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The impact of geographic origin, vintage and wine estate on sensory properties of *Vitis vinifera* cv. Riesling wines

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Abstract

The official quality designation for German wines is solely based on the degree of ripeness in grapes, while most other wine producing countries in Europe rely on a geographic classification system. A descriptive analysis (DA) investigated the sensory properties of commercial Riesling wines from two vintages, five wine estates and six vineyard designations within the viticulture region Rheingau. Based on the number of significant *F*-ratios among 10 odor and 4 orally perceived attributes, vintage and wine estate proved to have a similar impact as vineyard designation. Principal component analysis revealed substantial variations within the same vineyard designation and demonstrated the strong impact of the individual wine estate and vintage. Hence, a classification system focusing on geographic origin alone would be rather confusing for consumers, because wines differ substantially regarding their sensory appearance within the same vineyard designation. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Wine; Riesling; Descriptive analysis; Terroir; Classification; Aroma

1. Introduction

In Germany, a long tradition focuses on distinct vineyard designations. As the country is located at the northern border of world viticulture, only those vineyard sites of superior sun exposure, wind and frost protection, and suitable soil types were utilized for viticulture (Hoppmann & Schaller, 1981a,b). However, the quality classification of German wines is based on grape maturity alone, which is determined by the sugar concentration in the grape juice, and a final sensory evaluation of the finished wine. In France, the determination of wine quality categories on the label relies on a geographic classification system. The underlying concept of 'terroir' includes all regional parameters with an impact on wine composition such as soil, climate, viticultural management, crop level and wine-making procedures. In Burgundy, the quality hierarchy of wine is established on a classification of vineyard sites only, while in Bordeaux, individual wine estates are classified, combining the impact of terroir with the various effects due to individual viticultural and enologic practices.

To establish a link between viticultural, climatic and soil parameters and wine composition, many studies have tried to classify white wines according to geographic origin (Maarse, S'lump, Tas & Schaefer, 1987; Moio, Schlich & Etiévant, 1994; Moret, Scarponi & Cescon, 1984; van der Voet & Doornbos, 1984), wine variety (González-Lara, Correa, Polo, Martin-Alvarez & Ramos, 1989; Maarse et al., 1987; Moret, Scarponi & Cescon, 1994; Noble, Flath & Forrey, 1980; Rapp & Güntert, 1985; Rapp, Güntert & Heimann, 1985a; Rapp, Suckrau, & Versini, 1993; Rapp, Volkmann, & Niebergall, 1993; Schreier, Drawert, Junker & Reiner, 1976), vintage (Moret, Di Leo, Giromini & Scarponi, 1984) or quality classification (Maarse et al., 1987) by utilizing data regarding their volatile composition (Maarse et al., 1987; Moret et al., 1984b; Noble et al., 1980; Rapp & Güntert, 1985; Rapp, Güntert & Ullmeyer, 1985b; Rapp et al., 1993a; Rapp et al., 1993b; Schreier et al., 1976), amino and organic acids (Maarse et al., 1987), proteins (González-Lara et al., 1989) and

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trace elements (Maarse et al., 1987; Moret et al., 1984b; Thiel, Bauer, Danzer & Eschnauer, 1998). The sensory properties of wines were also classified by multivariate statistical methods regarding varieties (Noble, 1988), geographic origin (Moio, Schlich, Issanchou, Etievant & Feuillat, 1993; Noble, Williams & Langron, 1984) or vintage (Noble & Shannon, 1987; Ohkubo, Noble & Ough, 1987). Attribute ratings during descriptive analysis yielded sufficient discrimination power to cluster wines into groups of different geographic origin (Guinard & Cliff, 1987; Heymann & Noble, 1987; Lebon et al., 1996). Using correspondence analysis, the frequency of mentioned sensory attributes and concentration of aroma compounds were related to each other to describe the properties of Chardonnay wines of different viticultural areas in France (Schlich & Moio, 1994). For the establishment of viticultural areas within the Napa Valley, Noble and Elliott-Fisk investigated not only soil- and vineyard-site-related parameters, but sensory properties of the Cabernet Sauvignon wines across three vintages and a range of wine estates (Noble & Elliott-Fisk, 1990). In Germany, Wahl moved seven different soil types to the same vineyard site in lysometers to study the impact of soil type on wine composition and sensory quality of Silvaner wines without any climatic interaction (Wahl, 1988; Wahl & Patzwald, 1997). He reported no significant impact on wine flavor of the investigated soil types, however the average yield varied by 100% between the soil types. Long-term investigations in the Rheingau region clearly demonstrated the strong effect of solar radiation and temperature regime for grape maturity within the meso-climatic scale of a vineyard site and the macro-climatic scale of a viticultural region (Hoppmann & Schaller, 1996). It was the objective of this study to investigate the sensory effects of vintage, wine estate and vineyard designation of Riesling wines produced within the viticultural region Rheingau.

