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Astringency subqualities and sensory perception of Tuscan Sangiovese wines

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ABSTRACT

Aim: The Sangiovese grape cultivar is at the basis of the most well-known Italian wines produced in the Tuscany region. However, little is known about the sensory characteristics of Tuscan Sangiovese wines, and the diversity in astringency subqualities has never been investigated. In this study we evaluated the sensory perception of 16 commercial Sangiovese wines belonging to four categories of denomination (Chianti DOCG, CH; Chianti Classico DOCG, CC; Morellino di Scansano DOCG, MS; Toscana IGT, TS), and again after 20 months of bottle aging.
Methods and results: A sensory evaluation was made, consisting of the astringency subqualities, taste, odor, and aroma profiles of wines. In addition, chemical analyses were carried out for the base parameters, polyphenols and some volatile compounds. Astringency subqualities varied depending on the percentage of Sangiovese in wines (from 80 % to 100 %). Blended Sangiovese wines were characterized by positive mouthfeel sensations. According to these, the drivers of liking the wines were associated with *soft*, *mouthcoat*, and *rich* subqualities. The Tuscan Sangiovese denominations were differentiated by volatile active compounds, whereas after about two years of bottle aging the astringency subqualities better achieved this task. Moreover, aging also influenced the evolution of wines: CC and CH wines positively evolved, revealing a complex odor profile; MS lost the fruity character; and TS was less involved in sensory modification.
Conclusions: For the first time, a detailed evaluation of the astringency subqualities of commercial Sangiovese wines was undertaken. Sangiovese subqualities differed according to the percentage of Sangiovese and denomination. Tuscan denominations were distinguished by peculiar sensory characteristics. In addition, bottle aging significantly influenced the evolution of the sensory perception of Sangiovese wine. In particular, mono-varietal Sangiovese wine needed a long period of aging to soften the astringency characteristics.
Significance and impact of the study: Sangiovese wine represents - with its denominations and styles - the best-known and high-quality Italian wine in the world, and its popularity is increasing worldwide. Tuscan Sangiovese wines are often a blend with other red varieties of the region, and these can vary according to the production regulations. This study aimed to improve the knowledge of the sensory characteristics of Sangiovese wines belonging to different denominations and made with different percentages of this grape cultivar. In particular, the astringency subqualities are fundamental to fully appreciating the quality of the red wine during tasting.

KEYWORDS

subquality, astringency, Sangiovese, perception

INTRODUCTION

Sangiovese is one of the most widespread grape cultivars in Italy. It is grown throughout the country and accounts for around 11 % of grapes planted in Italian vineyards, and its popularity is increasing worldwide (ISTAT, 2010). Sangiovese is the base grape variety of Tuscan wines, including seven Denomination of Controlled and Guaranteed Origin wines (DOCG), and several Denomination of Controlled Origin (DOC) or Typical Geographical Indication (IGT) wines. The percentage of Sangiovese in these wines varies from a minimum of 50 % to a maximum of 100 %: Carmignano (50 %), Chianti (70-100 %), Nobile di Montepulciano (70 %), Chianti Classico (80-100 %), Morellino di Scansano (85 %), Montecucco (90 %), and Brunello di Montalcino (100 %). Tuscan wines have gained renown and appreciation in Italy and abroad as a result of marketing strategies aimed at the exploitation of Sangiovese (Gallenti and Cosmina, 2001). The genotype Sangiovese is highly plastic and highly responsive to the environment (Egger *et al*., 1996; Bandinelli *et al*. 2001; Bertuccioli *et al*., 2001; Giannetti *et al*., 2001), and in the delimited areas of Tuscany provinces it can express varietal potential in relation to a specific *terroir* (Brancadoro *et al*., 2006) through wines with peculiar sensory characteristics. Owing to Sangiovese's ability to take on the characteristics of the region, the climate and those imparted by the winemaker, wines made from this grape widely vary in taste and mouthfeel.

