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DETERMINING THE ORIGIN OF WINE BASED ON THE SELECTED QUALITY PARAMETERS

S u m m a r y

Background. Wine is a commonly consumed alcoholic beverage. The quality and characteristics of this beverage are influenced by various factors, such as winemaking technique, the quality of the raw material, the degree of its maturity, grape variety, human talent, and the most importantly, a territory or rather its climate, height above sea level, topography and soil. The aim of the research was to investigate the impact of grapevine origin on the selected quality parameters of Cabernet Dorsa red wine. Additionally, the possibility of identifying the origin of Cabernet Dorsa wine based on differentiating criteria was verified. The research material consisted of Polish, German and Swiss dry red wine made from the grape variety Cabernet Dorsa. The following parameters were used to compare the quality of the chosen wines: the concentration of alcohol, total dry extract (TDE) and volatile acids (VA), titratable acidity (TA) and total phenolic content (TPC). Additionally, a sensory analysis was performed.

Results and conclusions. The results show that wines produced from grapes of the same cultivar (Cabernet Dorsa) grown in different countries differ statistically significantly in TDE, TA and TPC. Despite producers' declarations, there were slight yet statistically significant differences in alcohol concentration. Moreover, the Swiss wines were assessed as having the highest rated color among tested products. The Principal Component Analysis showed that, on the basis of chemical and sensory parameters, it is possible to distinguish between wines from the three selected countries. The results obtained provide an excellent basis for further research, also concerning different countries and grape cultivars.

Keywords: Cabernet Dorsa; polyphenols; red wine; sensory quality; wine discrimination

Introduction

Wine consumption has a long tradition as its history dates back to 5500 B.C. [12]. Nowadays, wine is still a very popular alcoholic beverage. In 2023, the estimated world wine production was 244 mhL [30]. Wine is characterized by a high content of

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polyphenols, which have anti-cancer and heart protective properties [20]. Consumers can, however, choose from plenty of different varieties and styles of wine. Their quality and characteristics can differ significantly. It is influenced by various winemaking techniques [15, 36], as well as the quality of the raw material and the degree of its maturity, grape variety and human talent. Correspondingly, the most important factor affecting the quality of grapes is terroir or rather its climate, height above sea level, topography and soil [14, 23, 35].

The values of physicochemical parameters determining the quality of wine depend on many factors, including climatic conditions, i.e. temperature, rainfall, irrigation, wind and sunlight. Grapes which are grown in warmer conditions contain more sugar, which generally results in a higher alcohol concentration in the finished product [31]. Higher temperatures also affect aromatic compounds [47]. However, high temperatures and solar radiation are likely to result in a reduction in acidity and flavonoid content in crops [25]. On the other hand, reduced irrigation promotes accumulation of phenolic compounds, especially anthocyanins, in grape berries [5]. Therefore, it can be assumed that the wine origin is associated with its quality [33, 40].

Germany, Switzerland and Poland are not among the world's largest wine producers. Climatic conditions for viticulture in those countries are worse than in typical wine regions. However, they can favor accumulation of certain compounds, including polyphenols. Wines are less sweet and more acidic, which results in a more fresh and crisp taste [13]. Moreover, there are certain grape varieties, the production of which requires a cool climate. Germany, Switzerland and Poland have favorable climatic conditions for cultivation of the Cabernet Dorsa grape. Consequently, Cabernet Dorsa wines have specific, full bodied characteristics [3, 43]. Nonetheless, even closely located regions may have their own individual terroir that affects the quality of wine [13].

The influence of wine origin on its quality has been studied by some scientists [13, 21, 25, 27]. For instance, Pieszko and Ogrodowczyk [37] conducted research into regional wine and the impact of its origin on tannin and polyphenol content. They showed that the greatest polyphenol content was found in dry red wines from France, Spain and Portugal. Jakkielska et al. [13] compared volatile compounds in wines produced in different regions of Poland, indicating the influence of terroir on the wine quality, whereas Kupsa et al. [21], using the example of Czech Riesling, identified the impact of geographical origin of wine on its phenolic profile. Nonetheless, research into Cabernet Dorsa wines is scarce. Consequently, little is known about the influence of origin on the characteristics of Cabernet Dorsa. Therefore, the aim of this study was to investigate the influence of origin on the selected quality parameters of Cabernet Dorsa red wine. Furthermore, geographical origin became an important attribute of wine, appreciated by consumers and associated by them with certain characteristics [7],

quality [36, 46] and value [35]. Therefore, sophisticated analytical methods, such as inductively coupled plasma-mass spectrometry (ICP-MS), isotope ratio mass spectrometry (IRMS), liquid or gas chromatography Fourier transform infrared spectroscopy (FTIR), near infrared spectroscopy (NIR), and nuclear magnetic resonance (NMR) are investigated as a methods of wine authentication. However, basic chemical parameters can also be a reliable alternative for that purpose [7, 35, 40]. Therefore, the possibility of the identification of the origin of Cabernet Dorsa wine based on differentiating criteria was also verified.