2. Materials and methods

2.1. Selection of experimental wines

Wines of the variety *Vitis vinifera* cv. Riesling of the Rheingau region were selected in a way that each of the participating wine estate provided wines from at least two vineyard designations and two vintages. Only those vineyard designations showing a high homogeneity regarding soil type, soil structure, water supply, meso-climate, clones and vine age were accepted. Overall, 20 wines were selected from five wine estates, two vintages and six vineyard designations (Table 1). To include the variance due to individual viticultural and enologic practices, only commercially produced wines were used and for this reason wines varied regarding residual sugar, alcohol and titratable acidity (Table 1).

Table 1
Origin and composition of Riesling wines from the Rheingau region selected for the descriptive analysis

Vintage	Vineyard designation	Wine estate	Grape maturity (°Brix)	Alcohol (g/l)	Titratable acidity (g/l)	Residual sugar (g/l)
1993	Erbacher Marcobrunn	Knyphausen[a]	22.0	90.3	6.6	20.2
1993	Hattenheimer Wisselbrunn	Knyphausen[a]	22.0	96.0	7.4	7.1
1994	Erbacher Marcobrunn	Knyphausen[a]	20.6	91.2	7.4	9.0
1994	Hattenheimer Wisselbrunn	Knyphausen[a]	23.0	93.3	8.4	8.3
1993	Erbacher Marcobrunn	Oettinger[b]	22.3	83.0	7.0	26.5
1993	Erbacher Hohenrain	Oettinger[b]	22.0	88.9	8.4	22.6
1994	Erbacher Marcobrunn	Oettinger[b]	22.7	86.8	8.6	32.3
1994	Erbacher Hohenrain	Oettinger[b]	19.4	82.2	9.1	16.4
1993	Erbacher Marcobrunn	Schönborn[c]	25.8	90.2	6.4	51.1
1993	Hattenheimer Wisselbrunn	Schönborn[c]	23.7	80.8	6.4	45.6
1994	Erbacher Marcobrunn	Schönborn[c]	21.1	71.5	8.4	51.8
1994	Hattenheimer Wisselbrunn	Schönborn[c]	20.8	70.5	9.2	48.2
1993	Rüdesheimer Berg Schloßberg	Wegeler[d]	22.7	96.4	7.8	8.5
1993	Winkeler Jesuitengarten	Wegeler[d]	22.3	92.5	8.5	6.6
1994	Rüdesheimer Berg Schloßberg	Wegeler[d]	21.8	92.0	8.7	7.6
1994	Winkeler Jesuitengarten	Wegeler[d]	22.3	92.5	8.5	8.7
1993	Rüdesheimer Berg Schloßberg	Breuer[e]	22.3	94.6	8.0	7.1
1993	Rauenthaler Nonnenberg	Breuer[e]	22.0	93.7	8.4	8.9
1994	Rüdesheimer Berg Schloßberg	Breuer[e]	21.8	88.0	9.4	7.9
1994	Rauenthaler Nonnenberg	Breuer[e]	22.3	90.8	9.1	8.1

[a] Weingut Freiherr zu Knyphausen.
[b] Weingut Eberhard von Oetinger.
[c] Domänenweingut Schloß Schönborn.
[d] Weingüter Geheimrat J. Wegeler Erben.
[e] Weingut Georg Breuer.

