GAMBELLARA ZONING: CLIMATE AND SOIL EFFECT ON THE AROMATIC FRESH AND DRIED GRAPE COMPOSITION AND WINE AROMA

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Abstract
The first aim of the work has been to value the relationship between climate-soil characteristic and grape composition; then we studied the same correlation with the dried grape and in the end we took into consideration the aromatic quality of the wine. The trial has been done in the Gambellara area (North-east Italy). The area of production of the DOC Gambellara and Recioto di Gambellara wine (Garganega variety) even though it is a small area (1.000 ha), it has a notable environmental variability due to the landscape morphology (hill and plain), soil characteristics and the climatic differences between sites. For the three year period, 2001-2003, in the seven homogeneous zones in which the area was subdivided, we analysed the grape chemical characteristics (sugar, acidity, pH, aromatic compounds etc) and the organolectic quality of the wine. The trial and analysis were carried out using both fresh and, after a period of drying process, dried grapes, the first to obtain the Gambellara wine, and the second to obtain the Recioto sweet wine. The analysis of the varietal aromatic compounds on the fresh grape (obtained through enzymatic and acid hydrolysis) confirmed the close relationship between sub-zone origin (climate and soil water holding capacity) and quantity of terpenoids, norisoprenoids and benzenoids compounds. These quantity were different for different zones, directing us towards a first chemical characterisation of the zones. The tasting of wine obtained with fresh grape, in large part, confirmed the relationship between the quantity of aromatic compounds in the grape and olfactory sensations in the wine, obtaining in this way a good wine characterisation. The same chemical analysis seen before, were done on dried grapes (five month drying period) giving us a different scale of relative quantity between zones if compared with the fresh one. This leads us to suppose that other factors should be taken into consideration. Only those dried grapes richest in aromatic compounds give the most perfumed wines. All of this confirms a certain aromatic differentiation due to the origin of the grape and of the climatic condition of the zones. With the drying of the grape, the aromatic composition increases in certain compounds (e.g. nerol in the monoterpenes group and norisoprenoids) while losing others (e.g. linalool in the monoterpenes group). So for the dried grape and its wine, the effects of climatic and soil characteristics are less evident, but there remains a sure relationship with the zone of origin of the grape.

Résume
La région de production de la Gambellara et Recioto di Gambellara DOC (variété Garganega), tout en n'intéressant qu'une surface limitée, présente une certaine variabilité de milieu due à la morphologie du territoire (colline et plaine), à l'état actuel des sols et aux variations climatiques entre les différents sites. Pour les années 2001, 2002 ed 2003, après avoir divisé la région en sept parcelles, ont été analysées les caractéristiques compositives des raisins et la qualité organoleptique des vins. L'essai a été conduit aussi bien sur le raisin frais, destiné a fournir le vin Gambellara, que sur le raisin sec à partir duquel est produit le vin doux Recioto. Aussi bien les raisins frais que ceux déshydratés appartenaient à ces sept parcelles. Le contrôle des précurseurs aromatiques de variété obtenus par hydrolyse chimique et enzymatique, a confirmé le lien entre zones d'origine et teneurs en terpénoides, norisoprénoïdes et benzénoïdes dans le raisin frais, avec des concentrations plus élevées dans certaines

zones par rapport à d'autres, obtenant ainsi une première caractérisation sur une base chimiques des différentes zones. La dégustation des vins obtenus à partir des raisins frais a confirmé, en grande partie, le lien entre la teneur en précurseurs aromatiques des raisins et les sensations olfactives, arrivant ainsi à une caractérisation organoleptique des vins et de leurs sites. L'analyse chimique des précurseurs aromatiques présents dans les raisins secs (cinq mois de passerillage) n'a pas donné la même échelle quantitative mise en évidence avec le raisin frais. Ceci nous amène à supposer que l'on doit faire une lecture plus attentive et plus approfondie des résultats. L'analyse organoleptique des vins secs (Recioto) a mis en évidence un lien quantitatif avec la teneur en précurseurs uniquement dans les cas présentant une plus grande richesse. Tout ceci confirme une différence aromatique certaine des raisins provenant des différentes zones, en fonction des facteurs de milieu étudiés. Avec le passerillage des raisins, le cadre aromatique s'enrichit pour certains composés (voir le néroli du groupe des terpènes et norisoprénoïdes par hydrolyse chimique), et il s'appauvrit pour d'autres (voir le linalol du groupe des terpènes). Le lien avec les facteurs climatiques et du sol devient maintenant moins certain, mais une différenciation persiste néanmoins en fonction des sites d'origine des raisins.

