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Consumer preferences in wine: traditional *vs* fungus-resistant varieties in Switzerland

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ABSTRACT

A growing interest in sustainable viticulture has led to the development of fungus-resistant grape (FRG) varieties, but their acceptance by consumers remains uncertain. This study explores Swiss consumers' perceptions of wines made from FRG varieties compared to traditional grape varieties. Specifically, it investigates (i) potential differences in consumer acceptance of FRG wines and traditional wines, (ii) segmentation of consumers based on their appreciation of FRG wines, and (iii) the influence of information about FRG on consumer perception. To address these questions, we conducted a multi-phase study combining chemical wine analysis, expert sensory profiling and consumer blind tastings of FRG wines and traditional and commercial wines in three cities across Switzerland (Nyon (Vaud), Liebefeld (Bern) and Wädenswil (Zurich)). Half of the participants were informed that they were tasting wines made from FRG varieties, while the other half were not. The results indicate that FRG wines are, on average, as appreciated as traditional varieties. Furthermore, consumers can be segmented into three distinct preference groups. This study identifies three key drivers of consumer acceptance: organoleptic attributes, wine-knowledge of the targeted consumer cluster and prior awareness of FRG. While additional information on the environmental benefits of FRG wines did not influence overall consumer appreciation, one cluster of consumers was affected by the information provided. These findings have important implications for winegrowers, suggesting that marketing strategies should be tailored to different consumer segments, emphasising sensory qualities while strategically using information disclosure.

KEYWORDS: Fungus Resistant Grape (FRG), white wine, red wine, consumer liking, consumer behaviour, tasting, PIWI

INTRODUCTION

In conventional viticulture, fungicides are mainly used to protect the vine from powdery mildew, downy mildew and *Botrytis* aggressions (de Baan, 2020; de Baan *et al.*, 2015; Guimier *et al.*, 2018; Spycher & Daniel, 2013). Due to a lack of effective alternatives, organic viticulture relies on copper fungicides, an option that has been shown to have a negative environmental impact (Mackie *et al.*, 2013; Mackie *et al.*, 2012). Consumer awareness and societal interest in sustainability viticulture issues are growing (Borrello *et al.*, 2021). Consequently, winegrowers are compelled to reduce the frequency and amount of plant protection agent applications. The use of fungus-resistant grape (FRG) varieties is recognised as an effective solution for reducing the use of fungicides (Merdinoglu *et al.*, 2009; Rousseau *et al.*, 2013). FRG are the result of interspecific crosses between two vines of different species; that is, the European species *Vitis vinifera* and North American or Asian *Vitis* species, such as *V. riparia*, *V. amurensis* and *V. rupestris*, which have a naturally high resistance to fungal diseases, including powdery mildew, downy mildew and *Botrytis* (Pedneault & Provost, 2016). In Switzerland, both federal and private breeding programmes have led to the development of numerous FRG, including white varieties, such as 'Divona' (the 'Bronner' × 'Gamaret' cross) or 'Sauvignac' (unknown cross), and red varieties, such as 'Divico' (the 'Gamaret' × 'Bronner' cross) or 'Cabernet Jura' (unknown cross) (Spring *et al.*, 2013; Spring *et al.*, 2018). Winegrowers in Switzerland also have access to resistant cultivars from European breeding institutes, including those in France and Germany.

In the early nineteenth century, initial attempts to establish FRG varieties were generally unsuccessful due to the unfavourable sensory properties of the wines, such as the presence of a "foxy note" (Leis *et al.*, 2017; Pedneault & Provost, 2016; Teissedre, 2018). In the last few decades, the quality of the new resistant grape varieties has improved considerably, resulting in wines with a quality often judged as equivalent or superior to some *V. vinifera* references (Biasoto *et al.*, 2014; Borrello *et al.*, 2021; Kiefer & Szolnoki, 2023; Mackie-Haas *et al.*, 2021; Pedneault & Provost, 2016; van der Meer *et al.*, 2010).

Despite the high quality of the wines produced from FRG varieties, it is assumed that gaining consumer acceptance of these new varieties will be a major challenge for their establishment within the wine industry. Several studies have already focused on the acceptance of FRG varieties in different countries, such as France, Switzerland, Germany, Italy, the UK, the USA and Brazil (Biasoto *et al.*, 2014; Espinoza *et al.*, 2018; Kiefer & Szolnoki, 2023; Pedneault & Provost, 2016; van der Meer *et al.*, 2010; Vecchio *et al.*, 2022). In general, these studies have confirmed that high-quality FRG wines can be produced (Espinoza *et al.*, 2018; van der Meer *et al.*, 2010) and that there is general consumer willingness to try FRG wines in countries such as Brazil, France and Germany (Biasoto *et al.*, 2014; Espinoza *et al.*, 2018; Kiefer & Szolnoki, 2023). Surveys across multiple countries show that providing positive information, such as environmental benefits, can increase interest and acceptance (Kiefer & Szolnoki, 2024a; Kiefer & Szolnoki, 2024b; Vecchio *et al.*, 2022).

The most recent FRG acceptance study in Switzerland was completed over a decade ago and it focused only on expert analyses without statistical analyses (van der Meer *et al.*, 2010). Since then, numerous new grape varieties have been developed, and consumer interest in sustainability has become more prevalent (Hoffet *et al.*, 2021). Thus, the present study addresses the following research questions: (i) Is there a difference in Swiss consumer acceptance of wines made from FRG varieties and wines made from traditional grape varieties? (ii) Can consumers be clustered according to their appreciation of FRG wines? (iii) Does providing information about FRG varieties influence how consumers evaluate the wines? The results of this work should support winegrowers in increasing the cultivation and production of FRG wines and retailers in promoting their sales. This, in turn, should lead to greater acceptance among winegrowers and thus to a reduction in the use of pesticides in viticulture.

MATERIALS AND METHODS

1. Wines

Ten wines – five white and five red – were studied (Table 1). To guarantee that the wines were comparable, wine production methods were limited, with no chaptalisation or wood contact. White wines from the Souvignier gris and Divona FRG varieties were studied. For red FRG varieties, we studied wines from Divico and a blend of different FRG varieties (40.5 % VB Cal 1-28, 31.5 % VB Cal 1-36, 22.5 % Divico, 3 % Cabaret noir, 2.6 % Regent). In addition, two benchmark wines made from traditional varieties were selected to represent the taste preferences of Swiss consumers: Chasselas 1 and Pinot noir. These commercial wines, made from the two main grape varieties planted in Switzerland (OFAG, 2024), were sold by one of the country's major retailers and, according to them, ranked within the top 10 best-selling white and red wines respectively.

2. Sensory profiling

Sensory profiling of the 10 wines was performed by the Agroscope's wine expert panel (n = 12). Each panellist rated the intensity of 17 attributes of the white wines and 22 attributes of the red wines on an unstructured line scale with labelled end points from 1-7. White and red wines were served at 13 °C and 17 °C, respectively in ISO wine tasting glasses. All tested wine samples were coded with a random three-digit number and presented based on a sequential monadic approach and a William Latin Square Design. Data were collected using FIZZ software (version 2.61, Biosystèmes, France).

TABLE 1. Details of the wines analysed in this study. FRG represents fungus-resistant grape varieties.

Colour	Grape variety	Type of variety	Location	Vintage
White	Chasselas 1	Conventional variety	Switzerland	2021
	Chasselas 2	Conventional variety	Leytron, Wallis	2021
	Divona 1	FRG	Wädenswil, Zurich	2021
	Divona 2	FRG	Pully, Vaud	2021
	Souvignier gris	FRG	Au, Zurich	2021
Red	Pinot noir/Gamay	Conventional variety	Leytron, Wallis	2018
	Pinot noir	Conventional variety	Switzerland	2020
	Divico 1	FRG	Wädenswil, Zurich	2021
	Divico 2	FRG	Switzerland	2021
	FRG *Cuvée**	FRG	Wädenswil, Zurich	2021

* FRG *Cuvée*: 40.5 % VB Cal 1-28, 31.5 % VB Cal 1-36, 22.5 % Divico, 3 % Cabaret noir, 2.6 % Regent.

3. Wine analysis

Classical wine parameters (alcohol, pH, residual sugar, glycerol, total titratable acidity, tartaric, malic, lactic, acetic acid and dry extract) were analysed using infrared spectroscopy by FOSS Winescan™ (Foss Electric, Hille-Roed, DK). Total and free SO_2 were measured using Winescan™ SO_2 titration module (Foss Electric, Hille-roed, DK). Total phenols were analysed using the Folin-Ciocalteu method (OIV-MA-AS2-10) with a spectrophotometer (Lamda Bio 10, Perkin Elmer, USA). The results were converted into quantitative data using catechin as a reference substance. The colour measurements were performed on an Agilent Cary 60 spectrophotometer using the CieLab uniform colour space (Agilent Technologies, Santa Clara, CA, U.S.A.). Colour intensity (I) and hue (H) were calculated with the OD420, OD520, and OD620 (the optical density of the extract) measured at 420, 520 and 620 nm, respectively, according to the OIV-MA-AS2-11 method (OIV, 2006). Moreover, for red wines, other colour variables were calculated: the amount of yellow expressed as (100 × OD420/I), the amount of red expressed as (100 × OD520/I), and the amount of blue expressed as (100 × OD620/I) (Philippidis *et al.*, 2017). Furthermore, in the red wines, the total proanthocyanidin content (total tannins) was measured by acidic butanolysis based on the Bate-Smith reaction. The analysis of 3-mercaptohexanol (3MH) in white wines was performed by UHPLC-MS/MS (S1).

