INFLUENCE OF SUGAR AND ACID CONCENTRATIONS TO SWEETNESS THRESHOLD OF STILL WHITE WINES

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Summary

The primary objective of this research was to determine the threshold of sensory detection of wine sweetness (sweetness threshold) modelled by adding a sucrose solution in dry white wines and identification of the possible influence of acidity on the wine sweetness threshold. The study was done on 11 samples of regional dry still white wines. The sugar content and total acidity of wines were measured in a laboratory, followed with the sensory evaluation of their quality (OIV rating scale up to 100 points). Seven experienced wine consumers tasted untreated dry wines and the same wines with modelled sugar concentrations trying to find the lowest concentration of sugar by which the sweetness of wine was undoubtedly recognized. The obtained results showed that the wine evaluators have registered wine sweetness thresholds at relatively low concentrations of sugar (the lowest 3.79 g/L, the highest 6.07 g/L). Analysis of the relations between the acid contents of the wines and the wines' sweetness thresholds pointed out their high positive correlation (correlation coefficient +0.786). This is in accordance with some previously published researches concluding that the sensory recognition of the sweetness of wine is conditioned by their acidity, i.e. that wine acidity to some extent suppress its sweetness.

Keywords: *dry white wine, organoleptic evaluation, wine sweetness threshold, wine acidity*

INTRODUCTION

Wine taste, as probably the most important indicator of its sensory quality, is influenced by a large number of dissolved substances. It is clear that the overall impression of a wine's taste is influenced, on the one hand, by the types and concentrations of the substances contained in it, and on the other hand by the sensitivity of the senses of a person who tastes or organoleptically analyses a wine. Although by its complexity far beyond the odor, the expert evaluation of the wine taste, combined with tactile sensations that wine triggers entering the mouth, needs highly trained wine testers. Ordinary wine consumers usually and with no doubts correctly detect acidity and possible bitterness, while facing some problems with correct interpretation of wine sweetness. Interestingly, although sweetness is one of

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the basic tastes, there are not many available research results (at least to this team of authors) on the interplay between sweetness and other wine basic flavors, as well as sensory sweetness thresholds in wines.

The objective sweetness of wine depends primarily on the amounts of reducing sugars (glucose and fructose) contained in it (Ough, Amerine, 1988 – cited by Thorngate, 1997). Glycerol (Noble, Bursick, 1984) and ethanol (Scinska *et al*., 2000) may bring some sweetness or at least an increase of experience of wine sweetness, although there are allegations that the high acidity of some dry wines (Riesling) does not allow the expression of glycerol and ethanol sweetness (Gawel *et al*., 2007) or that ethanol does not contribute to the perception of wine sweetness (Nurgel, Pickering, 2006; Cretin *et al*., 2018). According to some reports, even aging in the oak barrel increases sensory experienced wine sweetness (Marchal *et al.,* 2013). On the other hand, the sweetness of the sweet substances of a wine is suppressed by its tannins (Ishikawa, Noble, 1995).

Here it should be emphasized that there are differing opinions on the effects of wine acids on the experience of its sweetness. According to some studies, higher acidity of wine reduces the experience of its sweetness (Pangborn *et al*., 1964; Bonnans, Noble, 1993; Zamora *et al*., 2006), but there are also studies according to which an increase in acid concentrations did not affect their sensory experienced sweetness (Amerine, Ough, 1967; Martin, 2002; Martin *et al*., 2002). It is worth mentioning some older studies reporting that increase of concentrations of different sugars in wines did not significantly affect the sensory experience of their acidity (Hinreiner *et al.,* 1955; Noordeloos, Nagel, 1972; Bonnans, Noble, 1993), although some more recent studies have found that the increase of the sugar content also increases the threshold of sensory perception of wine acidity (Martin, 2002; Martin *et al.,* 2002).

The need for research into the sensory perception of wine sweetness is also indicated by some studies according to which consumers prefer wines of moderate sweetness that can undoubtedly be organoleptically detected (Duitschaever *et al*., 1980; Blackman *et al.,* 2010; Bruwer *et al*., 2011; Williamson *et al.,* 2012; Sena - Esteves *et al.,* 2018).