Astringency is one of the characteristics that mainly affect the sensory perception of red wine, and includes a wide range of sensations: drying, dynamic, harsh, unripe, particulate, surface smoothness, and complex (Gawel *et al*. 2001). Thirty-three different subqualities are used to describe the complex perception of astringency, due to a perceptual phenomenon involving tactile sensations, tastes and mouthfeel (Chen and Engelen, 2012). Red wine is also a complex matrix in which both basic components (pH, ethanol, sugars, polysaccharides; Lawless *et al.,* 1994; De Miglio and Pickering, 2008; Rinaldi *et al.,* 2012) and the occurrence of different amounts and typologies of proanthocyanidins (Vidal *et al.,* 2003) and flavonols (Hufnagel and Hofmann, 2008) can influence astringency. This may all explain why astringency is not easy to discern and requires experts or specially trained panels. In addition, the recognition and familiarization with subqualities are difficult tasks to master. Recently, a sensory method has been designed that combines the check-all-that-apply (CATA) question and training in astringency subqualities with touch-standards, which is used to investigate the astringency characteristics of red wines aged with enological tannins, including Sangiovese wine (Rinaldi and Moio, 2018). However, fewer studies have been carried out on the sensory characteristics of Sangiovese wines from Tuscany. Descriptive sensorial analysis revealed that the Sangiovese wines aged with different barrel aging techniques were described as either fruity, woody or spicy (Arfelli *et al.,* 2011): oak barrel aging led to vanilla, toasted, and spicy notes, and the chestnut barrel aging characteristics were more fruity (Castellari *et al.,* 2001). Wood descriptors have been considered the main sensory attributes that determined the experts' appreciation of the Sangiovese wine aroma quality. In the same manner, the Sangiovese wines preferred by consumers were those with the most intense wood and vanilla attributes (Torri *et al.,* 2013). However, an overall sensory evaluation has not yet made of the astringency subqualities of Tuscan Sangiovese wines from different denominations.

In this study, we evaluated the sensory characteristics of 16 Sangiovese wines produced in the Tuscany region from four denominations: Chianti DOCG (CH), Chianti Classico DOCG (CC), Morellino di Scansano DOCG (MS), and Toscana IGT (TS). The astringency subqualities, the taste, odor, and aroma profile of wines were evaluated by a trained and expert panel. The polyphenolic content and some volatile odor active compounds of the wines were also analyzed. The drivers of liking according to the mouthfeel of Sangiovese wines were also found. The wine sensory evaluations were repeated after 20 months of bottle aging to assess the evolution of the flavor.

MATERIALS AND METHODS

1. Reagents

Solvents of HPLC grade were purchased from Merck Millipore (Darmstadt, Germany). L(+)-tartaric acid, bovine serum albumin (BSA) and vanillin were from SIGMA Life Science (USA).

2. Tuscan Sangiovese wines

The Tuscan Sangiovese wines (variety number VIVC 10680), from the four denominations (Chianti DOCG (CH), Chianti Classico DOCG (CC), Morellino di Scansano DOCG (MS), and Toscana IGT (TS)) were all commercial wines

TABLE 1. The 16 Tuscan Sangiovese wines from four denominations.

Code	Tuscany Province	Denomination	Category	Vintage	% Sangiovese
MS1	Magliano in Toscana (GR)	Morellino di Scansano DOCG	MS	2014	85
MS2	Fonteblanda (GR)	Morellino di Scansano DOCG	MS	2014	85
MS3	Magliano (GR)	Morellino di Scansano DOCG	MS	2014	85
MS4	Grosseto (GR)	Morellino di Scansano DOCG	MS	2014	85
CC1	Castellina in Chianti (SI)	Chianti Classico DOCG	CC	2014	100
CC2	Greve in Chianti (FI)	Chianti Classico DOCG	CC	2014	100
CC3	Gaiole in Chianti (SI)	Chianti Classico DOCG	CC	2013	90
CC4	Gaiole in Chianti (SI)	Chianti Classico DOCG	CC	2015	80
TS1	Panzano in Chianti (FI)	Toscana IGT	TS	2013	100
TS2	Palaia (PI)	Toscana IGT	TS	2015	100
TS3	Greve in Chianti (FI)	Toscana IGT	TS	2015	100
TS4	Montalcino (FI)	Toscana IGT	TS	2015	100
CH1	Sovicille (SI)	Chianti Colli Senesi DOCG	CH	2015	100
CH2	Rufina (FI)	Chianti Rufina DOCG	CH	2014	80
CH3	Lastra a Signa (FI)	Chianti DOCG	CH	2015	80
CH4	San Gimignano (SI)	Chianti Colli Senesi DOCG	CH	2013	90

CH, Chianti DOCG; CC, Chianti Classico DOCG; MS, Morellino di Scansano DOCG; TS, Toscana IGT GR, Grosseto; SI, Siena; FI, Florence.

elaborated in three different provinces of the Tuscany region (Grosseto (GR), Siena (SI), and Florence (FI)), with different percentages of Sangiovese grapes (80-100 %), and from different vintages (2013-2015), as shown in Table 1.