Introduction

The research was conducted in a vine-growing area with an ancient tradition, attempting to define the complex interactions between vine and site. To ascertain these close associations, importance was paid to the aromatic components of the grapes - these being fresh (Gambellara DOC wine) or dried (Recioto DOC wine) - in order to evaluate their quantity in relation to the areas of origin. It is well recognised (Allen M.S. *et al* 1993) that the aromatic compounds are strongly influenced, not only by cropping factors (training system, yield per vine, harvesting date, etc.), but also by climate (Tomasi D. 2000, Marais J. *et al* 1992a, Marais J. *et al* 1992b) and soil characteristics (e.g. available water). A qualitative description of the grapes and wines is necessary for the improvement of our viticulture and to safeguard the typical characteristics. Zoning is therefore synonymous with knowledge and progress, in order to understand and make good use of the environment and what it produces.

In addition to chemical characterisation of the grapes, organoleptic analysis of the wines is necessary for an overall judgement on the producing areas. In the specific case of Gambellara DOC, this was done on both fresh and sweet wines made from semi-dried grapes, thus also highlighting different potential use of the sites.

Materials and methods

The investigation was conducted over the three years 2001-2003 in the area of Gambellara DOC and Recioto di Gambellara, which is planted exclusively with the Garganega variety. Most of the area is hilly and rests on eruptive alkaline rock (basalts), so the soils derive from metamorphosed alkaline volcanic rock. Only in a restricted zone (Creari), the base material is composed of calcarenite, whereas the plains area is formed of clay deposits deriving from the erosion of the basalt soils from the hillsides. The climate of this area is characterized by low rainfall particularly low during the summertime. During the growing period, the daily temperatures ranged from 25 to 27°C in the year 2002 and from 28 to 29°C in the year 2003, that were not affecting the plant physiology. On the other hand, during the nights the temperatures dropped down thus providing a mean thermal excursion ranged between 9 and 13°C.

The area was divided, on a pedological, morphological and climatic basis, into 7 zones (5 in 2001, with Taibane and Selva being added in 2002-03), examining a total of 34 vineyards. In 2002 and 2003, 15 days prior to harvest, 100 kg of grapes were harvested from the vineyards in each zone (excluding the plain, which is historically unsuited to obtain wines from dried grapes). These were placed in plastic boxes and left to dry in aired premises for about 5 months. So that, on December the 12th, 2002 and November the 26th, 2003, the dried grapes were pressed to make Recioto wines. The weight loss of the grapes and the increase in sugar content obtained by drying are reported in fig. 1. When the fresh grapes were harvested and when the dried grapes pressed, for each a sample of 1000 berries was collected from the vineyards in each zone. From these, 100 berries were extracted at random for chemical assessment of the aromas, using the method reported by Di Stefano (Di Stefano R. 1996). In order to compare the aromatic contents of fresh and dried grapes, the quantities of aromatic compounds were expressed in μg per 100 berries.

The wines obtained from the fresh and semi-dried grapes were tasted and evaluated by a panel of experts, using cards with a scale from 1 to 9 for each quality attribution. The comparison of wines was done on the median of the judgements.

To evaluate the differences among areas it has been used the multivariate analysis (SPSS statistical software).