4. Consumer acceptance

The consumer tests were conducted in November 2022 at three different sites in the French- and German-speaking parts of Switzerland (Nyon (VD), Liebefeld (BE) and Wädenswil (ZH)); therefore, the questionnaire was available in both languages. Participants were recruited *via* invitation on social media channels and by email, as well as *via* the distribution of flyers at each of the three test sites. Consumer participation was not monetarily incentivised; however, participation was encouraged by organising a lottery in which various prizes could be won. It is important to note that the use of convenience and voluntary response sampling may introduce selection bias and limit the generalisability of the findings to the broader population. By using both digital and local recruitment strategies, including targeting external institutions at each site, a uniform consumer profile was prevented. Tasting sessions were distributed throughout the day to limit the impact of the consumers' level of hunger. At each of the three test sites, one half of the participants was randomly assigned to a group that received information about the type of grape variety (conventional, FRG) of the wine samples (in both French and German, the term "pilzwiderstandsfähige Rebsorten" or "PIWI" was used). No information on the grape varieties of the wines was given to the other half. All participants judged the five white wine samples first, followed by the five red wine samples, using a sequential monadic approach. Within each of the two-test series, the order of the sample presentation followed a William Latin Square Design. Before tasting a wine, participants were asked to rate their expectations of the sample, based on visual evaluation, on a nine-point category scale, with "do not like it at all" at the left end and "like it extremely" at the right end. The same scale was used to judge the subjective overall impression after the evaluation of the wine in the mouth. A diagram of the experimental design is presented in Figure 1.

Between the two wine series, participants were asked to answer questions about their wine consumption, the occasions on which they drink wine and their knowledge of wine and grape varieties. For the test, each consumer occupied an individual sensory booth. Until testing, white wine and red wine bottles were kept at 14 °C and 18 °C, respectively. All samples were served in ISO wine tasting glasses coded with random three-digit numbers. Still water and unsalted crackers were provided to neutralise the mouth. Both questionnaires, with and without information, are available in S2 and S3, respectively.

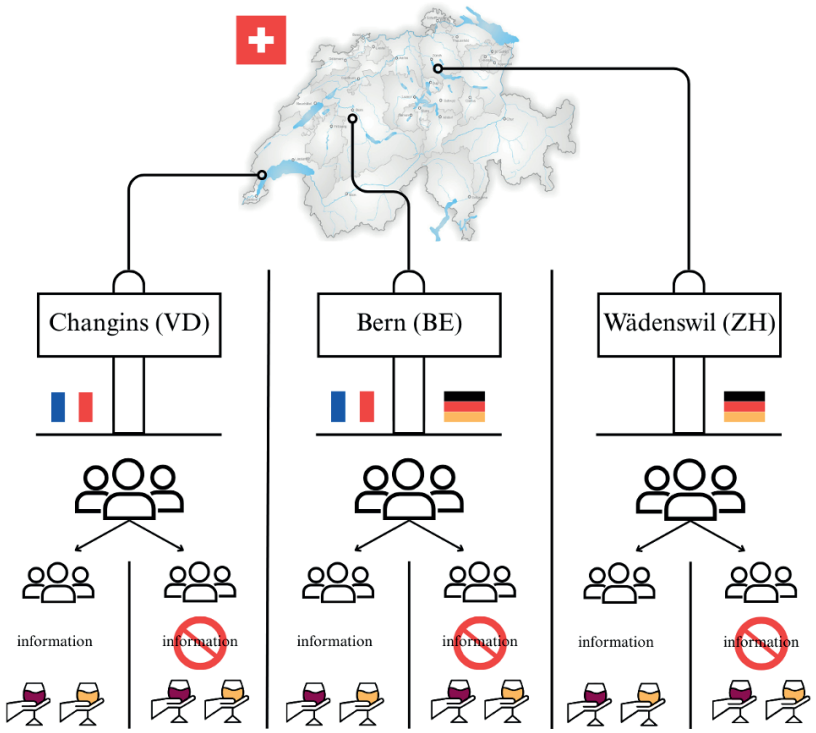

FIGURE 1. Experimental design of the consumer acceptance test.

5. Statistical analysis

Statistical analyses were performed using R software (R 4.3.3). The sensory profiling data of the wines were analysed by an analysis of variance (ANOVA), considering wine as a fixed factor and judge as a random factor, followed by a Tukey's test to highlight the significant differences between wines. Normality and homoscedasticity of the residues were checked using a Shapiro-Wilk test and a Levene test, respectively. The consumers were clustered by carrying out a hierarchical cluster analysis of a set of dissimilarities based on a Euclidian distance matrix and using a ward.D2 method (Murtagh & Legendre, 2014). The wine ratings were not standardised prior to performing the hierarchical cluster analysis, as we aimed to preserve inter-individual differences in overall appreciation (liking), which we considered informative to identify different consumer profiles. Although the mean silhouette coefficients indicated a slightly less robust clustering solution that comprised three groups, we nonetheless selected this option, as a two-cluster solution would have primarily reflected differences in rating scale levels, rather than distinct patterns of preferences. For both the consumer hedonic response and the cluster hedonic response, a Kruskal–Wallis test was performed with a significance level of 5 %. It was followed by a *post hoc* test, using Fisher's least significant difference. The Holm adjustment method was used *(agricolae (version 1.3-7))*. To characterise the consumers within the different clusters, we used the *catdes* of the FactoMineR R package (Husson *et al.*, 2011). This function gives a description of the categories of one factor (cluster) by categorical variables and/or by quantitative variables. For the qualitative variables, Chi-square tests were performed, and for the quantitative variables, an F-test in a one-way analysis of variance was performed. We used a significance threshold of 10 % to characterise the categories. To highlight which characteristics of the wines were preferred by each cluster, we performed a multiple factor analysis (MFA), with the sensory profiling results and the analytical results as active variables. For each cluster, the mean hedonic rating for each wine was projected as an illustrative variable. Finally, the influence of the information was evaluated using a Kruskal–Wallis test, because the ANOVA conditions were not met.

RESULTS

1. Sensory profiling and wine analytical characterisation

The results for the white wines showed significant differences in colour, vegetal notes of the bouquet and acidity (Table 2). Regarding colour, the differences between the wines were not specific to grape varieties. Chasselas 1 was described as having the highest vegetal notes in the bouquet, while Divona 1 had the lowest. The Souvignier gris wine was described as being the most acidic, unlike Chasselas 2 and Divona 2, which were described as being the least acidic.

Regarding the red wines, numerous attributes were found to be significant, including colour, vegetal and acidity, as was found in the white wines (Table 3). The colour differences between the wines were significant, with all three wines made from FRG variety having a more intense colour compared to Pinot noir and Pinot noir/Gamay blend. Green and vegetal notes were more present in the Divona 2 and FRG *Cuvée* wines. The two Divico wines had significant

TABLE 2. White wine sensory profile (5 % significance level). Letters show significant differences after adjustments based on Tukey's test.

		Chasselas 1	Chasselas 2	Divona 1	Divona 2	Souvignier gris	*p*-value
Visual	Colour	3.94 b	4.11 ab	4.29 a	3.90 b	4.16 ab	**
Bouquet	Reduction	1.03	1.07	1.16	1.07	1.03	
	Oxidation	1.11	1.06	1.19	1.07	1.25	
	Volatile	1.03	1.02	1.03	1.21	1.03	
	Fruity	3.54	4.07	4.23	4.06	3.89	
	Floral	2.66	3.35	2.69	3.15	2.97	
	Vegetal	2.12 a	1.56 bc	1.55 c	1.57 abc	2.11 ab	*
	Mineral	1.29	1.80	1.83	1.37	1.43	
	Stress	1.46	1.20	1.33	1.25	1.38	
	Milky	1.78	1.54	1.76	1.48	1.43	
	Empyreumatic	1.17	1.21	1.29	1.27	1.28	
Mouthfeel	Volume	4.12	3.92	4.19	4.28	4.35	
	Acidity	3.74 ab	3.55 b	3.96 ab	3.49 b	4.07 a	*
	Balance	3.87	3.91	3.91	3.88	3.99	
	Bitterness	1.92	1.86	2.15	2.06	2.40	
Significance codes: '***' $p < 0.001$, '**' $p < 0.01$, '*' $p < 0.05$							

TABLE 3. Red wine sensory profile (5 % significance level). Letters show significant differences after adjustments based on Tukey's test.