3. Analyses

Wines were analyzed according to the OIV Compendium of International Methods of Wine and Must Analysis (OIV, 2007). All spectrophotometric determinations were performed using a Shimadzu UV-1800 spectrophotometer. Wine color intensity (CI) and hue were analyzed by the method from Glories (1984). Flavans reactive to vanillin (VRF) were determined according to Di Stefano and Guidoni (1989). Total anthocyanins, long polymeric pigments (LPP), short polymeric pigments (SPP), BSA-reactive tannins (BSA-rt), and total phenolics were determined by the method from Habertson *et al.* (2003). Volatile compounds were analyzed by SARCO laboratory (Bordeaux, France). The thiolic compounds 3MH and 3MHA were quantified by mass gas chromatography (GC-MS) according to Tominaga *et al.* (1998) and other volatile compounds were separated by HS-SPME extraction and quantified by mass gas chromatography (GC-MS) according to Antalick *et al.* (2010). All analyses were made in triplicate.

4. Wine evaluation

A panel composed of 13 judges from the Division of Sciences of Vine and Wine, Department of Agriculture, University of Naples Federico II, in Avellino (Italy), participated at wine evaluation sessions; they were experts in odor and aroma evaluation and trained for astringency and mouthfeel sensations (Rinaldi and Moio, 2018). The panel was composed of five women (age 35-50 years) and eight men (age 25-44 years). Tuscan Sangiovese wines were evaluated in duplicate. Each session comprised of two tasting evaluations of four unknown samples. These were presented in balanced random order at room temperature (18 ± 2 °C) in black tulip-shaped glasses coded with three-digit random numbers. The panel evaluated the odor (-OD) and aroma (-AR) (fruity-, floral-, spicy-, balsamic-, herbaceous-, woody-) profile according to a five-point scale. The in-mouthfeel sensations were evaluated using the method described in Rinaldi and Moio (2018). After rating the overall astringency (maximum of the perceived intensity), the judges used the CATA question with the 16 terms describing astringency subqualities (*silk*, *velvet*, *dry*, *corduroy*, *adhesive*, *aggressive*, *hard*, *soft*, *mouthcoat*, *rich*, *full-body*, *green*, *grainy*, *satin*, *pucker*, *persistent*), checked the subqualities if present, and then rated the intensity of the sensation (rate-all-that-apply, RATA). The judges were also asked to express their personal liking of the Tuscan Sangiovese wines according to in-mouth sensations using a five-point hedonic scale.

5. Data analysis

Correspondence analysis (CA) was performed on the contingency table containing the average citation frequency of terms. The average score of astringency subqualities grouped for percentage (%) of Sangiovese in wine was projected as an illustrative variable in the CA map. CA and principal component analysis (PCA) were carried out using XLSTAT software (Addinsoft, XLSTAT 2017). Drivers of liking were evaluated using Pearson's correlation coefficients between the standardized CA residuals of attributes and liking scores. Multiple factor analysis (MFA) was performed using the FactoMineR (Lê *et al.*, 2008) package.

RESULTS

1. The astringency subqualities of Tuscan Sangiovese wines

1.1. The astringency subqualities according to Sangiovese percentage (%)

An evaluation of the astringency subqualities of Tuscan Sangiovese wines was made for the first time using a sensory method that combined the training for astringency subqualities and the CATA question (Rinaldi and Moio, 2018). Vintage had no significant effect on the perception of astringency subqualities ($p > 0.05$), but the percentage of Sangiovese did. Independent from vintage, the percentage of Sangiovese influenced the perception of astringency. Citation frequencies of the 16 subqualities included in the CATA question were organized in a contingency table and correspondence analysis (CA) was applied to visualize the relationships between astringency subqualities and wines categorized for Sangiovese percentage (Figure 1).