The objective of this study was to determine the threshold of sensory detection of wine sweetness (sweetness threshold) of some regional dry white wines modelled by adding a sucrose solution and identification of possible influence of acidity on the wine sweetness threshold.

MATERIALS AND METHODS

Materials

In the study 11 samples of dry white still wines obtained from a retail network in the city of Sarajevo were used. The basic information on wines analysed in this resarch are listed in Table 1. The table also lists the marks allocated to the wines that will be used in the rest of this paper.

Table 1. Basic information on dry white still wines used as research material

Mark	Variety	Origin	Vintage (year)	Quality category	Alcohol (% vol)	Package
V-1	Smederevka	Macedonia	2012	QW GI**	11.0	1 L, screw cap
V-2	Žilavka	Macedonia	2011	QW GI**	11.5	1 L, screw cap
V-3	Žilavka	BiH*	2011	QW GI**	12.5	1 L, screw cap
V-4	Graševina	Croatia	2011	QW GI**	12.4	1 L, screw cap
V-5	Graševina	Croatia	2011	QW GI**	13.1	1 L, screw cap
V-6	Temjanika	Macedonia	2012	QW GI**	11.0	1 L, screw cap
V-7	Chardonnay	BiH*	2011	QW GI**	13.5	0.75 L, cork
V-8	Žilavka	BiH*	2011	QW GI**	13.0	0.75 L, cork
V-9	Chardonnay	Serbia	2010	HQW GI***	12.5	0.75 L, cork
V-10	Smederevka	Serbia	2011	Table wine	10.5	1 L, crown cap
V-11	Žilavka	BiH*	2011	QW GI**	12.0	0.75 L, cork

*BiH – Bosnia and Herzegovina; **QW GI – Quality wine with geographical indication;
***HQW GI – Premimum quality wine with geographical indication

As the Table 1 shows, for the research were used four dry white still wines originating in Bosnia and Herzegovina, two in Croatia, three in Macedonia, and two in Serbia. Of the total of 11 wines, nine belonged to the declarative quality category of quality wines with geographical origin, with one premium wine with geographical origin and one table wine without geographical origin. All wines were purchased in four bottles, each with the same lot number. Three bottles were used for laboratory determination of sugar and acid content and the other one for organoleptic testing.
For the purpose of wine sweetening, i.e. programmed raising of sweetness of wines, a 5% sucrose solution in water was used.

Methods

Sugar and total acid contents in wines

Sugar content in wines was determined by the Lane-Eymon /Fehling redox) method (Daničić, 1988). The total acid content of the wines was determined by the method of neutralization with 0.1 M NaOH, using the bromothymol blue as an indicator (Daničić, 1988). The sugar and total acid contents in the wines were determined in the Laboratory for Technology of Plant Origin Products at the Faculty of Agriculture and Food Sciences, University of Sarajevo, in June 2013.

Organoleptic evaluation of wines

Organoleptic evaluation of wines was performed in July 2013 by seven evaluators, experienced and regular wine consumers, in a semi-closed-type restaurant near Sarajevo. The rating was done with a system of up to 100 points recommended by the International Organization for Vine and Wine (OIV) for wine judgments under its auspices. The rating sheet is shown in the Table 2.
The temperature of all wines served for judging was between 13 and 14°C. The wines were served in glasses that comply with the ISO recommended wine tasting glass (ISO 3591:1977 Sensory analysis - Apparatus - Wine-tasting glass).

Sensory detection of wine sweetness threshold

The wine sweetness threshold was tested in all 11 analyzed dry wines. All evaluators were served with the series of glasses with 10 mL of analyzed wine, to which, according to the planned scheme of the experiment, increasing amounts of 5% sucrose solution were added. The plan for the sweetening of dry wines, with their initial sugar content, is presented in the Table 3.
Seven evaluators were expected to mark a glass of the lowest ordinal in which they with no doubt detected the sweetness of the wine in a separate table (Table 4).