Materials and methods

Samples

The research material consisted of Polish, German and Swiss dry red wine made from the single grape (*Vitis vinifera* L.) variety – Cabernet Dorsa (as declared by their producers). Seven wines from different vineyards located in the Podkarpackie region (Poland), Rheinhessen region (Germany) and Aargau region (Switzerland) were collected. Wines were produced following the standard winemaking procedures [42]. The wines were produced in 2018. Samples were collected in 2020 from three different barrels and bottles. The bottles were kept in controlled conditions (a temperature of 15 °C) until the analyses.

Chemical analysis

The assessment of the quality of wines was based on an analysis considering the following parameters analyzed according to Compendium of International Methods of Wine and Must Analysis [6]:
−   concentration of alcohol in % v/v according to OIV-MA-AS312-01 using a pycnometer,
−   amount of total dry extract in g/L according to OIV-MA-AS2-03B,
−   concentration of volatile acids according to OIV-MA-AS313-02,
−   titratable acidity (TA) in g of tartaric acid/L according to OIV-MA-AS313-01,
−   total phenolic content (TPC) according to the Folin-Ciocalteu method (OIV-MA-AS2-10) and based on a calibration curve expressed in mg of gallic acid per 1 L of wine.
    All analyses were performed in triplicate.

Sensory analysis

In addition to the physicochemical assessment, a sensory analysis was also performed. The samples were evaluated by a team of 12 selected assessors, chosen according to guidelines of the ISO 8586 Standard [10]. The sensory panel assessed the color, odor, flavor and clarity of wines using a five-point descriptive scale according to

the methodology presented in the PN-A-79122:1996/Az1 Standard [38]. The analyses were conducted in a sensory laboratory that was designed in accordance with the guidelines of the ISO 8589 Standard [11]. They were performed at room temperature (22 °C – 24 °C) and under artificial daylight.

Statistical analysis

To account for variance due to the wine manufacturer, differences between the origin of wine were analyzed using linear mixed models with the producer as a random effect and the origin of wine as a fixed effect. To identify differences between the Polish, German and Swiss wines tested, a Principal Component Analysis (PCA) was performed. As a result, a two-dimensional sample map was developed. For the purpose of PCA, variables were standardized. Statistical analyses were performed using statistical package R, version 4.0.5 [39]. A value of 0.05 was required for statistical significance.

Results and discussion

Chemical parameters

Despite the identical declared alcohol content, slight differences between the tested wines were detected. The discrepancies did not exceed the tolerance level of 0.5 % allowed by EU law [41]. However, as confirmed by the results of the statistical analysis (Table 1), the Swiss wines were distinguished by the significantly highest concentration of alcohol, while the German ones had the lowest. The differences may be a result of the slightly different climate between the countries of wine origin. A warmer climate (higher temperatures and more sunny days) increases sugar content in grapes, and hence results in a higher alcohol concentration in the finished product [16, 47], even over 15 % v/v [22]. Correspondingly, also vinification procedures used by producers might have influenced alcohol concentration in the tested wine [1]. The concentrations of alcohol noted in the tested wines (10.98 ÷ 11.25 % v/v) are lower than the average determined by Kapusta et al. [17] for Polish Cabernet Dorsa wine (13.21 % v/v) and for Polish red wines produced from other hybrid grapes (from 11.86 to 12.77 % v/v).

The tested wines also differed significantly in the content of total dry extract. The Swiss wines contained what were statistically significantly the highest amounts of these compounds. By contrast, the Polish wines were characterized by what were significantly the lowest amounts of these compounds. The differences might be attributed to the varying concentrations of polyphenols in the tested wines, and therefore be a consequence of varying cultivation conditions and procedures, as well as variations in processing [36]. Total dry extract for analyzed Cabernet Dorsa wines (18.2 ÷ 20.98 g/L) were much lower than for Merlot wines (26.4 ÷ 20.9 g/L) examined by Visan et al

[48] and for Cabernet Sauvignon, Frankovka, Merlot and Pinot Noir (26 ÷ 29.67 g/L) studied by Kojić and Jakobek [19].

