results also highlight the importance of regularly assessing the quality and characteristics of sparkling wines to ensure that they meet industry standards and health requirements.

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Conflicts of Interest: The authors declare no conflict of interest.

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