

Profiling factors, flavour parameters of port wines

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Abstract . In the multifaceted world of fortified sweet wines, port wines occupy a special place. Authentic Porto is a group of wines that is the hallmark of Portugal's unique wine region, which stretches along the picturesque valley of the Douro River. The name ~~to~~ regulated by European legislation can only be worn by wines made from grapes grown and vinified in this fertile land. It is worth mentioning that port wines are among the elite of the best dessert wines in the world, harmoniously complementing both ~~desert~~ dishes and acting as an independent delicacy. The variety of port wines amazes the imagination of connoisseurs of this noble drink. They differ in color (white, pink, red, brown), aging time (multiple of 10 years) and degree of sweetness (from ~~dry~~ sweet). Inexperienced port wine lovers often face a situation when they purchase wine that does not meet their expectations. This may be due, among other things, to the fact that there are wines on the market that imitate authentic Porto, but have nothing in common with it except the name. Here lies an important point: in the Russian Federation, wines are traditionally produced under the name "Port Wine", however, in terms of their parameters, style and taste, they differ significantly from their Portuguese counterparts. It is quite difficult for consumers to understand these nuances. These wines are of a national Russian character, and according to European legislation, they cannot be exported abroad because they do not comply with strict regulations established for authentic Porto, in particular, by geographical designation of origin. In this regard, grounds are required for the correct classification of this group of wines in order to avoid uncertainty in their places of sale and subsequent consumer ~~disapp~~ discrepancy due to the discrepancy between the desired and real flavor palette of the purchased port. An important factor influencing the taste and aroma of port wines is not only the grape variety used in its production, but also the place where it is grown, and the process of aging the wine. Aging plays a key role in the formation of a flavor bouquet of port wines. For this purpose, the wine is aged for a long period of time in bottles, tanks, and the ~~last~~ barrels. At the same time, the finished wines ~~es~~ require unique aromatic and taste parameters. The duration of aging can vary from several years to several

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decades, depending on the desired style and quality of the port. During the aging process in oak barrels, port wines undergo a complex biochemical process that forms the unique aromas and taste of the wine. Oak barrels also make their natural contribution to the bouquet of wine, adding delicate woody notes that give port wines depth and complexity. Thus, port wine is not just wine, it is a real art that combines the skill of winemakers, the natural characteristics of grapes, as well as the unique conditions of viticulture and winemaking. Its rich bouquet and complex taste make the wine a unique and inimitable drink that can satisfy the most refined tastes. The purpose of this article is an in-depth acquaintance with the nuances of the flavor parameters of this unique wine, as well as revealing the differences between authentic Porto and Russian port wines.

1 Introduction

Port wine is a legendary wine with a protected designation of origin. Port wine is a unique fortified wine, known all over the world for its rich taste and aroma. Its production is strictly regulated in Portugal, the country where it has a protected designation of origin (PDO). The PDO "Porto" is recognized and protected:

- In Portugal;
- In the European Union;
- In the participating countries of the Madrid Agreement (55 countries, including Russia, signed in 2023);
- At the World Trade Organization (WTO), where the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement) was signed by all WTO member countries (160 countries, including Russia);

This means that only wine produced in a strictly defined wine region of Douro (Portugal) and meeting established standards can be called Porto.

Porto production is strictly regulated by the Port and Douro Wines Institute (IVDP), a government organization responsible for protecting and maintaining the quality of this national wine [1]. The main requirements of viticulture and winemaking include:

- Grapes are necessarily grown in a certain viticulture region of Douro, which has unique climatic and soil conditions;
- Only certain grape varieties are used in viticulture, among which three traditional ones must be present: Touriga Nacional, Touriga Franca and Tinta Barroca;
- The grapes are harvested by hand and mainly processed in traditional granite vats (lagars that hold up to 10.5 tons of grapes in each);
- During the fermentation process, grape alcohol is added, which results in a fortified wine with a high alcohol content (from 19 to 20%);
- The wine is aged in stainless steel tanks and oak barrels for a certain period, which varies depending on the style of the port.

Porto has a rich history dating back to the 17th century. It has become synonymous with quality and elegance, making it still one of the most popular wines in the world. There are many types of port wine, each of which has its own unique taste and aroma. The protection of the Protected Designation of Origin "Porto" guarantees the authenticity and quality of the wine, preserving its heritage and the future for generations of wine connoisseurs around the world.