		Pinot noir	Pinot noir /Gamay	Divico 1	Divico 2	FRG *Cuvée*	*p*-value
Visual	Colour	3.41 c	4.05 b	5.98 a	6.37 a	5.91 a	***
Bouquet	Reduction	1.00	1.09	0.99	1.30	1.00	
	Oxidation	1.55 a	1.18 ab	1.15 ab	1.08 b	1.09 b	*
	Volatile	1.18	1.09	1.02	1.09	1.00	
	Fruity	4.18	3.95	4.12	4.02	3.95	
	Floral	2.18	2.32	2.55	2.13	2.68	
	Vegetal	1.45 b	1.91 ab	1.64 b	2.33 ab	2.77 a	**
	Spicy	2.68 b	2.73 b	3.92 a	3.36 ab	3.27 ab	*
	Animal	1.36 b	1.27 b	1.60 ab	1.96 a	1.41 b	*
	Milky	1.59	1.55	1.39	1.73	1.45	
	Empyreumatic	1.59	1.27	1.21	1.32	1.27	
Mouthfeel	Volume	3.64 b	4.09 ab	4.17 ab	4.28 a	4.09 ab	*
	Acidity	3.32 bc	3.18 c	3.83 ab	3.49 abc	3.95 a	**
	Tannin intensity	3.32 b	3.45 b	4.32 a	4.21 a	4.32 a	***
	Tannin quality	3.36 b	3.95 ab	4.34 a	3.82 ab	3.36 b	**
	Dry tannins	2.95 ab	2.82 b	2.65 b	3.34 ab	3.91 a	*
	Smooth tannins	3.5 ab	3.82 a	3.71 a	3.33 ab	2.86 b	*
	Structured tannins	2.00 c	2.27 bc	3.20 a	2.74 abc	2.95 ab	**
	Bitterness	2.09	1.86	2.23	2.16	2.50	
Significance codes: '***' $p < 0.001$, '**' $p < 0.01$, '*' $p < 0.05$							

spicy notes, while Divico 2 also had the strongest animal notes. Regarding mouthfeel, the volume of the Pinot noir wine was significantly lower than the volume of the Divico 2 wine. The acidity of both the Pinot noir and the Pinot noir/Gamay wines was lower than that of the three FRG wines. The FRG wines had the most intense tannins; in terms of tannin quality, there were significant differences between the wines, which did not depend on grape variety.

In addition to the sensory analysis, the wines were chemically analysed (Table 4). Regarding the white wines, those made from FRG seemed to have higher alcohol levels, with a mean value of 13.7 % compared to 12 % for those made from Chasselas. The residual sugar levels in the wine were also quite different, with values ranging from 0.5 to 6.9 g/L, and Chasselas 1 and Souvignier gris wines having the highest values: 6.9 and 4.2 g/L, respectively. The pH values ranged from 3.30-3.69. The lowest pH was found for the Souvignier gris wine, which also had the highest total titratable acidity of 6.1 g/L. The other wines had a total titratable acidity of between 4.0 and 4.7 g/L. In terms of tartaric acid, the two Divona wines had the highest values (2.0 and 2.1 g/L with a mean of 1.4 g/L for the other wines). None of the wines underwent malolactic fermentation in view of their malic and lactic acid content, except for Chasselas 1, which underwent partial malolactic fermentation. The acetic acid value ranged from 0.3-0.5 g/L. The glycerol content ranged from 5.6-6.7 g/L. The total and free SO_2 values ranged from 126-181 mg/L and 21-35 mg/L, respectively. In terms of total phenols, values ranged from 209-329 mg GAE/L, with Divona 1 and Souvignier gris wines having the highest values (306 and 329 mg GAE/L, respectively). The 3MH content was higher in the two Divona wines, with a mean value of 505 ng/L, followed by the Souvignier gris wine (271 ng/L) and lastly the Chasselas wines, with a mean value of 126 ng/L. Finally, in terms of colour, the L* values ranged from 98.673-99.096, the a* values from –1.196 to –0.672 and the b* values from 5.562-7.144.

TABLE 4. Chemical analysis of the wines.

	White					Red				
	Chasselas 1	Chasselas 2	Divona 1	Divona 2	Souvignier gris	Pinot noir	Pinot noir/Gamay	Divico 1	Divico 2	FRG *Cuvée*
Alcohol (% vol)	12	12.1	13.9	13.4	13.9	13.1	14	13.7	12.2	12.2
pH	3.45	3.69	3.35	3.51	3.30	3.70	3.85	3.69	3.68	3.78
Residual sugar (g/L)	6.9	0.5	1.5	0.7	4.2	1.9	0.9	1.8	2.5	7.1
Glycerol (g/L)	5.6	6.7	5.9	6.2	5.8	8.0	9.0	9.8	8.4	7.8
Total titratable acidity (g/L)	4.4	4.0	4.7	4.2	6.1	4.5	3.8	4.9	4.3	5.2
Tartaric acid (g/L)	1.7	1.0	2.0	2.1	1.6	1.7	1.3	1.7	2.4	1.8
Malic acid (g/L)	1.1	2.9	1.5	1.1	3.1	0.1	0.1	0.5	0.1	0.1
Lactic acid (g/L)	1.3	0.3	0.2	0.1	0.1	2.2	2.1	2.0	1.2	3.0
Acetic acid (g/L)	0.4	0.4	0.3	0.5	0.4	0.6	0.5	0.4	0.5	0.5
Total SO_2 (mg/L)	167	181	146	126	179	143	84	124	56	137
Free SO_2 (mg/L)	35	31	25	21	21	25	11	38	16	32
Extract (g/L)	24.1	20.2	19.8	18.3	23.8	28.8	25	30.3	28.4	38
Total phenols (mg GAE/L)	219	209	306	222	329	2,182	1,592	3,102	3,598	3,619
3MH (ng/L)	147	105	447	563	271	-	-	-	-	-
Total tannins (g/L)	-	-	-	-	-	2.56	1.48	3.7	4.32	3.52
Intensity	-	-	-	-	-	3.764	4.964	15.939	17.723	24.265
Hue	-	-	-	-	-	11.639	9.159	6.948	7.873	5.758
L*	98.916	99.036	98.673	99.096	98.79	41.649	31.993	6.644	4.217	2.591
a*	–0.672	–1.144	–1.011	–1.196	–1.126	48.443	52.904	35.961	27.886	18.933
b*	5.562	6.141	6.659	5.841	7.144	44.256	40.411	11.451	7.271	4.467
Amount of yellow (%)	-	-	-	-	-	48.6	42.9	35.9	38.3	32.0
Amount of red (%)	-	-	-	-	-	41.8	46.8	51.7	48.7	55.6
Amount of blue (%)	-	-	-	-	-	9.6	10.3	12.4	13.0	12.4

Regarding red wines, the alcohol levels ranged from 12.2-13.7 %, and the residual sugar in wines ranged from 0.9-7.1 g/L. The pH values ranged from 3.68-3.85, whereas the total titratable acidity ranged from 3.8-5.2 g/L, with higher values for the two wines from Wädenswil. The tartaric acid concentration ranged from 1.3-2.4 g/L, with a mean value of 1.78 g/L. The highest value was found for Divico 2. All the wines underwent malolactic fermentation based on their malic and lactic acid concentrations. Acetic acid levels ranged from 0.4-0.6 g/L with the highest value for the Pinot noir wine. The total and free SO_2 values ranged from 56-143 mg/L and from 11-38 mg/L, respectively. The dry extract content seemed to differ between traditional and FRG grape varieties, with a mean value of 26,9 g/L and 32.2 g/L, respectively. Total phenols values ranged from 1,592-3,619 mg GAE/L, with values for the FRG wines being nearly three times higher than those found for the Pinot noir and the Pinot noir/Gamay wines. A similar pattern was found for total tannin content, with values ranging from 1.48-4.32 g/L, and the three FRG wines having the highest values. Finally, in terms of colour, the intensity of the wine made from FRG varieties was between three and five times higher than the intensity of the wine made from traditional grape varieties, with mean values of 19.309 and 4.364, respectively. The hue also seemed to differ between FRG and traditional grape varieties, with higher values for wines made from traditional grape varieties. The amount of yellow was higher in the Pinot noir and the Pinot noir/Gamay wine, with a mean value of 45.750 compared to 35.400 for the FRG wines. The opposite was found for the amount of blue, with a mean value of 12.600 for the FRG wines compared to 9.950 for the wines made from traditional grape varieties.

2. Consumer demographics

A total of 266 consumers participated in the consumer tastings across three separate locations. The demographic data of the sample are described in Table S1. A total of 177 German-speaking (66.5 %) and 89 French-speaking (33.5 %) consumers participated in the tastings. Compared to the national distribution reported in the M.I.S. Trend (2017) study (*i.e.*, 73 % German-speaking, 23 % French-speaking, and 4 % Italian-speaking), our sample contains a relatively higher proportion of French-speaking consumers. No tastings were conducted in the Italian-speaking region (Ticino), and this segment of the population is therefore not represented in our panel. Despite the convenient sampling of the consumers that took part in the tastings, the panel was composed of 48.1 % male consumers, 51.5 % female consumers and one non-binary person. The average age of the participants was 40.5 ± 14.1 years. 34.2 % of participants held a university-level degree (bachelor's, master's or doctorate). This percentage was similar in previously published data on Swiss wine consumers (M.I.S. Trend, 2017). Finally, self-reported wine knowledge had an average score of 35.5 ± 22.5 out of 100 (0: no knowledge, 100: expert), with a median of 33, indicating a generally moderate level of perceived expertise among participants.

3. Consumer hedonic responses

The distribution and average liking scores (mean/median) for the tested wines are shown in Figures 2A and 2B.

Regarding the white wines (Figure 2A), the mean values are higher than 5. Therefore, all the wines were appreciated overall. The preferred wine was Chasselas 1, followed by Divona 2. Both wines were significantly preferred to Divona 1. Souvignier gris and Chasselas 2 were intermediate, with no significant differences, except for Chasselas 1. The violin diagram represents the distribution of numerical data using density curves. The width of each curve corresponds to the approximate frequency of the data points in each region.

