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Sensory and Chemical Characterization of the Aroma of a White Wine Made with Devín Grapes

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The aroma profile of a Slovak white wine made with Devín grapes was evaluated by 13 expert judges. The panel evaluated the orthonasal and retronasal aroma profiles, as well as the profile of residual wine aroma found in the empty glass after the consumption. For the majority of attributes, the orthonasal perception was the most intense, followed by retronasal, and finally by the residual odor. Varietal wine Devín possessed primarily a "Muscat" odor by nose, together with intense fruity, sweet, and herbaceous notes. Data were analyzed by generalized procrustes analysis. Two primary clusters separated orthonasal ratings from both retronasal and residual odor ratings. Similar results were obtained by analysis of variance. The relative proportion of "heavy" aroma notes, likely related to polar odorants, increased in retronasal and residual odor profiles. The gas chromatography−olfactometry profile revealed a great complexity and showed that the characteristic aroma of this variety seems to be a mixture of Muscat, Gewürztraminer, and Sauvignon-Blanc, being rich in linalool, *cis*-rose oxide, and 4-methyl-4-mercaptopentanone.

KEYWORDS: Varietal aroma; sensory analysis; orthonasal; retronasal; residual; GC-olfactometry

INTRODUCTION

Slovakia is located at the northern border of the climatic zone suitable for planting of *Vitis vinifera* vines. The concomitant socioeconomical changes that took place after 1989 had a deep impact on the Slovakian wine industry, which completely changed the share of planted vine varieties. During the Communist era, white cultivars giving neutral wines, e.g., Vlašský rizling (Welschriesling) or Veltlínske zelené (Grüner veltliner), were chiefly planted. The change of political system caused a drastic reduction of grape production and increased the share of those varieties with more specific aroma properties (e.g., Chardonnay, Sauvignon Blanc, Riesling) (*1*). Nowadays, the second most planted variety in Slovakia is Devín. It is a genuine Slovakian vine hybrid, bred by crossing Tramín červený (Roter traminer) and Veltlínske červeno-biele (Rot-weisser veltliner). Devín grapes were introduced into the Slovakian list of approved cultivars in 1997, but up to this day, its aroma has not been seriously profiled.

The main objective of the present paper is to characterize a representative sample of wine made from Devín grapes using both sensory and aroma chemical analyses. The chemical characterization of wine aroma is a demanding task, as the volatile fraction of wine is composed of a large number of compounds belonging to different chemical families (*2*). Only a small proportion of all of the volatiles present in wine are concentrated enough to be really odor active. In addition, the active odorants can be present at concentrations ranging from parts percent to parts per trillion (*3*). This explains why the chemical aroma profiling should primarily rely on gas chromatography−olfactometry (GC-O) (*4*). This technique uses human assessors to monitor the presence of aroma active compounds in the effluent of a chromatographic column. Although GC-O data have some limitations, it has been shown that under certain conditions, GC-O signals can be related to the sensory properties of the product (*5*).

The sensory assessment of wine has in general three basic steps: (i) visual inspection, (ii) smelling, and (iii) tasting in the mouth. Although all of the perceptions are deeply interrelated, we have focused our attention on aroma characteristics, trying to leave aside visual, taste, and mouth−feel perceptions. Being aware of the fact that wine aroma properties can be strongly dependent on the perception route (orthonasal or retronasal), both perceptions have been profiled. In addition, the aroma profile of the small amount of wine remaining in the cup after it was finished has also been studied, as we think that there is some relationship between the aroma perceived via retronasal and the aroma of the last drops of wine in the cup. So far, every

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Table 1. Adjusted Frequencies Obtained for 25 Descriptors in Orthonasal, Retronasal, and Residual Odor Profiling[a]