High saturation and depth of taste is one of the key features of port wines. In its bouquet you can find notes of cognac, fruits and sometimes even spices and honey. In addition, port wines also have a slight caramel sweetness. These flavor parameters of authentic Porto appear

mainly during the special stage of its winemaking, called "aging, senescence in the production of authentic Porto, the Solera method (Crianza y Solera System) is used for port wine, which involves multiple blending of wines and their aging in oak barrels. This method allows to achieve the necessary identification features of Porto. The main technological technique that forms the identification signs of authentic Porto, according to experts, is the long-term aging of young wine, fortified with wine alcohol, in oak barrels. During the aging process, the wine is subjected to systematic blending- mixing of various batches of wine. For the first year, blending is carried out every three months, and in subsequent years a year. This process gives authentic Porto a distinctive taste and aroma. This method ensures a stable level of quality of the finished wine by eliminating fluctuations in flavor parameters between wines of different ages and different harvest years. As a result, for many years, winemakers have been producing Porto that are homogeneous in age and style. The Solera method speeds up the process of maturing of authentic Porto.

The winemaking of Russian port wine producers provides for the stage of "Port wine vinification" by heating and aging wine at elevated temperatures (from 45°C to 65°C) for a long time (from 6 to 30 days). There are other technological techniques of port wine used in the production of Russian port wines. For example, some Russian winemakers briefly heat the grape pulp to 70-75°C before pressing in order to increase the efficiency of the extraction process. Also, some manufacturers of Russian port wines raise the fermentation temperature of the wort above 28°C in order to increase the concentration of flavor compounds. However, the latter two methods are not widely used, since their advantages are preserved only in young wines, and over time, with maturing and aging of port wines, they are erased.

Table 1. The place of Russian bottled Porto exports in global volume, for 2023 [3].

Countries of the world	Porto's global export volume		Standard style Porto*		Premium style Porto*			Share of premium in the total volume (I), %
	Share in commodity turnover (€), %	€	l	€	l	€	l	
Portugal	20.1	59 264 145	9 319 128	30 656 884	7 452 841	28 607 260	1 866 287	20.0
France	17.8	51 381 604	12 565 988	43 797 015	11 683 408	7 584 589	882 580	7.0
United Kingdom	12.7	37 178 060	6 169 849	7 308 405	1 941 166	29 869 655	4 228 683	68.5
RF	0.6	1 717 999	434 017	434 017	419 391	161 028	14 626	3.4
Other countries	48.8	144 052 559	23 534 843	74 220 075	18 124 204	69 832 484	5 410 639	23.0
Total	100.0	293 594 366	52 023 825	157 539 350	39 621 011	136 055 016	12 402 815	23.8

Note to Table 1: *standard- Porto aged in concrete or stainless steel tanks, Tawny 3-year-old, and Whitepremium style Porto aged in oak barrels: Tawny aged, Colheita, Fine White, etc.

The Russian Porto market in 2023 (Table 1) was not the largest in the world in terms of exports and ranked only 16th after France, Great Britain and other countries (Table 1

largest share of Porto produced in 2023 (20.1%) was consumed in Portugal itself. The volume of Russian Porto exports in monetary terms in 2023 amounted to €1,717,999: the standard Porto style is estimated at €1,556,971, the premium - €161,028 (9.4% of the total Porto exports). It should be noted that the total volume of Russian Porto exports fell by more than 1/4 compared to last year. At the same time, the total number of Porto sold for world exports fell by only 2.8% in 2023. As for the leader in the Porto export market, there was a noticeable surge in demand in the UK in 2023 and exports increased by almost 1/3. The weighted average export price of 1 liter of bottled Porto in 2023 for Russia was €3.96. This price decreased by 4.7% in 2023 compared to last year. At the same time, standard Porto styles have an export price level for the Russian Federation of €3.71 per 1 liter, and the export price of premium Porto increased during the specified period and amounted to €11.01 per 1 liter. It should be noted that Russia exports Porto at a special price, which is about 1/3 lower than the average world export price.

The high popularity of authentic Porto causes the desire of winemakers from different countries to compile them, illegally indicating the word Porto on the labels of their analogues. Such compilations, according to the information of the said Porto and Douro IVDP Wine Institute, revealed [3]:

- Porte d'Or, Puerto Casal, Porte Puerto Gallero (Belgium);
- Porte Noir (Netherlands);
- Porto Fino (Poland);
- Porto (Croatia);
- Porto K. S. S. (Turkey).