2.2. Sensory analysis

The panel for descriptive analysis consisted of nine trained enology students selected on the basis of availability and interest. During training, the judges generated descriptive terms using wines from the study and, by consensus, 10 aroma and 4 orally perceived terms were selected. Reference standards were prepared daily as described in Table 2 and were smelled by the judges prior to wine evaluation. For taste and retronasal attributes, no standards were provided. Wines were served in random order using an incomplete block design. A volume of 30 ml wine was evaluated in tulip-shaped ISO (International Standardization Organization) tasting glasses at 20°C. Intensity ratings were scored on a 10-cm unstructured scale, anchored with the terms "not perceivable" at the low end and "very strong" at the high end. All wines were scored in duplicate and the tasting sessions were held in February and March 1996.

2.3. Data analysis

Analysis of variance (ANOVA) was performed using a mixed model with judges as random effects and wine, judge and replication as main effects. Least significant differences between wine means were computed by a *t*-test (df = 152) and are included in Figs. 2–5. Table 3 shows only *F*-ratios of the main effect wine and the wine×judge interaction for all sensory attributes. To investigate the significance of vintage and wine estate to the overall variability, a second ANOVA (Table 4) used judge, vintage and wine estate as main effects. Due to the fact that not all wine estates contributed wines from the same vineyards to the study, the effect wine estate was nested into vineyard designation. A third ANOVA (Table 5) studied the impact of vineyard designation by using the main effects judge, vintage and vineyard designation, nested into wine estate. Principal component analysis (PCA) based on a covariance matrix was computed using the (proc factor) procedure of SAS without rotation for the means of all significant sensory attributes (Table 3; SAS/STAT, 1997).

Table 3
Mixed model ANOVA with degrees of freedom, *F*-ratios, and error mean squares of the sensory terms for Riesling wines from the Rheingau region ($n = 9J \times 2Rep$)

Source of variation	Wine	Wine×judge	Error mean square
Degrees of freedom	19	1	285
Odor attributes			
Passion fruit	6.05***	1.23	2.55
Grapefruit	1.77*	0.90	7.81
Citrus	2.48**	1.10	2.82
Apple	1.30	1.17	2.58
Pear	0.52	1.45*	2.51
Floral	1.86*	1.01	4.19
Grassy/green	2.75***	1.02	2.72
Artificial fruit	2.32**	1.77***	1.97
Nutty	1.74*	1.39*	2.00
Licorice	1.91*	1.27	1.07
Oral attributes			
Body	6.40***	1.27	1.40
Flavor intensity	1.90*	1.01	6.28
Density	5.13***	0.81	2.14
Persistence	3.25***	1.42*	2.02

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

3. Results and discussion

3.1. Significance of vintage, wine estate and vineyard designation

According to the ANOVA in Table 3 only the odor of apple and pear were insignificant. As summarized in Table 4, variation in the meso-climate during both vintages altered significantly only two odor and three orally

Table 2
Recipes for the preparation of odor reference standards for the Riesling descriptive analysis

Attribute	Recipe
Passion fruit	20 ml of passion fruit nectar (Vaihinger) in 50 ml base wine
Citrus	10 ml freshly pressed citrus juice in 50 ml base wine
Grapefruit	2 cm^2 grapefruit peel extracted for 10 min in 40 ml base wine plus 10 ml freshly pressed grapefruit juice
Apple	20 µl of commercial apple aroma (Vögele) in 50 ml base wine
Pear	8 ml of pear juice (Granini) in 50 ml of base wine
Artificial fruit	12 chopped 'Gummibärchen' (Haribo) extracted for 15 min in 75 ml base wine
Floral	1 ml stock solution (20 µl linalool, 30 µl 2-phenylethanol and 10 µl phenylethyl acetate in 100 ml 10% v/v ethanol, respectively) in 50 ml base wine
Grassy	1 ml 3-hexen-1-ol stock solution (200 µl in 100 ml water) in 50 ml base wine
Nutty	0.5 walnut and 2 hazelnuts chopped, without base wine
Licorice	1 chopped piece licorice candy (Katjes Katzenkinder) extracted for 60 min in 50 ml base wine
Base wine	1995 Rheingauer Landwein, estate research station Geisenheim

