



UNIVERSITÀ DEGLI STUDI DI PADOVA

Dipartimento di Agronomia, Animali, Alimenti, Risorse naturali e
Ambiente (DAFNAE)

Department of Agronomy, Food, Natural resources, Animals and
the Environment (DAFNAE)

Corso di laurea magistrale/Second Cycle Degree (MSc)
in Italian Food and Wine

Investigation on the factors affecting the sensory
properties of the Cabernet-based wines from the
Euganei Hills

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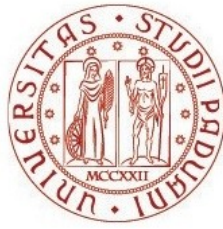
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Abstract

2-Furanemethanethiol (2FM) has been known for over 60 years as the descriptor of a roast coffee-like odour. It is present not only in coffee but also in other thermally treated foods such as cooked beef, pork and chicken as well as roasted sesame seeds, popcorn, white bread, roasted hazelnuts and in fermented products such as wine. Previous studies have shown that furfuryl mercaptan will form upon reaction of pentose sugars or furfural and a reactive sulfur source. Different studies in the literature have highlighted the presence of an aroma that can be linked to coffee / roast in Cabernet-based wines.

The territory of the Euganei Hills, with its heterogeneity of soils and climates, has seen the presence of Cabernet Franc and Cabernet Sauvignon vines since 1800, giving it unique characteristics that cannot be replicated in other territories. This thesis investigates the presence, by means of sensory analysis techniques, of a coffee-like odor correlated by the presence of 2-Furanmethanethiol as an aromatic marker from 15 Cabernet wines elaborated without oak contact and sourced from representative vineyards located in the Euganei hills wine region. Results indicated that Cabernet-based wines from this territory have two different expressions: one dominated by toasted-like aromas and a second characterized by green-like aromas which has interesting implications also on the market. This can be useful for the communication of the territory of the Euganei Hills and for the birth of a style of wines attributable to it. More important, the aspect related to the presence of a toasted-like aroma, not coming from the use of the wood barrel, can increase the environmental sustainability that is a key aspect for the consumers nowadays.

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List of Abbreviations used

2FM	2-Furanmethanethiol
FFT	Furfurylthiols
CT	Cluster Thinning
BLR	Basal Leaf Removal
CT + BLR	Cluster Thinning + Basal Leaf Removal
NNE	North North-East
NE	North-East
N	North

1. Introduction

Mercaptans, or thiols, are a very interesting class of food constituents, and up to now, over 100 volatile compounds have been identified, and among them several have been shown to be very potent aroma compounds. Although usually occurring in low concentrations, thiols can be key contributors to food aromas due to their often extremely low odor threshold due to the human odorant receptors' being very sensitive to some sulfur compounds. Among the most interesting thiols occurring in foods, 2-furanmethanethiol (2FM, in the Figure 1.1) is a compound exhibiting a pleasant coffee-like odour quality at a very low concentrations and it was first identified in roast and ground coffee by Reichstein and Staudinger (1955). 2FM has also been found in a wide range of other thermally treated foods such as cooked beef, pork and chicken as well as roasted sesame seeds, popcorn, white bread, roasted hazelnuts and in fermented products such as wine (Schoenauer and Schieberle, 2018).

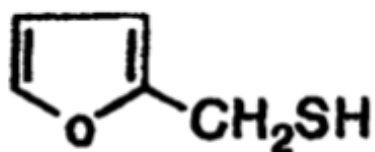


Figure 1.1 - Chemical structure of 2-Furanmethanethiol (2FM), Tominaga et al., 2003

The importance of furfuryl mercaptan as a characterizing flavor component has been known for more than 60 years. Several workers have reported the organoleptic importance of this compound. Aractander (1969) described it as being powerful, penetrating and coffee-like at suitable dilution. Tressl and Silwar (1981) considered it to be either a positive impact component or off-flavor component depending upon its concentration. Previous studies have shown that furfuryl mercaptan will form upon reaction of pentose sugars or furfural and a reactive sulfur source. Of the sugars, the pentoses are equally effective and significantly more effective than the hexoses. Furfural, a dehydration product of pentoses, produced the greatest amount of furfuryl mercaptan and is probably the immediate precursor to the formation of furfuryl mercaptan. Arabinogalactan also produced furfuryl mercaptan and since it is present in coffee in large amount is the most likely precursor for furfural. Of the sulfur sources, the

cysteine containing tripeptide, glutathione, was more effective than free cysteine in formation of the furfuryl mercaptan. In summary, the literature indicates that potential pentose precursors are small amounts of ribose and a larger pool of polymeric arabinose; the major sulfur source appears to be proteinaceous cysteine although cysteine or inorganic sulfur sources may also play a role (Parliament and Stahl, 1995). All these compounds highlighted by Parliament and Stahl are present in wine, or they encounter the wine during its processing. This explains how the presence of these aromatic notes, related to this compound, is possible in wine.

2. Literature Review

2.1. 2-furanmethanethiol (2FM) in wine

In the literature, different are the authors that investigated over time the presence 2FM in wine. They showed that the formation of this molecule can be due to different sources.

Tominaga et al. in 2000 identified the presence of 2FM analyzing different wines made from Petit Manseng from an estate in the Jurancon appellation (France) and the red Bordeaux wines that were analyzed came from the Graves (Chateau Carbonnieux from 1996, 1995 and 1994 vintages) and Pomerol appellations (Chateau Trtanoy from the 1996, 1995, 1994 and 1989 vintages). All the wines analyzed were barrel aged. They found that its perception threshold in a model hydro alcoholic solution is extremely low (0.4 ng/L). According to Tressl and Slwar (1981) and Tressl et al. (1980), it has a strong roast coffee aroma at levels between 0.01 and 0.5 µg/L. 2FM is absent in the toasted oak staves before toasting. However, all the toasted staves contain a quantifiable amount of 2FM (approximately 0.2 ng/g of shavings). The presence of 2FM in staves does not exclude the possibility that this compound may also be formed in wine for other mechanisms. For instance, Sauvignon blanc wines do not contain any 2FM, whether they are fermented in new or used oak barrels; the same experiment done with Petit manseng showed that levels of this compound were the same when fermented in new barrels or used ones. Thus, 2FM could not come directly from toasted staves (Tominaga et al., 2000).

Marchand et al. in 2000 analyzed the involvement of the cysteine in the genesis of wine flavours. According to Strecker, cysteine degradation leads to the formation of small very reactive molecules such as hydrogen sulfide, ammonia, or ethanal. These molecules of low molecular mass could be reagents in the aromatic heterocyclic compound formation. The reaction products presented odors close to those developed during Maillard reactions. 2-Furanmethanethiol was detected only in α -diketone solutions and only when they were kept at 40°C. According to the tests done from the authors, only the wines from Pomerol and Saint-Emilion, the Crus Classés of Burgundy wines and some Champagnes, presented 2-furanmenthanethiol. The average content reached 350 ng/L for the wines of Burgundy and 10 ng/L for Champagnes (Marchand et al., 2000).

Blanchard et al. in 2001 investigate the formation of Furfurylthiols (FFT) during oak barrel fermentation. They analyzed white wines from the 1999 vintage: Petit manseng from Juracon (Domaine Cauhapé), Sauvignon blanc and Semillion from Graves (Bordeaux, Clos Floridène) and Chardonnay from Puligny Montrachet (Domaine Leflaive). FFT was assayed in these wines that had been fermented and aged, either in stainless steel tank or in new or used barrels for 1 month after the end of alcoholic fermentation. The results showed that FFT was present only in barrel-fermented wines. Furfural is a precursor of FFT, released by toasted wood when it comes into contact with wine. The wines fermented in new barrels logically had a higher FFT content. The formation of FFT by yeast in the presence of furfural increased when the conditions were favorable for the production of HS-anions in excess of the amounts required for protein synthesis: high sulfur content (cysteine, sulfates) and relatively low nitrogen levels. It is closely related to the yeast's sulfide synthesis mechanisms (Blanchard et al., 2001).