The first and second dimensions of the CA explained 82.47 % of total inertia and allowed a clear separation between the wines made up with 90 % and 100 %, from 80 % and 85 % of Sangiovese grapes. The first dimension (F1 = 59.99 %) comprised the projected wines with 100 % and 90 % of Sangiovese. Wines made with 100 % of Sangiovese were considered by the judges to be *hard*, *aggressive*, *pucker*, and *persistent*, revealing that these sensations are long-lasting in the mouth. The 90 % Sangiovese wines were mainly characterized by the terms *dry* and *green* (astringent and acid). On the opposite dimensions of the CA the wines made with 85 % and 80 % of Sangiovese had different positive subqualities. The terms *mouthcoat* and *silk* highly characterized the wines with 85 % Sangiovese, while *full-body* and *rich* were associated with 80 % Sangiovese. The astringency characteristics revealed the tannins as *silk*, *soft*, *mouthcoat* and *satin* in 85 % Sangiovese wines, while velvet tannins and full-body sensations plus a richness in aroma highly represented the 80 % Sangiovese wines.

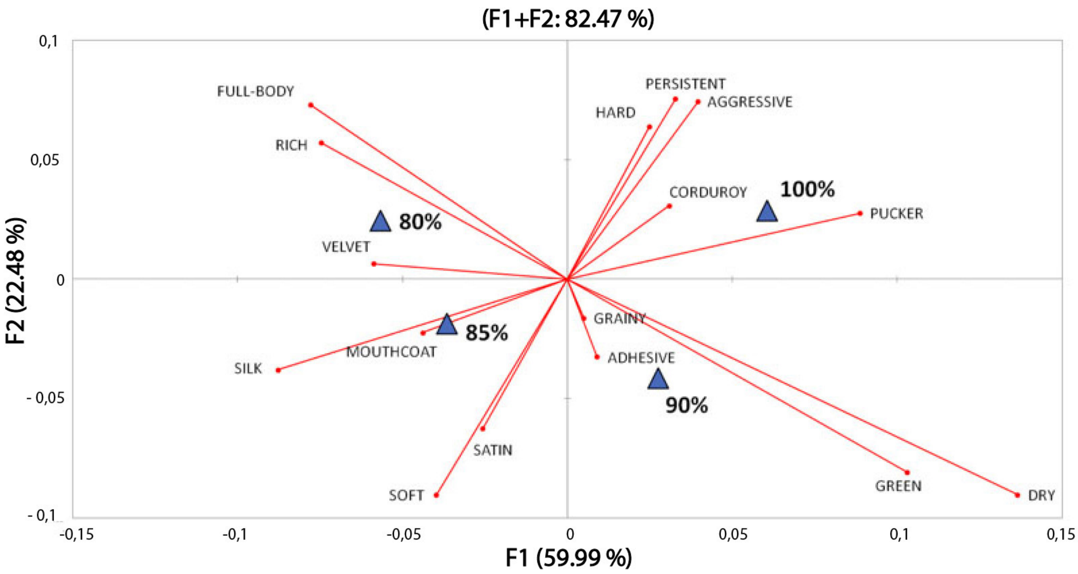

FIGURE 1. The astringency subqualities according to Sangiovese percentage (%).
Correspondence analysis performed on the average citation frequencies of the astringency subqualities included in the check-all-that-apply question and grouped for Sangiovese percentage (%).