Table 4
Mixed model ANOVA with degrees of freedom, *F*-ratios, and error mean squares of the sensory terms for Riesling wines from the Rheingau region. Impact of vintage and wine estate nested into vineyard designation and their interactions ($n = 9J \times 2Rep$)

Source of variation	Judges	Vintage	Vineyard designation (wine estate)	Vintage×vineyard designation (wine estate)	Error mean square
Degrees of freedom	8	1	5	5	285
Odor attributes					
Passion fruit	2.05	13.02***	4.40**	6.54***	3.05
Grapefruit	5.83*	0.74	2.36	0.25	7.89
Citrus	4.64*	2.00	3.07*	1.24	3.20
Apple	18.53***	2.14	1.68	0.65	2.82
Pear	7.33***	0.44	0.42	0.40	2.82
Floral	16.33***	0.45	1.45	1.24	4.07
Grassy/green	4.88*	2.24	2.25	2.01	3.01
Artificial fruit	4.85**	0.65	1.81	2.07	2.77
Nutty	11.20***	2.49	1.07	0.80	2.23
Licorice	4.64**	4.86*	2.38	2.75*	1.19
Oral attributes					
Body	8.75***	12.11**	7.39***	2.63*	1.63
Flavor intensity	1.89	1.11	1.33	2.83*	5.52
Density	16.82*	11.61**	3.54**	1.76	2.09
Persistence	11.51***	21.80***	1.49	1.45	2.51

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 5
Mixed model ANOVA with degrees of freedom, *F*-ratios, and error mean squares of the sensory terms for Riesling wines from the Rheingau region. Impact of vintage and vineyard designation nested into wine estate and their interactions ($n = 9J \times 2Rep$)

Source of variation	Judges	Vintage	Wine estate (vineyard designation)	Vintage×wine estate (vineyard designation)	Error mean square
Degrees of freedom	8	1	4	4	294
Odor attributes					
Passion fruit	2.63	11.67**	1.48	8.20***	8.61
Grapefruit	5.26*	0.04	2.41*	2.46*	7.48
Citrus	4.33*	5.15	0.37	2.94*	3.02
Apple	25.62***	3.58	1.66	2.50*	2.79
Pear	7.41***	0.23	0.22	0.90	2.87
Floral	14.11***	0.45	2.68*	0.54	4.03
Grassy/green	4.68*	3.94	0.43	4.96***	2.80
Artificial fruit	4.26**	0.02	4.78***	2.58*	2.63
Nutty	9.38***	4.44	1.63	1.20	2.09
Licorice	4.68*	16.06**	2.23 a	3.53**	1.19
Oral attributes					
Body	7.66**	11.88**	15.06***	2.75*	1.60
Flavor intensity	3.70	2.51	1.43	0.83	6.40
Density	7.64**	13.94**	7.16***	1.51	1.94
Persistence	8.20***	20.68**	4.65***	3.57**	2.35

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

perceived attributes. Individual viticultural and enological practices utilized by the wine estates had a significant impact on three odor and three orally perceived attributes. Presumably, the variations in oral attributes are affected by variables such as residual sugar, titratable acidity or ethanol content which can be directly altered by wine-making techniques, such as chaptalization or deacidifcation, and which substantially varied between wine estates and vintages (Table 1). In contrast, wine aroma is formed by a complex mixture of natural and processing variables, such as degree of maturity at harvest, percentage of solids in the fermented grape juice,