In 2003, Tominaga et al. studied the role of volatile thiols, among which 2-furanmethanethiol, in the bouquet of aged Champagne wines. They analyzed the Champagne Cristal and Grand Siècle respectively from Louis Roederer and Laurent Perrier Champagne companies. The results showed that Champagne wines contain 2FM (together with other thiols: benzenemethanethiol and ethyl 3-mercaptopropionate) at concentrations considerably higher than their perception threshold and it is expected to contribute to the empyreumatic nuance in the bouquet of old Champagne wines. However, unlike the benzenemethanethiol and ethyl 3-mercaptopropionate (that their content reached a peak after 13-15 and then drop), the 2FM content in wines from both companies increased in proportion to bottle aging time. It was also demonstrated that disgorging leads to a significant increase in the concentration of these compounds in Champagne.

Again **in 2003, Tominaga et al.** pointed out how white wines fermented in new barrel have a high 2FM content, irrespective of the grape variety. This volatile thiol is only present in trace amounts in white wines fermented in stainless-steel vats. Higher concentrations were found in wines aged in new barrels. The concentration of this volatile thiol in red wines is, however, always lower than in white wines. However, the concentration/perception threshold ratio of 2FM in certain red wines is quite high,

making it likely that this compound contributes to the “roasted coffee” nuances of their aroma. Through their experiments, the results suggest also that 2FM is formed inside the yeast cell, then released (Tominaga et al., 2003).

2.2. Aromatic characterization of Cabernet grape variety

In the literature, different are the authors that investigated over time the aroma of Cabernet franc and Cabernet sauvignon grape varieties in function of the production method and the zones.

In 2006, Gürbüz et al. identified seventy-four aroma active compound in Cabernet Sauvignon produced wines from California and Australia. Volatiles were sampled using solid phase microextraction and analyzed using time-intensity gas chromatography-olfactometry and gas chromatography-mass spectrometry (GC-MS). The most intense odorants were 3-methyl-1-butanol, 3-hydroxy-2-butanone, octanal, ethyl hexanoate, ethyl 2-methylbutanoate, β -damascenone, 2-methoxyphenol, 4-ethenyl-2-methoxyphenol, ethyl 3-methylbutanoate, acetic acid, and 2-phenylethanol. Aroma compounds were classified according to their aroma descriptor similarity and summed into nine distinct categories consisting of fruity, sulfury, caramel/cooked, spicy/peppery, floral, earthy, pungent/chemical, woody, and green/vegetative/fatty.

In 2010, Rezaei Hakimi J. and Reynolds G. Andrew conducted on nine and eight experimental Niagara Peninsula Cabernet franc, respectively of the vintages 2005 and 2006, to illustrate differences that might support subappellation system in Niagara. Twelve trained judges evaluated six aroma and flavour (red fruit, black cherry, black currant, black pepper, bell pepper and green bean) and three mouthfeel (astringency, bitterness and acidity) sensory attributes plus color intensity. In 2005, wines from Châtrau des Charmes, Henry of Pelham and Hernder sites showed highest red fruit aroma and flavour. Wines from Lakeshore and Niagara River sites showed higher bell pepper and green bean aroma and flavour due to the cool growing conditions in proximity to the large bodies of water. In 2006, all the sensory attributes expect for black pepper aroma resulted different.

Di Profio et al. in 2011 submitted Merlot, Cabernet franc and Cabernet sauvignon vines from Niagara-on-the-Lake, Ontario to four treatments in a randomized complete block

experiment: hedged control, cluster thinning at veraison (CT), basal leaf removal (BLR) and CT+BLR. Musts from each treatment replicate (CT+BLR excepted) were there after either left untreated or treated with one of ColorPro or Color X enzymes. Both viticultural and enological treatments had noteworthy impacts on individual wine phenolic compounds and anthocyanins, although the viticultural treatments were more efficacious. The viticultural treatments enhanced the intensities of several aroma and retronasal descriptors (e.g., black fruit, black pepper, tobacco) and reduced those of others (e.g., bean/pea, mushroom). On 2004 Cabernet franc two aroma attributes were impacted (black fruit, bean/pea) as well as three retronasal descriptors (black fruit, black pepper, tobacco). All treatments exceeded the control in black fruit aroma intensity, while BLR and CT+BLR both had lowest bean/pea aromas. All treatments increased the intensities of black fruit and black pepper retronasally, although CT and CT+BLR wines were clearly the most intense; tobacco was most intense in the CT+BLR wines. There were few sensory differences among enological treatments. Both enzymes increase the intensities of black fruit aroma and retronasal aroma. On 2005 Cabernet franc, sensory aspects were less impacted by both viticultural and enological treatments than in 2004. The CT+BLR wine was rated the highest in canned vegetable and chocolate aromas and flavors and had the most viscosity and length. Both CRT and CT+BLR wines had highest acidity, and CT wines had highest astringency. There were only three significant effects of the enological treatments: Color X produced wines with lowest chocolate and spicy aromas, and both enzyme treatments had highest astringency.

Cadot et al. in 2012 studied the relationship between the sensory profile of the wines and the ripening stage of the berries (harvest date) and the extraction time (maceration duration) from a plot with Cabernet franc variety. The results show that the harvest date discriminates the sensory profiles and the typicality of the wines. In contrast, the maceration time had a little effect on the sensory profiles and the typicality scores. Thus, phenolic composition contributes greatly to sensory judgement of the wines, or distinctive style. This study demonstrates the importance of the harvest date on the typicality of the wines.

2.3 Cabernet in Euganei hills

Cabernet franc comes from the South-West region of France, precisely from the Gironde district. We are not sure about the date of its introduction in Italy from France, while the existence of a *Cabernets* vineyard (Cabernet franc and Cabernet sauvignon) on the Euganei Hills in 1870 is certain (Calò et al., 2001).

The Euganei Hills Regional Park is composed of hilly reliefs of volcanic origin, situated in the south-western area of the Province of Padua, and is one of the largest economic and tourist attractions of the Veneto Region, which hosts renowned wine-growing activities but also cultivation of olive groves and other activities such as beekeeping. A territory of great economic and environmental value that assumes an important role for the Veneto Region and the whole of north-east Italy in general (Rami Ceci, 2005).

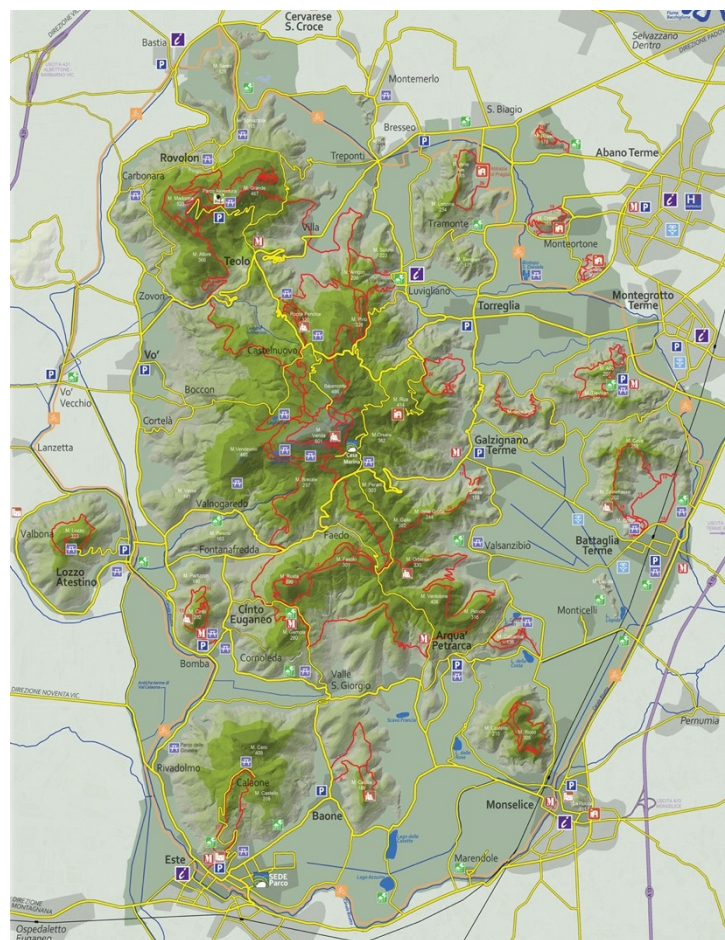


Figure 2.3.1 - Map of the Euganei Hills regional park, Regional Park of Euganei Hills

The structure of the Euganei Hills is a very particular geological and morphological formation (Martinis, 2003), if compared to the near Berici Hills or the Lessini Mountains, this is because the Euganei have a singular variety of rock formations of volcanic origin manifested 43 million years ago. The current form of the Euganei area originates from the second phase, which took place about 35 million years ago at the beginning of the Oligocene. The soils originate from the disintegration of volcanic rocks, have a good skeleton, are well drained and rich in minerals and microelements. Depending on the level of disintegration of the volcanic rocks over the millennia, in the different areas of the Hills, different types of soils emerge: volcanites (rhyolites, trachytes, basalts, basaltic tuffs), sedimentary rocks (biancone, red scale and marl), alluviums (conoids of dejection, alluvial valley floor) (Lares, 2002).