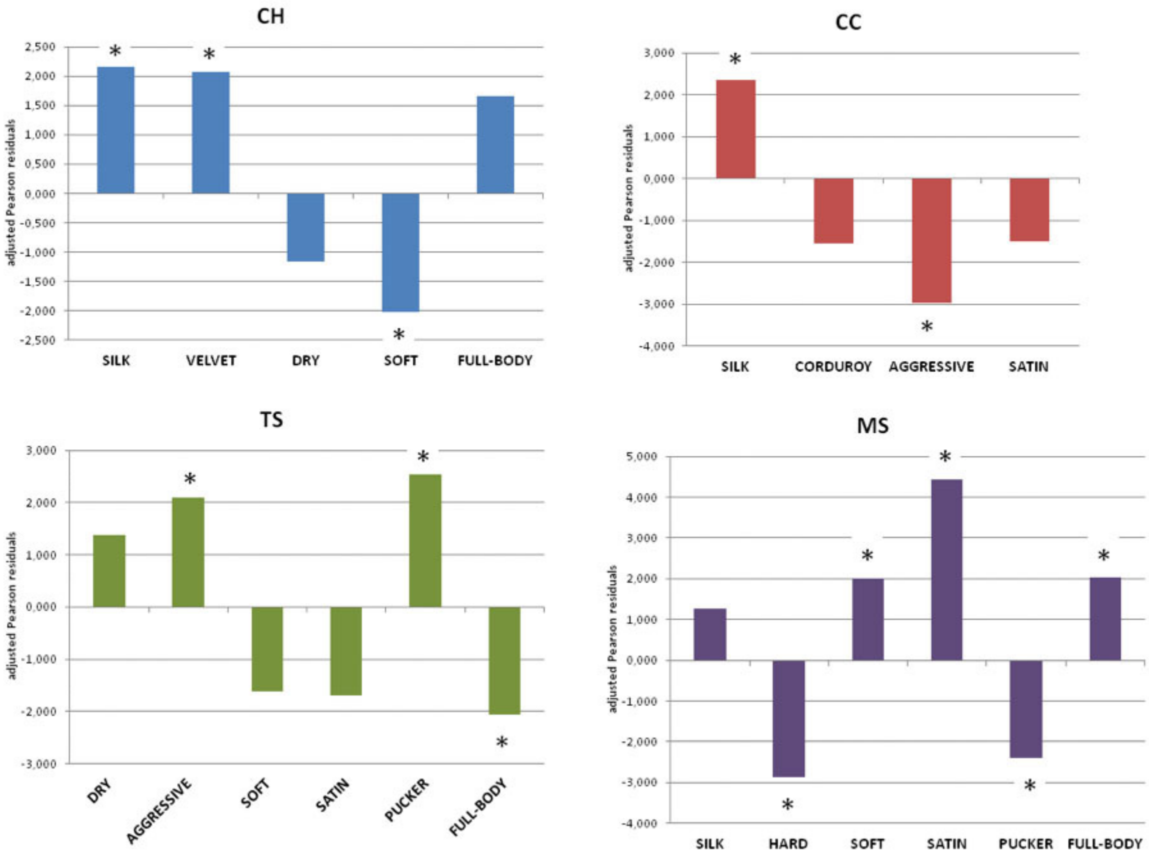

FIGURE 2. The astringency subqualities according to Sangiovese denomination.
The main astringency subqualities of each Sangiovese denomination expressed as adjusted Pearson residuals obtained from the chi-squared test (*significant at $p < 0.05$). CH, Chianti; CC, Chianti Classico; MS, Morellino di Scansano; TS, Toscana.

1.2. The astringency subqualities according to Sangiovese denomination

In order to identify the astringency subqualities that may characterize each denomination (CH, CC, TS, MS), the chi-squared test ($\alpha = 0.05$; $p < 0.001$) was applied to the contingency table of the average citation frequency of wine astringency subqualities. In Figure 2, the adjusted Pearson residuals (aPr) revealed the main associations (aPr > ±1) between the astringency subqualities and Sangiovese wines of each denomination, which represented the possible combination observed significantly more (or less) than expected (*significant when aPr > |critical value| at $p < 0.05$).

The Chianti (CH) wine can be significantly ($p < 0.05$) associated with *satin* and *velvet* subqualities and negatively with *soft*, and tends to be *full-bodied* and not *dry*. In the same way, Chianti Classico (CC) wine can be positively associated with *silk* and negatively with *aggressive* terms, and a tendency to be not *satin* and *corduroy* was observed. The astringency of Toscana wines (TS) was mainly characterized by the negative terms *aggressive*, *pucker*, and *dry*, and was not associated with positive terms like *soft*, *satin* and *full-body*. The Morellino di Scansano (MS) wine, instead, was significantly associated with *satin*, *soft* and *full-bodied*, and negatively with *hard* (astringent and bitter) and *pucker*.