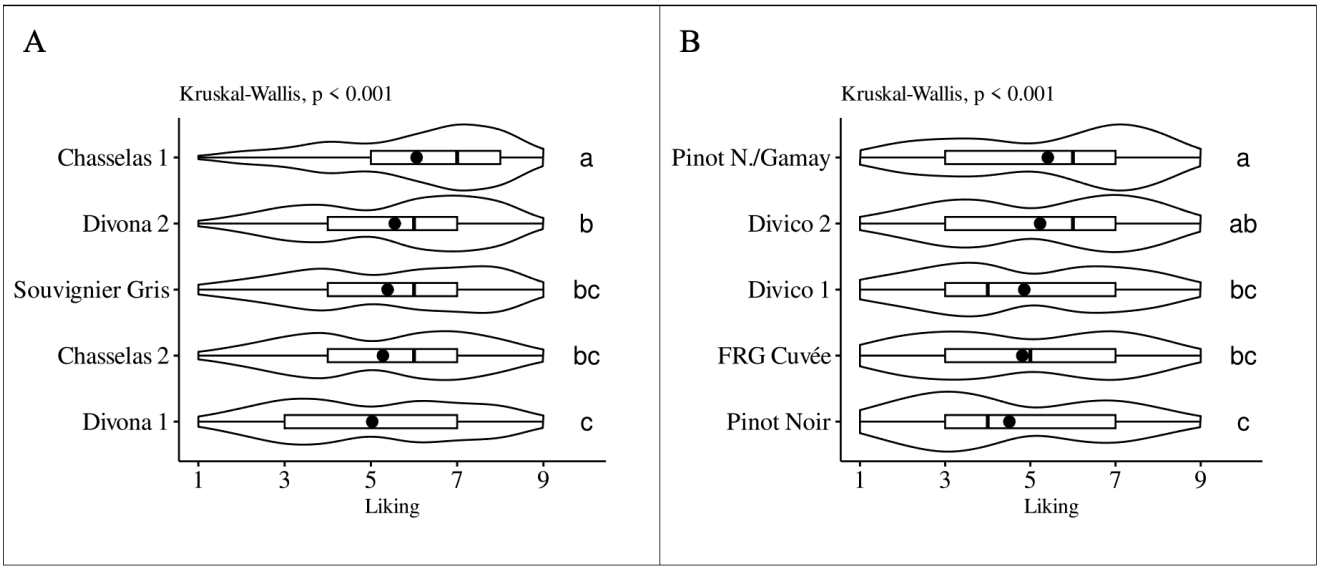

FIGURE 2. Distribution of liking for each wine. The box plot indicates the median and the black circle indicates the mean. Different letters show significant differences after adjustments based on the Holm method and at a 5 % significance level (A – white wines/B – red wines).

The majority of consumers liked Chasselas 1 wine, as illustrated by the width of the violin curve peaking around 7. Regarding the other wines, two peaks are noticeable on the curve at around 4 and 6-7, with a depression at around 5, suggesting a divergence in consumer appreciation of these wines, with some enjoying them more than others.

Among the red wines (Figure 2B), the highest scores were given to the Pinot noir/Gamay blend and Divico 2, with a mean liking value higher than 5. They were followed by Divico 1 and FRG *Cuvée*. Pinot noir wine obtained the lowest score, with most consumers having a low appreciation of this wine. As with Chasselas 1, there seems to be a consensus among consumers in terms of appreciation of Pinot noir/Gamay. This was not the case for Divico 2 wine, given the two peaks on the violin curve. Two peaks were also observed for Divico 1 and FRG *Cuvée*.

4. Consumer cluster characterisation

Considering the shape of the violin charts (Figure 2), we observed different types of consumers with different appreciations of wines. Therefore, we performed hierarchical clustering to explore whether participants could be characterised according to their liking patterns. For both types of wine, the clustering resulted in the segmentation of consumers into three clusters. The clustering was carried out separately for white and red wines. The ratings for each of the wines for each cluster are shown in Figures 3A and 2B for the white and red wines, respectively. While internal validation indicated a modest degree of separation between clusters, the results nonetheless revealed meaningful trends in consumer preferences. This outcome is not unexpected given the subtle sensory differences between wines and the inherent variability in individual perception, preferences and scale usage. Indeed, as is often observed in *post hoc* segmentation, it is rare to identify perfectly distinct consumer groups; rather, there is a continuum of preferences where the boundaries between segments are blurred and some individuals fall between several groups (Næs *et al.*, 2011). Despite the relatively moderate segmentation, the analysis enabled the identification of distinct consumer patterns, offering valuable insights into preference diversity across wine types. We attempted to characterise the consumer clusters based on demographic variables and responses to the questionnaire. Only characteristics that showed statistically significant differences between clusters were retained to describe and interpret the profiles of the different groups.

4.1. White wine cluster characterisation

Regarding the white wines, Clusters 1 and 3 showed higher appreciation for the wines than the second cluster, in which all the wines were rated similarly and differed mainly in the appreciation of the Souvignier gris wine and, to a lesser extent, Divona 1 wine (Figure 3A).

Cluster 1 was the largest in terms of the number of consumers, with 133 consumers. Based on the answers to the questionnaire, Cluster 1 comprised significantly more people who said they were familiar with Solaris and Regent FRG varieties and knew the term "FRG" and its meaning. This group also contained a higher proportion of consumers for whom FRG varieties have good sensory quality and for whom trying something new is important when making wine purchases. This cluster includes significantly more consumers with a master's degree.

Conversely, the second cluster, which comprised 74 consumers, had a higher proportion of consumers who said they did not know what the "FRG" term meant. They also did not know the FRG varieties Regent, Solaris, Divico or Léon Millot. In this cluster, the proportion of consumers

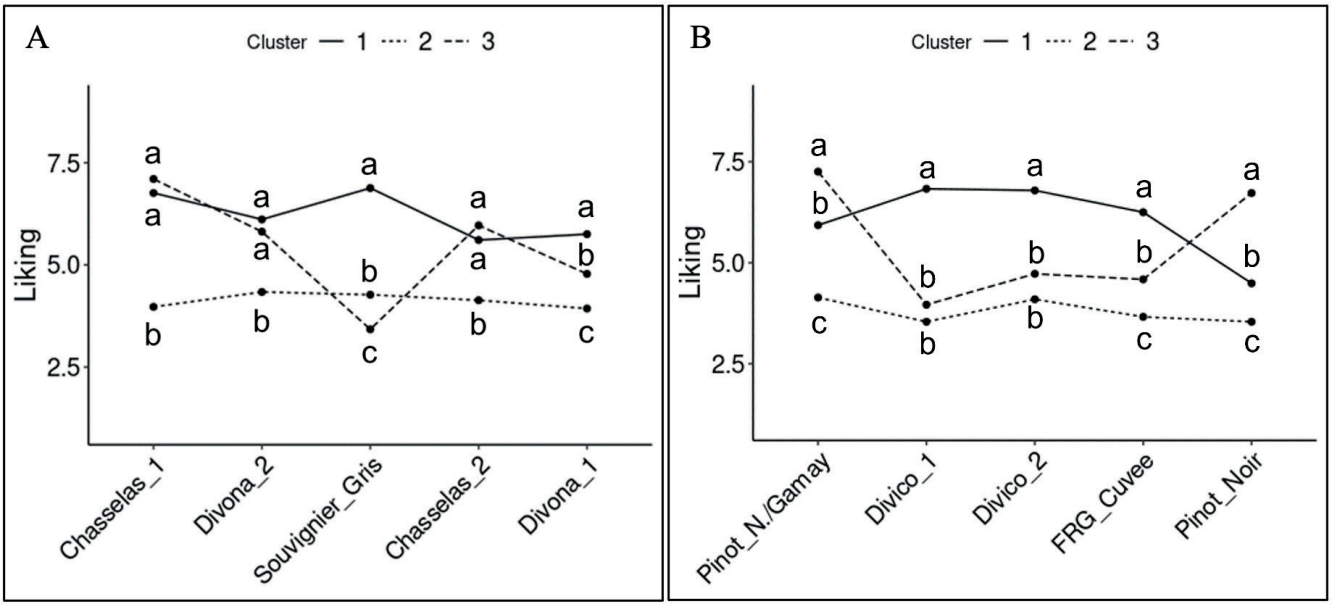

FIGURE 3. Mean likings for different preference clusters. Different letters show significant differences after adjustments based on the Holm method and at a 5 % significance level (A – white wines/B – red wines).

A: Cluster 1, *n* = 133; Cluster 2, *n* = 74; Cluster 3, *n* = 59; B: Cluster 1, *n* = 100; Cluster 2, *n* = 115; Cluster 3, *n* = 51

surveyed in the cantons of Basel City and Basel Country was higher than in the other clusters. Compared to the other two clusters, there was also a higher proportion of consumers who had a gross monthly household income of 7,000-9,000 CHF. These were people who spent a little less on wine than the average consumer surveyed, the average expenditure being around 150 CHF/per month. Furthermore, their wine knowledge was lower, and for them, tasting new or unknown wines was not important in their purchasing decisions.

Finally, the third cluster, which comprised 59 consumers, had a higher number of consumers surveyed in the cantons of Fribourg and Glarus. Out of the three clusters, this group contained the highest proportion of consumers who did not find FRG varieties to have good sensory quality and who rarely bought wine in supermarkets compared to the other two clusters.

4.2. Red wine cluster characterisation

Consumers were also segmented into three clusters according to their liking of red wines (Figure 3B). Cluster 1, which comprised 100 consumers, showed more appreciation of wines made from Divico grape varieties and FRG *Cuvée* and gave lower scores to the two wines made from traditional grape varieties. The opposite was true for Cluster 3, which preferred wines made from traditional grape varieties and gave low marks to wines made from FRG varieties; this cluster comprised 51 consumers. Finally, the ratings assigned by the 115 consumers in Cluster 2 were lower than those of the other two clusters but similar across all the wines.