Table 4. Table used to record the detection of wine sweetness threshold

Wine	Mark on the glass										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
V-1											
V-2											
V-3											
V-4											
V-5											
V-6											
V-7											
V-8											
V-9											
V-10											
V-11											

The processing of the data from these tables was completed in such a way that the glass labels were replaced by the modeled sugar content in wine. From the wine sweetness sensory detection levels of all seven evaluators, the average values are calculated.

Table 2. Rating sheet used for organoleptic evaluation of wines

Indicator		Excellent	Very good	Good	Passable	Bad
APPEARANCE	Clearness	5	4	3	2	1
	Color	10	8	6	4	2
ODOR	Purity	6	5	4	3	2
	Intensity	8	7	6	4	2
	Quality	16	14	12	10	8
TASTE	Purity	6	5	4	3	2
	Intensity	8	7	6	4	2
	Durability	8	7	6	5	4
	Quality	22	19	16	13	10
HARMONY		11	10	9	8	7

Table 3. Sweetening plan for dry wines in which wine sweetness threshold was sensory detected

Mark on the glass	Sugar content in wine (g/L)	Wine										
		V-1	V-2	V-3	V-4	V-5	V-6	V-7	V-8	V-9	V-10	V-11
		Sugar content found in wines (g/L)										
1	Actual sugar content	**1.30**	**2.21**	**2.46**	**3.17**	**3.40**	**1.82**	**2.31**	**1.91**	**2.71**	**1.62**	**2.08**
	Modeled sugar content in wine	Added amounts of 5% sucrose solution (mL) in 10 mL of wine										
2	**3.5 g/L**	0.44	0.26	0.21	0.07	0.02	0.34	0.24	0.32	0.16	0.38	0.28
3	**4.0 g/L**	0.54	0.36	0.31	0.17	0.12	0.44	0.34	0.42	0.26	0.48	0.38
4	**4.5 g/L**	0.64	0.46	0.41	0.27	0.22	0.54	0.44	0.52	0.36	0.58	0.48
5	**5.0 g/L**	0.74	0.56	0.51	0.37	0.32	0.64	0.54	0.62	0.46	0.68	0.58
6	**5.5 g/L**	0.84	0.66	0.61	0.47	0.42	0.74	0.64	0.72	0.56	0.78	0.68
7	**6.0 g/L**	0.94	0.76	0.71	0.57	0.52	0.84	0.74	0.82	0.66	0.88	0.78
8	**6.5 g/L**	1.04	0.86	0.81	0.67	0.62	0.94	0.84	0.92	0.76	0.98	0.88
9	**7.0 g/L**	1.14	0.96	0.91	0.77	0.72	1.04	0.94	1.02	0.86	1.08	0.98
10	**7.5 g/L**	1.24	1.06	1.01	0.87	0.82	1.14	1.04	1.12	0.96	1.18	1.08
11	**8.0 g/L**	1.34	1.16	1.11	0.97	0.92	1.24	1.14	1.22	1.06	1.28	1.18

Data analysis and statistics

In addition to the descriptive statistics tools used to summarize and present the research data, the research results were analyzed through one-way ANOVA (sugar and total acids contents in wines; wine organoleptic rating; wine sweetness threshold). Testing for significance of differences in means was performed by Tukey *post hoc* test.
Correlation coefficients and graphically interpreted correlations between the following indicators were calculated: sugar content of wine - sensory evaluation of wine; content of total acids in wine - sensory evaluation of wine and organoleptically detected sweetness threshold - content of total acids in wine. The Bill Miller OpenStat (2014) package was used for statistical data processing.

RESULTS AND DISCUSSION

The results of the study will be presented in the sub-chapters related to: sugar content in wines, total acid content of wines, organoleptic evaluation of wine, organoleptic detection of wine sweetness threshold and correlations between sweetness, acidity and wine quality.

Sugar content in wines

The sugar contents in the 11 analyzed wines are presented on the Figure 1.