During tasting of Sangiovese wines, judges were asked to express their personal liking related to the mouthfeel sensations perceived. Drivers of liking were identified using Pearson's correlation coefficients between the standardized CA residuals and liking scores, indicating that subqualities such as *mouthcoat* (0.74, $p = 0.001$), *soft* (0.69, $p = 0.003$), and *rich* (0.62, $p = 0.011$) positively influenced the liking of Tuscan Sangiovese wines, while the sensation of *corduroy* (-0.72, $p = 0.002$) was negatively correlated, and adversely affected appreciation. This means that a Sangiovese wine with a balanced astringency characterized by a soft and mouthcoating tannin and with a high richness in aroma compounds was highly appreciated by the panelists.

The different mouthfeel sensations that a red wine can elicit during tasting (Gawel *et al.*, 2001) can widely vary depending on several factors, including wine matrix (Demiglio and Pickering, 2008; Laguna *et al.*, 2017) and polyphenols (Gonzalo-Diago *et al.*, 2013), and those involving perception of aroma compounds (Ferrer-Gallego *et al.*,2014) and tastes (Brannan *et al.*, 2001).

2. General composition of Tuscan Sangiovese wines

Chemical analyses were also carried out, including base parameters, polyphenols, volatile compounds. The general composition of wines was shown in Table 2, reporting the minimum, maximum, and mean of basic, polyphenolic and volatile analyses of Sangiovese wines.

The alcohol content ranges from 12.3 to 15.1 % v/v, showing the high variability in alcoholic degree of Sangiovese wine. The residual sugars were around 2 g/L, the pH ranged from 3.31 to 3.75, and the tritatable acidity was around 5.4 g/L of tartaric acid for wines of all categories. A great heterogeneity of composition characterized Sangiovese wines for polyphenolic classes and, given the high difference between the minimum and maximum values, no statistical differences were found ($p > 0.05$). The denomination with the maximum value of color intensity (CI) was TS, while MS showed the maximum value in total anthocyanins, SPP, and total phenolics. TS, made with 100 % Sangiovese grapes, showed also a high content of flavans (VRF) at around 3 g/L, and BSA-reactive tannins (BSA-rt) at around 1400 mg/L. The volatile analysis showed a high content of the 3-mercapto-1-hexanol (3MH) over the analyzed volatile compounds, revealing a strong impact of varietal thiols on the aroma of Sangiovese wine. The concentration levels found for the two thiols 3MH and 3-mercaptohexan-1-ol acetate (3MHA) are in the same order of magnitude as those reported by others in Bordeaux red wines (Bouchilloux *et al.,* 1998), acting as enhancers of the fruity aroma perception. The highest concentration of 3MH was found in a CC Sangiovese wine (592 ng/L), while the 3MH4 was very variable within wines of the same denomination, but similar in mean between denominations and not present in MS. The 2-phenylethanol concentration showed similar ranges between categories. In addition, the other volatile compounds did not differ between denominations.

TABLE 2. Analyses of base parameters, polyphenols, and volatile compounds of Tuscan Sangiovese wines.