no.	descriptor	ortho1	ortho2	ortho3	grand AF ortho	retro1	retro2	retro3	grand AF retro	resid1	resid2	resid3	grand AF residual
1	cauliflower	0	0	0	0	0	16	0	9	0	0	0	0
2	sulfhydric	30	47	32	37	16	23	0	16	16	16	0	13
3	gum/plastic	36	30	34	33	16	0	23	16	23	23	0	18
4	fermentation/yeast	23	0	16	16	16	0	0	9	0	0	16	9
5	dirty/disagreeable	0	23	32	23	0	23	23	18	0	28	0	16
6	banana	48	60	47	52	36	42	28	36	36	34	36	35
7	apple/pear	53	61	58	57	60	49	45	52	36	34	32	34
8	ripe fruit/sauce	54	57	48	53	28	51	32	38	47	34	45	42
9	tropical fruits	55	53	38	49	42	28	23	32	32	41	11	31
10	other fruits	0	0	25	15	0	0	0	0	0	0	16	9
11	citrus	62	63	57	61	60	42	28	45	42	38	30	37
12	herbaceous	36	49	49	45	44	34	42	40	0	32	28	24
13	fusel	28	39	53	41	53	42	53	50	23	32	28	28
14	winy	28	23	0	21	0	16	0	9	28	16	16	21
15	toffee/coffee/liquorice	55	39	39	45	53	42	44	47	55	41	45	48
16	cooked vegetables	16	0	0	9	0	16	23	16	0	0	0	0
17	meaty	0	16	11	11	0	0	0	0	0	0	0	0
18	cider	32	25	32	30	23	36	36	32	23	23	23	23
19	muscat	85	88	92	88	60	69	58	62	70	78	69	72
20	aromatic herbs (rosemary, thyme, basil)	51	57	62	57	60	54	60	58	60	53	62	58
21	anise	42	25	0	28	28	16	16	21	16	23	16	18
22	caramel	60	49	58	56	36	44	49	43	36	45	36	39
23	peach/lactone	59	64	59	61	53	48	32	45	32	38	48	40
24	lactic	0	0	0	0	0	0	0	0	0	0	20	11
25	other	32	0	0	18	0	16	0	9	16	0	0	9

[a] Three repetitions; the grand AF values were obtained by merging the three repetitions.

wine taster knows that the emptied wine glass still elicits odors (termed "l'odeur du fond de verre" in French), slightly different from that of the original one and enriched in "heavy" aroma nuances. Once the wine glass has been emptied, there remains a thin film of liquid covering the glass surface. In this situation, the air−liquid interface is much bigger than the one found in a filled glass. We hypothesize that this would roughly correspond to the situation in the mouth after swallowing, when a small amount of liquid, mixed with saliva, stays spread over the surface of tongue and mouth mucosa. Such residuals most likely determine concentration of volatiles in the nose during retronasal perception (*6*, *7*).

MATERIALS AND METHODS

Wine. Samples were provided by the company Víno Matyšák (region Malokarpatský, Slovakia) after selection by a jury of professional tasters as the best representative of Devín varietal wine (97 points in the degustation according to the official system of the "Union Internationale des Oenologues" for calm wines).

Sensory Characterization. An expert wine panel (13 judges, nine women and four men) used a list of descriptors previously agreed in three free-choice profiling sessions (**Table 1**). All judges belonged to the laboratory staff. Descriptors were rated according to their intensity on an anchored scale with seven levels of intensity: zero; 1 = weak, hardly recognizable odor; 2 = clear but not very intense odor; 3 = extremely strong odor; intermediate values did not bear description. The use of the scale was remembered in two training sessions with various standards (*7*). In the formal sessions, the panelists were provided with 30 mL of wine in coded standard clear wine glasses (*8*), closed with lids until the moment of evaluation in a tasting room (*9*). The judges had to start with evaluation of the orthonasal odor (first without moving the glass, then moving it gently) and then, after a short break, they evaluated the profile of the retronasal odor. After this, the glasses were emptied and closed with the lids; the judges rinsed their mouths with water, waited for 5 min, and evaluated the intensity of the odor remaining in the glass. This experiment was carried out in triplicate in three independent sessions.

To represent the response of complete panel to a certain note, the "adjusted frequencies" were used [AF; the Dravnieks' percent applicability (*10*, *11*)]. This concept represented both average intensity and frequency of citation of the note. It was calculated as follows:

$$\mathrm{AF} = \sqrt{F\,(\%) \times I\,(\%)}$$

where F (%) was the detection frequency of an aromatic attribute expressed as percentage and I (%) was the average intensity expressed as percentage of the panel maximum intensity. Adjusted frequencies were calculated for each odor note and repetition (**Table 1**). Grand AFs were calculated by merging all repetitions (i.e., as if $3 \times 13 = 39$ judges evaluated the wine), and they are also shown in **Table 1**.

Extraction of Volatiles for GC-O. GC-O was performed on the extracts obtained from the "artificial mouth" extractor, which in fact represents a purge-and-trap type of extraction with artificial saliva added to wine (1:4). The trap was a cartridge filled with 400 mg of LiChrolut EN resins (Merck, Darmstadt, Germany), previously washed with 2 mL of methanol (Merck) and 20 mL of dichloromethane (Fisher Scientific, Loughborough, United Kingdom), and was dried with a N_2 flow for 20 min. The trap was then placed on the top of a bubbler flask containing a mixture of 80 mL of wine and 20 mL of artificial saliva [20 mmol/L $NaHCO_3$, 2.75 mmol/L K_2HPO_4, 12.2 mmol/L KH_2PO_4, and 15 mmol/L NaCl with 200 units mL^{-1} of porcine pancreas R-amylase (*12*)]. The mixture was continuously stirred with a magnetic stir bar and kept at a constant temperature of 37 °C by immersion in a water bath. A stream of nitrogen (flow 100 mL min^{-1}) was then connected and let pass through the liquid for 200 min. Volatile wine constituents released in the headspace were trapped in the cartridge containing the sorbent and were further eluted with 3.2 mL of dichloromethane. The extract was kept at −30 °C for 2 h to eliminate any water content by freezing and further decantation.