Results and discussion

Aromatic compounds in fresh berries (fig. 2). A low amount of aliphatic alcohols was found in the grapes and no important differences were observed among zones. The concentration of these compounds did never exceed the olfactory threshold thus they did not affect the sensory evaluation of the wines obtained with these grapes. The monoterpenoids account for flower and citrus fruit aroma, were much higher in the first two years respect to 2003; during this year the high temperatures are though to be responsible for the lower occurrence of these aromatic compounds. Among the areas, Faldeo and Creari reported higher amounts of monoterpenoids. The main aromatic compounds that represent the Garganega variety are the benzenoids (Versini G. *et al.* 1998), which are associated with fruity or spicy aromas; for this group of aroma compounds the highest temperatures registered during the year 2003 did not affected their concentration. Among the zones, the grapes analysed in Monti di Mezzo, Creari and Taibane areas were appeared much richer of these compounds, and temperatures registered during the day (maximum temperatures) in the years 2002 and 2003 were very similar (tab.1). The concentration of C_{13}-norisoprenoids (accounting for mature and tropical fruity aroma) was similar in the three years, but among all the areas Taibane and Monti di Mezzo zones reported the highest amount of these compounds. By considering throughout all the aromatic groups, Faldeo, San Marco and Monti di Mezzo zones were much affected by the season course (weather conditions) in comparison with the other areas, mainly during the year 2003 that was particularly hot and dry. In order to understand if the grape origin is the main important grouping factor for the grape chemical composition, all the aromatic compound data were then processed through discriminant analysis (fig. 3),. The first two discriminant roots were found to explain the 90,4 % of the total variance; as showed in the fig 3, among the areas Taibane, Faldeo and Monti di Mezzo zones were clearly separated from the others. Pianura and Selva and San Marco and Creari zones were partly shared, even if they present different environmental characteristics. The principal component analysis thereafter revealed the aromatic compounds which were mainly responsible of the differences among zones, that were: piran linalool oxide isomer 2; trans-8-OH-linalool; dihydroconiferil alcohol; benzyl alcohol; metoxyeugenol; linalool; vomifoliolo, 8-OH-1,2-cineol; methylsalicilate.

Sensory evaluation of fresh wines. (fig. 4) In the year 2001, Monti di Mezzo, Faldeo and Creari wines empasized an olfactory richness and complexity that was probably correlated with a higher amount of monoterpenoids, while San Marco wines obtained a excellent evaluation because of their mouth-feel aspects. By considering the same descriptors, Pianura seemed to be penalized. In the year 2002, the olfactory analysis has given the best score to Taibane, San Marco, Pianura and Selva, characterizing in this way the different grape origin (fig 4). Faldeo zone did not provide wines with the same olfactory marks, even if the grapes were much rich in monoterpenoids. The judgement did probably suffer the marked acidity taste of the Faldeo wines in comparison with the others. In the year 2003 Taibane and Creari wines were evaluated as best because of their olfactory characteristics (see richness in benzenoid compounds); in this year citrus fruits, vegetable and floreal descriptors were much lower than 2002, probably to be related with the lower amount of monoterpenoids. Monti di Mezzo grapes reported high contents of aromatic compounds, but the sensory response of the related wines did not agree the expectations. A lack in freshness and balance (absence of malic acid) probably caused a less appreciation of this wine in comparison with the others (i.e. see tab. 2).

Aromatic compounds in dried berries (fig 5). A comparison of the aromatic compounds in fresh and in the related dried berries, revealed that there was a important reduction of linalool (linalool oxydate forms were increased by drying process) and an increase in geraniol and nerol content. In the year 2003 the dried grapes were characterised by the presence of the monoterpenoid furfulal (toasted aroma) that was particularly abundant in San Marco, Monti di Mezzo and Selva grapes. A slight increase in the concentration of aliphatic alcohols was found meanly ranged from 15-20 μg/100 berries in fresh grapes to 25-30 μg/100 berries in dried grapes. An opposite behaviour was observed in Faldeo and Selva grapes in the year 2002 and in Taibane grapes in 2003 thus revealing a reduction of these compounds through the grape drying process. In the year 2002 the monoterpenoids in the dried grapes maintained the ratio between zones that was found in fresh grapes (fig 6). In 2003 San Marco and Faldeo zones reported a much higher increase of the monoterpenoid compounds. The benzenoid concentration confirmed their importance in Garganega variety, with a slight increase if compared