Cluster 1 had a higher proportion of consumers from the cantons Luzern and Bern, who spoke German and had a gross monthly household income of between 7,000-9,000 CHF. Compared to the overall consumer sample, more consumers were familiar with the Regent and Léon Millot FRG varieties. Regarding their purchasing decisions, these individuals attached importance to the provenance of the wine, the labels and the opportunity to try something new. For them, the FRG wines had good sensory quality, and respect for the environment was important.

In Cluster 2, the proportion of consumers from the canton of Zurich was higher than in the other two clusters. Most of these consumers came to taste wines in Wädenswil. The cluster also included the highest proportion of consumers who said they did not know the FRG varieties Regent, Cabernet Jura, Léon Millot, Divico or Carbernet Cortis. However, this cluster included a higher number of consumers who knew the FRG Souvignier gris. These were consumers who did not judge the sensory quality of the FRG varieties positively, and for whom the origin of the wine was less important when choosing which wine to buy.

Cluster 3 was mainly composed of French-speaking consumers from the canton of Vaud who came to the tasting in Nyon. This group also included a higher number of people who knew the "FRG" term and the Cabernet Cortis and Divico FRG varieties. These consumers tended to be older than the average age of all the participants, and they also had better wine knowledge. Considering the criteria that guided their wine purchases, the region of production, the producer and the grape variety stood out, while environmental impact was of lower importance.

4.3. Wine composition and consumer preferences

To examine which chemical and sensory characteristics of the wines might have influenced the observed differences in appreciation between the clusters, a separate MFA was conducted on white and red wines using the data from the chemical analysis and sensory profiling. The average scores attributed to the wines per cluster are shown in Figure 4 as illustrative variables. Regarding white wines, the first two dimensions explained 66.5 % of the variability between the wines. The people in Cluster 1 seemed to prefer wines with a higher residual sugar content and more vegetal notes in the bouquet (Figure 4B). Cluster 3 was not characterised by any sensory descriptor or analysis value but was the opposite of wines judged to be bitter, acidic and full-bodied from a sensory point of view. In terms of analytical data, these wines were judged to have the highest levels of total acidity and total polyphenols. Finally, Cluster 2 was not well defined and was closer to the middle of the correlation circle.

Figure 5 shows the same analysis performed for the red wines. The two first dimensions of the MFA explained 71.0 % of the variability. Regarding the bouquet, wines preferred by Cluster 1 were characterised by spicy and animal notes; they had a higher tannin intensity and more structured tannins. This was portrayed by both expert sensory perception and tannin measurements. These wines also had a high colour intensity, with a dominance of blue, and a full volume. By contrast, the wines preferred by the consumers of Cluster 3 had lower colour intensity and a higher hue, meaning that the red colour shifted to orange hues, which was also confirmed by the high percentage of yellow. These consumers seemed to dislike bitterness and acidity and preferred more fruity wines. Finally, Cluster 2 was intermediate and less defined than the other two clusters. Consumers in this cluster seemed to dislike floral notes and, as in Cluster 3, bitterness and acidity.

5. Expectations based on initial visual perception

Prior to smelling and tasting the wine, consumers were asked to rate the wine solely based on its appearance. To assess whether the visual aspects of the wines provoked a positive surprise or disappointment, we subtracted the appreciation score based solely on the visual evaluation from the overall appreciation score. A positive score indicates a positive surprise, while a negative score indicates disappointment. The results are presented as clusters in Figures 6 and 7 for the white and red wines, respectively.

The results differed between the different clusters. For the white wines, the consumers in Cluster 2, which had similar ratings for all the wines, were equally disappointed with all

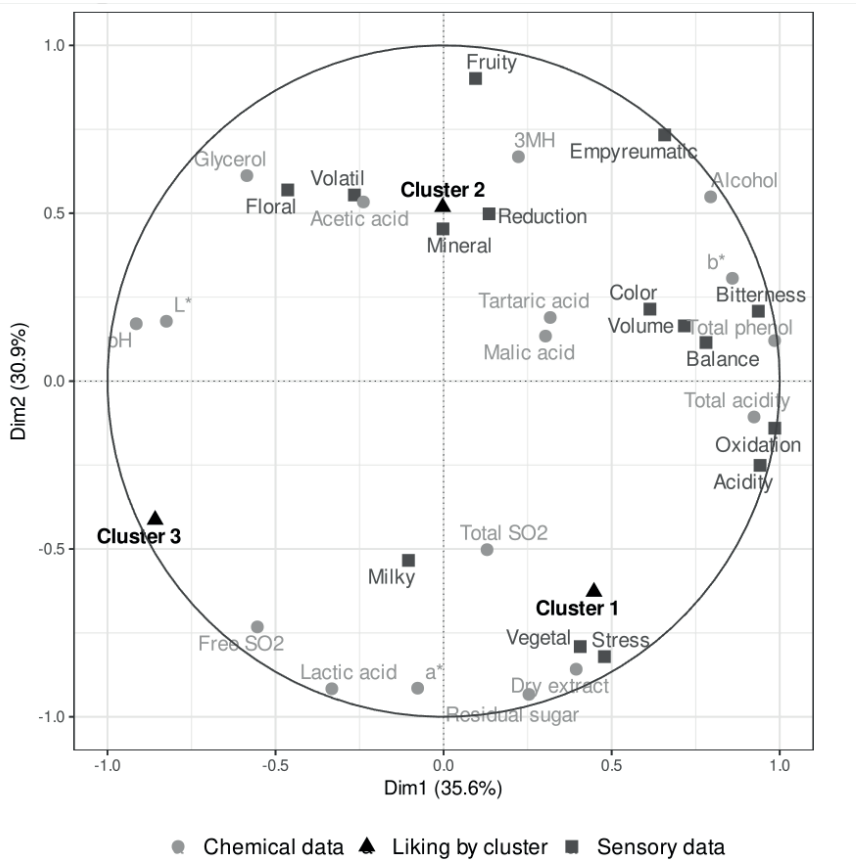

FIGURE 4. Correlation circle of the multiple-factor analysis of white wines.

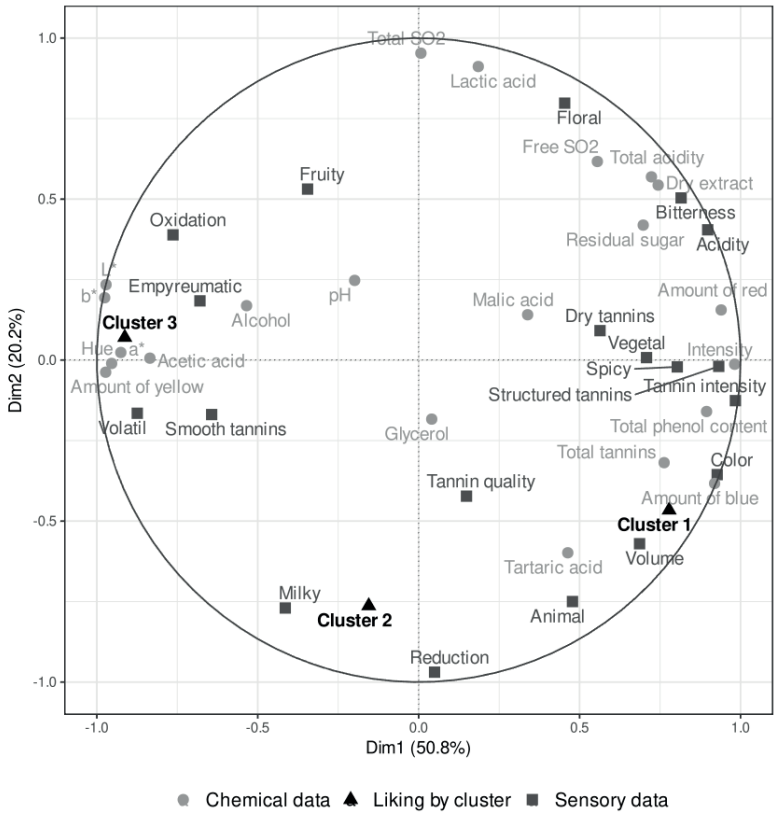

FIGURE 5. Correlation circle of the multiple-factor analysis of red wines.

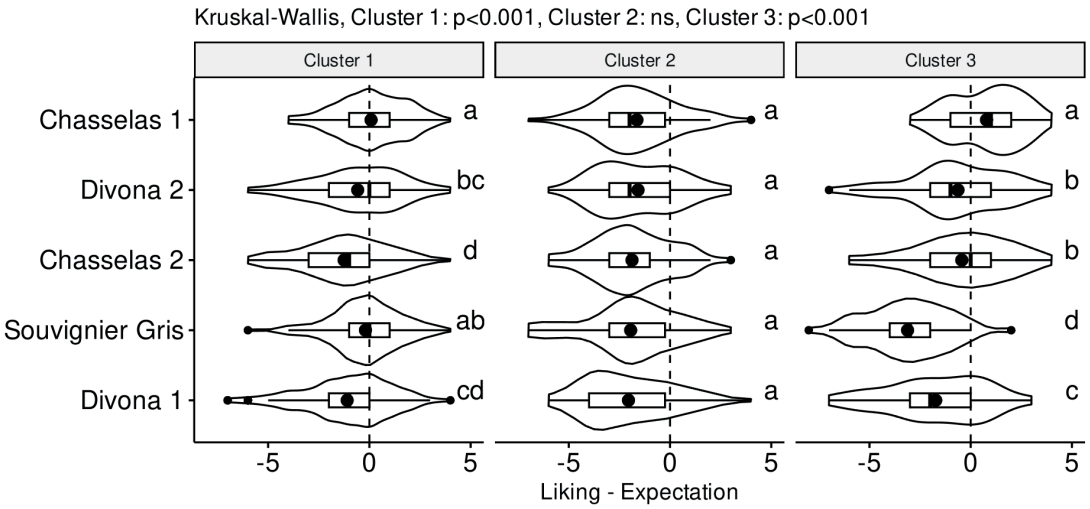

FIGURE 6. Positive surprise or disappointment shown as distribution of "Liking – visual expectation" of white wine per consumer cluster. The box plot indicates the median and the black circle the mean. Different letters show significant differences after adjustments based on the Holm method and at a 5 % significance level.