GC-O. A panel of eight judges, seven women and one man from the laboratory staff, carried out the sniffings. All panelists had extensive experience with GC-O. The duration of sniffings did not exceed 30 min. Panelists used the same seven-point category scale for intensity evaluation of the eluting odor. A Fisons 8360 gas chromatograph equipped with a polar fused silica column J&W DB-Wax (30 m ×

Table 2. Results of Analysis of Variance for Those Descriptors, Which Showed at Least One Significant Difference[a]

factor		way of evaluation				repetition			
data treatment		raw data		normalized		raw data		normalized	
no.	descriptor	F	SPD	F	SPD	F	SPD	F	SPD
2	sulfhydric	18.13**	O:C, O:R	9.50*	O:C	7.32*	NS	7.30*	NS
6	banana	10.77*	O:C, O:R	NS		NS		NS	
7	apple/pear	13.79*	O:C, R:C	10.54*	R:C	NS		NS	
9	tropical fruits	7.62*	NS	NS		NS		NS	
11	citrus	8.89*	O:C	NS		NS		NS	
13	fusel	NS		10.62*	R:C, R:O	NS		NS	
15	toffee/coffee	NS		24.33**	R:O, C:O	NS		27.08**	1:2, 1:3
19	muscat	30.65**	O:R, O:C, C:R	NS		NS		NS	
20	aromatic herbs	NS		11.58*	R:O	NS		NS	

[a] F, F factor; SPD, significant pairwise differences; O, orthonasal; R, retronasal; C, residual; *, **, significant at $P < 0.05$; and NS, not significant.

0.32 mm × 0.5 μm) was used. One microliter of the extract was injected in splitless mode, and the compounds were separated using the following oven program: 40 °C (3 min), 5 °C min^{-1}, 200 °C (8 min). Eluting compounds were split at the end of the column at a 1:1 rate between the flame ionization detector (250 °C) and the olfactory detector port ODO-1 (SGE, Ringwood, Australia). To prevent condensation of high-boiling compounds on the port, this was heated sequentially using a laboratory-made rheostat to 90 °C at 80 °C oven temperature, to 140 °C at 120 °C oven temperature, and to 200 °C at 180 °C oven temperature. Similarly, 1 μL of extract was injected into a ThermoQuest Trace GC (Rodano, Italy) gas chromatograph in splitless mode and separated on a semipolar fused silica column [AFE-73, Analisis vinicos, Tomelloso, Spain (30 m × 0.33 mm × 1 μm)] using the following oven program: 40 °C (5 min), 5 °C min^{-1}, 200 °C (15 min), 30 °C min^{-1}, 250 °C (15 min). The same type of olfactometric port as before was used. Linear retention indices were calculated using a standard mixture of *n*-alcanes C_6-C_{28}.

Quantitation of Volatiles. Major volatiles were quantified using the method published by Ortega and colleagues (*13*), trace volatiles using the method published by López and colleagues (*14*), with an additional calibration for *cis*-rose oxide (based on the *m*/*z* fragment 139). Mercaptans were determined according to the method published by Escudero and colleagues (*15*).

Statistical Analysis. The effects of the way of sensory evaluation and order of presentation were tested by a parametric two-way analysis of variance ANOVA (the assumptions on normality and equal variance were fulfilled) separately for raw data and data normalized for each sensory profile by the largest AF. Significance of the pairwise comparisons was tested using a Holm−Sidak test at $p < 0.05$ (SigmaStat 3.1; Systat Software Inc., Richmond, CA). The descriptive sensory analysis data were analyzed by means of generalized procrustes analysis (GPA) (Senstools 2.2; Oliemans, Punter and Partners, Utrecht, The Netherlands). In this study, the data for each of the replications for each sample evaluated by each assessor were treated as individual results. Average configuration plot dimensions were interpreted taking into account the descriptors used by each of the assessors, which were most highly correlated with each dimension (*16*).