with fresh grapes. In both years a reduction of benzenoid compounds was revealed for Creari grapes, and in the year 2003 the higher amount of this aromatic group was obtained in San Marco zone. The content of C_{13}-norisoprenoids in dried grapes in 2002 was as similar as discovered in fresh grapes; Creari zone reported a loss in C_{13}-norisoprenoid and benzenoid by drying the grapes. In the year 2003, San Marco area resulted as better in terms of concentration of aromatic compounds.
The areas where the concentration of aromatic compounds was increased by drying process resulted Monti di Mezzo, San Marco and Faldeo in all three years, and Selva only in the year 2003.
The discriminat analysis was applied to the total aromatic groups thus obtaining two discriminant roots which explained together the 93,2 % of the total variance. The fig 7 shows that there was a good separation of the areas and thus revealing a good interaction aroma per location.
Sensory evaluation of dried wines (fig. 8). In the year 2002, the olfactory aspect has been more evident in the San Marco, Monti di Mezzo, Taibane and Creari zones. The wines obtained with Faldeo and Selva dried grapes were appreciated because of their apple and pear tastes, the former (Faldeo) also reported mouth-feel balance and retro-olfactory richness. A good relationship between aromatic concentration and sensory evaluation emerged in the wines of the year 2002. In the year 2003, San Marco wines were judged as the best in terms of olfactory aspects, thus revealing a good correlation with the aromatic concentration in grapes. A good score was also obtained by Selva and Faldeo wines, that were identified by an abundant amount of C_{13}-norisoprenoids which are related to tropical fruit, candied fruit and honey tastes. Creari and Monti di Mezzo wines were interesting because of their flower and mature fruit aromas.

Conclusions

The analysis of the aromatic compounds in fresh grapes allowed to discover a good differentiation of the Monti di Mezzo, Taibane and Faldeo zones by multivariate analysis. The environmental characteristics of these areas (i.e. see tab. 1) are well defined thus providing differences also in the resulting wines. In same cases, the mouth-feel and the olfactory properties have been suffered because of the high acidity of the wines. On the other hand, a good relationship was found between grape aromatic content and related olfactory descriptors in the wines; there was also a seasonal variability to be linked to the terroir of the different areas.
The aromatic compounds were usually more concentrated in dried grapes because of the berry weight reduction, but with less evidence in the aliphatic alcohols; the concentration enhancement allowed to obtain a better discrimination among areas in comparison with fresh grapes. The organoleptic analysis of the Recioto wines has demonstrated a good link between aromatic compounds and olfactory aspects in wines, particularly in San Marco, Faldeo and Selva areas for both years of investigation. Summarising, there is a relationship between aromatic compounds and location origin of the grapes, but not between fresh and dried aromatic composition.

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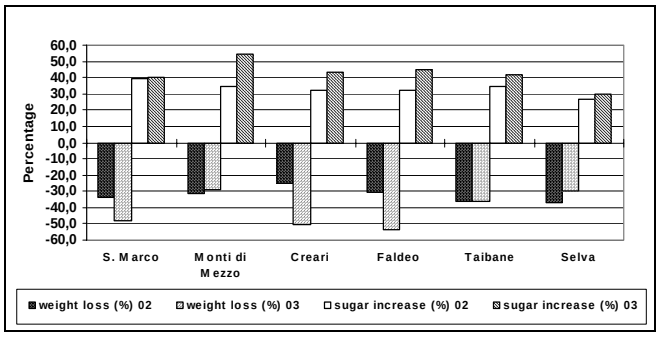

Figure 1: effect of the grape drying on weight loss and sugar increase during the years 2002 and 2003