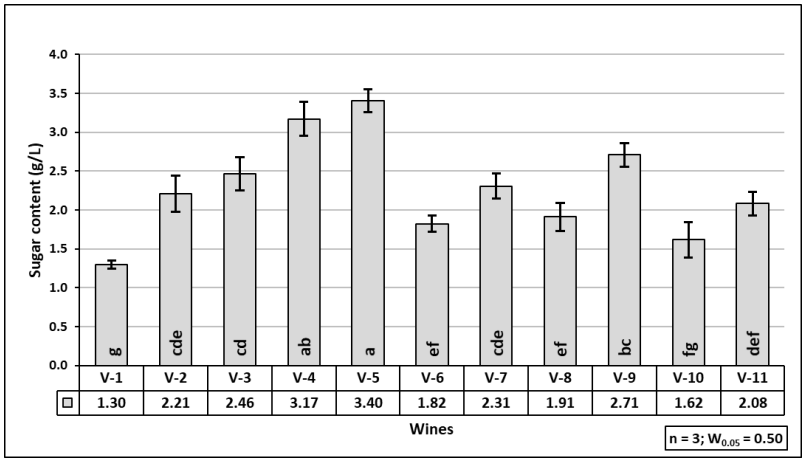

Figure 1. Sugar content (average with standard deviation graph) in the 11 analyzed dry white wines

As the Figure 1 shows, the sugar content of the declared dry white wines ranged from 1.30 g/L (wine V-1) to 3.40 g/L (wine V-5). The results of the mean differences

significance test showed that, with 3.40 and 3.17 g/L sugar, wines V-5 and V-4, respectively, had significantly higher sugar content than the other nine analyzed dry white wines, excluding the difference between the sugar content in wines V-4 (3.17 g/L) and V-9 (2.71 g/L). Wine V-1 had a statistically significantly lower sugar content (1.30 g/L) compared to the other analyzed still dry white wines, excluding excluding difference with the V-10 wine containing 1.62 g/L sugar. The sugar content of all analyzed wines was in line with the prescribed ranges for declared wine sweetness (dry wines, up to 4 g/L sugar).

Total acids in wines

The following figure presents the total acid content of the analyzed still white wines.

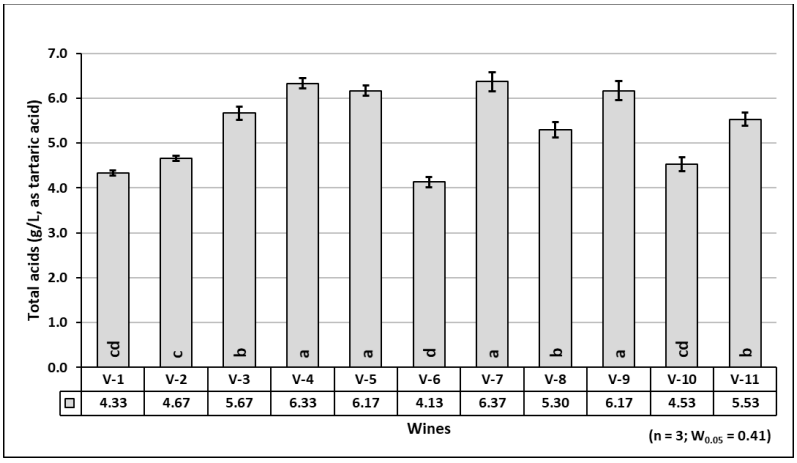

Figure 2. Total acid content (average with standard deviation graph) in the 11 analyzed dry white wines

The measurement and calculation results shown in the Figure 2 show that the total acid content of all the wines analyzed ranged from the minimum of 4.13 g/L (wine V-6) to the maximum of 6.37 g/L (wine V-7). With the exception of V-1, V-2, V-6 and V-10 wines with less than 5 g/L total acids, the determined total acid contents indicate satisfactory acidity of the analyzed regional wines. The significance test of the differences among means shows that the analyzed wines according to the content of total acids can be divided into three groups: the first with a statistically significant higher content of total acids (wines: V-7 with 6.37 g/L, V-4 with 6.33 g/L, and V-5 and V-9 with 6.17 g/L); the second with the average acid content (wines: V-3 with 5.67 g/L, V-11 with 5.53 g/L, and V-8 with 5.30 g/L); and the third group with, for this surrounding, low acid contents (wines: V-2 with 4.67 g/L, V-10 with 4.53 g/L, V-1 with 4.33 g/L, and V-6 with 4.13 g/L). The wines in the third group could be

characterized as wines with a low content of total acids, which may have influenced the evaluation of their taste.