The climate of the Euganei Hills is temperate, characterized by almost Mediterranean thermal conditions, mild winters, hot and dry summers and good temperature variations between day and night. On clear days and early in the morning, the phenomenon of thermal inversion is frequent, so the hilly areas enjoy a higher temperature than the plain (Consortium for the Protection of Euganei Hills Wines).

Table 2.3.1 - Area planted with vines in Veneto, ISMEA

Hectares	2016	2017	2018	2019	Average 16-19
Prosecco		22.763	19.320	24.839	22.307
Conegliano Vald. Prosecco		8.300	7.146	9.562	8.336
Delle Venezie			18.067	9.545	13.806
Valpolicella		7.844	8.189	8.189	8.074
Soave		4.527	4.055	4.055	4.212
Bardolino		2.679	2.635	2.635	2.650
Asolo Prosecco		824	864	1.253	981
Bianco di Custoza		1.371	1.198	1.198	1.255
Venezia		1.989	1.183	1.113	1.428
Lugana		737	854	1.015	869
Valdadige		866	857	991	905

Colli Berici		703	547	547	599
Garda		479	355	528	454
Colli Euganei		409	389	446	415
Breganze		293	243	243	260
Piave		336	341	211	296
Gambellara		249	201	201	217
Veneto Orientale		122	114	148	128
Lessini Durello		204	206	145	185
Colli Euganei Fior d'Arancio		129	116	140	128
Lison Pramaggiore		123	143	129	132
Soave Superiore		56	65	65	62
Montello Colli Asolani		62	54	65	60
Arcole		109	49	49	69
Bardolino Superiore		56	43	43	47
Vallagarina		61	55	38	51
Bagnoli Friularo		36	29	32	32
Lison		34	26	28	29
Colli di Conegliano		22	27	25	25

Table 2.3.2 - Hectoliters of wine bottled in Veneto, ISMEA

HI/1000	2016	2017	2018	2019	Average 16-19
Prosecco	2.462.000	2.635.730	2.784.970	2.921.480	2.701.045
Delle Venezie		145.952	872.842	1.163.970	727.588
Conegliano Vald. Prosecco	669.837	670.507	663.745	659.784	665.968
Soave	261.804	383.001	354.289	336.291	333.846
Valpolicella Ripasso	168.106	207.870	205.535	223.014	201.131
Bardolino	152.845	189.395	182.103	178.207	175.638
Valpolicella		147.987	140.938	139.731	142.885
Asolo Prosecco	58.063	80.059	92.564	125.884	89.142
Amarone della Valpolicella	75.348	112.166	101.529	111.864	100.227
Valdadige	111.765	107.753	110.838	102.639	108.249
Bianco di Custoza	68.482	91.846	90.090	85.6.6	84.006
Lugana	56.701	60.140	64.017	79.048	64.977
Venezia	85.246	88.112	63.696	58.944	73.999
Garda	12.840	13.778	30.472	38.517	23.902
Colli Euganei	20.956	21.480	19.348	21.028	20.703
Colli Berici	10.271	13.504	12.419	12.701	12.224
Veneto Orientale	10.610	9.187	15.799	10.502	11.525
Breganze	5.934	8.799	9.124	8.709	8.141

Lessini Durello		8.518	7.301	7.882	7.900
Lison Pramaggiore		6.878	6.189	7.051	6.706
Colli Euganei Fior d'Arancio	6.565	7.229	6.815	6.767	6.844
Piave	10.220	7.259	7.489	6.599	7.892
Gambellara	6.302	6.246	5.230	4.986	5.691
Montello Colli Asolani		2.291	2.675	4.363	3.109
Soave Superiore	963	5.002	4.175	2.653	3.198
Recioto della Valpolicella	1.910	2.640	2.228	2.093	2.218
Arcole		1.300	1.305	2.046	1.550
Vallagarina		2.419	1.933	2.019	2.124
Bagnoli Friularo		1.699	1.093	1.562	1.452
Bardolino Superiore		1.813	1.411	1.452	1.559
Recioto di Soave		927	966	915	936
Lison		933	807	753	831
Colli di Conegliano		1.005	649	707	787

For these peculiarities, the area is ideal for growing vines, indeed in 2019 the hectares of vines were 446 with the addition of 140 hectares dedicated to the cultivation of Moscato Giallo for the production of Colli Euganei Fior d'Arancio (Table 2.3.1). In the 2019, the production reached 21.028 hectoliters of wine destined for bottling, with the addition of 6.767 hectoliters of Colli Euganei Fior d'Arancio (Table 2.3.2). The average annual rainfall fluctuates between 700 and 900 mm with two peaks, in spring and autumn. Relative humidity varies between the plains and the hills, where the values are considerably lower; the prevailing winds come from NNE, NE and N with low velocities and frequencies.

The oldest presence of vines and wine in the Euganei Hills area is testified by archaeological finds in terracotta, bowls and goblets related to the consumption of wine, dating back to pre-Roman civilization (VII - VI century BC). In Roman times the widespread presence of the vine in the Paduan area is mentioned by several Latin historians. Between the ninth and tenth centuries the cultivation of vines in many municipalities of the Euganei Hills is witnessed. The nobles who lived in the area were among the first in the Veneto after 1850 to introduce Merlot and Cabernet which acclimatized to the soil and climatic conditions of the area (Code of practice for the Production of the DOC wines "Colli Euganei").

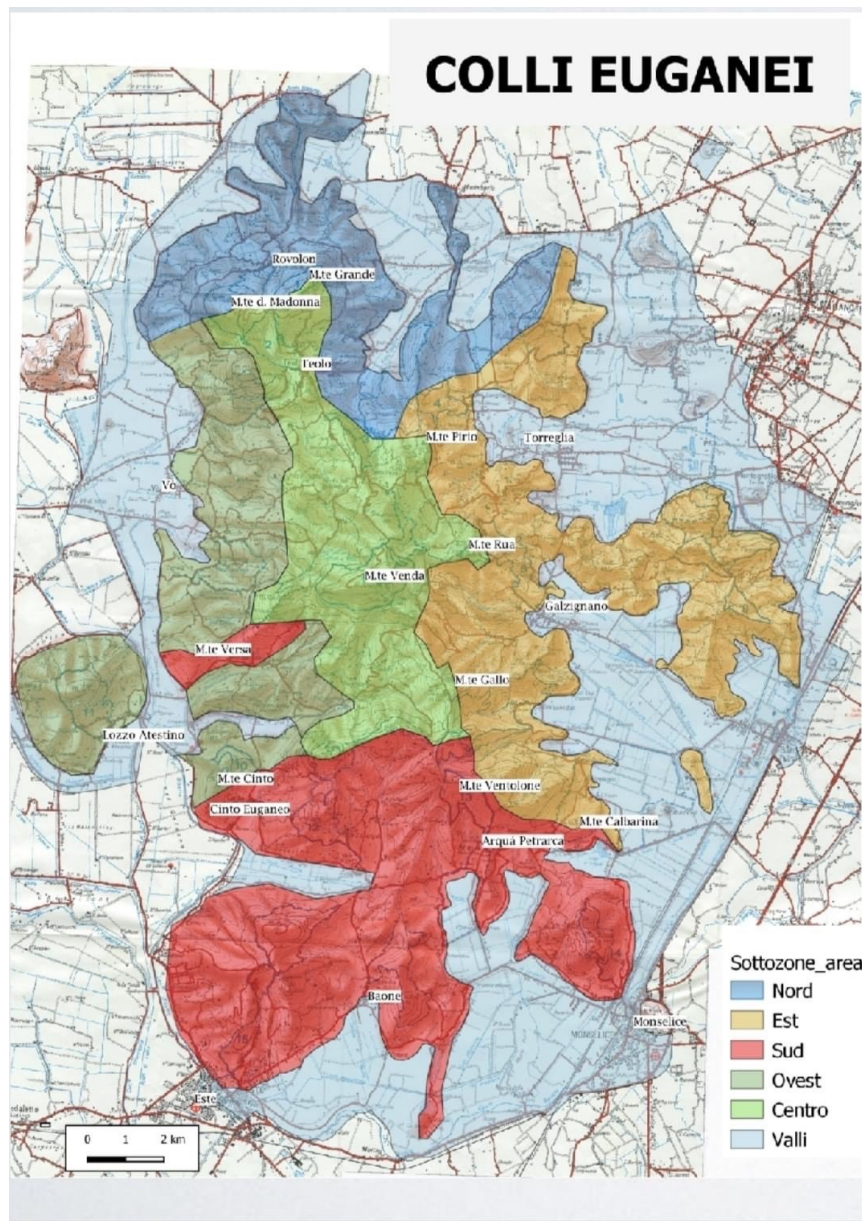


Figure 2.3.2 - Provisional zoning of the Eugenei Hills area, Consortium for the Protection of Eugenei Hills Wines