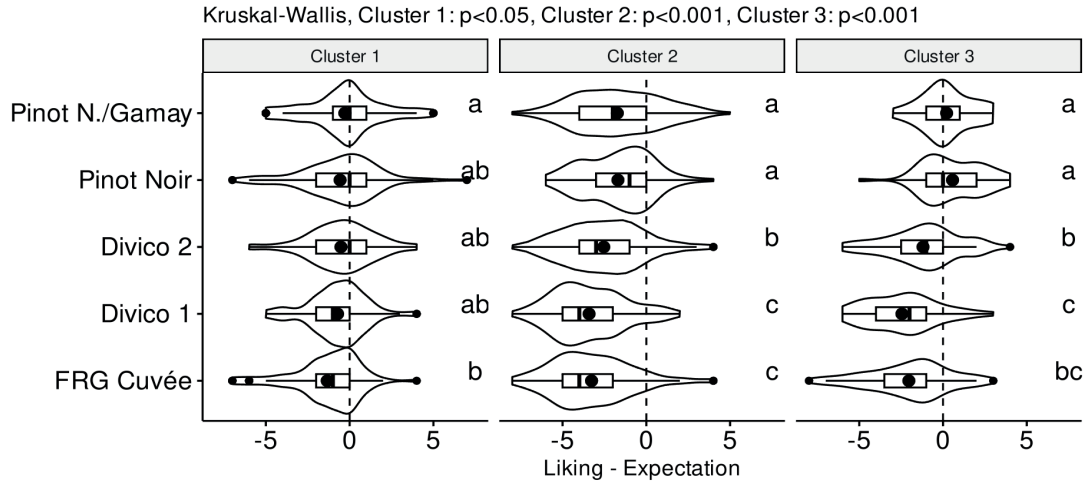

FIGURE 7. Positive surprise or disappointment shown as distribution of "Liking – visual expectation" of red wine per consumer cluster. The box plot indicates the median and the black circle the mean. Different letters show significant differences after adjustments based on the Holm method and at a 5 % significance level.

the wines. In Cluster 1, Chasselas 1, Souvignier gris and Divona had mean values of around 0, suggesting that these three wines were as expected (Figure 6). Meanwhile, the consumers in Cluster 1 were disappointed in Chasselas 2 and Divona 1. In Cluster 3, Chasselas 1 induced a positive surprise, and Chasselas 2 was as expected, with a mean value of around 0. The disappointment with Divona 2 was not significantly different from that of Chasselas 2, but we observed that the distribution of the participants was much wider, with low levels of disappointment (Figure 6). Regarding the red wines, the participants in Cluster 2 were disappointed in all of them, with a higher disappointment for the three wines made from FRG varieties (Figure 7). In Cluster 1, the only significant difference was between the Pinot noir/Gamay blend and the FRG *Cuvée* wines. In Cluster 3, the Pinot noir/Gamay blend and the Pinot noir were as expected, and the consumers were disappointed with the three FRG wines.

6. Influence of information on fungus-resistant grapes

As mentioned in the "Materials and methods" section, half of the participants received information about the grape varieties used to produce the evaluated wines (FRG or traditional), and the other half did not. The influence of information on the overall liking score of each wine was compared between the two groups of consumers, with or without information within each consumer cluster. Regarding the white wines, the test results were not statistically significant across all clusters (Cluster 1: H = 0.867, p = 0.352; Cluster 2: H = 1.090, p = 0.297; Cluster 3: H = 0.031, p = 0.860). By contrast, for red wines, a significant effect was observed in Cluster 1 (H = 8.200, p = 0.004), while no significant effects were found for Cluster 2 (H = 0.008, p = 0.928) and Cluster 3 (H = 0.352, p = 0.553). In red Cluster 1, consumers who were aware that they were tasting wines made from FRG gave significantly higher ratings compared to those who had not been informed.

DISCUSSION

1. Sensory profile and consumer acceptance

Previous studies have shown that specific sensory attributes influence consumer acceptance (Biasoto *et al.*, 2014; Espinoza *et al.*, 2018). Our results confirm that FRG wines have some attributes that tend to differ from their traditional counterparts. The white FRG wines leaned towards a higher alcohol content compared to Chasselas. This is likely due to the early ripening of the grapes in the vineyard, as late harvesting leads to higher sugars and more alcohol (Schumacher *et al.*, 2021a; Schumacher *et al.*, 2021b; Spring *et al.*, 2018). Souvignier gris (FRG) stood out as having a significantly higher total acidity compared to Divona (FRG) and Chasselas wines, which is typical for the variety (Schumacher *et al.*, 2021a; Schumacher *et al.*, 2021b). The acidity and pH values for Souvignier gris and Divona, although highly contrasting, were similar to those found by Salmon *et al.* (2018) in other FRG white varieties. Thiol compounds, such as 3MH, are known to bring much-appreciated fruity notes to wines (Roland *et al.*, 2011). Their higher concentration in Divona wines supports studies that describe Divona as "having a complex bouquet rich with exotic fruits, citrus and floral notes", while Souvignier gris has been defined as only "slightly fruity" (Leis *et al.*, 2017; Mackie-Haas *et al.*, 2023). Chasselas 1, which had the highest residual sugar content, was the most appreciated by all participants. By contrast, although Souvignier gris also contained residual sugar, its high acidity likely influenced the overall perception of its taste. This suggests that while sugar content plays a role in liking, its balance with acidity is key to overall consumer perception. These results suggest that despite their similar appearance, evidenced by their similar colour, white FRG wines had distinct characteristics.

Regarding the sensory profile of the red wines, more significant differences were found than in that of the white wines, as has also been noted by Mackie-Haas *et al.* (2023). In terms of bouquet, Divico tended to show more animal notes, and all FRG red wines tended to be spicier. This aligns with previous studies describing Divico and the varieties in the FRG *Cuvée* as fruity, spicy and herbaceous (Mackie-Haas *et al.*, 2023; Pedneault & Provost, 2016; Spring *et al.*, 2013). No clear patterns related to acidity, alcohol or pH were observed in the FRG or grape varieties, but similar values have been found in other studies, suggesting that the chosen wines were within the expected ranges (González-Centeno *et al.*, 2019; Mackie-Haas *et al.*, 2023; Spring *et al.*, 2013). However, it is important to note that these results may not be representative of all FRG red wines, as other varieties have shown higher total acidity and lower pH levels (Salmon *et al.*, 2018). In contrast to the white wines, the red wines were significantly defined by colour. A darker colour, with more purple notes, has been observed for many red FRG wines and can be explained by their high phenol and high total anthocyanin content (González-Centeno *et al.*, 2019; Kontić *et al.*, 2016; Spring *et al.*, 2013). González-Centeno *et al.* (2019) observed similar hue and yellow, red and blue colours as in our study; however, the intensity of colour from Divico and the FRG *Cuvée* is considerably higher (FRG mean value 19.31 compared with 11.2 Bouquet FRG).

Based solely on their initial perception of wine colour, consumers had expectations of both aromatic and tasting attributes. The level of disappointment was least for the wine made of traditional varieties: the Chasselas 1 and the Pinot noir and Pinot noir/Gamay wines. Although Chasselas is predominately grown and made in the western region of Switzerland, wines made from this variety are sold in wine shops and restaurants across the country. Pinot noir is the most widely planted grape variety in Switzerland and can be found in every canton that produces wine (OFAG, 2024). The Chasselas 1 and the Pinot noir wines are, according to the Swiss retailer that provided the wines, among the 10 best-selling white and red wines, respectively. These grape varieties are therefore likely to be well known to most, if not all, consumers. One study has shown that consumers tend to be comfortable with familiar sensory characteristics, and if the wines looked the same, consumers were likely to expect them to smell and taste the same (Kiefer & Szolnoki, 2023).

By contrast, FRG wines are not well known by Swiss consumers (Hoffet *et al.*, 2021). These varieties are most widely planted in the German-speaking regions of Switzerland, where they are also sold in small quantities through direct sales (Finger *et al.*, 2023; Mackie-Haas *et al.*, 2023). This suggests that when consumers are familiar with the new varieties, the level of disappointment is very likely to decrease. For the red FRG wines, a discrepancy was observed between the visual liking and overall liking of consumers. One hypothesis regarding this observation could be that the dark colour of FRG red wines may lead to the assumption that they have a stronger tannin presence than lighter coloured wines. In this study, the tannin content of FRG wines was higher than that of wines made from traditional varieties. However, it is important to note that the tannin analysis was carried out using a spectrophotometric method and that the tannin content may be overestimated in wines with a high anthocyanin content (Bátora *et al.*, 2024; Zeng *et al.*, 2021). The mismatch between colour and the perception of tannins has previously been described as the "PIWI Gap" by Pedneault and Provost (2016). Despite this, the mean liking ratings were similar between FRG and traditional wines, aligning with previously published data (Kiefer & Szolnoki, 2023; Rousseau *et al.*, 2013; van der Meer *et al.*, 2010).