Organoleptic evaluation of wine quality

Seven evaluators rated all 11 dry white still wines by the OIV rating scale of up to 100 points. The following figure shows the average (all evalautors) total ratings for the wine judged.

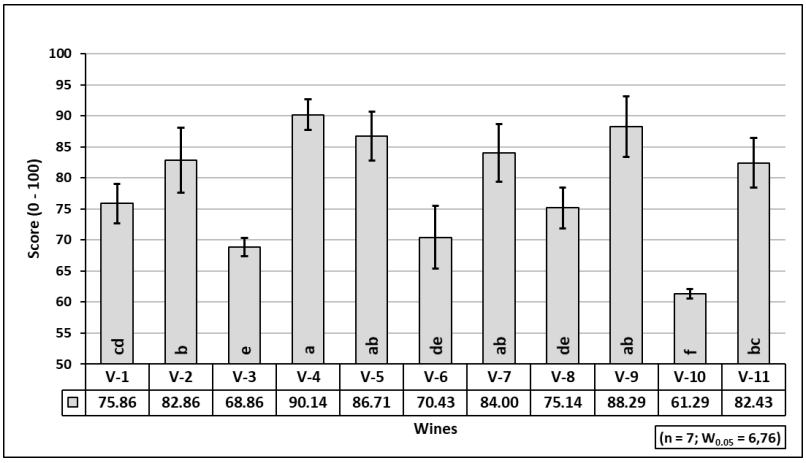

Figure 3. Organoleptic evaluations of the analyzed dry white still wines

According to the data on the Figure 3, the highest average rating was registered with the wines V-4 wine (90.14 points), and V-10 wine (61.29 points). As you can see from all the ratings, six out of 11 wines are rated more than 80 points (wines: V-2, V-4, V-5, V-7, V-9 and V-11), which is a decent if not the very good quality of still white wines, true on a small sample, offered to consumers at retail outlets in Sarajevo. Although, according to the test of significance, a number of statistically significant differences were observed between the average organoleptic ratings of the analyzed wines. The ratings for wines: V-4 (90.14 points), V-9 (88.29 points), V-5 (86.71 points), and V-7 (84 points) were significantly higher than the ones for other wines. A significantly lower rating, compared to all other wines, was attributed to the wine V-10 (61.29 points).

Sensory detection of wine sweetness threshold

According to the experimental plan, various growing quantities of sucrose solution were added to the analyzed dry wines, increasing the amount of sugar in the wines from the starting (laboratory determined) by 0.5 g/L in the range from 3.5 to 8.0 g/L (Table 3). Seven evaluators were asked to test the first sweet taste of wine by tasting wine from a series of glasses with increasing concentrations of sugar. After processing

the data collected from the evaluators, the derived data presented in the following figure were obtained.