As can be seen in Figure 2.3.4, the partial zoning of the Eugenei Hills highlights 6 sub-areas: North, East, South, West, Center and Valleys with important differences from area to area.

In the **southern area**, which includes the municipalities of Cinto Euganeo, Arqua Petrarca and Baone, there are two types of soils:

1. White calcareous: an arid soil where the plant freezes due to the lack of water and it is possible to reach more balanced ripening.
2. Red calcareous soil composed of trachyte with onion exfoliation.

Another discriminating factor is represented by the hours of sunshine, as this area receives about double the light compared to the Northern area of the Euganei Hills. All these factors make the southern area optimal for the cultivation of Cabernet Sauvignon and from which more alcoholic wines tend to be obtained (Zanaica M., February 2022). In contrast, the **western area** of the Euganei Hills has a colder climate, with lower temperatures and fewer hours of sunshine not suitable in all the cases for the cultivation of Cabernet Sauvignon grape variety. (Gamba F., March 2022). Here, the exposure of the vineyards is fundamental, one of the best is the South or South-East to receive the maximum amount of sun during the day (Strazzacappa G., March 2022). Usually, the Cabernet sauvignon from this area are thinner than those from the southern area of the Euganei Hills, with a more herbaceous aroma, greater acidity and a more marked tannic texture (Gamba F., March 2022). Finally, the **northern area** of the Euganei Hills has more pronounced temperature ranges and a soil composed of clay for the first 1-1.5 meters deep with subsequent volcanic rocks. These conditions allow to obtain wines that tend to be finer and more subtle (Benato M., March 2022).

On calcareous soils the Cabernets turn on aromas of red fruit such as red cherry, raspberry (especially Cabernet Franc), violet (for Cabernet Franc), graphite, cassis, blueberry and tobacco, while for Cabernet Sauvignon we have different facets depending on the places where they are produced (VinariusChannel, Youtube, June 2020).

3. Aim

Given that some Cabernet-based wines produced in the Padua Hills have been reported to express coffee-like and toasted notes despite not being produced in oak barrels, this thesis investigates the potential factors (e.g. soils, climates, exposition, clones, vinification, yield, etc.) that could result in the inclusion of these sensory attributes in the wines. The approach included a literature review on the above-mentioned factors, and on the molecules potentially responsible for these aromas. Additionally, a sensory analysis approach was used to better understand the sensory profiles of Cabernet-based wines, comparing samples sourced from the Euganei Hills with those from neighboring wine regions (Colli Berici and Colli Orientali del Friuli).

4. Materials and methods

4.1. Sampling

A total of 15 wine samples were selected for the experiments. Wines originated from the area of Euganei (Padua, Veneto region) and Berici (Vicenza, Veneto region) hills, Sdricca di Manzano (Udine, Friuli-Venezia Giulia region) and Spessa di Cividale del Friuli (Udine, Friuli-Venezia Giulia region) (Figures 4.1.1 and 4.1.2).

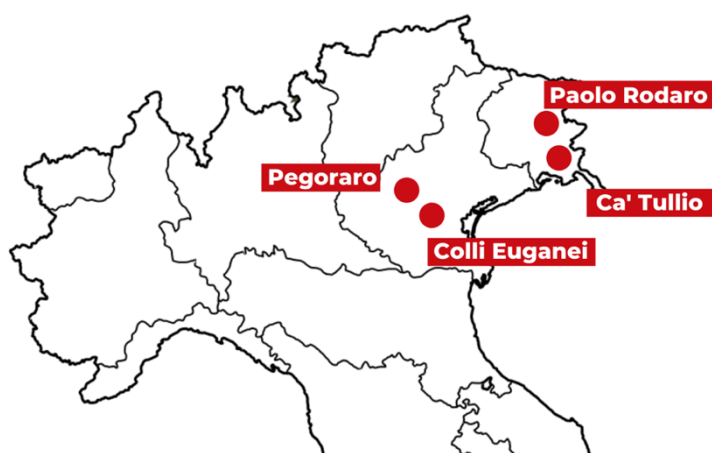


Figure 4.1.1 - Map of sample collection locations

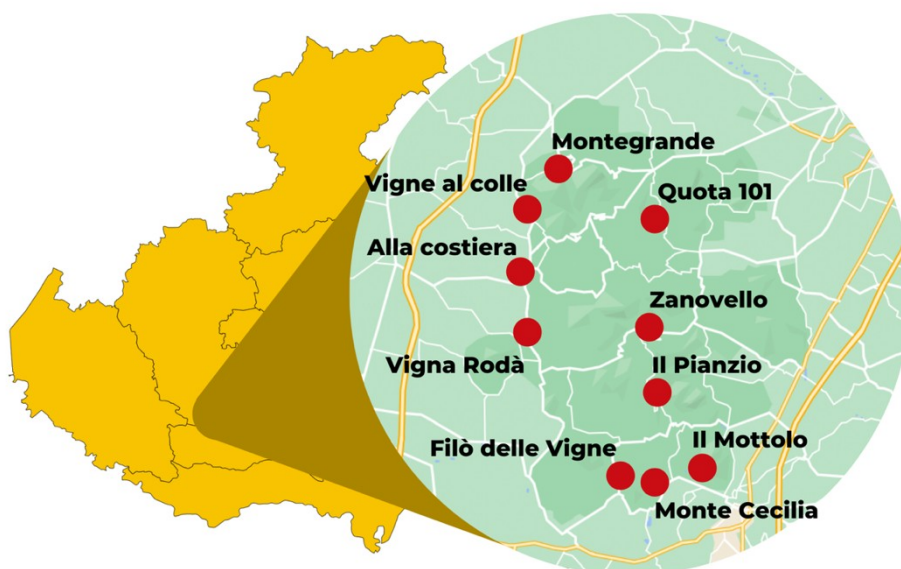


Figure 4.1.2 - Focus on sample collection areas in the Euganei hills

The selection of wines was made on the basis of the grape variety used for their production, namely Cabernet Franc and Cabernet Sauvignon. The production areas involved the Friuli-Venezia Giulia, Trentino-Alto Adige and Veneto regions with a very important focus on the Euganei Hills area: in this area the producing companies were selected in order to have a representation as homogeneous as possible of the territory. The nature of soils and climates changes not only from region to region, but also within the same viticultural area: an example of this can be seen in the Euganei Hills as explained in the chapter 2.3.

4.2 Sensory Evaluation of wines

4.2.1 Panel Training

Fourteen panellists (8 men and 6 women aged between 23 and 52) from the departments sensory panel, which had been selected and trained according to ISO standards (ISO 8586, 3972, 5496), were chosen to participate in the study. The panellists underwent a 3-weeks training period, in which they acquired familiarity with red wine evaluation in general and Cabernet in particular. Different aroma recognition tests of odour notes typically detectable in red wine aroma were conducted (Figure 4.2.1), initially as pure aromas and in the later training sessions, they were added to a neutral red wine.



Figure 4.2.1.1 - Material used in the sessions for the panel training

The panel also evaluated Cabernet from different producers, and were asked to describe and discuss the wine, also with use of the aroma wheel of Ann C. Noble. As a part of their training, panellists also conducted three rankings test on Cabernet spiked with different concentration of important aroma compounds, namely Eugenol, β -cyclocitral, and benzaldehyde.