RESULTS

Descriptive Sensory Analysis. Results of wine tastings are given in **Table 1**. Data in the table are AFs, as explained in the Materials and Methods. Seventeen out of 25 descriptors obtained the highest grand AF in the orthonasal ratings. This number may rise even up to 21, when the separate evaluations are taken into account. If we arbitrarily take as the most important descriptors those with grand AF > 45, then the orthonasal character of wine Devín is defined by the following 11 notes: Muscat, citrus, peach/lactone, apple/pear, aromatic herbs, caramel, ripe fruits/sauce, banana, tropical fruits, herbaceous, and toffee/coffee/liquorice, ranked in descending order of AF. Similarly, the retronasal profile is composed of the following seven notes: Muscat (the same position as by nose), aromatic herbs (+3 places as compared with its orthonasal rank), apple/pear (+1), fusel, toffee/coffee/liquorice (+5), citrus (−4), and peach/lactone (−4). The residual odor was the least intense, and only the notes Muscat (the same position as by nose), aromatic herbs (+4 places as compared with its orthonasal rank), and toffee/coffee/liquorice (+7) passed the limit.

Differences between the three different sensory scores, as well as the impact of repetition, were tested using ANOVA (**Table 2**, columns headed by "raw data"). It can be seen that only sulfhydric was affected by repetition, and so far, no difference was found in pairwise comparisons. This result is not surprising, since the sulfhydric character of a wine is very elusive and it is known to change when the wine makes contact with the air, a factor that it is very difficult to control in the wine tastings.

As expected, the most important factor is the way of evaluation, and the sensory scores of six of the most important odor nuances were found to depend significantly on it. In most cases, the orthonasal odor was more intense than the residual one (sulfhydric, banana, apple/pear, and citrus) and, to a lesser extent, more intense than retronasal as well (sulfhydric, banana, and Muscat).

Similar ANOVAs were run for data obtained by normalization of the profiles by the largest adjusted frequency (**Table 2**, columns headed as "normalized"). In this case, repetition was found to exert a significant effect on sulfhydric and toffee/coffee notes. Both descriptors are most probably linked to the presence of elusive mercaptans, which can explain the differences between the repetitions. As for the effect of the way of evaluation, now five descriptors were found to significantly depend on this factor: sulfhydric and apple/pear, in coincidence with the previous study, and fusel, toffee/coffee, and aromatic herbs. In these three last cases, retronasal was more intense than orthonasal.

The raw intensity ratings were treated by GPA too, resulting in three significant principal axes accounting for 53% of the original variance. Residual variance showed that the panel responded consistently (**Figure 1**).

The location and orientation of GPA ellipsoids in the graph of group consensus show a similar pattern for all three evaluation types (**Figure 1**). Orthonasal perception was separated from both in-mouth perception and residual odor along the first component (21% of the original variance explained). The second dimension (18% of the original variance explained) separated the first evaluation from the remaining two, and the third component (not shown) again separated the three modes of evaluation (14% of the original variance explained). Influence of separate notes