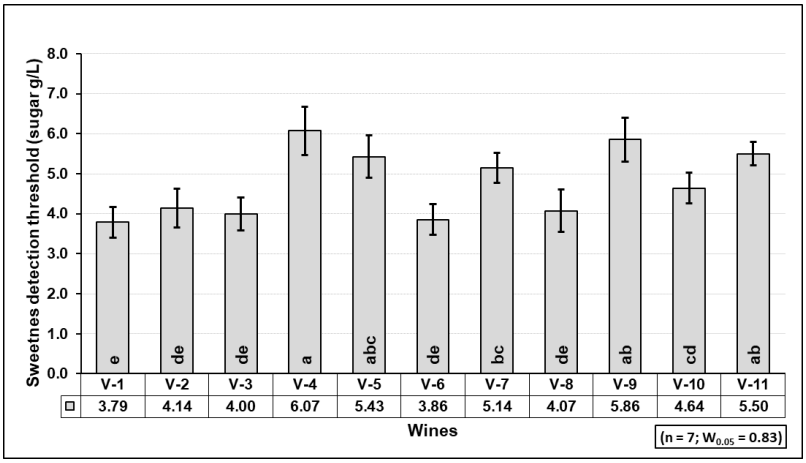

Figure 3. The average sugar contents in wines as wine sweetness thresholds

According to the data on the Figure 3, the sweetness of the wines was sensory detected at a sugar concentration of at least 3.79 g/L (wine V-1) to a maximum of 6.07 g/L (wine V-4). Interestingly, for three wines (V-1, V-3 and V-6), the sweetness of the wines was sensory detected at sugar concentrations that are below the regulatory limit set for categorization of dry wines (up to 4 g/L sugar). Although the results of similar studies were not found in the recent available literature, it can be said that the evaluators in this research sensory detected sweetness at low sugar concentrations (from about 0.4 to about 0.6%). Given that average wine consumers often describe the taste of dry wines as sour or harsh, similar research might need to be conducted with a larger group of less experienced wine consumers.

According to the test of significance of differences from the previous table, the sweetness threshold in wines V-4, V-9, V-11 (6.07 g/L, 5.86 g/L and 5.50 g/L, respectively) was found at a statistically significantly higher concentrations of sugar than in other wines, excluding differences with wine V-5 (sweetness threshold at 5.43 g/L) and wine V-7 (at 5.14 g/L). At the same time, in wines V-1, V-2, V-3, V-6 and V-8, the sweetness threshold was detected at significantly lower sugar concentrations than the sugar concentrations at which the sweetness thresholds were detected in other wines, except for the difference between the sugar concentrations at which the sweetness threshold was detected in wines V-2 (4.14 g/L) and V-10 (4.64 g/L).

Generally, the detection of sweetness threshold in the analyzed wines was at fairly low sugar concentrations (as indicated, ranging from 3.79 g/L to 6.07 g/L; average for all wines: at 4.77 g of sugar per liter of wine). This average detection of sweetness threshold of seven evaluators was therefore found at sugar concentrations just slightly higher than the upper regulatory limit for declared dry still wines (4 g/L).

Relationships between sweetness threshold and acidity of wine

Of particular interest for this research was the determination of the relationship between the sugar concentrations at which the sweetness of the wines was sensory detected and the determined acid content of the analyzed wines. The following figure shows that.

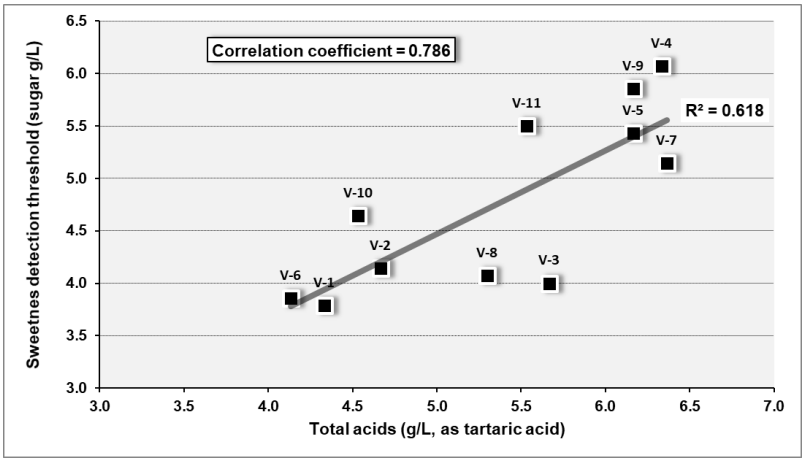

Figure 4. Relationship between the sweetness thresholds and the total acid contents of the wines

According to the data in the Figure 4, including a calculated correlation coefficient of 0.786, there was a strong positive correlation between the total acidity of the wines and their sweetness thresholds. In other words, in wines with higher total acid content the sensory detection of sweetness threshold was with higher sugar concentrations than in wines with lower total acid contents. This may partly explain the very low sugar concentrations (below 4 g/L), by which regular consumers and wine connoisseurs found sweetness in wines V-1 and V-6 that had low total acid contents (V-1 = 4.33 g/L; V-6 = 4.13 g/L).