2 Material and methods

This article uses original materials and review articles that have been published in an open database over the past 5 years. Samples of bottled Porto and Russian port wine were purchased in retail to conduct physicochemical studies. When measuring the water fraction of ethyl alcohol, the method described in GOST 322053 was used [4]. The analysis of sugar concentration in wine samples was carried out using the direct titration method in accordance with GOST 13192 [5]. The analysis of flavonoid aromatic chemical compounds in wine samples was carried out in an accredited laboratory of physicochemical and thermal engineering measuring instruments of the State Regional Center for Standardization, Metrology and Testing in the Kemerovo Region, Kuzbass (FSFI Kuzbass CSM) using the standard GLC method specified in GOST R 51298 [6]. All laboratory studies were carried out three times, and then the results were verified using mathematical statistics to determine the average values (\bar{x}) and their standard deviation (δ). To measure the degree of correlation, the Pearson coefficient was used, and then the closeness of correlation was estimated on the scales of Chaddock and Evans (r), as well as Spearman (ρ). (The Spearman correlation coefficient is a quantitative assessment of the statistical relationship between phenomena and is used in nonparametric methods that allow processing data from small-volume samples with variables whose distribution is little or nothing unknown. The organoleptic parameters of the port wines were evaluated by the "blind" method, where experts evaluated the tested samples of port wines previously placed in a decanter at a temperature of 15 °C [14,15,16,17,18]. This made it possible to obtain an objective assessment of the taste and aromatic characteristics of port wines [19].

3 Results and discussion

Most researchers agree that acetic aldehyde is the most significant factor in the formation of the flavor characteristics of grape wines. This substance is formed from pyruvic acid as a result of the decarboxylation reaction, which is catalyzed by the enzyme carboxylase. Further, with the help of the enzyme alcohol dehydrogenase, acetic aldehyde is converted into ethyl alcohol. It is important to note that ethyl alcohol and other fermentation products also play an important role in shaping the taste and aroma of port wines. During the production of port wines, the concentration of methyl and butyl alcohols, as well as other fermentation products, play a crucial role in the formation of their taste and aromatic characteristics of finished wines.

According to the fermentation theory, not all acetic aldehyde is converted into ethyl alcohol, and some remains in the wine. This amount depends on various factors such as the pH of the medium, the fermentation temperature and other parameters. Acetic aldehyde is a key factor in the formation of fermentation products that affect the flavor characteristics of wines, it has long been known [7,8]. Hypothetically, the concentration of acetic aldehyde in wines can be used to identify port wines based on their base or alcohol based drink.

In addition, esters play an important role in the formation of the aroma of grape wines. They are formed in the process of biochemical esterification. The significant are the esters of acetic acid with methyl (methyl ether) and ethyl (ethyl ether) alcohols. Acetic esters and aldehyde are important components that affect the quality and characteristics of grape wines, including port wines. In this case, the esterification of the esters mentioned above leads to the formation of acetic acid and corresponding alcohols. On the other hand, during the transesterification of these esters, acetamides are formed, which can give the wine an unpleasant mouse hue of the bouquet. Early studies show that the methyl ester of acetic acid has a more significant effect on the characteristics of wine than ethyl. The concentration of esters in wines varies depending on the factors of viticulture and winemaking, the traditions of winemakers and the country of origin. Research in this area continues, and scientists are striving to deepen their understanding of the processes occurring during the fermentation of grape wines and their effect on the final product. This will allow producers to directly control biochemical processes and create a variety of wines for consumers.

Authentic Porto have their own characteristics with respect to the content of the above compounds. To understand the factors influencing the formation of their flavor parameters in them in this study, the values of mass concentrations of acetic aldehyde and acetic acid esters (methyl and ethyl) in the analyzed samples of Porto and Russian port wines were measured.

Table 2 shows that the mass concentration of acetic aldehyde in authentic Porto is approximately the same and ranges from 40.6 to 46.8 mg/dm³, however, the Porto Cockburn's Ruby sample shows a slight deviation downwards, where the mass concentration of this chemical compound is 33.4 mg/dm³. If we compare these values with previous studies [7, 8, 9, 10], then we can conclude that they correspond to the data of other authors. It should be noted that the quantitative measure of the mass concentration of acetic aldehyde in authentic Porto significantly exceeds the values of a similar indicator in authentic red wines from Merlot grapes (6-20 mg/dm³), as shown in the work of Orlov A.A. [10]. This can be explained by differences in the winemaking process of these types of wines, which affect the completeness of the fermentation process and, consequently, the concentration of acetic aldehyde.

The value of the mass concentration of ethyl ether of acetic acid is also approximately the same for most samples of port wines and ranges from 36.6 to 42.1 mg/dm³, however, the Porto Weise & Krohn sample differs by a value 2.5 times less (16.7 mg/dm³) than the values of

the mass concentration of ethyl ether of acetic acid for authentic Porto are lower than for dry grape wines, data on which are shown in previous studies [9, 10]. Thus, authentic Porto products have their own unique parameters in relation to the values of the content of acetic aldehyde and acetic acid esters (methyl and ethyl), as indicated in Table 3. These indicators differ from other types of grape wines, which is explained by differences in the processes of fermentation and winemaking in general. Research in this area is ongoing, and further discoveries may give us more information about the composition and characteristics of authentic Porto, which are important factors in their selection and evaluation.