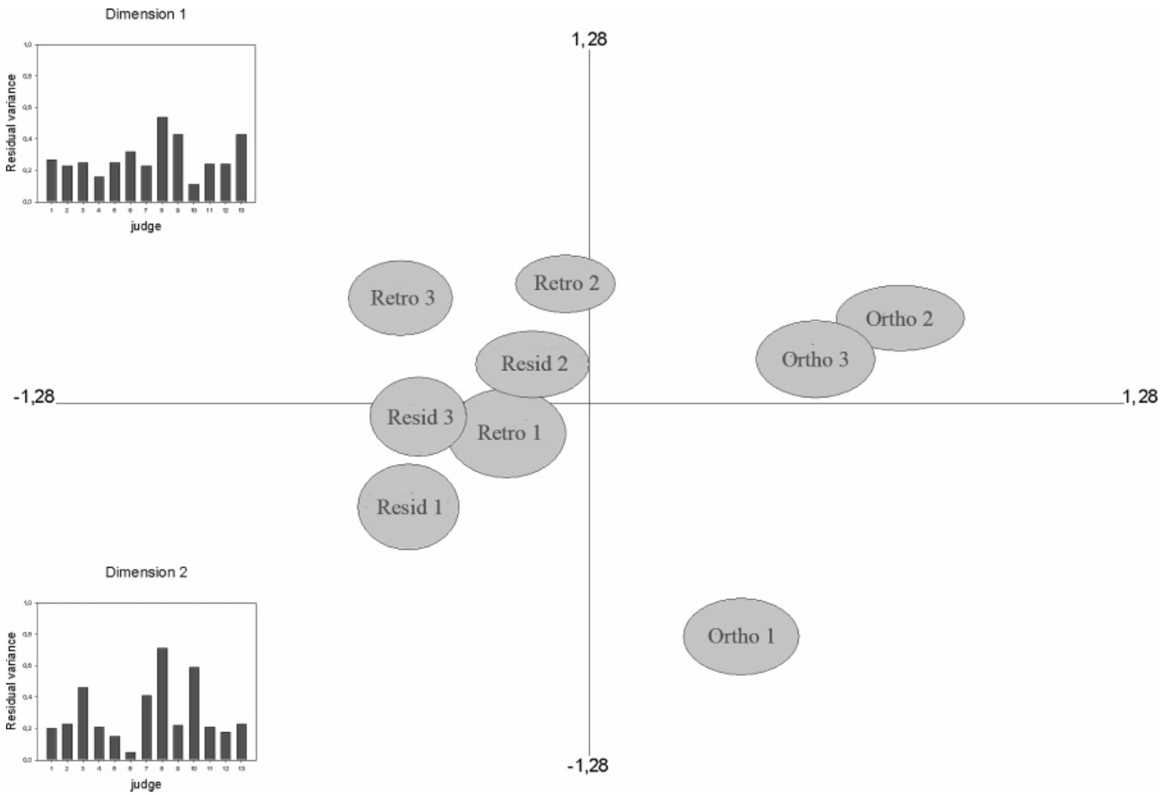

Figure 1. GPA residual variance (in %) and group consensus graphics for the first (21% of the original variance explained) and second dimension (18% explained).

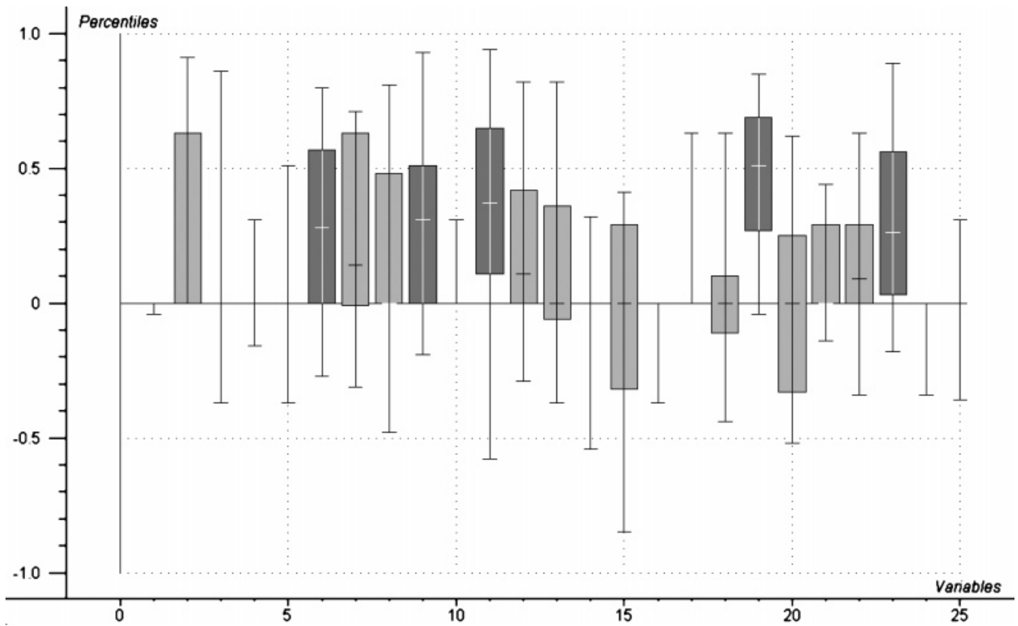

Figure 2. Box plots (percentiles) of the correlations of panelists' responses for every note in GPA. Numbers on the *x*-scale correspond to descriptors in **Table 1**. The descriptors with the highest impact are dark gray.

on distribution of consensus ellipsoids was assessed by drawing box plots (percentiles) of correlation of panelists' responses with separate notes. The largest effect on the first dimension was for the note Muscat, followed by citrus, peach, tropical fruits, and banana (**Figure 2**). Most of these descriptors are most likely due to nonpolar compounds, such as linalool, *cis*-rose oxide, or isoamyl acetate. The box plots of the second dimension show much disagreement among the panel (larges distances between 25 and 75% percentiles, as well as between minima and maxima). The note citrus and Muscat exerted a negative effect on the second component, while the notes fusel and aromatic herbs were positively correlated. The note Muscat had again a positive effect on the separation along the third component, while citrus had a negative effect together with the note apple/pear.