Although these are a small number of wines analyzed, it can be certainly concluded that there is a positive correlation between the sweetness threshold and the acidity of the wines and that more acidic wines require more sugar to make it taste sweet. Using truthfully higher concentrations of sugar in model solutions (80 to 120 g/L sucrose) with different citric acid concentrations, Bonnans and Noble (1993) found that acidity growth suppresses sweetness more than sweetness growth suppresses acidity. The results similar to those here presented, i.e. that higher wine acidity increases concentrations of sugars by which wine sweetness was sensory detected were published by Pangborn *et al*. (1964), Bonnans and Noble (1993), and Zamora *et al*. (2006).

This, however, should still be taken with caution, since Amerine and Ough (1967) and, more recently, Martin (2002) and Martin *et al*. (2002) in contrast, found that the total wine acidity had no or very low effect on the sensory perception of wine sweetness. In this regard, it would be interesting to carry out research on sensory acidity detection in wines with different increasing sugar contents, which may, possibly, confirm or disprove the findings regarding the acidity and sweetness of the wine as indicated by the results of this research.

Relationships between sugar and acid content and organoleptic evaluation of wine quality

Although they were not among the first planned objectives of this research, the data collected allow a review of the relationship between total acidity and sugar content of wines with the organoleptic ratings assigned to the analyzed wines. It is important to emphasize that these considerations take into account the organoleptic ratings for the taste of the wine and not the overall organoleptic ratings of the wine (otherwise presented in Figure 3). It should be noted that there was a very high positive correlation between overall organoleptic ratings and wine taste ratings (PCC = 0.981). The Figure 5 shows the relationship between sugar content and organoleptic grades for the wines analyzed.

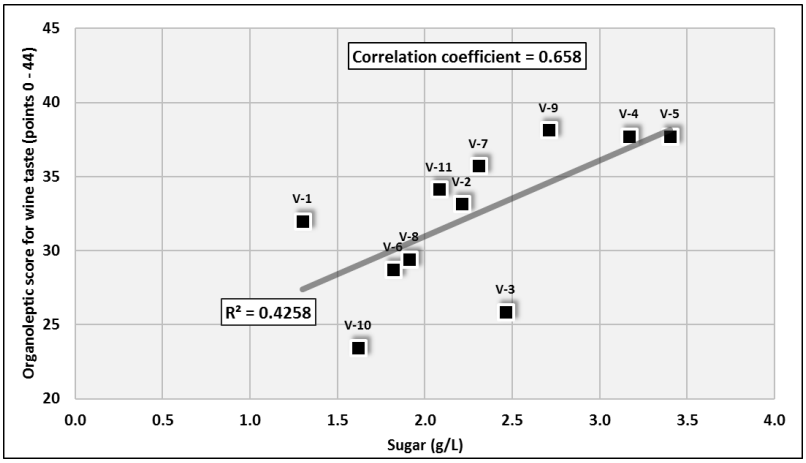

Figure 5. Relationships between sugar content and organoleptic rating of taste of the analyzed wines

When looking at the relations between the sugar content of the analyzed dry wines and the organoleptic ratings given to them in the Figure 5, it can be concluded that there is a moderate positive correlation between the sugar content of the dry wines and the assigned organoleptic ratings (correlation coefficient 0.658). Here, however, some

caution is needed in concluding, primarily due to the very small differences in sugar content identified in the analyzed 11 dry wines. It would be useful to determine the possible effects of a lower or higher concentration of sugars in dry wines on the quality of their taste through a more specific and more detailed study.
There remains a review of possible relationships between acid content and organoleptic evaluation of the wines. These relationships are presented in the Figure 6.

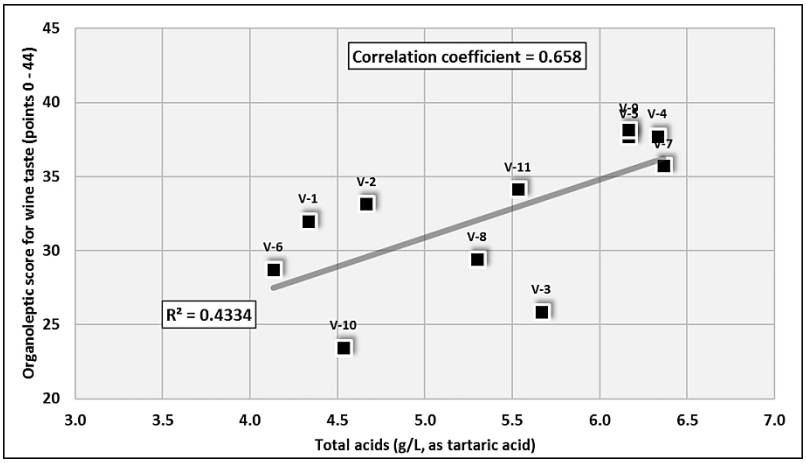

Figure 6. Relationships between total acid content and organoleptic rating of wine taste