Table 2. Mass concentration of esters and aldehyde of acetic acid in the analyzed samples of port wines, mg/dm³

Name of the samples	Acetic Acid Esters		Acetic Aldehyde
	ethyl	methyl	
Sample 1	330.2	1.0	19.5
Sample 2	57.0	8.0	42.4
Sample 3	48.1	3.3	25.9
Sample 4	42.7	4.4	33.4
Sample 5	38.9	0,01	18.4
Sample 6	38.1	2.7	40.6
Sample 7	36.6	2.5	46.8
Sample 8	19.4	1.3	24.3
Sample 9	16.7	1.0	46.3
Sample 10	14.2	2.0	18.7

Note to the table: Sample 1 Strong port wine. Red (Amzara); Sample 2 Port 777 (Protos); Sample 3 Porto Alushta Crimean. Red (Dionysus); Sample 4 Porto Cockburn's Ruby. Special Reserve; Sample 5- Alushta Port Wine. Rose (Massandra); Sample 6 Porto Cruz. Tawny. Vieilli Dans Porto; Sample 7 Porto Don Pablo. Tawny; Sample 8 Porto Alushta Crimean. White (Dionysus); Sample 9 Porto Weise & Krohn. Wait Port. Vale Douro. Vila Nova de Gaia; Sample 10 Port of Taurida. Red (Dionysus).

Table 3. Mass concentration of esters and aldehyde of acetic acid in the analyzed samples of port wines, mg/dm³

Indicators	Acetic Acid Esters				Acetic Aldehyde	
	ethyl		methyl		1	2
	1	2	1	2		
\bar{x}	33.50	84.60	33.50	2.60	41.80	24.90
$\pm\sigma$	11.48	121.42	11.48	2.85	6.26	9.14

Note to the table: 1-authentic Porto port wines; 2-Russian port wines

Table 2 also shows the values of the mass concentrations of the analyzed esters and acetic acid aldehyde of samples of Russian port wines. From the above data, it can be seen that only one sample of port wine, namely Port 777 (Protos), corresponds to the value of the mass concentration of acetic aldehyde characteristic of authentic Porto. All other samples have a significantly lower value of this indicator.

Studies conducted by A.A. Orlov [10], show that the mass concentration of acetic aldehyde in red wines from Merlot grapes is important in the formation of taste and bouquet of wines. This value is an indicator of the depth of the fermentation process and serves as an important factor in assessing the quality of wine in terms of the formation of its flavor parameters. It should be noted that the sample Port 777 (Protos), containing a high amount of acetic aldehyde, has a particularly deep and powerful bouquet, which differs from other samples of port wines. This is probably due to the increased content of this aldehyde, which is an indicator not only of the depth of the fermentation process, but also may indicate the peculiarities of wine production and usage. Port 777 (Protos) demonstrates that a high content of acetic aldehyde can give wine unique qualities and taste characteristics. This

component can be a key factor that makes the wine unique and attractive to connoisseurs. Thus, acetic aldehyde is an important component of wine, which can affect its taste and aroma. The high content of this substance can give the wine a special character and makes it unique among other samples of port wine. The indicator of the mass concentration of acetic acid methylester in samples of Russian port wines generally corresponds to the values of authentic port wines. However, the samples Port Rose Alushta (Massandra) and Port 777 (Protos) have deviations from the average values. The first sample has a very low value of this indicator (0.01 mg/dm^3), while the second sample has a significantly higher value (8.0 mg/dm^3).

The value of the mass concentration of ethyl ether of acetic acid in Russian port wines ranges from 14.2 to 57.0 mg/dm^3 , which corresponds to the values of this indicator for authentic Porto (36.6 to 57.0 mg/dm^3). However, Russian port wine produced using the Imeretian fermentation technology on pulp (sample 1- Strong Red Port Wine (Amzara)) have a significantly higher content of this substance (60.2 mg/dm^3). This approach gives the port a distinctive taste and aroma. These differences affect the taste and aroma of Abkhazian port wine, making it unique and attractive to wine connoisseurs.