GC-O. Overall, the panel reported 108 separate perceptions in the GC-O experiment. To reduce this large number, we set an arbitrary limit to AF > 30 or OAV > 1, and then, the number decreased to 34 (**Table 3**), out of which 32 were identified and 24 were quantified (the majority of the most intense odors). It can be seen that 21 of the quantified compounds were present in the extract at concentrations above their threshold. Data in

Table 3. Odorants Found in the Extract of Varietal Wine Devín (AF > 30 or OAV > 1)[a]

no.	RI		identity	descriptor	AF		quantity (μg L^{-1})	threshold (μg L^{-1})	OAV
	DB-Wax	AFE-73			DB-Wax	AFE-73			
1	1223	744.7	isoamyl alcohol[b]	fusel, rancid, marker, cheese	84	73	295757	30000 (*23*)	9.86
2	1247	996.3	ethyl hexanoate[b]	anise, fruity, liquorice	79	73	240	14 (*31*)	17.1
3	1002		diacetyl[b]	strawberry, cream, sweet	76				
4	1560	1098.8	linalool[b]	lemon, camomile, herbal, floral	76	84	559	25 (*31*)	22.4
5	1684		isovaleric acid[b]	rancid cheese, feet, floral	70		1170	33 (*31*)	34.4
6	1082	855.3	ethyl isovalerate[b]	anise	66	18	5.7	3 (*31*)	1.9
7	1358	1110.4	cis-rose oxide[b]	bitter, green lemon, camphor, fresh	66	61	1.702	0.2 (*23*)	8.51
8	1382		4-mercapto-4-methylpentan-2-one[c]	green, mint, exotic fruits	64		0.014	0.0008 (*25*)	17.5
9	1134	876.8	isoamyl acetate[b]	banana	63	60	150	30 (*31*)	5
10	<1000	738.4	ethyl propanoate[b]	fruity, alcoholic, buttery	60	47			
11	1112		isobutanol[b]	fusel, rancid, solvent	59		81260	30000 (*23*)	2.70
12	1052	802.0	ethyl butyrate[b]	fruity, strawberry, hazelnuts	57	67	160	20 (*31*)	8
13	1066	850.4	ethyl 2-methylbutyrate[b]	anise, sweet strawberry	57	69	11.2	18 (*31*)	0.62
14	1397		*cis*-3-hexenol[b]	green, lemon, liquor, sweet	57		140	400 (*31*)	0.35
15	1031		isobutyl acetate[b]	nail polish, adhesive, anise	48		48	1600 (*19*)	0.03
16	1840	1390.0	β-damascenone[b]	dry plum, cooked apple	48	80	3.1	0.05 (*23*)	61.6
17	1880		geraniol[b]	honey, lemon, liquor, floral	48		655	36 (*15*)	18.2
18	1944		β-phenyletanol[b]	roses	48		36900	14000 (*31*)	2.64
19	1460		acetic acid[b]	vinegar, acetic	46				
20	1634		acetylpyrazine[c]	burnt, toasted	46				
21	1287	964.2	unknown	shoe store, gasoline, solvent, fruity	42	25			
22	1313		2-methyl-3-furanthiol[c]	fried, meal, barbecue	38				
23	1914		ethyl dihydrocinnamate[c]	pollen, floral, phenolic	34				
24	1237		isoamyl alcohol[b]	chlorine, marker, fruity	31				
25	1438		3-isopropyl-2-methoxypyrazine[c]	dirty, strange, burnt, grass	30				
26	<1000	766.1	ethyl isobutyrate[b]	fruits, anise, alcoholic, buttery	29	69	281	15 (*31*)	18.8
27	1647	823.9	butanoic acid[b]	fatty acid, cheese, sweet	25	31	18080	173 (*31*)	105
28	2243		4-vinylguaiacol[c]	leather, phenolic, stall	22		615	10 (*31*)	61.5
29	1728		3-mercaptohexyl acetate[c]	floral, anise	21		0.04	0.0042 (*25*)	9.52
30	1655		2-phenylethanal[b]	sweet, burnt, pneumatic, toasted	19		2.0	1 (*18*)	2
31	1444	1194.5	ethyl octanoate[b]	beer, flowery	18	24	130	5 (*31*)	26
32		827.6	unknown	herbal, solvent, bitter		45			
33		1363.9	γ-nonalactone[c]	floral, pollen		25	47	29 (*32*)	1.63
34		1225.6	citronellol[b]	sweet, roses		18	243	100 (*3*)	2.43

[a] Retention indices on polar and apolar columns, chemical identity, descriptors assigned to the odorant, adjusted frequencies (AF) on the two columns, quantity, odor threshold, and odor activity value (OAV, ratio of concentration and odor threshold). [b] Identification based on coincidence of retention indices and mass spectra with those of the pure standards. [c] Tentative identification based on coincidence of retention indices with those of the pure standards.