The results presented in the Figure 6 indicate a possible correlation between the contents of total acids and the taste organoleptic ratings of the analyzed wines (moderate positive correlation; PCC = 0.658). However, due to the small number of samples, the indicated relationship should be verified by more extensive and detailed research, thus reaching a more solid conclusion about the positive influence of moderate acidity on the taste of wine, which is otherwise indicated by the oenological literature.
It is extremely interesting (to the extent possible) that the correlation coefficients for the relations "total acidity - wine taste rating" and "sugar content - wine taste rating" are the same: 0.658. Here it could be concluded that in this analysis of dry white wines the increase in the total acid content and the increase in the sugar content, albeit in a narrow range, still had a moderately positive effect on the organoleptic evaluation of wine taste.

CONCLUSIONS

According to the measurements of sugar content, all analyzed wines were in the regulatory group of dry wines (<4 g/L sugars), with a low average content of reducing sugars for all wines of 2.27 g/L. Four of the 11 analyzed wines had relatively low total acidity (less than 5 g/L), while the acidity of the other seven wines could be characterized as moderate (the average: 5.93 g/L). Wines were evaluated with a relatively high average organoleptic rating (average for all wines 78.7 out of a possible 100 points). In wines spiked with the different concentrations of the sucrose solution (in the range from 3.5 to 8 g/L sugars) the organoleptic sweetness threshold ranged from at least 3.79 g/L sugar to a maximum of 6.07 g/L sugar (average for all wines at 4.77 g/L sugar). A slightly positive correlation was found between contents of total acids and initial wine sweetness, on the one hand, and organoleptic evaluation of wine taste, on the other. The strong positive correlation between the total acidity of the wines and their sweetness thresholds was found (PCC = 0.786), indicating that the increase of the content of total acids in the analyzed wines increased the sugar concentration at which the sweetness of the analyzed wine could be organoleptically detected.

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UTICAJ KONCENTRACIJA ŠEĆERA I KISELINA NA DETEKCIJU SLASTI MIRNIH BIJELIH VINA

Rezime

Primarni cilj ovog istraživanja bio je utvrditi prag organoleptičke detekcije slasti vina modeliranih dodavanjem rastvora saharoze u uskom rasponu i identifikacija mogućeg uticaja kiselosti na prag detekcije slasti vina. Ispitivanje je provedeno na 11 uzoraka regionalnih suvih bijelih vina. Sadržaj šećera i ukupna kiselost vina mjereni su u laboratorijski, uz naknadno organoleptičko ocjenjivanje njihovog kvaliteta (OIV skala do 100 bodova). Sedam iskusnih potrošača vina ocjenjivalo je vina u stanju u kojem su ona nabavljena na tržištu te su u istim vinima modeliranim rastućim koncentracijama saharoze kasnije organoleptički utvrđivali prag detekcije slasti. Dobijeni rezultati pokazali su da su ocjenjivači vina registrovali slast vina pri relativno niskim koncentracijama šećera (od najniže 3,79 g/L do najviše 6,07 g/L). Analiza odnosa između sadržaja kiselina u vinima i pragova detekcije njihove slasti ukazala je na njihovu visoku pozitivnu povezanost (PCC: +0.786). To je u skladu s rezultatima nekih ranije objavljenih istraživanja kojima se zaključuje da je organoleptičko prepoznavanje slasti vina, između ostalog, uslovljeno njihovom kiselošću, odnosno da kiselost vina u određenoj mjeri potiskuje njegovu slast.

Ključne riječi: *suvo bijelo vino, organoleptičko ocjenjivanje, prag slasti vina, kiselost vina*