fermentation temperature or yeast strain applied for alcoholic fermentation. Obviously, the fact that the 1993 wines were a year older than the 1994 wines at the date of the tasting was a further source of variation between vintages. However, aroma attributes such as artificial fruit, apple or pear which are mainly elicited by esters yielded insignificant *F*-ratios between vintages, although their concentration should decrease during wine aging due to hydrolysis at low wine pH (Ramey & Ough, 1980). The interaction between vintage and wine estate produced seven significant *F*-ratios among odor attributes and two among orally perceived attributes indicating that the impact of individual grape growing and wine-making techniques applied by the wineries differed regarding their sensory impact from year to year. As summarized in Table 5 vineyard designation nested into wine estate yielded two significant odor and orally perceived attributes, respectively. The same was true for the vintage×vineyard designation interaction.

3.2. Impact of vineyard designation

The mean sensory ratings of all but the insignificant pear and apple attributes were analyzed by a PCA shown in Fig. 1. The first principal component (PC1) was characterized by the contrast of fruity and floral attributes having positive loadings and the green/grassy odor displaying a negative loading. All orally perceived attributes correlated with the fruity and floral attributes. For the second PC, the attributes licorice and nutty showed positive loadings, while citrus and, to a lesser degree, grapefruit were loading negatively on PC2. Overall, both principal components explained 62% of total sensory variability. The scores of the 1994 wines (bold letters) were strongly determined by the green/grassy, citrus and grapefruit attributes, whereas the

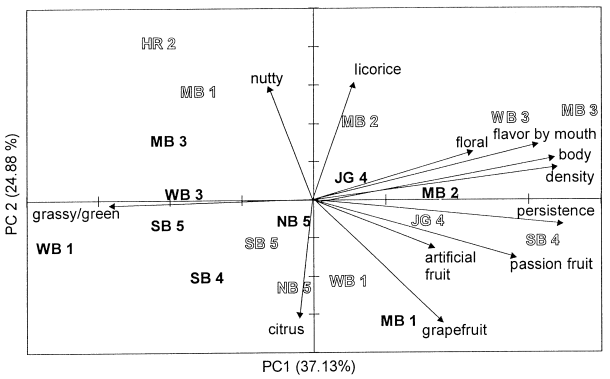

Fig. 1. Principal components analysis for Riesling. Projection of intensity ratings of sensory attributes on principal components PC1 and PC2. Loading vectors of sensory attributes and wine scores of different wine estates (1, Knyphausen; 2, Oettinger; 3, Schönborn; 4, Wegeler; 5, Breuer), vintages (1993, open letter; 1994, bold letters) and vineyard designations (MB, Marcobrunn; WB, Wisselbrunn; HR, Hohenrain; SB, Schloßberg; JG, Jesuitengarten; NG, Nonnengarten).

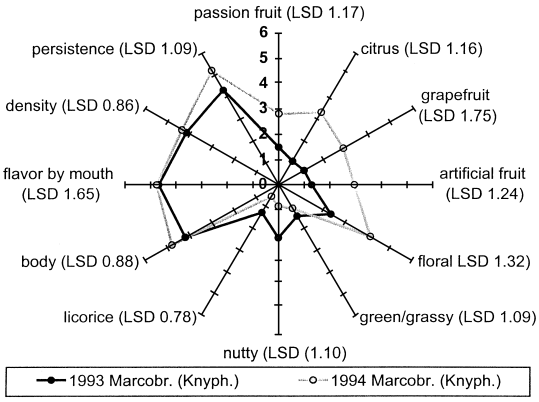

Fig. 2. Descriptive analysis aroma profile for Riesling ($n=9J\times2Rep$). Sensory impact of vintage for wines of equal origin (Erbacher Marcobrunn) and the same producer (wine estate Freiherr von Knyphausen).