Fermentation is a process in which alcohols are formed as a result of fermentation of various substances. During fermentation, various alcohols are formed, including fusel, aromatic and aliphatic. Their chemical structure determines their aromatic properties, and they enrich the bouquet of alcoholic beverages of fermentation. They are formed from amino acids and ketoacids when exposed to yeast through oxidative deamination and transamination. One of the interesting aspects of this process is the formation of fusel and aromatic alcohols, which contain a phenolic ring in their chemical structure. Unlike aliphatic alcohols, these substances have a more pleasant aroma. One example of an aromatic alcohol is phenylethyl alcohol, which, for example, is the main component of rose essential oil. Its pleasant aroma makes it popular in the perfumery and cosmetics industry. Phenylethyl alcohol is formed as a result of fermentation and is an important component of many aromatic products. R.R. Gaifulina, using the example of dry wines, pointed out that phenylethyl alcohol, which is one of the most important aromatic compounds that give characteristic notes to wines, has the greatest influence on the formation of a bouquet of wine [8]. In this study, it was found that for white wines there is a negative correlation between the organoleptic assessment of the bouquet and the value of the mass concentration of phenylethyl alcohol in them ($r = -0.74$), while for red wines such a dependence was not observed. This suggests that for white wines, a higher concentration of phenylethyl alcohol may negatively affect the assessment of their aromatic parameters.

Aliphatic alcohols such as methyl and butyl alcohol have a pungent odor. However, with an increase in the length of the carbon chain, aliphatic alcohols begin to acquire a more favorable flavor. For example, hexyl alcohol, which contains six carbon atoms, has a pleasant aroma, which is why it is often used in the production of perfumes.

Higher alcohols, in addition to aldehydes and esters, play an important role in shaping the taste and aroma of grapes, including port wines. Many authors have studied the influence of higher alcohols on the taste and aroma characteristics of wines, and some of them were especially significant. Fusel spirits also have a rich aroma and are always present in alcoholic beverages such as wine. For example, isoamyl alcohol gives a banana flavor to fermented alcoholic beverages.

Fusel alcohols (C_3 – C_6), in which butyl and amyl alcohols account for about 85%, according to M. Berthelot and E. Peynaud [11, 12] significantly influence the formation of a bouquet of wines. Authentic Porto, maturing in oak barrels, have the peculiarity of an increased concentration of fusel spirits in this category of wines. It can be assumed that it is during the aging process in oak barrels that the main characteristics of Porto are formed. In this article, we present data demonstrating the role of fusel spirits in Porto in comparison with

Russian port wines and their impact on the quality and taste of the drink. Fusel alcohols are one of the important components of grape wines, contributing to their aromatic profile. On average, the total content of fusel alcohols in wines is about 250 mg/dm³, but this value can vary widely, from 162 to 394 mg/dm³. E. Peynaud, in a study of Bordeaux wines, found that red wines contained about 30% more fusel alcohols than white wines. This may be explained by differences in the fermentation and aging process of different types of wines [12]. Thus, fusel alcohols play a role in the formation of the aromatic profile, but their influence is not the main one. A more significant factor is the presence of phenylethyl alcohol, which gives the wine its characteristic aromatic notes. Interestingly, this dependence may differ for white and red wines, which requires further research to fully understand the mechanisms of formation of a bouquet of different types of wines. Research in this area is ongoing, and further data will help to better understand the mechanisms of alcohol influence on wine.

Research conducted by Peynaud [12] showed that the content of fusel alcohols (C3 ÷ C6) in port wines is 539.0 ± 50.1 mg/dm³. A particularly interesting fact is that the sum of C4 ÷ C5 averages 453.5 mg/dm³, which is 84% of the sum of the mass concentration values of all fusel alcohols. These data are confirmed by studies, which indicate that the concentration of fusel alcohols in port wines usually averages 250 mg/dm³, but the maximum value reaches 400 mg/dm³ [1].

What factors contribute to the difference in the values of the quantitative concentration of fusel alcohols? Research by I.M. Skurikhin [13] indicates that the prolonged process of aging alcohols in oak barrels leads to the hydrolysis of lignin, which in turn increases the concentration of organic acids and reducing gases. It is possible that these groups of substances are the basis for the formation of higher alcohols, both aliphatic and aromatic, in Porto when they are aged in oak barrels. On this basis, it can be argued that it is the aging process in oak barrels that forms the unique taste and aroma parameters of authentic Porto, unlike Russian port wines, which do not produce this process.

Table 5, which contains generalized values of mass concentrations of alcohols in authentic Porto and Russian port wines, allows to get an idea of the variety of their alcohols present in various categories and varieties of port wine. These tables confirm that not only categories, but also trademarks, as well as styles of port wines have their own unique combination of fusel alcohols, which gives them individuality and uniqueness.