4.2.2 The focus group

A focus group (Kempt et al., 2011) was held on the 16th of May 2022 and it aimed to select the wines to be submitted to the official analysis by the tasting panel. The session was held in the sensory analysis room located in the Pentagon building in the Agripolis Campus of the University of Padua. The session was moderate by a trained moderator in charge of guiding a discussion among group members. The group was made up of four men between 25 and 42 years old, all with experience in the world of tasting and wine. The 15 samples collected were poured ISO wine glasses. Wines were protected from oxidation by using the Coravin system. Tasters adopted the napping approach to sort wines (Lê S. et al., 2015) according to the key characteristics that emerged from the guided discussion.

4.2.3 Ranking Analysis

Following the result obtained during the focus group, it was decided to structure the official sensory analysis (held on the 17th of May 2022) session as follows: **two sets of ranking analysis** with seven wines each served in a randomized order and anonymized using a 3-digit code; one based on the intensity of the aroma of tobacco, coffee and chocolate (1 = not very intense, 7 = very intense), and the second based more on vegetable and spicy notes, giving primary importance to the former (1 = not very intense, 7 = very intense intense). Furthermore, the panellists were asked to indicate the wine they preferred most for each set. The tasting sheet adopted in the session is shown in the Figure 4.2.3.1, while Figure 4.2.3.2 shows the set-up of the ranking analysis.

Data were collected on pre-set paper questionnaires (Figure 4.2.3.1), then a sum of ranks was performed.

Nome Giudice:

Hai davanti a te sette campioni, con intensità diversa di **tostato/caffè/cioccolato**.

Assaggia i campioni e metti in ordine di intensità:

Intensità :	Numero campione:
1 = poco intenso	
2	
3	
4	
5	
6	
7= tanto intenso	

Indica il vino che preferisci

Hai davanti a te sette campioni, con intensità diversa di **verde/speziato**.

Assaggia i campioni e metti in ordine di intensità:

Intensità :	Numero campione:
1 = poco intenso	
2	
3	
4	
5	
6	
7 = tanto intenso	

Indica il vino che preferisci

Figure 4.2.3.1 - Ranking instructions



Figure 4.2.3.2 - Ranking analysis for toasty aromas

4.2.4 Statistical Analysis of sensory data

Statistical analysis was performed using Fizz v2.47b software program (Biosystems, France), with statistical significance determined using an alpha value of 0.05. Sensory data collected during the ranking analysis were analyzed by applying a non-parametric multiple comparisons Friedman pairwise test (Meilgaard et al., 1999). The Friedman test is for comparing three or more related samples and makes no assumptions about the underlying data distribution.

5. Results and discussion

As discussed in the chapter 2.3, the Euganei Hills, if compared to the near Berici Hills or the Lessini Mountains, are completely different due to the variety of rock formations originate from the disintegration of volcanic rock. Nowadays, the soils have a good skeleton, are well drained and rich in minerals and microelement. However, the project of zoning of the Euganei Hills highlights important differences and six subareas: in the southern area we have soils composed of white and red limestone. This area receives twice as much light when compared to the Northern area of the Euganei Hills making this zone optimal for the cultivation of Cabernet Sauvignon. The same conditions cannot find be found in the western area that is characterized by lower temperature and fewer hours of sunshine. Therefore, the cultivation of the Cabernet Sauvignon grape variety is possible in the western area only in function of exposure of the vineyards that become a crucial factor. Usually, the Cabernet sauvignon wines from this area are less ripened than those from the southern area of the Euganei Hills, with a more herbaceous aroma, greater acidity, and a more marked tannic texture. Finally, the northern area of the Euganei Hills has more pronounced temperature ranges, a soil composed mainly of clay with subsequent volcanic rocks; these conditions allow to obtain wines that tend to be finer and more subtle.

To sum up, the sensory performances of Cabernet Franc and Sauvignon in the Euganei Hills differ greatly according to the area and, above all, the exposure of the vineyards.

Additionally, it has been observed that often wines obtained from Cabernet grapes sourced in the Euganei Hills present toasted-like aromas linked to aromatic notes of coffee. Interestingly, these aromas are typically associated with ageing wines in wooden barrels, are detectable also in wines that are aged in tanks not made of wood. In order to better understand this phenomenon, the experimental part of this thesis included the sourcing of 15 wine samples from 3 different production areas located in north-east of Italy, namely the Euganei Hills, Berici Hills and Colli Orientali del Friuli. The sampling was focused on the Euganei Hills that were represented with 12 wines.

Table 5.1 - Commercial and agronomical information of the collected wine samples

Code	Winery	Vintage	Denomination of Origin	Grape Variety	Zone of Production	Soil
	Cantina Pegoraro	2020	Cabernet - DOC Colli Berici	60% Cabernet Franc 40% Cabernet Sauvignon	Barbarano Mossano, Vicenza	Medium clay Prevalent limestone skeleton
	Paolo Rodaro	2019	Cabernet Franc - DOC Friuli Colli Orientali	100% Cabernet Franc	Spessa di Cividale del Friuli, Udine	Ponca
	Ca' Tullio	2019	Cabernet Franc - DOC Friuli Colli Orientali	100% Cabernet Franc	Sdricca di Manzano, Udine	Prevailing skeleton Little fine earth
	Zanovello	2019	<i>Sgussa</i> - IGT Veneto Cabernet	60% Cabernet Franc 40% Carmenere	Cinto Euganeo, Padua	Volcanic origin Sandy soil
	Cristofanon Montegrande	2019	<i>Borgomoro</i> – DOC Cabernet Colli Euganei	80% Cabernet Sauvignon 20% Cabernet Franc	Rovolon, Padua	Volcanic origin Medium mixture tendentially calcareous Presence of skeleton
	Filò delle Vigne	2018	<i>Cecilia di Baone</i> - DOC Colli Euganei Cabernet	50% Cabernet Sauvignon	Baone, Padua	Volcanic origin Red and white

			Riserva	50% Cabernet Franc		limestone soils
	Alla Costiera	2019	<i>Cabernet "S"</i> - DOC Colli Euganei Cabernet Sauvignon	100% Cabernet Sauvignon	Vo' Euganeo, Padua	Volcanic origin Calcareous soil
	Vigna Ròda	2019	<i>Espero</i> - DOC Colli Euganei Cabernet	90% Cabernet Sauvignon 10% Carmenere	Vo' Euganeo, Padua	Volcanic origin Calcareous soil
	Vigne al Colle	2020	DOC Colli Euganei Cabernet Franc	70% Cabernet Franc 30% Carmenere	Rovolon, Padua	Volcanic origin Medium mixture tendentially calcareous Presence of skeleton
	Vigne al Colle	2018	DOC Colli Euganei Cabernet Franc	70% Cabernet Franc 30% Carmenere	Rovolon, Padua	Volcanic origin Calcareous clayey soils.
	Vigne al Colle	2014	DOC Colli Euganei Cabernet Franc	70% Cabernet Franc 30% Carmenere	Baone, Padua	Volcanic origin Calcareous clayey soil
	Quota 101	2019	<i>Poggio Ameno</i> - DOC Colli	50% Cabernet Franc	Torreglia (for	Volcanic origin

			Euganei Cabernet	50% Cabernet Sauvignon	Cabernet Franc), Padua Baone (for Cabernet Sauvignon), Padua	Calcareous clayey soil White scale in Torreglia and red scale in Baone
	Monte Cecilia	2021	DOC Colli Euganei Cabernet Franc	100% Cabernet Franc	Baone, Padua	Volcanic origin Calcareous clayey soil
	Il Mottolo	2019	<i>A Marè</i> - DOC Colli Euganei Cabernet	50% Cabernet Franc 50% Cabernet Sauvignon	Baone, Padua	Volcanic origin Calcareous clayey soil
	Il Pianzio	2020	DOC Colli Euganei Cabernet	90% Cabernet Franc 10% Cabernet Sauvignon	Galzignano Terme, Padua	Volcanic origin Almost peaty soils in the valley and clayey soils in the hills

As explained in the chapter 4.1 and as shown in the Table 5.1, the selection of wine samples was made in function of the grape variety used for their production, namely Cabernet Franc and Cabernet Sauvignon, involving three production areas distributed in two different regions: Friuli-Venezia Giulia and Veneto. The most important focus was on the Euganei Hills area due to the great heterogeneity of the zone. An example of this can be seen in the Euganei Hills as explained in the chapter 2.3.