1993 (open letters) wine scores were characterized by higher intensities of passion fruit, artificial fruit, licorice, nutty and floral odors, and higher ratings in all orally perceived attributes. The scores of the four wines made from grapes of the Rüdesheimer Berg Schloßberg (SB4 and SB5) were closely grouped on the left side of the PCA, with the exception of the 1993 wine from the Wegeler estate (SB4), which scored on the right side due to its high intensity of passion fruit. In contrast, the scores of the six wines made from the Erbacher Marcobrunn (MB1, MB2 and MB3) were spread over the whole plane defined by both principal components with the exception of the lower left quadrant defined by high citrus and green/grassy flavors. The same was true for scores of the four wines made from the Hattenheimer Wisselbrunn (WB1 and WB3) which are distributed in all four quadrants of the PCA plane. The tremendous variation observed among wines from the same vineyard designation demonstrated the huge sensory variability within the same designation. Clearly, for those

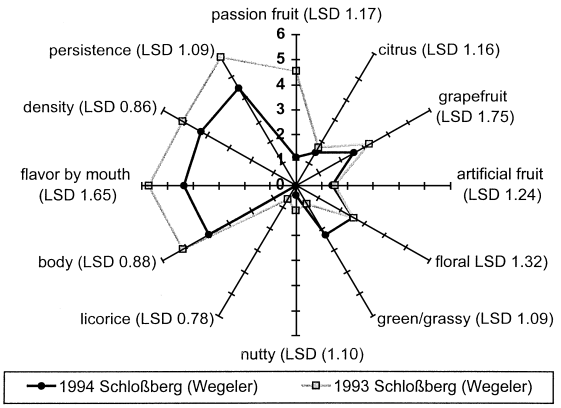

Fig. 3. Descriptive analysis aroma profile for Riesling ($n=9J\times2Rep$). Sensory impact of vintages for wines of equal origin (Rüdesheimer Berg Schloßberg) and the same producer (wine estate Geheimrat J. Wegeler Erben).

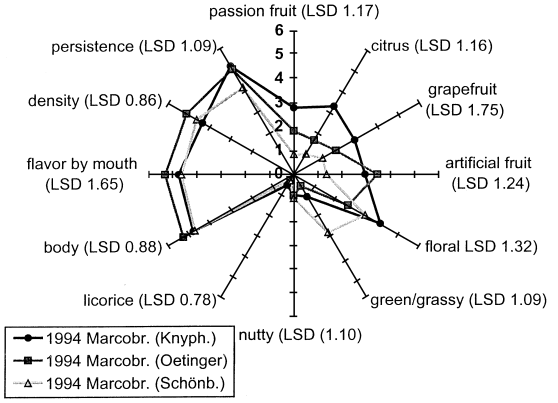

Fig. 4. Descriptive analysis aroma profile for Riesling ($n=9J\times2Rep$). Sensory impact of different wine estates for wines of the same geographic origin (Erbacher Marcobrunn) and vintage (1994).

wines the terroir of the vineyard had only a minor impact on their sensory properties compared to the major influence caused by vintage and wine estate. Therefore, a classification of wine quality based on geographic units such as vineyard designation alone, as is common for wines from the Burgundy region in France, seems not to be suitable for a range of vineyards in this study because of the dominant sensory impact of vintage and wine estate. These findings coincide with the statement of Hoppmann and Schaller, that solar radiation income and temperature regime, which deviate substantially between vintages, is much more important for grape maturity in cool climates than site-specific water availability (Hoppmann & Schaller, 1996).

3.3. Impact of vintage

Comparing the sensory profile of a 1993 and 1994 wine from the same producer (Knyphausen) and vineyard designation (Erbacher Marcobrunn) in Fig. 2, significant differences occur in all odor attributes except for green/grassy, but no significant variation could be found in the orally perceived terms. For the 1994 wine, the odor attributes citrus and grapefruit were rated three-fold higher than for the 1993 wine. Both wines did not differ substantially regarding yield at harvest (55 vs 60 hl/ha), degree of *Botrytis cineria* infection (both 25%), grape maturity (22 vs 20.6° Brix) or enologic treatment. Thus, the significant variation in flavor composition between both vintages suggests a strong impact of other vintage-related factors which have not been controlled in this study. However, comparing wines from both vintages from the vineyard designation Rüdesheimer Berg Schloßberg and vinified by the estate Wegeler in Fig. 3, only significant differences occurred for the odors of passion fruit and green/grassy. Although residual sugar, titratable acidity and alcohol content were within a narrow range (Table 1), all orally perceived attributes varied significantly.