The authenticity of Porto is the most important aspect that can be determined by paying attention to the totality of various indicators. The data presented in Table 5 can serve as a useful guide in this process. One of the key indicators is the variability of their values, within the same types and styles, which indicates that port wines belong to a certain category, type, style, brand. Table 5 shows that the analyzed indicators have low deviation from the average value of indicators within the category of authentic Porto (6.7%). This suggests that port wines have a stable composition and do not lose their characteristic qualities over time. However, it is worth noting that the largest deviation from the average value was noted for phenylethyl alcohol, while the smallest was for propyl alcohol. Fusel alcohols, such as isopentyl and isobutyl alcohols, play an important role in forming a bouquet of authentic Porto. Interestingly, they have very low values of deviation from the average value (deviates by 8.4% and 7.3%, respectively). This may indicate their importance in creating a unique aroma and taste of this category of port wines. To get a more complete picture of the authenticity of Porto, it is advisable to compare the values of these indicators with similar indicators of Russian port wines, which are presented in the same Table 5. Such a comparison will help to establish how authentic Porto is and how their composition correlates with their Russian counterparts. It should be noted that authentic Porto aged in oak barrels have an increased concentration of fusel spirits in comparison with Russian port wines, which distinguishes the distinctive taste and aroma characteristic of Porto. This is the basis of the

data in Table 5 makes it possible to identify the category of authentic Porto and Russian port wines based on the values of alcohol indicators.

Russian port wines are known to consumers for their unique taste and aromatic characteristics. Comparing the data presented in tables 4 and 5, it can be noted that the mass concentrations of alcohols in Russian port wines vary significantly, with the exception of ethyl alcohol, the content of which is established by both Portuguese and Russian regulations. The heterogeneous method of regulating the concentration of ethyl alcohol, thus, does not significantly affect its mass concentration in port wines corresponding to its type. However, the concentration values of other alcohols in the categories of authentic Porto and Russian port wines differ significantly. Note that the coincidence of the values of the mass concentration of hexyl alcohol is observed only for the sample "Port Rose Alushta (Massandra)". It is interesting to note that these coincidences are accompanied by high scores in the organoleptic evaluation of "bouquet" and "taste" (more than 7 points out of 10). Thus, it can be concluded that this alcohol is important for the formation of quality port wines. Sample 5 "Port Rose Alushta (Massandra)" showed the values of mass concentrations of butyl and hexyl alcohols, which, taking into account the error, coincide with similar values of samples of authentic Porto

Table 4. The mass concentration of alcohols in the analyzed samples of port, mg/dm³

Name of the samples	1	2	3	4	5	6	7	8
Sample 1	244.0	19.9	54.3	85.4	3.0	361.5	27.2	39.3
Sample 2	237.3	18.7	53.9	94.5	3.3	401.5	46.3	33.0
Sample 3	211.3	18.9	48.7	92.2	2.9	365.8	31.6	18.4
Sample 4	159.2	18.7	47.6	80.3	1.9	326.5	27.7	16.3
Sample 5	127.2	17.9	17.3	36.9	2.4	193.0	47.1	62.4
Sample 6	99.0	12.3	40.5	45.0	1.3	141.0	126.7	47.3
Sample 7	54.8	17.5	13.5	22.1	1.3	100.9	17.9	19.1
Sample 8	52.7	17.3	8.0	17.8	1.2	78.6	10.1	20.4
Sample 9	41.1	18.5	12.3	20.6	3.1	53.6	78.5	6.6
Sample 10	40.4	17.5	11.3	14.0	1.2	80.6	11.9	23.0

Note to the table. Names of alcohols: 1 Methyl alcohol; 2 Ethyl alcohol; 3 Propyl alcohol; 4 Butyl alcohol; 5 Isobutyl alcohol; 6 Isopentyl alcohol; 7 Hexyl alcohol; 8 Phenylethyl alcohol.

Names of port wine samples: Sample 1 - Porto Cruz. Tawny. Vieilli Dans Porto; Sample 2 - Porto Don Pablo. Tawny; Sample 3 - Porto Cockburn's. Ruby. Special Reserve; Sample 4 - Porto Weise & Krohn. Wait Port. Vale Douro. Vila Nova de Giala; Sample 5 - Porto Alushta Port Wine. Rose (Massandra); Sample 6 - Strong port wine. Red (Amzara); Sample 7 - Porto Alushta Crimean. Red (Dionysus); Sample 8 - Porto Alushta Crimean. White. (Dionysus); Sample 9 - Port 777 (Protos); Sample 10 - Port Taurida. Red (Dionysus);

Table 5. Generalized indicators of the mass concentration of alcohols in the analyzed categories of port wines, mg/dm³