The samples coming from the territories of the Colli Berici and Friuli Colli Orientali (respectively from the following wineries: Pegoraro, Paolo Rodaro and Ca' Tullio wineries) originate from predominantly clayey soils. While, for the samples coming from the Euganei Hills the heterogeneity of the soils is very high (see Table 5.1). As explained in Chapter 2.3, the origin of the soils of the Euganei Hills is volcanic but with substantial differences between the north, south, east and west areas. The samples from the northern area, i.e. those of Cristofanon Montegrande and Vigne al Colle wineries, come from medium-textured soils, tending to be calcareous with a good amount of skeleton. The most common rock in this area is the *Scaranto*, a volcanic rock that degrades rapidly over time. Given the proximity of the municipalities of the northern area of the Euganei Hills (E.g. Rovolon), this rock is also common in the soils of the Berici Hills. As regards to the samples of the companies Il Mottolo, Il Filò delle Vigne, Monte Cecilia and Quota101 (only for Cabernet Sauvignon grapes in this last winery), these come from calcareous-clayey soils with the presence of red flakes in the Baone area with an important presence of another type of volcanic rock, the Trachyte. The east and west areas, from which the samples of the Zanovello, Alla Costiera, Vigna Ròda and Il Pianzio wineries come, have clayey soils in the hills, while on the valley they are almost peaty soils.

As can be seen in Table 5.2, wines were produced from vineyards managed with conventional, sustainable and certified organic or in organic conversion. All companies no longer use weeding and practice grassing between the rows with spontaneous emergence of essences as weeds, trifolium, fescue, poa, mint, mallow, chamomile, dandelion, etc. The companies that practice conventional agriculture utilize, in addition to cover products, from 2 to 4 annual treatments with systemic products. The yields for all companies never exceed

1 ton per hectare with a production per vine that lies within a range between 1-1.5 and 2-2.5 kg.

The sensory spectrum of wines changes not only according to the area, but also according to the used clone of Cabernet Franc or Cabernet Sauvignon grape variety. Unfortunately, it was not possible to collect the information on the clones used in all cases as several companies own vineyards over 40 years of age and in which it was not possible to trace the clone. Where possible, the most interesting for this thesis were: for Cabernet Sauvignon the clone R5 (Figure 5.1), while for Cabernet Franc the clones VCR2 (Figure 5.2) and VCR10 (Figure 5.3) which show a more pronounced sensory profile based on spice and phenol than the average varietal. The vinification of the various wines was a key element and of absolute importance for the choice of samples. A discriminating factor was the maturation in steel or wood but only in barrels with a minimum third/fourth passage to avoid the release of wood-related aromas to the wines. Other factors of significant importance were the yeasts used for the fermentation, which must be neutral or indigenous and, possibly, the use of tannin. All these criteria were applied in the choice of samples to try to best express the varietal character of the grapes and the territory of origin.

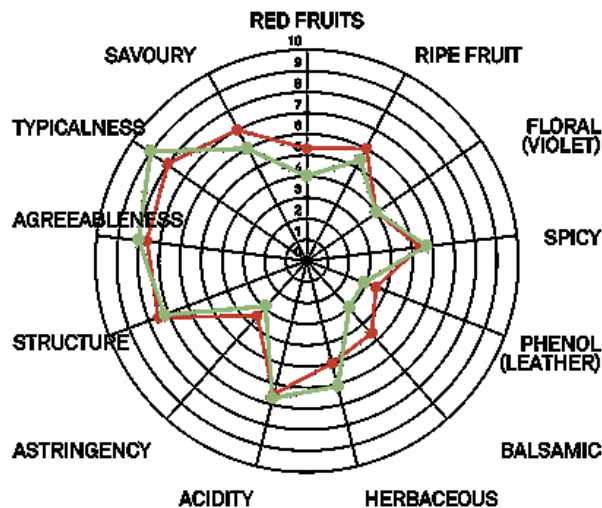


Figure 5.1 - Spiderplot of Sensory analysis of Cabernet Sauvignon Clone R5,

Vivai Cooperativi Rauscedo

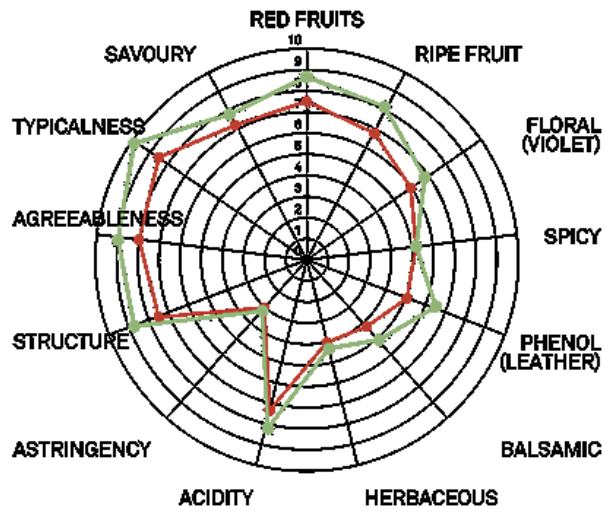


Figure 5.2 - Spider plot of Sensory Analysis of Cabernet Franc Clone VCR2, Vivai Cooperativi Rauscedo

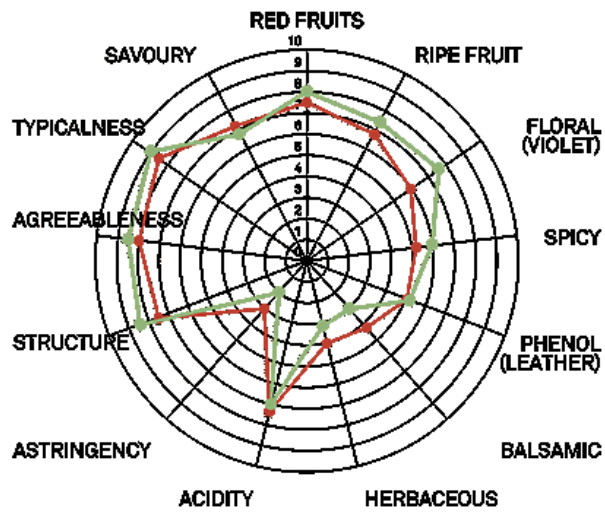


Figure 5.3 - Spider plot of Sensory analysis of Cabernet Franc Clone VCR10, Vivai Cooperativi Rauscedo

Table 5.2 - Vineyard management and winemaking practices of the collected samples

Winery	Management of the vineyard	Yield per hectare	Utilized clones	Utilized Yeast	Aging
Cantina Pegoraro	Conventional agriculture	0.8 tons/ha	-	Enartis Es488	Stainless steel tanks
Paolo Rodaro	Sustainable viticulture	0.6 tons/ha	-	Indigenous	Stainless steel tanks for 12-24 months
Ca' Tullio	Conventional agriculture	1.1 tons/ha	VCR10	IT CAB90 Ever SRL	Stainless steel tanks for 6 months
Zanovello	Certified organic	0.35 tons/ha	-	Indigenous	12 months in oak barrel with a capacity of 500-1000 Lt 6 months in concrete
Cristofanon Montegrande	Sustainable viticulture	0.8 tons/ha	VCR9 (for Cabernet Sauvignon), VCR2 e VCR10 (for Cabernet Franc)	IOC R 9008	Stainless steel tanks for 12 months 12 months in bottle
Filò delle Vigne	Conventional	0.25-0.35 tons/ha	VCR10 for Cabernet	Uvarum	2 years in concrete

	agriculture		Franc, R5 for Cabernet Sauvignon		10 months in bottle
Alla Costiera	Certified organic	0.6 tons/ha	-	Indigenous	12 months in unroasted oak barrel 12 months in bottle
Vigna Ròda	Organic viticulture from 6/7 years but not certified	0.8-0.9 tons/ha	-	BM45 - Alleman	7/8 months in concrete 6 months in bottle
Vigne al Colle	Conventional agriculture	0.8 tons/ha	-	Yeast in cream Bioenologia	Until 11 months in tonneau
Quota 101	Certified organic from 2018	0.7 tons/ha	-	Indigenous	12 months in concrete At least 6 months in bottle
Monte Cecilia	Certified organic	0.8 tons/ha	115 INRA	Indigenous	Stainless steel tanks for 6 months
Il Mottolo	In organic conversion from 2019	0.6 tons/ha	VCR5 - FV5	F15 LaForte	14-16 months in tonneau and barrique

					6 months in bottle
Il Pianzio	Conventional agriculture	< 1 tons/ha	-	F15 LaForte	6-12 months in concrete 4 months in bottle

5.1 The result of the focus group

Initially, the sensory characteristics of the selected wines, whose characteristics are summarized in Tables 5.1 and 5.2, were assessed by a focus group. This exercise was performed to gather sensory information on the wines, to discuss about their distinctive features, to group them based on similar characteristics using a napping approach, and ultimately to decide the type of sensory method most suitable for sensory assessment by trained sensory panel.