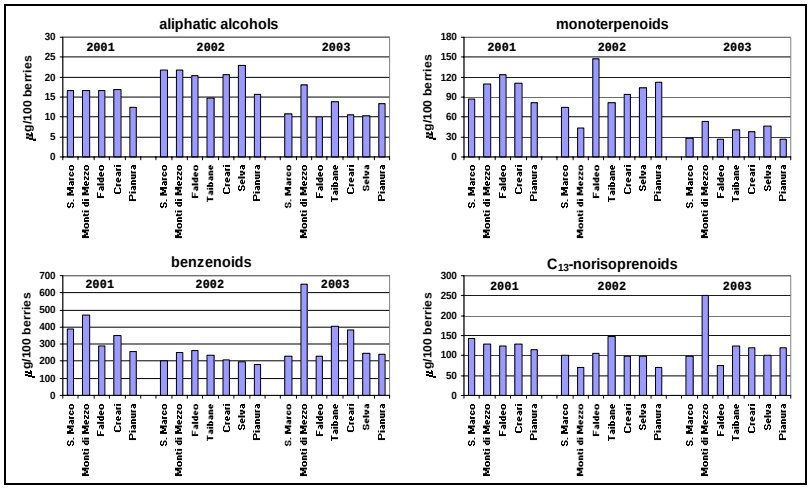

Figure 2: concentration of aromatic compounds in fresh berries as affected by zone and year of production.

Table 1: mean temperatures (T) and thermal excursion (Exc.) in the different zones

	01/08.30/09/2002				01/04-30/09/2003				01/08-30/09/2003			
	T mean	T min	T max	Exc. mean	T mean	T min	T max	Exc. mean	T mean	T min	T max	Exc. mean
SAN MARCO	19.9	14.9	26.1	11.2	22.6	16.5	29.1	12.6	24.0	17.9	30.9	13.0
TAIBANE	19.5	15.7	25.2	9.4	22.0	17.2	28.4	11.2	23.8	19.1	30.4	11.3
FALDEO	21.23	17.1	26.4	9.36	21.7	16.7	27.2	10.5	23.5	18.5	29.3	10.8
CREARI	20.4	16.5	25.3	8.8	22.3	17.5	28.0	10.4	24.0	18.9	30.0	11.0
SELVA	20.2	16.3	25.2	8.9	22.6	17.7	28.1	10.4	23.6	18.8	29.3	10.5
PIANURA	20.7	14.5	27.8	13.3								

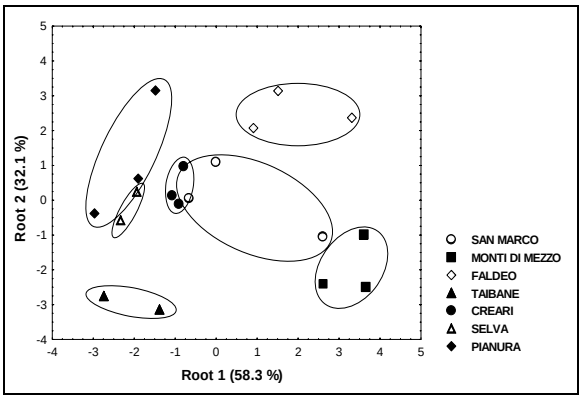

Figure 3: zone grouping of fresh Garganega grapes as resulted by disciminant analysis.