Indicators	Designation of the analyzed alcohols															
	1		2		3		4		5		6		7		8	
\bar{x}	21	69	19	16	51	17	88	26	2.	1.	36	10	33	48	26	29
	3.0	.2	.1	.8	.1	.1	.1	.1	7	7	3.8	7.9	.2	.7	.7	.8
$\pm\sigma$	38.	35	0.	2.	3.	11	6.	12	0.	0.	30.	50.	9.	46	11	20
	5	.6	6	3	4	.8	5	.2	6	8	6	9	0	.4	.2	.8

Symbols. Names of alcohols: 1 Methyl alcohol; 2 Ethyl alcohol; 3 Propyl alcohol; 4 Butyl alcohol; 5- Isobutyl alcohol; 6 Isopentyl alcohol; 7 Hexyl alcohol; 8 Phenylethyl alcohol.

Table 4 presents generalized data on the category of Russian port wines. From these data, it can be concluded that according to most indicators (with the exception of ethyl, butyl and hexyl alcohols), Russian port wines do not correspond to authentic **Porto**. However, there is one curious exception. This indicates the need for further research and improvement of the production process of Russian port wines in order to more fully comply with the taste and aromatic parameters of authentic Porto.

Thus, based on the presented data, it can be concluded that it is important for identification in order to categorize port wines of the mass concentrations of alcohols in the analyzed port wines in order to achieve authenticity and meet the needs of consumers.

An important aspect that should be noted is the high variability of the values of alcohols involved in the formation of the taste and aroma parameters of Russian port wines (with the exception of ethyl alcohol), very low values of deviation from the average of the values ($\pm\sigma$ deviates by $17.5 \div 160.0\%$, respectively).

This indicates differences both in grape varieties, places of its cultivation, and in the technologies of viticulture and winemaking. The variability is also largely due to the lack of a stage of the Solera method in the winemaking of Russian port wines, which, as mentioned above, allows you to maintain the flavor parameters of authentic Porto at the level of stability required for a particular type, style and category of Porto. This requires further research in order to control the quality of Russian port wines in the production process in order to achieve stability of the values of flavor parameters.

Categorical differentiation of authentic Porto and Russian port wines makes sense from the point of view of satisfying consumer expectations of the flavor characteristics of the finished wines.

For a deeper understanding of the importance of chemical compounds in the profiling of the port wine category, a correlation analysis was performed on these compounds with the organoleptic evaluation of samples (Table 6). The data obtained in this analysis are the basis for the profile categorization of port wines, and also help to better understand which chemical compounds are important for achieving certain consumer benefits and which changes in these substances during the production of port wines can improve the quality of finished drinks. The study showed that there is a definite connection between the chemical compounds and the organoleptic evaluation of the analyzed samples of port wines. This confirms the importance of taking into account the composition and chemical characteristics in the production of port wine in order to achieve the desired taste and aroma. In addition, the results of the study may be useful for producers of Russian port wines, allowing them to optimize the winemaking process to improve their flavor parameters. Also, retailers can use this data when purchasing port wines to achieve full satisfaction of the preferences and expectations of their consumers.

From the data obtained, it can be seen that the mass concentration of methyl alcohol has the greatest effect on the bouquet and taste of port wines ($r = 0.79$ and $r = 0.81$, respectively). However, it is important to note that the value of this indicator in the specified taste and aroma characteristics of port wines is not related to its own taste and aroma, since methyl alcohol has an unacceptable taste and smell for wine. Most likely, methyl alcohol acts as an indicator of the depth of biochemical transformations occurring during fermentation, maturation and aging of port wines. Butyl alcohol has the second most significant effect on the taste and aromatic parameters of port wines ($r = 0.81$ for the bouquet and $r = 0.77$ for the taste). Similarly to methyl alcohol, butyl alcohol can serve as an indicator of the depth of biochemical processes in wines. Isopentyl alcohol takes the third place in the rating of importance in the formation of flavor parameters of port wines ($r = 0.72$ for the bouquet and $r = 0.77$ for the taste), and isobutyl alcohol takes the fourth place ($r = 0.64$ for the bouquet and $r = 0.69$ for the taste). Comments on these compounds are similar to those on methyl alcohol. Propyl alcohol, acetic aldehyde and phenylethyl alcohol also play a significant role

in the formation of the flavor parameters of port wines. Different coefficients of the tightness of the paired correlation of the mass concentrations of these compounds indicate a noticeable relationship with the values of the flavor parameters of port wines (Table 6).