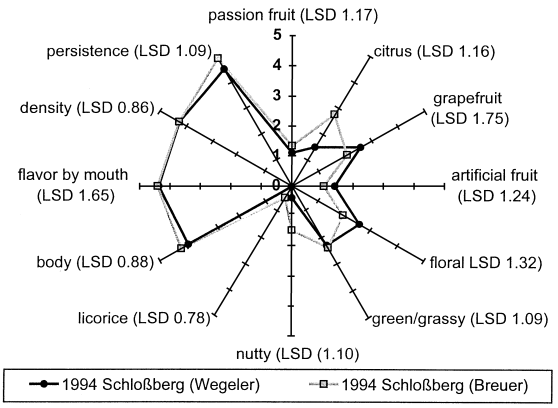

Fig. 5. Descriptive analysis aroma profile for Riesling ($n=9J\times2Rep$). Sensory impact of different wine estates for wines of the same geographic origin (Rüdesheimer Berg Schloßberg) and vintage (1994).

3.4. Impact of wine estate

Comparing sensory variation between wines made from the same vineyard and in the same year, but produced from different wine estates, the wines from the Erbacher Marcobrunn in Fig. 4 varied significantly in all attributes except for body, flavor by mouth and the aging odors nutty and licorice. In contrast, the 1994 wines from the Rüdesheimer Schloßberg in Fig. 5 produced no significant sensory differences, except for the citrus and nutty odors. Comparing the different impacts of vintage (Figs. 2 and 3) and wine estate (Figs. 4 and 5) for both vineyard designations, the sensory profile of the Erbacher Marcobrunn varied tremendously due to vintage and the individual viticultural and enologic practices applied by the wine estates, whereas the Rüdesheimer Berg Schloßberg displayed a rather robust aroma profile with a very limited impact of the factors vintage and wine estate. This may lead to a hypothesis that the Rüdesheimer Berg Schloßberg has a rather stable terroir and both participating wine estates have developed a method of grape growing and vinification which yields wines of similar sensory profiles across vintages and wine estates. Thus, for consumers who seek specific sensory properties from a wine, vineyard designation is a meaningful orientation for the Rüdesheimer Berg Schloßberg wines while vintage and wine estate is much more relevant for Erbacher Marcobrunn wines. Due to the fact that no consumer studies have been done with these wines, it is not possible to make any concluding statement regarding overall quality. The results of the descriptive analysis clearly demonstrate the degree of sensory variation but it remains unclear how the intensity ratings translate into perceived quality and which of the recorded flavor attributes are the most important to define overall quality.

4. Conclusion

Utilizing descriptive analysis of commercial wines from two vintages, five wine estates and six vineyard designations, vintage and wine estate proved to have as equal an impact as vineyard designation on the sensory properties of Riesling wines from the Rheingau. Although grapes were harvested from the same vineyard designation, wines from the Erbacher Marcobrunn varied substantially, presumably due to different viticultural and enology treatments applied by the wine estates. However, for the vineyard designation Rüdesheimer Berg Schloßberg, across two vintages and two wine estates only minor sensory variations were observed. This leads to the hypothesis that some vineyards seem to be more stable regarding seasonal climatic variation and the impact of the human factor during grape production and wine-making than other vineyard sites. Clearly, a classification system solely based on vineyard designation would be rather confusing for consumers, because wines differ substantially within the same vineyard designation in their sensory appearance.

Due to its very limited scope, this pilot study cannot be representative for all variation occurring across viticultural areas, vine varieties, vintages, viticultural and enologic treatments. Hence, there is a strong need to study further the impact of meso- and macro-climate, soil type, viticultural and wine-making practices on wine composition, sensory properties and finally on consumer preferences. Without a better understanding of these important links, the classification of wine quality on the basis of geographic origin alone seems to be inappropriate.

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