2. Consumer clusters

The liking rating clearly shows a polarisation, especially for red FRG with a clear violin shape (Figure 2B), with some consumers liking a wine and others disliking it. This has already been observed by van der Meer *et al.* (2010), who demonstrated that one group of tasters rated certain wines very differently to the other tasters. Therefore, this study confirms the importance of identifying consumer

groups prior to assessing the consumer preferences mentioned in previous studies (Biasoto *et al.*, 2014; Kiefer & Szolnoki, 2023; Nesselhauf *et al.*, 2020; Schäufele & Hamm, 2017; Vecchio *et al.*, 2022). In our study, although the clustering structure appeared relatively subtle, the analysis still uncovered informative patterns in consumer preferences. This is likely influenced by the nuanced sensory differences between the wines. It is important to note that these observations are specific to this sample of consumers, but they nevertheless offer valuable insights that could guide future investigations on larger populations.

Each wine series included one cluster that rated all wines similarly (Francis & Williamson, 2015; Torri *et al.*, 2013). These non-discriminating consumers are known within consumer behaviour studies but will not be discussed further here.

In the case of white wines, the other two clusters were mainly defined by sensory attributes which can be predetermined by the grape variety, but which can also be promoted by the winemaker, such as acidity, vegetal notes and residual sugar. Thus, it is not possible to determine whether it was the grape varieties that were preferred or the wine styles. Cluster 3, which largely represented consumers from canton Fribourg, preferred less acidic wines and, therefore, did not like Souvignier gris. This variety is likely unfamiliar to the residents of Fribourg, as it is predominantly grown in German-speaking regions of Switzerland (Mackie-Haas *et al.*, 2023; OFAG, 2024). This regional unfamiliarity could help explain the lower appreciation for the wine. However, this phenomenon did not hold true for the participants from the other regions from the western part of Switzerland, all of whom are less familiar with FRG.

The remaining two consumer clusters of the red wines seem to be initially defined by traditional varieties and FRG. Considering the large colour difference between the varieties, this could again be a response to organoleptic attributes and not to the grape variety itself. For red wines, we conclude that cultural influence based on region and language plays a large role in consumer acceptance. The western region of Switzerland can be characterised by a dominant wine tradition and an interest in supporting local producers (OSMV, 2024), which could explain their preference for known varieties and sensory profiles. The German-speaking regions of Switzerland are more open to new and unknown wines. Overall, evidence confirms the existence of consumer groups that prefer wines made from FRG varieties (Biasoto *et al.*, 2014; Kiefer & Szolnoki, 2023). Additionally, it is known that beyond traditional wine-drinking consumer groups, there is also a group of young, curious and environmentally aware consumers who are very open to trying new or FRG wines (Hoffet *et al.*, 2021). This knowledge offers marketing possibilities to wine producers and substantiates the idea that tasting can help gain customer interest.

3. Knowledge of FRG

Providing information regarding the sustainability characteristics of, for example, FRG varieties, has, however, proven to change consumer acceptance, purchasing decisions and willingness to pay (WTP) (Espinoza *et al.*, 2018; Kiefer & Szolnoki, 2024a; Kiefer & Szolnoki, 2024b; Masset & Raub, 2023; Schäufele & Hamm, 2017; Vecchio *et al.*, 2022). This effect is not systematic and, once again, seems to depend on the consumer group or the means by which the information is communicated (Schäufele & Hamm, 2017). On the one hand, this was confirmed in our study by the cluster characteristics: consumers who were familiar with FRG names prior to the blind tasting belonged to the clusters where wines from these varieties were liked just as much as or preferred to traditional varieties. This prior knowledge seems to have contributed to their overall preferences. On the other hand, providing additional information on wines made from FRG only had an impact on the consumers from Cluster 1 for the red wines; this is the group that attached importance to respect for the environment and who consider the wines made from these varieties to have good sensory quality. However, the moderate effect of the information on the majority of the consumers surveyed suggests that wine quality is the most important attribute for Swiss consumers.

Nevertheless, quality is defined differently depending on the consumer cluster. Mann *et al.* (2012) found that Swiss consumers prioritise the origin of wine as the most important factor in purchasing decisions, followed by price and then system of production, which in their study was conventional or organic. This underscores the importance, or lack thereof, of the environmental friendliness of wines for Swiss consumers. Interestingly, they concluded that those who are likely to choose organic wines over conventional wines are not influenced by their taste but rather by their wine knowledge (Mann *et al.*, 2012). Both our study and theirs reached the same conclusion: knowledge of whether a wine is organic or made from FRG is of limited importance, as consumers place a stronger emphasis on wine quality; however, for some consumers, familiarity with the environmental friendliness of the wine increases the likelihood of a positive quality perception. How we provide information to consumers can have a large impact on how they receive it. As shown by Finger *et al.* (2023), small- to medium-sized wineries in Switzerland are more likely to be successful with FRG wines, which is likely due to "hand sales" or "story-telling" that accompanies selling wines directly to the customer instead of through a middle man or in a supermarket. Multiple factors can influence purchasing decisions. Although knowing whether a variety is FRG only has a moderate impact on its appreciation, prior knowledge and how additional information is conveyed can be crucial.

CONCLUSION

Wines made from fungus-resistant grape varieties are increasing their market share in Europe and Switzerland. However, their impact remains low, which could be due to low consumer acceptance of these varieties and thus the low demand for them. In the present study, differences in consumer acceptance between FRG and traditional wines were due to three main drivers: sensory attributes, cluster identification and prior knowledge of FRG. Wine sensory characteristics were important in defining subjective preferences. Knowledge of these preferences and of the consumer cluster that they represent is essential for winemakers to identify their wine style. The clusters were also influenced by consumer background, and clusters characterised by a preference for FRG wines were also found to be characterised by prior familiarity with FRG varieties. This information can be used to support regional and national marketing strategies. By providing consumers with access to new varieties and making information about them visible, we can nudge consumers to increase their liking of them based on familiarity. Finally, the additional knowledge of FRG provided prior to tasting showed a moderate effect, influencing only the red wine cluster that was characterised as having consumers with environmental awareness. Therefore, we can conclude that hedonic appreciation, although subjectively defined depending on the consumer, was more important to the participants than the "environmental impact" of wine. The sale of FRG wines should first and foremost be based on wine quality and sensory attributes, which can be best highlighted during tastings and direct sales. Despite growth in FRG production areas, large gaps remain in research on consumer acceptance and willingness-to-pay for FRG wines. Future studies should focus on choosing and comparing grape varieties with similar sensory attributes. This would allow us to disentangle variety from wine style, especially in the case of red wines, whose colour plays a large role. Although the best way in which information should be conveyed remains unclear, this study shows that a written definition and labelling of FRG wines has no influence on our Swiss customers' preferences.

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REFERENCES

Bátora, D., Dienes-Nagy, Á., Zeng, L., Gerber, C. E., Fischer, J. P., Lochner, M., and Gertsch, J. (2024). Hypersensitive quantification of major astringency markers in food and wine by substoichiometric quenching of silicon-rhodamine conjugates. *Food Chemistry: X*, *23*, 101592. https://doi.org/10.1016/j.fochx.2024.101592

Biasoto, A. C. T., Netto, F. M., Marques, E. J. N., and da Silva, M. A. A. P. (2014). Acceptability and preference drivers of red wines produced from Vitis labrusca and hybrid grapes. *Food Research International*, *62*, 456-466. https://doi.org/10.1016/j.foodres.2014.03.052

Borrello, M., Cembalo, L., and Vecchio, R. (2021). Consumers' acceptance of fungus resistant grapes: Future scenarios in sustainable winemaking. *Journal of Cleaner Production*, *307*, 127318. https://doi.org/10.1016/j.jclepro.2021.127318

de Baan, L. (2020). *Agrarbericht 2020: Verkauf und Einsatz von Pflanzenschutzmitteln*.

de Baan, L., Spycher, S., and Daniel, O. (2015). Einsatz von Pflanzenschutzmitteln in der Schweiz von 2009 bis 2012. *Agrarforschung Schweiz*, *6*(2), 48-55.

Determination of chromatic characteristics according to CIELab. (2006).

Espinoza, A. F., Hubert, A., Franc, C., Giraud-Heraud, E., and Raineau, Y. (2018). Resistant grape varieties and market acceptance: An evaluation based on experimental economics. *OENO One*, *52*(3), 247-263. https://doi.org/10.20870/oeno-one.2018.52.3.2316

Finger, R., Zachmann, L., and McCallum, C. (2023). Short supply chains and the adoption of fungus-resistant grapevine varieties. *Applied Economic Perspectives and Policy*, *45*(3), 1753-1775. https://doi.org/10.1002/aepp.13337

Francis, I. L., and Williamson, P. O. (2015). Application of consumer sensory science in wine research. *Australian Journal of Grape and Wine Research*, *21*, 554-567. https://doi.org/10.1111/ajgw.12169

González-Centeno, M. R., Chira, K., Miramont, C., Escudier, J.-L., Samson, A., Salmon, J.-M., Ojeda, H., and Teissedre, P.-L. (2019). Disease Resistant Bouquet Vine Varieties: Assessment of the Phenolic, Aromatic, and Sensory Potential of Their Wines. *Biomolecules*, *9*(12). https://doi.org/10.3390/biom9120793

Guimier, S., Delmotte, F., Miclot, A., Fabre, F., Mazet, I., Couture, C., Schneider, C., and Delière, L. (2018). OSCAR, a national observatory to support the durable deployment of disease-resistant grapevine cultivars. XII International Conference on Grapevine Breeding and Genetics, 1248. https://doi.org/10.17660/ActaHortic.2019.1248.4

Hoffet, F., Blackford, M., Burdet, F., Steinemann, B., and Mackie-Haas, K. (2021). Vins suisses du futur – quelles sont les attentes des consommatrices et des consommateurs? *Recherche agronomique Suisse*.