The outcome of the focus group, that was held on the 16th of May 2022, showed wines having a great heterogeneity despite they came from the same grape varieties and, at least for 12 samples, from the same wine region. Tasters applied a simplified version of the napping technique and were asked to organize the wines in the table in front of them based on perceived similarities/differences.

Despite the great heterogeneity noticed, this exercise clearly led to the organization of wines in two large groups on the basis of their prevalent aromas, as depicted in Figure 5.1.1. Four families of typical red wine aroma compounds were considered, namely Fruity (F), Green (G), Toasty (T, tobacco, coffee-like, chocolate) and Oaky (O, i.e. aromas that can be linked to the use of wood).

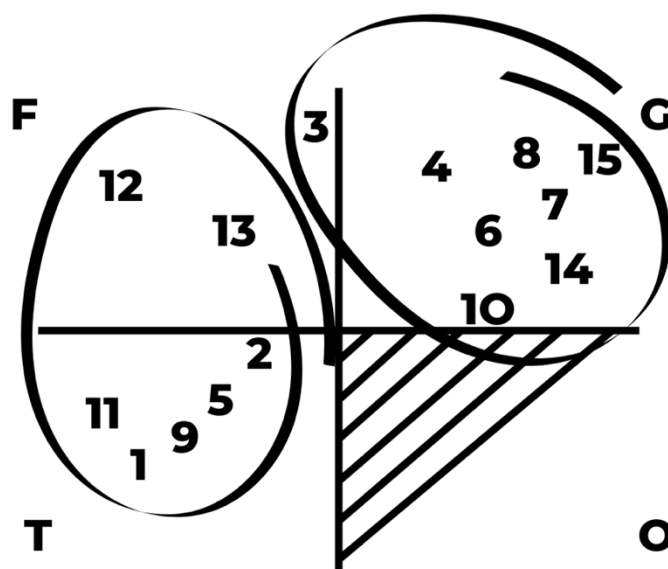


Figure 5.1.1 – Napping of the collected sample during the focus group. Legend: Fruity (F), Green (G), Toasty (T, tobacco, coffee-like, chocolate) and Oaky (O, i.e. aromas that can be linked to the use of wood such as vanilla, etc.). Wines' codes are listed in Table 5.1

Result showed that a group of 5 wines was characterized by spicy notes of tobacco, coffee and chocolate, while a second group of 7 wines was mostly characterized by vegetal notes reminiscent of cut grass, pepper, pea and black pepper, notes that are more typical of Cabernet Franc. Only 2 wines were grouped as fruit-driven, while no wine was perceived as oaky, a result that confirms the vinification information provided in Table 5.2, proof of the fact that these wines have been aged only in stainless steel tanks during the refinement phase or in minimum 3rd step woods used only for the benefit of micro-oxygenation and not for the release of their typical aromas and/or substances like tannins to give should and structure to the wines.

One wine was excluded from the sensory analysis to be conducted by the trained panel. This was the Cabernet Franc DOC Colli Euganei 2014 of the winery Vigne al Colle (n° 4 in the Figure 5.1.1), and the reason for its exclusion was mostly drive by the age of this wine (8 years old) as this was not in line with the age of the other wines samples (1-3 years old).

The overall outcome of the focus group was the decision to carry out the sensory analysis session with the trained panel using the 2 ranking tests: one for the toasty/coffee/chocolate-like aromas and the other for the green/spicy-like notes, that are the two groups visible in the circles drawn in Figure 5.1.1.

5.2 The results of the Official Sensory Analysis

The 14 wines, organized in two groups of 7 as a result of the focus group, were subjected to the assessment by the trained panel, composed by fourteen panellists. The panel assessed the two sets of wines by ranking analysis, and results for the toasted-like aromas are shown in Table 5.2.1.

Table 5.2.1 - Details of the ranking analysis of the 7 wines belonging to the series assessed for toasted-like aromas. Different letters indicate a significant difference ($p < 0.05$) obtained from Friedman test

Position	Name of the wine and winery	Vintage	Origin	Grape variety	Vinification	Sum of ranks	Significance letters
P1	“Borgomoro” – Cristofanon Montegrande	2019	Rovolon-Padua	80% Cabernet Sauvignon 20% Cabernet Franc	Stainless steel tank	52	AB
P2	Cabernet – Il Pianzio	2020	Galzignano Terme, Padua	90% Cabernet Franc 10% Cabernet Sauvignon	Concrete	39	B
P3	Cabernet - Pegoraro	2020	Barbarano Mossano, Vicenza	60% Cabernet Franc 40% Cabernet Sauvignon	Stainless steel tank	44	B
P4	Cabernet Franc – Ca’ Tullio	2019	Sdricca di Manzano, Udine	100% Cabernet Franc	Stainless steel tank	80	A
P5	Cabernet Franc – Vigne al Colle	2020	Rovolon, Padua	70% Cabernet Franc 30% Carmenere	Until 11 months in tonneau	79	A
P6	Cabernet Franc – Vigne al Colle	2018	Rovolon, Padua	70% Cabernet Franc 30% Carmenere	Until 11 months in tonneau	54	AB
P7	Cecilia di Baone – Filò delle Vigne	2018	Baone, Padua	50% Cabernet Sauvignon 50% Cabernet Franc	Concrete for 2 years	44	B

Data in Tables 5.2.1 showed the results of the first ranking analysis for the toasted-like aromas.

The samples P2 (Sum of ranks 39 – Significance letter B), P3 (Sum of ranks 44 – Significance letter B), P4 (Sum of ranks 80 – Significance letter A), P5 (Sum of ranks 79 – Significance letter A) and P7 (Sum of ranks 44 – Significance letter B) present differences from the others present in the series: three of them (P2, P5, P7) comes from the zone of Euganei hills, while the samples P3 and P4 comes respectively from the Berici hills and Aquileia, in the province of Udine.

Interestingly, the two wines presenting significantly higher toasted-like aromas were produced with 100 and 70% Cabernet Franc in the blend, suggesting a potential role of varietal features in the development of these aromatic notes. However, other wines samples (e.g. P2) made with majority of Cabernet Franc in the blend scored poorly for toasted attributes.

When focusing only on the samples coming from the Euganei hills, the observed differences cannot be attributable to the cultivation area, given that the samples come from three areas of the Euganei hills that are completely different in terms of soils, hours of sunshine per day that the vines receive and average temperatures, but they should be identified more in the clones used and, above all, the vinification methods. The only known clone is the one relating to the sample P7 (Cecilia di Baone – Filò delle Vigne): VCR10, as explained in the Figure 4.1.5, shown an aromatic spectrum that turns more on the spice, phenol and leather than the clones VCR5 and VCR2.

The other relevant factor is the vinification method. As explained in the article of Tominaga et al. in 2000, the toasted-like aromas do not come out immediately but with the years of aging. Indeed, all the three wines age at least for 6-12 months in concrete and exhausted oak barrels. The assumption is that, thanks to the exchange of micro-oxygenation that these containers guarantee between wine and the external environment, there is the formation and release of this compound which gives toasted notes to the wine.

After assessing the first set of wines, the panel was asked to rank based on their intensity in green-like aromas the second set of wines (see Table 5.2.2).