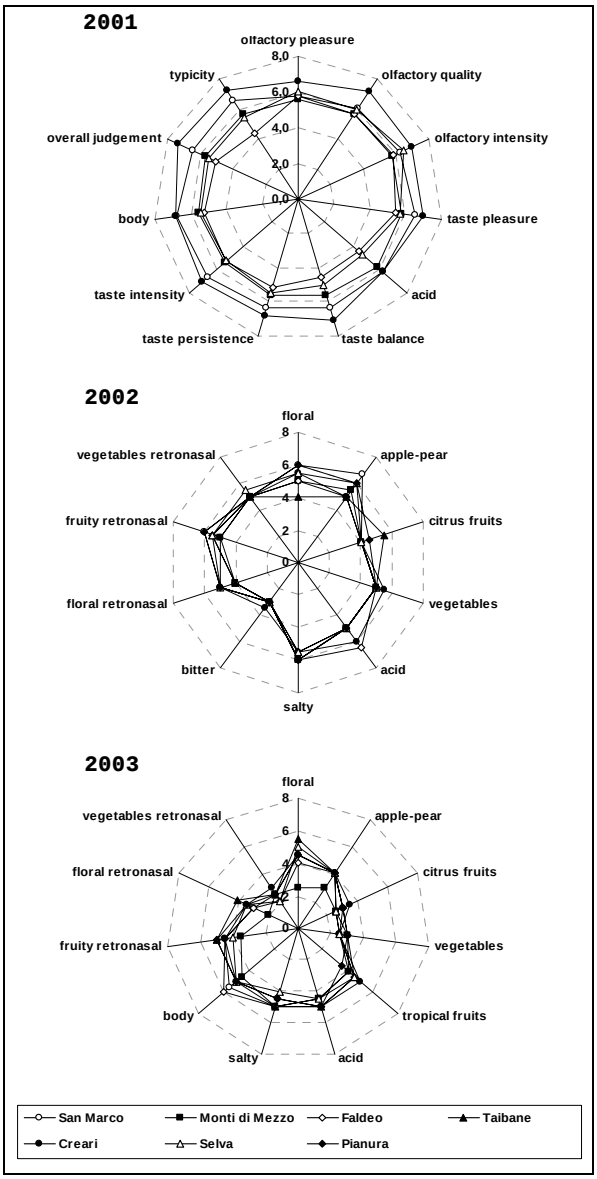

Figure 4: radar graphs of the sensory analysis of the fresh Garganega wines.

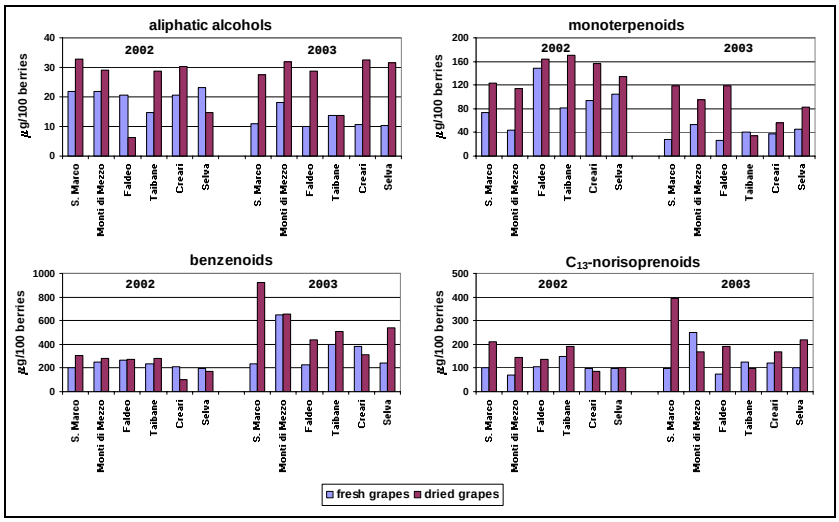

Figure 5: comparison of the aromatic compounds in fresh and dried grapes

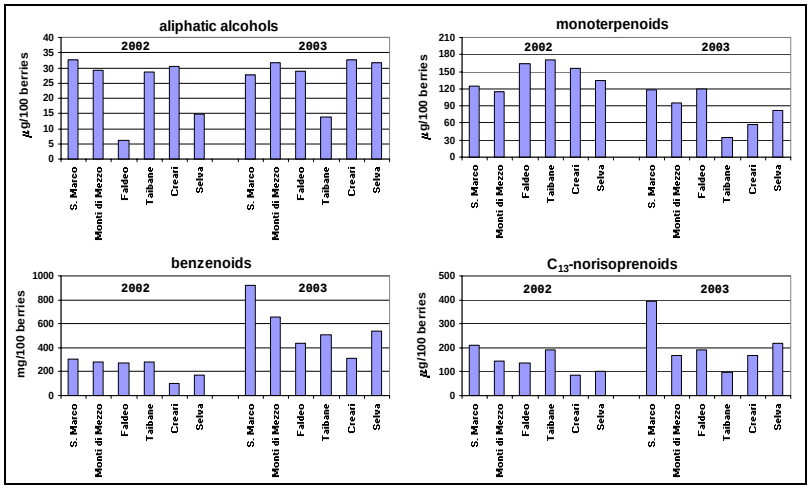

Figure 6: concentration of aromatic compounds in dried berries as affected by zone and year of production.