Table 1. The results of chemical analyses of selected quality parameters of wine
Tabela 1. Wyniki analiz chemicznych wybranych parametrów jakościowych wina

Parameter / Parametr	Origin / Pochodzenie			Linear mixed models / Liniowe modele mieszane		
	D	PL	CH	PL vs D	CH vs D	CH vs PL
Alcohol / Alkohol [% v/v]	10.98±0.10	11.05±0.14	11.25±0.12	$p < 0.001$*	$p < 0.001$*	$p < 0.001$*
Titratable acidity [g of tartaric acid/L/ / Kwasowość miarecz-kowa [g kwasu winowego/L]	5.57±0.09	5.49±0.11	5.49±0.09	$p = 0.036$*	$p = 0.025$*	$p = 0.882$
Volatile acids (g of acetic acid/L) / Kwasy lotne (g kwau octowego/L)	0.35±0.09	0.31±0.07	0.27±0.07	$p = 0.181$	$p = 0.027$*	$p = 0.109$
Total dry extract / Cakowity suchy ekstrakt (g/L)	19.37±0.2	18.2±0.13	20.98±0.08	$p < 0.001$*	$p < 0.001$*	$p < 0.001$*
TPC (mg GAE/L)	986±42	899±29	1,904±41	$p < 0.001$*	$p < 0.001$*	$p < 0.001$*

Explanatory notes: – mean values ± SD; SD – Standard Deviation; *statistically significant ($p < 0.05$); D – Germany, PL –Poland, CH – Switzerland; TPC – total phenolic content
Objaśnienia: – wartości srednie ± SD; SD – odchylenie standardowe; *istotne statystycznie ($p < 0,05$); D – Niemcy, PL – Polska, CH – Szwajcaria; TPC – całkowita zawartośc polifenoli

Volatile organic acids (VA), among other constituents, have influence on the sensory profile of wine, mainly so-called 'fermentative' flavor. Therefore, their overpresence in wine is unwanted [49]. Comparing to the literature data [19, 28, 33, 48], the concentration of volatile acids in the tested wines was at a low level, but slightly higher than determined by Marchi et al [24] for Swiss Cabernet Dorsa wine (0.23 g acetic acid/L). It ranged between 0.27 and 0.35 g of acetic acid/L. The statistically significant differences concerned German and Swiss wines, i.e. wines characterized by the highest and lowest amount of these compounds.

The German wines were also distinguished by the highest titratable acidity (TA) among the tested wines ($p < 0.05$). The acidities noted are typical of Cabernet Dorsa red wine, as Kapusta et al. [17] determined a similar value for Polish wine of this kind – 5.63 g of tartaric acid/L. On the other hand, Marchi et al. [24] noted higher titratable acidity for Swiss Cabernet Dorsa wine – 7.1 g of tartaric acid/L. Nevertheless, all the determined values are also generally characteristic of red wine. Kapusta et al. [17] showed that Polish red wines produced from hybrid grapes had acidity ranging from 4.41 to 7.6 g of tartaric acid/L. Navarro et al. [28] showed that TA of Spanish Cabernet

Sauvignon ranged between 5.4 and 5.7 g of tartaric acid/L, depending on the year of production. Similarly, TA of Romanian Merlot differed between vintages (from 5.42 to 6.48 g of tartaric acid/L) [48]. Ranaweera et al [40] compared Australian Cabernet Sauvignon wines (TA from 5.5 to 6.0 g of tartaric acid/L) with French Bordeaux (TA of 5.0 g of tartaric acid/L) indicating statistically significant differences in TA between products of different origin. The differences in TA between wines produced from different grape varieties were shown by Kojić and Jakobek [19] and Samoticha et al [44]. However, they may also be a consequence of divergent viticulture techniques, climatic conditions or winemaking practices [40, 44], which most probably caused the discrepancies in the tested Cabernet Dorsa wines.