the table are ranked according to the AF measured in the DB-Wax column. When compared with the studies performed on total extracts (*17*, *18*), the most apparent is a lack of "heavy" compounds such as octanoic acid, furaneol, sotolon, vanillin, or phenols. This was caused first by the extraction technique in use, which is in fact dynamic headspace. Second, the wine studied was not aged in wood, which may deliver some "heavy" aroma compounds to wine. The most potent aroma on the polar column was isoamyl alcohol, which possess a fusel character. Similar results were obtained by López and colleagues in the study on wines from the Canary Islands (*17*). This result is in apparent contrast to the fact that the fusel aroma note was rather weak in the wine tastings, and so far, only in the retronasal perception did it reach 50% (**Table 1**). This fact may be attributed to the good solubility of this alcohol in wine (which makes it better perceived by mouth) and to the fact that this compound is a fixed constituent of wine aroma and forms part of the general concept of wine aroma. Something similar happens to the second and third most intense odorants, ethyl hexanoate and diacetyl, and to many other compounds in the list that are generic contributors to wine aroma (*15*, *19*).

Therefore, the first compound that could make this wine different is linalool (which was the most intense perception on the apolar column). Linalool is the compound that contributes the most to the Muscat character of wine (*5*), although the other odor active monoterpenols may contribute to this aroma too (*20*−*23*). *cis*-Rose oxide has a particularly high score and will play most likely a very important role in the aroma perception. This compound has been found to play an outstanding role in the lychee character of some Gewürtztraminer wines (*23*, *24*), and together with linalool may play an important role in Muscat and floral−sweet character of the wine (*5*). Another compound not forming part of the generic aroma perception and having a high GC-O score is 4-mercapto-4-methylpentan-2-one. This compound is the impact compound of Sauvignon Blanc wines (*25*) and has been found to play a key role in wine aroma even at very low concentrations (*15*). Its presence and relatively high concentration could explain the high score of the tropical fruits note.

Despite some exemptions (ethyl isovalerate), the AFs obtained on the apolar column correspond well to the polar one. Obviously, a smaller amount of odor responses was observed on the apolar column, which is an usual phenomenon (*18*, *23*). The differences in AF can be explained in terms of different chromatographic processes and in terms of panel reproducibility (*11*). No conclusions are drawn from odor activity values (**Table 3**), as this approach erroneously assumes that intensity rises with concentration equally for all compounds (*26*) and so may underestimate the role of some compounds in wine aroma (*15*).

Campo et al. (*5*) published recently a work on Spanish white wines, performed with the same research strategy as in this paper. The panel who carried out the GC-O evaluation was also the same. This offers us the possibility to compare the GC-O profile of Devín directly with those wines, which represent a wide range of white monovarietal wines. Results for such comparisons can bee seen in **Table 4**. At a first glance, it is evident that there are four perceptions not reported in Devín (hexyl and β-phenylethyl acetates and two unknowns) and

Table 4. Comparison of Slovak Varietal Wine Devín with Spanish (ES) Varietal Wines (*5*), Based on Adjusted Frequencies of the Most Potent Volatiles Perceived by GC-O[a]

compound	Devín	ES mean	ES max	ES min
isoamyl alcohol	84	80	83	73
ethyl hexanoate	79	81	87	76
linalool	76	24	66	0
diacetyl	76	73	84	54
isovaleric acid	70	49	57	41
ethyl isovalerate	66	69	72	65
cis-rose oxide	66	missing		
4-mercapto-4-methylpentan-2-one	64	24	40	10
isoamyl acetate	63	77	80	70
ethyl propanoate	60	42	48	26
isobutanol	59	43	53	37
ethyl butyrate	57	76	80	69
ethyl 2-methylbutyrate	57	63	72	54
cis-3-hexenol	57	40	55	20
isobutyl acetate	48	42	63	20
beta-damascenone	48	57	68	48
beta-penylethanol	48	50	62	40
geraniol	48	missing		
acetic acid	46	44	59	13
acetylpyrazine	46	37	48	22
unknown RI 1287	42	missing		
2-methyl-3-furanthiol	38	45	75	27
ethyl dihydrocinnamate	34	missing		
3-isopropyl-2-methoxypyrazine	30	49	62	16
3-*sec*-butyl-2-methoxypyrazine	27	14	41	0
unknown RI 1204	25	15	36	0
m-cresol	25	18	32	0
3-mercaptohexyl acetate	21	18	63	0
2-isobutyl-3-methoxypyrazine	20	50	63	23
beta-phenylethanal	19	16	38	0
unknown RI 1746	17	18	32	0
unknown RI 1259	missing	7	34	0
hexyl acetate	missing	13	31	0
beta-phenylethyl acetate	missing	29	50	7
unknown RI 1871	missing	7	32	0