Table 6. Values of the closeness (η, ρ) of Pearson correlation coefficients between alcohol concentrations and indicators of organoleptic evaluation of port wines of the "Porto" and "Russian port wines" categories

Flavor and aromatic compounds	Pearson correlation coefficients (r) and correlation closeness (η, ρ)							
	Type		taste		bouquet		total organoleptic assessment	
	r	η, ρ	r	η, ρ	r	η, ρ	r	η, ρ
1	0.80	high	0.81	high	0.79	high	0.82	high
4	0.78	high	0.77	high	0.81	high	0.79	high
6	0.73	high	0.77	high	0.72	high	0.77	high
5	0.65	high	0.69	high	0.64	notable	0.69	high
3	0.52	notable	0.56	notable	0.52	notable	0.56	notable
8	0.48	notable	0.45	notable	0.45	notable	0.45	notable

Symbols: 1- Methyl alcohol; 3 Propyl alcohol; 4 Butyl alcohol; 5 Isobutyl alcohol; 6 Isopentyl alcohol; 8 Phenylethyl alcohol

A study conducted in this field showed that some chemical compounds with a pleasant aroma, such as ethyl ether of acetic acid and methyl alcohol, did not significantly affect the taste and aroma characteristics of the analyzed port wine samples (Table 6). The data presented in this table demonstrate significant differences in the Pearson pair correlation coefficients (r) between the mass concentrations of the following volatile compounds in the analyzed categories of port wines.

Acetic aldehyde and ethyl ether of acetic acid. For authentic Porto, there is a strong negative pair correlation between the values of the mass concentration of acetic aldehyde and acetic acid ethyl ether ($r = -0.66$). This indicates that as the concentration of acetic aldehyde decreases, the content of ethyl ether of acetic acid in port wines increases. No such relationship has been found for Russian port wines. It is significant that the ratio of the mass concentration of acetic aldehyde and acetic acid methyl ester differs significantly between the two categories of port wines. It is: 16.6 for authentic Porto and 9.6 for Russian port wines. The values of this ratio strongly correlate with the taste and aroma characteristics in the category of authentic Porto ($r = -0.88$).

Methyl and ethyl esters of acetic acid. In the category of authentic Porto, a strong positive correlation was found between the values of mass concentrations of methyl and ethyl esters of acetic acid ($r = 0.91$), which indicates their joint change. For Russian samples, the correlation has not reached the level of significance. The ratio of the values of the mass concentration of ethyl and methyl esters of acetic acid also differs significantly in the analyzed categories of port wines: 12.9 for authentic Porto and 32.5 for Russian port wines. In Russian samples, this ratio has a strong positive correlation with flavor and aroma indicators ($r = 0.89$).

Methyl alcohol and methyl ester of acetic acid. Another notable difference between the analyzed categories of port wines concerns the ratio of the values of mass concentrations of methyl alcohol and methyl ester of acetic acid. For authentic Porto, the specified ratio is 81.9,

and for Russian 26.6. This ratio strongly correlates with the flavor parameters in the category of authentic Porto ($r = 0.87$).

4 Conclusions

Correlation and regression analysis showed that the categories of authentic Porto and Russian port wines differ significantly both in organoleptic and physico-chemical parameters. The nature of the relationship between the values of mass concentration of volatile chemical compounds in these two categories also differs significantly, which emphasizes the expediency of taking these differences into account when categorizing them by region of origin.

Based on the above, it can be assumed that the classification and differentiation of port wines based on their profiling makes commercial sense. The results of the study showed that the mass concentration of methyl alcohol has the greatest influence on the formation of taste and aroma of authentic Porto (Pearson correlation coefficient $r=0.79$ for the bouquet and $r=0.81$ for the taste). The second most important factor is butyl alcohol ($r=0.81$ for the bouquet). These substances are indicators of the depth of the biochemical processes occurring during fermentation, maturation and aging of authentic Porto port wines.

Three classification criteria have also been identified that can be taken into account in order to categorize port wines. Such signs may be the values of the mass concentration of acetic aldehyde, methyl and ethyl esters of acetic acid. An additional feature may be the value of a similar indicator for methyl alcohol in the analyzed port wine. To identify a specific sample of port wine in order to profile it, it is advisable to use the ratio of the values of the mass concentration of volatile chemicals in the composition of the wine. Thus, authentic Porto have a mass concentration ratio of the first and second of the above substances equal to 16.1 ($r=0.88$), and the ratio of the mass concentration values of the second and third of these substances is 81.9 ($r=0.87$). The data obtained will allow us to more accurately meet customer expectations and help sellers purchase wines that fully meet customer expectations. Russian port wines, which are not included in the category of authentic Porto, also have unique taste and aroma characteristics that make these wines in demand by consumers both on the Russian market and abroad [19, 20, 21, 22].

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