Wine is a product rich in polyphenols, which contribute to the formation of color, aroma and flavor of wine [4]. Red wines are characterized by the highest TPC, followed by rosé and white wines [32]. In the current research, total phenolic content (Table 1) varied significantly between the tested wines of different origin. It was the highest (1,904 mg GAE/L) for the Swiss wines and the lowest (899 mg GAE/L) for the Polish samples. The lower content of polyphenols in Polish Cabernet Dorsa red wine was noted by Kapusta et al [17] – 770.15 mg GAE/L. In their research, other Polish red wines contained from 608.1 mg GAE/L (Cabernet Cortis) to 1,860.8 mg GAE/L (Regent) of polyphenols. Socha et al. [45] determined TPC ranging from 996.17 to 1,668 mg GAE/L for seven Polish red wine varieties. The differences in TPC content concerning the examined samples of red wine can be ascribed to many factors. Among them, the most important ones seem to be: the variety of grapes, environmental conditions (especially temperature) and the degree of maturity of grapes during the harvest, the fertility of soil, water availability [9, 34, 44] and winemaking practices [29], particularly post-fermentation and clarification treatment, as well as the length of storage and aging [4, 27, 33]. However, similarly to the research conducted by Belmiro et al [2], further topic-focused studies are required to verify exact mechanisms.

Sensory analysis

The sensory characteristics of wine are driven by its composition, which in turn is influenced by terroir, winemaking practices typical of the region, and grape variety. Therefore, it can be representative for a certain geographical area of origin [46].

The results of the sensory analysis (Table 2) show that all the tested wines were of high sensory quality. All of them had perfect clarity. Polyphenol compounds, especially anthocyanins, have a major effect on the color [18, 32]. In the current study, wines with the highest TPC (Swiss wines) were distinguished by significantly the highest and almost perfect scores for color ($p < 0.05$). The German wines, by contrast, received significantly better scores for flavor in comparison to the Polish samples ($p < 0.05$). Meillon et al [26] and Goldner et al [8] showed that the content of alcohol affects the

perceived amount and strength of aromas in wine. Although, in the current research, wines differed significantly in alcohol content, the differences for odor ratings were statistically insignificant. Most probably the variability of alcohol concentrations was too low to influence the aroma in such a way to be perceived by the sensory assessors.

Table 2.   Results of sensory analysis
Tabela 2.   Wyniki analizy sensorycznej

Parameter / Parametr	Origin / Pochodzenie			Linear mixed models / Liniowe modele mieszane		
	D	PL	CH	PL vs D	CH vs D	CH vs PL
Color / Barwa	4.87±0.25	4.79±0.35	4.99±0.08	$p = 0.213$	$p = 0.004*$	$p < 0.001*$
Odor / Zapach	4.79±0.25	4.79±0.32	4.68±0.31	$p = 1$	$p = 0.085$	$p = 0.119$
Flavor / Smak	4.83±0.24	4.64±0.42	4.76±0.34	$p = 0.012*$	$p = 0.264$	$p = 0.154$
Clarity / Klarowność	5.00±0.00	5.00±0.00	5.00±0.00	$p = 1$	$p = 1$	$p = 1$

Explanatory notes: – mean values ± SD; SD – Standard Deviation; *statistically significant ($p < 0.05$); D – Germany, PL –Poland, CH – Switzerland
Objaśnienia: – wartości srednie ± SD; SD – odchylenie standardowe; *istotne statystycznie ($p < 0,05$); D – Niemcy, PL – Polska, CH – Szwajcaria

Verification of the differences between wines of different origin with the use of Principal Component Analysis (PCA)

In order to illustrate the differences between the wines of the selected origins, the PCA method was employed. The results are presented in Figure 1. The first two main components explained 70.65 % of the total variance; while the first component explained 51.9 % and the second one 18.75 %.

The first component indicates a high content of alcohol, TPC and total dry extract, along with a low concentration of volatile acids and high scores in the sensory assessment of color and low scores in odor assessment. The second component indicates high taste ratings and high titratable acidity.