Table 5.2.2 - Details of the ranking analysis of the 7 wines belonging to the series assessed for green-like aromas. Different letters indicate a significant difference ($p < 0.05$) obtained from the Friedman test

Position	Name of the wine and winery	Vintage	Origin	Grape variety	Vinification	Sum of ranks	Significance letters
P1	"A Marè" – Il Mottolo	2019	Baone, Padua	50% Cabernet Franc 50% Cabernet Sauvignon	14-16 months in tonneau and barrique	83	AB
P2	"Poggio Ameno" – Quota 101	2019	Torreglia and Baone, Padua	50% Cabernet Franc 50% Cabernet Sauvignon	Concrete for 12 months	71	AB
P3	Cabernet Franc – Paolo Rodaro	2019	Spessa di Cividale del Friuli, Udine	100% Cabernet Franc	Stainless steel tank	73	AB
P4	"Sgussa" – Zanovello	2019	Cinto Euganeo, Padua	60% Cabernet Franc 40% Carmenere	12 months in oak barrel	55	B
P5	Cabernet "S" – Alla Costiera	2019	Vo' Euganeo, Padua	100% Cabernet Sauvignon	12 months in unroasted oak barrel	69	AB
P6	"Espero" – Vigna Ròda	2019	Vo' Euganeo, Padua	90% Cabernet Sauvignon 10% Carmenere	Concrete for 7/8 months	51	B
P7	Cabernet Franc – Monte Cecilia	2021	Baone, Padua	100% Cabernet Franc	Stainless steel tank	102	A

The Tables 5.2.2 shows that the samples P4 (Sum of ranks 55 – Significance letter B), P6 (Sum of ranks 51 – Significance letter B) and P7 (Sum of ranks 102 – Significance letter A) present differences from the others present in the series. All of them comes from the same region, the Euganei hills, but from different zones: P4 from Cinto Euganeo in the east part of the Regional Park of Euganei hills, P6 from Vò Euganeo in the west part, while P7 from Baone in the south part. Giving this aspect, we cannot say that they have green-like aroma due to the cultivation area because they come from three different zones.

However, for the sample P6 ("Espero" of Vigna Ròda winery) is possible to assume that the provenance played an important role. The zone of Vò Euganeo is known to be a cold zone with fewer hours of sunshine per day. In this case, the exposition of the vineyards is crucial. The winery Vigna Ròda planted the Cabernet Sauvignon with a south exposition (Strazzacappa G., March 2022), that is a good solution for the current situation. However, the sun is a fundamental element for lowering the content of methoxypyrazine of which Cabernet Sauvignon and Franc are notoriously rich in. The following factors, i.e. the low sunshine-hours per day together with the lower average temperatures, probably favoured a maintenance of the methoxypyrazine content, allowing us to find them later in the final product in the bottle with these green-like aromatic notes.

In the other two cases, the assumptions are that two different aspects play a crucial role. In the case of the sample P4, the blending percentages of the varieties were a determining factor. Carmenere is known for having strongly herbaceous notes due to its high content in methoxypyrazines. This compound, which have a very low sensory threshold of around 10 ng/L in wine (Kotseridis Y., Belouqui Anocibar A., 1998), probably masked the aromatic notes coming from Cabernet franc. Furthermore, it is possible that the vinification in wooden barrels with micro-oxygenation has favored the development of toasted-like aromatic notes but not in such quantities as to be perceived by the panel.

In the last case, that of the P7 sample, a wine made with 100% Cabernet Franc that was identified as the most intense in green-like aromas, it is likely that the vinification in steel has played a crucial role for the green-like aroma of the wine. As it's known, steel is an inert material that doesn't release components and doesn't allow an exchange of oxygen between wine and the external environment: for this reason, probably the container used

for winemaking preserved the aromatic notes of the wine linked to the methoxypyrazine, i.e. the green-like aroma.

While some indications can be taken from the above-described data, it has to be kept in mind that the results presented in this thesis need to be considered preliminary/exploratory and can provide a basis for a future more in-depth characterization of the sensory characteristics of Cabernet-based wines from the Euganei Hills with possible actions of zoning, study of the various soils and analysis of the aromatic components.

6. Conclusions

Thiols are very interesting class of aromatic compounds present in food matrices, including wines. Among them, one of the most interesting is the 2-furanmethanethiol (2FM), a compound exhibiting a pleasant coffee-like odour at a very low concentration. The mechanism of formation of this compound foresees the reaction between pentose sugars (or hexoses but in a significantly less effective way) or furfural and a reactive sulfur source (cysteine containing tripeptide was shown to be more effective than free cysteine) (Parliament and Stahl, 1995). All these compounds are present in wine, and this can explain how the presence of these aromatic notes, related to this compound, is possible in wine. In addition, different studies in the literature highlighted the presence of a coffee-like aroma in Cabernet-based wines.

The results of the sensory analysis sessions show how the Euganei Hills territory produces wines with very diverse sensory characteristics and styles. While this study is explorative and therefore clear conclusions cannot be drawn from it, what can be affirmed, based also on the data collected about the Euganei Hills regions, is that this is an extremely varied territory in terms of climate, soils, producers and styles of interpretation of its wines. As a result, it seems certain that within this great diversity lies a great potential for the production of high-quality red wines, and for a generalized improvement of the quality and image of the red wines produced in this region as a whole.

From the experimental part of this thesis, and in particular from the data collected by the focus group, it can be seen that the wines from Cabernet grapes grown in this production area essentially have two souls: one linked to the green aspect with aromas of pepper, cut grass and green beans, and another that turns towards toasted aromas such as the coffee, liquorice and caramel. Obviously, there are multiple reasons behind these quality results, and it is up to the producers to take actions, from the vineyard to the vinification techniques, resulting in the production of Cabernet-based wines belonging to one of these two main styles. What seems certain is that the region offers enough variability and diversity to be able to produce both styles of wines. This type of stylistic choice obviously has interesting implications also on the market, as different styles could potentially satisfy the needs of different consumers. Indeed, wines with a predominant scent of methoxy-pyrazines

and green flavors are certainly appreciated in the provincial and regional market (to a much lesser extent in Italy too), while in the rest of Italy and especially abroad, wines with green notes are generally considered as faulty.

On the other hand, the toasty aromas related to the presence 2-furanmethanethiol (2FM) molecule become intriguing and find more appeal especially in markets outside the regional territory. What makes it more interesting under the research point of view is the fact that the development of this molecule and the consequent aromas are not due to a passage in oak wood, but in containers that have been seen to be inert such as steel, concrete and/or barrels of exhausted wood capable of allowing only micro-oxygenation but not the exchange of molecules, some of them aromatic.

From an aroma chemistry research perspective, it would be interesting to further investigate if the development of toasty notes in non-barrel aged Cabernet is a peculiarity of wines from the Euganei Hills, as, if this was the case, this could be exploited for devising tailored communication strategies.

Additionally, and more importantly, having wines that taste as if they are aged in barrels without the need to use wood would increase their environmental sustainability which is an aspect to which consumers are paying more and more attention. Nowadays the whole world is facing the problem of the scarcity of raw materials with a consequent rise in prices, and one of all that has seen this change is wood.

Furthermore, this could be a possibility for the development of a wine production style attributable to the Euganei Hills territory. The large majority of the wines produced in Veneto region are whites (Glera, Garganega and Pinot Grigio), with only a few wine regions famous for their reds (Valpolicella, Piave, Euganei Hills and at minor extent Berici Hills). The production of white wines requires extensive use of refrigeration. This, combined with the fact that white wines are harvested in the hotter period of the year, makes their production energy intensive. Given the current energy crisis, an increase in the production of red wines can contribute to lowering the energy costs for wineries, thus increasing the environmental and economical sustainability. In this scenario, given the suitability of the Euganei Hills territory for the production of red wines and the space in the market for premium red wines coming from Veneto region, there could be in the future the opportunity for this zone of

production for a development of recognizable styles of red wines that could become the ambassadors for this production area. Indeed, nowadays, consumers still do not recognize and understand the potential of this territory also because of the fact that each winery typically has a portfolio of at least 10 products that can create confusion in the minds of consumers.

In conclusion, further studies are needed to investigate the origin of these aromas; the here presented sensory results have to be considered preliminary/exploratory, but can be useful to provide a basis for a future more in-depth characterization of the sensory characteristics of Cabernet-based wines from the Euganei Hills in order to understand the character of the wines coming from this territory.

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Sitography

Code of practice for the Production of the DOC wines “Colli Euganei”:
<https://www.colleuganeidoc.com/wp-content/uploads/2014/10/DOC-Colli-Euganei.pdf>

Consortium for the Protection of Euganei Hills Wines: <https://www.colleuganeidoc.com>

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