Husson, F., Lê, S., and Pagès, J. (2011). *Exploratory multivariate analysis by example using R* (Vol. 15). CRC press Boca Raton. https://doi.org/10.1201/b10345

Kiefer, C., and Szolnoki, G. (2023). Consumer Acceptance of Fungus-Resistant Grape Varieties—An Exploratory Study Using Sensory Evaluation Tests among Consumers in Germany. *Sustainability*, *15*(13). https://doi.org/10.3390/su151310664

Kiefer, C., and Szolnoki, G. (2024a). Exploring market potential and consumer preferences for fungus-resistant grape varieties: A discrete choice analysis in Germany. *Future Foods*, *10*, 100449. https://doi.org/10.1016/j.fufo.2024.100449

Kiefer, C., and Szolnoki, G. (2024b). Influence of Information about Fungus-Resistant Grape Varieties on Hedonic Ratings by Consumers–a Central Location Test in Germany. *Wine Economics and Policy*. https://doi.org/10.36253/wep-16110

Kontić, J. K., Jelušić, I. R., Tomaz, I., Preiner, D., Marković, Z., Stupić, D., Andabaka, Ž., and Maletić, E. (2016). Polyphenolic Composition of the Berry Skin of Six Fungus-Resistant Red Grapevine Varieties. *International Journal of Food Properties*, *19*(8), 1809-1824. https://doi.org/10.1080/10942912.2015.1107844

Leis, D., Renner, W., and Leitner, E. (2017). Characterisation of wines produced from fungus resistant grape varieties. *Flavour Science*, *Proceedings of the XV Weurman Flavour Research Symposium*, Graz University of Technology, Austria.

M.I.S. Trend. (2017). *Étude sur le marché du vin en Suisse 2017: notoriété, habitudes de consommation et d'achat, image*. M. I. S. Trend.

Mackie-Haas, K., Egli-Künzler, L., Wins, T., Blackford, M., and Hoffet, F. (2023). Du vignoble au verre: the current state of robust grape cultivars in Switzerland. *Acta Horticulturae*(1370), 67-82. https://doi.org/DOI 10.17660/ActaHortic.2023.1370.10

Mackie-Haas, K., Künzler, L., Blackford, M., Steinemann, B., Hoffet, F., and Deneulin, P. (2021). Wein der Zukunft - PiWiWeine kommen gut an. Schweizer Zeitschrift. *Obst und Weinbau*, *8*, 10-11.

Mackie, K. A., Müller, T., and Kandeler, E. (2012). Remediation of copper in vineyards–a mini review. *Environmental Pollution*, *167*, 16-26. https://doi.org/10.1016/j.envpol.2012.03.023

Mackie, K., Müller, T., Zikeli, S., and Kandeler, E. (2013). Long-term copper application in an organic vineyard modifies spatial distribution of soil micro-organisms. *Soil Biology and Biochemistry*, *65*, 245-253. https://doi.org/10.1016/j.soilbio.2013.06.003

Mann, S., Ferjani, A., and Reissig, L. (2012). What matters to consumers of organic wine? *British Food Journal*, *114*(2), 272-284. https://doi.org/10.1108/00070701211202430

Masset, P., and Raub, S. (2023). The impact of wine tasters' expectations on wine quality ratings and willingness-to-pay. *Journal of Wine Economics*, *18*(2), 156-172. https://doi.org/10.1017/jwe.2023.15

Merdinoglu, D., Merdinoglu-Wiedemann, S., Mestre Artigues, P. F., Prado, E., and Schneider, C. J. (2009). Apport de l'innovation variétale dans la réduction des intrants phytosanitaires au vignoble: exemple de la résistance au mildiou et à l'oïdium.

Murtagh, F., and Legendre, P. (2014). Ward's hierarchical agglomerative clustering method: which algorithms implement Ward's criterion? *Journal of classification*, *31*, 274-295. https://doi.org/10.1007/s00357-014-9161-z

Næs, T., Brockhoff, P. B., and Tomic, O. (2011). *Statistics for sensory and consumer science*. John Wiley & Sons. https://doi.org/10.1002/9780470669181

Nesselhauf, L., Fleuchaus, R., and Theuvsen, L. (2020). What about the environment? A choice-based conjoint study about wine from fungus-resistant grape varieties. *International Journal of Wine Business Research*, *32*(1), 96-121. https://doi.org/10.1108/IJWBR-09-2018-0049

OFAG. (2024). *L'année viticole 2023 - Statistiques vitivinicoles*. https://www.blw.admin.ch/fr/statistiques-arboricoles-et-viticoles

OIV. (2006). OIV-MA-AS2-11 - Determination of chromatic characteristics according to CIELab.

OSMV. (2024). *Rapport annuel 2023 - Marché Suisse des vins*. https://www.changins.ch/app/uploads/Rapport_OSMV_Marche_suisse_des_vins_2023.pdf

Pedneault, K., and Provost, C. (2016). Fungus resistant grape varieties as a suitable alternative for organic wine production: Benefits, limits, and challenges. *Scientia Horticulturae*, *208*, 57-77. https://doi.org/10.1016/j.scienta.2016.03.016

Philippidis, A., Poulakis, E., Basalekou, M., Strataridaki, A., Kallithraka, S., and Velegrakis, M. (2017). Characterization of Greek wines by ultraviolet–visible absorption spectroscopy and statistical multivariate methods. *Analytical Letters*, *50*(12), 1950-1963. https://doi.org/10.1080/00032719.2016.1255748

Roland, A., Schneider, R., Razungles, A., and Cavelier, F. (2011). Varietal thiols in wine: discovery, analysis and applications. *Chemical reviews*, *111*(11), 7355-7376. https://doi.org/10.1021/cr100205b

Rousseau, J., Chanfreau, S., and Bontemps, É. (2013). Les Cépages Résistants aux Maladies Cryptogamiques. *Bordeaux: Lattes Groupe ICV*.

Salmon, J.-M., Ojeda, H., and Escudier, J.-L. (2018). Disease resistant grapevine varieties and quality: the case of Bouquet varieties. *OENO One*, *52*(3), 225-230. https://doi.org/10.20870/oeno-one.2018.52.3.2139

Schäufele, I., and Hamm, U. (2017). Consumers' perceptions, preferences and willingness-to-pay for wine with sustainability characteristics: A review. *Journal of Cleaner Production*, *147*, 379-394. https://doi.org/10.1016/j.jclepro.2017.01.118

Schumacher, P., Mackie-Haas, K., and Wins, T. (2021a). Souvignier gris: Eine Piwi-Sorte mit grossem Potenzial. *Obst + Wein*, (8), 16-18.

Schumacher, P., Mackie-Haas, K., and Wins, T. (2021b). Souvignier gris: Praxxisversuche mit unterschiedlichen Ernteterminen. *Obst + Wein*, (9), 25-27.

Spring, J.-L., Gindro, K., Laprand, F., Zufferey, V., Verdenal, T., Rösti, J., Amiet, L., Lorenzini, F., Duruz, P., Barmes, E., Bailly, S., May, S., Bonvin, Y., Reymond, R., Viret, O., and Carlen, C. (2018). Divona, nouveau cépage blanc résistant aux principales maladies de la vigne sélectionné à Agroscope. *Revue suisse de viticulture arboriculture horticulture*, *50*(5), 286-296.

Spring, J.-L., Gindro, K., Voinesco, F., Jermini, M., Ferretti, M., and Viret, O. (2013). Divico, premier cépage résistant aux principales maladies de la vigne sélectionné par Agroscope. *Revue suisse Viticulture, Arboriculture, Horticulture*, *45*(5), 292–303.

Spycher, S., and Daniel, O. (2013). Agrarumweltindikator Einsatz von Pflanzenschutzmitteln–Auswertungen von Daten der Zentralen Auswertung Agrarumweltindikatoren (ZA-AUI) der Jahre 2009–2010. *Forschungsanstalt Agroscope Changins-Wädenswil ACW*.

Teissedre, P.-L. (2018). Composition of grape and wine from resistant vines varieties. *OENO One*, *52*(3), 211-217. https://doi.org/10.20870/oeno-one.2018.52.3.2223

Torri, L., Noble, A. C., and Heymann, H. (2013). Exploring American and Italian consumer preferences for Californian and Italian red wines. *Journal of the Science of Food and Agriculture*, *93*(8), 1852-1857. https://doi.org/10.1002/jsfa.5979

van der Meer, M., Weibel, F., Lévite, D., Häseli, A., Vombach D., and D., W. (2010). Acceptation des vins de cépages résistants par les consommateurs - Résultats du projet TOPiwi 2007–2008. *Revue suisse de viticulture arboriculture horticulture*, *42*(2), 147-150.

Vecchio, R., Pomarici, E., Giampietri, E., and Borrello, M. (2022). Consumer acceptance of fungus-resistant grape wines: Evidence from Italy, the UK, and the USA. *PLOS ONE*, *17*(4), e0267198. https://doi.org/10.1371/journal.pone.0267198

Zeng, L., Dienes-Nagy, Á., Blackford, M., Siebert, P., Vuichard, F., Bourdin, G., Lorenzini, F., and Bach, B. (2021). Analyser les polyphénols du vin rouge avec un spectrophotomètre? : Reprenons depuis le début. *Revue suisse de viticulture arboriculture horticulture*, *53*(6), 284-293.