The individuals factor map (Fig. 1a) shows that the first component perfectly separates the Swiss wines from the German and Polish samples. The Swiss samples are characterized by a high content of alcohol, TPC and total dry extract, while having a low concentration in volatile acids. They are also noted for their high color and received low odor ratings in the sensory assessment. The second component separates the Polish wines from the German ones. The German samples have higher taste ratings and higher titratable acidity.
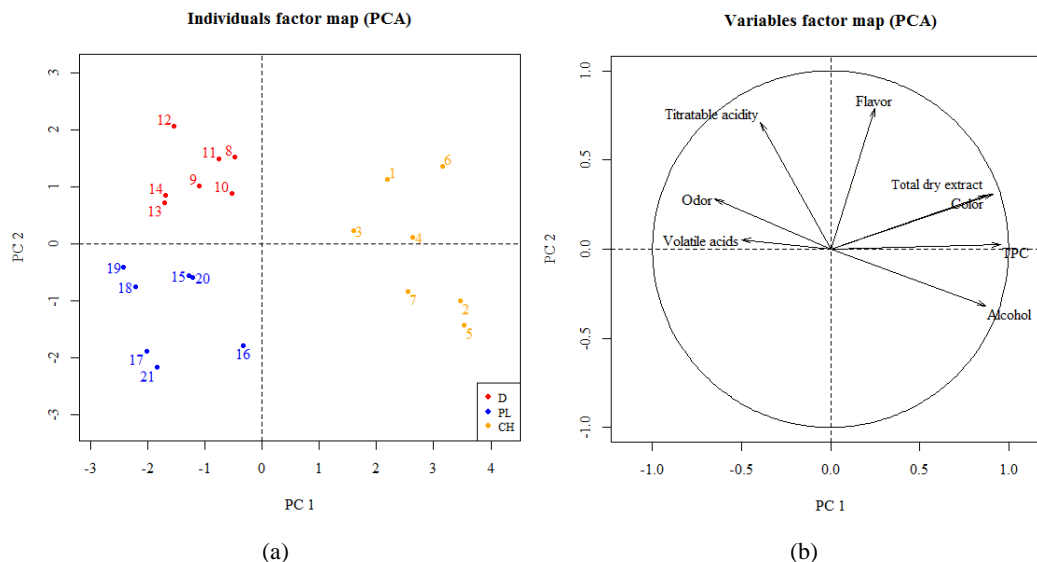
Figure 1.   The results of the Principal Component Analysis (PCA)
Rycina 1.   Wyniki analizy głównych składowych (PCA)

Conclusions

The research results confirm that wine manufactured from grapes of the very same cultivar grown in different regions vary in quality. When considering the wine made from grapes of Cabernet Dorsa cultivar originating from Poland, Switzerland and Germany, differences concerned alcohol concentration, total dry extract content, titratable acidity, TPC, as well as color ratings. The discerned variations may be ascribed to distinct terroirs and vinification processes, complemented by local know-how. The PCA analysis also showed that, on the basis of physicochemical and sensory parameters, it is possible to distinguish between wines from the three selected countries. Due to the low number of samples tested, the study should be considered preliminary. However, the results obtained in the research presented provide an excellent basis for further research, also concerning different countries and different grape cultivars.

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OKREŚLANIE POCHODZENIA WINA NA PODSTAWIE WYBRANYCH PARAMETRÓW JAKOŚCIOWYCH

S t r e s z c z e n i e

Wprowadzenie. Wino jest powszechnie spożywanym napojem alkoholowym. Na jakość i właściwości tego napoju ma wpływ wiele czynników, a wśród nich: technika produkcji wina, jakość surowca, stopień jego dojrzałości, odmiana winogron, talent ludzki i co najważniejsze obszar uprawy, a raczej jego klimat, wysokość nad poziomem morza, topografia i gleba. Celem badań było zbadanie wpływu pochodzenia winorośli na wybrane parametry jakościowe wina czerwonego Cabernet Dorsa. Dodatkowo zweryfikowano możliwość identyfikacji pochodzenia wina Cabernet Dorsa na podstawie kryteriów różnicujących. Materiał badawczy stanowiło polskie, niemieckie i szwajcarskie wino czerwone wytrawne produkowane ze szczepu Cabernet Dorsa. Do porównania jakości wybranych win wykorzystano następu-

jące parametry: zawartość alkoholu, ekstraktu całkowitego (TDE), i kwasów lotnych (VA), kwasowość miareczkową (TA) i całkowitą zawartość fenoli (TPC). Dodatkowo przeprowadzono analizę sensoryczną.

Wyniki i wnioski. Wyniki badań wskazują, że wina produkowane z winogron tej samej odmiany (Cabernet Dorsa) uprawianych w różnych krajach różnią się istotnie zawartością ekstraktu całkowitego, kwasowość miareczkową i całkowitą zawartość związków fenolowych. Pomimo deklaracji producentów, występowały również niewielkie, ale statystycznie istotne różnice w zawartości alkoholu. Ponadto barwa win szwajcarskich została oceniona najwyżej. Dzięki analizie głównych składowych wykazano, że na podstawie parametrów chemicznych i sensorycznych możliwe jest rozróżnienie win z trzech wybranych krajów. Uzyskane wyniki stanowią doskonałą podstawę do dalszych badań, także dotyczących innych krajów i innych odmian winogron.

Słowa kluczowe: Cabernet Dorsa; polifenole; czerwone wino; jakość sensoryczna; różnicowanie wina ⚙