[a] AFs of the Spanish wines are expressed as mean, maximum, and minimum AFs of the six wines studied.

another four found in Devín and not detected in the Spanish wines (*cis*-rose oxide, geraniol, ethyl dihydrocinnamate, and an unknown). Also remarkable is that Devín has the highest scores in ethyl propanoate, 4-mercapto-4-methylpentan-2-one, linalool, and isovaleric acid. The rest of odorants are approximately in the same range as the Spanish wines.

It is, therefore, remarkable that Devín wine contains relatively high amounts of three odorants, which are considered key compounds of single varieties: linalool for Muscat varieties, *cis*-rose oxide for Gewürztraminer, and 4-methyl-4-mercapto-pentan-2-one for Sauvignon Blanc and Schereube.

DISCUSSION

Both sensory and chemical analyses show that Devín could be roughly assigned to the aromatic, Muscat type of wines. Nevertheless, both wine tastings and GC-O revealed that its odor is far from the simplicity of pure Muscat type wines, usually overwhelmed by the terpenic Muscat character. The overall richness of the headspace extract, the presence of powerful mercaptans and pyrazines, as well as “sweet” odors suggest a more complex wine experience sharing characteristics with wines from three different varieties (Muscat, Sauvignon Blanc, and Gewürztraminer).

The comparison of the three sensory profiles also has some interest. To our best knowledge, only one work compared ortho- and retronasal odor profiles of wine and no work studied the residual odor of emptied glass. In a wine profiling study on Burgundy wines, Aubry and colleagues (*27*) reported a higher intensity in orthonasal profiles for the majority of wine descriptors, what in general corresponds with works performed on single compounds (*28*, *29*). Furthermore, Aubry and colleagues observed a worse discriminative performance of oral ratings as compared to nasal ratings. They also reported significantly higher retronasal scores for descriptors grilled, vanilla, and kirsch. At least two of these terms (grilled and vanilla) probably appeared due to the presence of some polar, less volatile compounds in wine. On the contrary, a term “cherry”, probably induced by some apolar ester, was reported to be the most important orthonasal percept.

The orthonasal perception of odor was in this study also more intense than retronasal for all notes, except fusel. The reason for the observed differences in intensity could be simply quantitative: In the orthonasal ratings, the volume of wine from which odorants are smelled is 30 mL; in the mouth, only 5−10 mL of wine is taken, and the empty glass contains barely 1 mL of wine. The orthonasal profile dominates notes connected to monoterpenols (Muscat, citrus), esters of short chain fatty acids (apple/pear, banana), mercaptans (tropical fruits and perhaps toffee/coffe/liquorice), alkyl-pyrazines (herbaceous), and to a lesser extent to some products of Maillard reaction or phenols (peach/lactone, caramel, toffee/coffee/liquorice, aromatic herbs). Monoterpenols, esters, mercaptans, and alkyl-pyrazines are rather nonpolar, and their importance in the orthonasal profile is more or less predictable. This is also reflected in the correlation of the aforementioned notes with the first component of GPA. The retronasal profile was a little bit less intense. Most of the notes decreased by about one-third, but sulfhydric notes decreased by about two-thirds. This note is linked to the presence of highly volatile mercaptans that can be blown out from the mouth very quickly. This would explain its low retronasal score (*30*). Also remarkable is the stability of the aromatic herbs and toffee notes in both retronasal and residual odor profiles, whose importance, in relative terms, even increased as compared with the orthonasal profile (ranking of descriptors; **Table 2**). In these cases, as happened to the fusel note, the notes are related to polar and soluble volatile compounds (e.g., furfurylthiol, guaiacol, cresol), which are most intensely perceived retronasally. In contrast, fusel did not increase its share in the residual profile. This could be explained either in terms of volatility of fusel alcohols (higher extent of losses due to evaporation) or in hedonic terms (rejection of such a disagreeable odor in the mouth and hence higher intensity scoring).

From ANOVA results (raw AF) as well as from group consensus graphics in **Figure 2**, it is possible to conclude that the residual odor profile was quite similar to the retronasal one. If we take into account the relatively large difference between the in-mouth temperature and the temperature of wine in the glass, then it seems that increase of air−liquid contact surface is a key factor, which promotes a more intense evaporation of polar compounds and underlies the differences between ortho- and retronasal odor profiles.

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