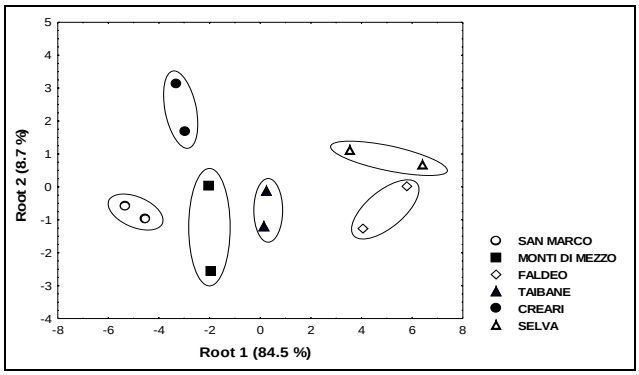

Figure 7: zone grouping of dried Garganega grapes as resulted by disciminant analysis.

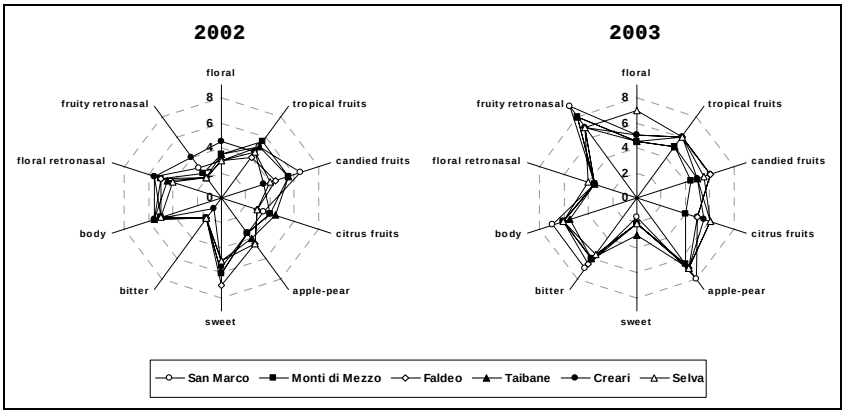

Figure 8: radar graphs of the sensory analysis of the Recioto wines.

Table 2: chemical composition of the grapes in the different zones.

	year 2001					year 2002					year 2003				
Zone	Sugars (Babo)	Titratable acidity (g L^{-1})	pH	Tartaric acid (g L^{-1})	Malic acid (g L^{-1})	Sugars (Babo)	Titratable acidity (g L^{-1})	pH	Tartaric acid (g L^{-1})	Malic acid (g L^{-1})	Sugars (Babo)	Titratable acidity (g L^{-1})	pH	Tartaric acid (g L^{-1})	Malic acid (g L^{-1})
San Marco	18.1	4.36	3.16			19.6	6.9	3.2	5.3	3.5	19.4	4.9	3.3	5.2	0.2
Monti di Mezzo	17.6	4.86	3.12			19.3	5.4	3.4	5.1	2.8	19.0	5.7	3.24	5.8	0.1
Faldeo	16.1	6.27	3.03			20.5	7.2	3.2	5.4	3.7	20.1	5.2	3.3	4.6	0.5
Taibane						21.8	6.3	3.2	5.4	3	19.9	5.6	3.2	4.9	0.3
Creari	17.9	5.09	3.12			20.9	5.2	3.3	5.3	2.1	19.2	5.5	3.0	5.1	0.4
Selva						19.8	6.4	3.3	4.9	3.9	19.7	5.1	3.3	4.7	0.5
Pianura	16.4	5.43	3.03			19.5	5.5	3.4	5.2	2.7	17.0	5.8	3.2	6.1	0.3