		Chianti Classico (CC)			Chianti (CH)			Toscana (TS)			Morellino Scansano (MS)		
	Analysis	Min	Max	*Mean*	Min	Max	*Mean*	Min	Max	*Mean*	Min	Max	*Mean*
Base parameters	Alcohol (% v/v)	13.0	14.4	*13.6*	12.3	13.8	*12.9*	12.9	15.1	*14.4*	13.3	13.9	*13.6*
	Residual sugars (g/L)	1.4	4.1	*2.1*	1.4	3.8	*2.3*	1.1	2.4	*1.7*	1.4	3.6	*2.2*
	pH	3.31	3.45	*3.38*	3.46	3.62	*3.55*	3.33	3.75	*3.6*	3.44	3.62	*3.54*
	Tritatable acidity (g/L tartaric acid)	3.81	6.04	*5.49*	5.08	5.63	*5.35*	4.61	5.98	*5.34*	5.09	5.58	*5.40*
	Volatile acidity (g/L acetic acid)	0.45	0.61	*0.53*	0.43	0.62	*0.50*	0.33	0.59	*0.49*	0.41	0.62	*0.54*
	Free SO_2 (mg/L)	0.0	19	*13*	6.0	24	*13.5*	0.0	19	*8.4*	10	19	*14.8*
	Total SO_2 (mg/L)	30	85	*66.8*	43	106	*64.0*	13	89	*41.4*	58	77	*70.3*
Polyphenols[a]	CI	5.38	9.25	*7.22*	4.85	6.91	*6.12*	6.02	13.26	*9.23*	4.85	9.56	*7.50*
	Hue	0.73	1.07	*0.95*	0.81	0.89	*0.86*	0.72	0.99	*0.87*	0.81	1.03	*0.90*
	Total anthocyanins	78	431	*181*	90	193	*151*	150	332	*238*	90	652	*269*
	SPP	0.98	3.73	*2.63*	0.84	4.20	*2.62*	1.03	4.46	*2.62*	2.42	5.48	*3.92*
	LPP	0.0	4.75	*1.39*	0.0	5.76	*1.85*	0.0	2.74	*0.89*	0.0	5.63	*1.47*
	Total phenolics	185	469	*373*	212	491	*299*	184	553	*297*	217	554	*404*
	VRF	677	1222	*955*	939	1493	*1201*	1152	3154	*2027*	677	2831	*1605*
	BSA-rt	246	456	*334*	261	575	*425*	428	1414	*816*	266	594	*455*
Volatile compounds	3-mercapto-1-hexanol (3MH) (ng/L)	376	592	*506*	294	467	*372.2*	257	522	*438.6*	243	476	*370*
	3-mercaptohexan-1-ol acetate (3MHA) (ng/L)	0.0	7.0	*4.4*	0.0	13	*4.3*	0.0	7.0	*4.6*	-	-	-
	2-phenylethanol (mg/L)	48	76	*61.8*	34	68	*55*	59	76	*67.2*	54	63	*59*
	Isoamyl acetate (mg/L)	0.6	0.9	*0.8*	0.7	1.4	*1.0*	1.0	2.5	*1.4*	0.5	1.6	*1.0*
	Ethyl butanoate (mg/L)	0.2	0.4	*0.3*	0.2	0.3	*0.3*	0.3	0.3	*0.3*	0.2	0.3	*0.3*
	Ethyl hexanoate (mg/L)	0.6	1.2	*0.9*	0.6	1.0	*0.8*	0.4	1	*0.8*	0.6	1	*0.8*
	Ethyl octanoate (mg/L)	2.1	3.3	*2.8*	2.2	3.6	*2.7*	2.5	5	*3.1*	1.5	3.3	*2.5*
	Ethyl decanoate (mg/L)	0.2	0.7	*0.5*	0.4	0.5	*0.4*	0.4	0.8	*0.6*	0.2	0.7	*0.5*
	Ethyl propanoate (mg/L)	0.4	0.6	*0.5*	0.4	0.5	*0.4*	0.4	0.6	*0.5*	0.4	0.5	*0.5*
	Ethyl 2-methylpropanoate (mg/L)	0.5	0.6	*0.6*	0.3	0.6	*0.5*	0.2	0.7	*0.4*	0.3	0.6	*0.5*
	Ethyl 2-methylbutanoate (mg/L)	0.1	0.2	*0.1*	0.1	0.2	*0.1*	0.0	0.1	*0.1*	0.0	0.1	*0.1*

[a]Anthocyanins are expressed as mg/L of malvidin-3-glucoside equivalent. Color intensity (CI) is the sum of 420, 520, 620 Abs. Hue is the 420/520 Abs ratio. SPP and LPP are expressed as 520 Abs. Vanillin reactive flavans (VRF) are expressed as mg/L. BSA-reactive tannins (BSA-rt) are expressed in mg/L of catechin equivalent.

3. Sensory differences of Tuscan Sangiovese wines by denomination

The overall sensory analysis of Sangiovese wines, including astringency intensity, taste, aroma and odor characteristics was also performed by the trained expert jury. In order to reveal if volatile compounds can contribute to in-mouth sensory characteristics of Tuscan Sangiovese wines, MFA was performed to consider six groups of sensory variables: "astringency" (astringency intensity); "tastes" (sweet, acid, bitter, sapid); "aroma" (floralAR, fruityAR, spicyAR, herbaceousAR, balsamicAR, woodyAR); "odor" (floralOD, fruityOD, spicyOD, herbaceousOD, balsamicOD, woodyOD); the continuous variable "volatiles"; and the categorical variable "denomination" (CC, CH, TS, MS). Considering these data, multivariate statistics made it possible to categorize wines according to designation as shown in Figure 3.

In Figure 3, the correlation circle showed the relationships between variables, and the correlation between variable and the dimensions; the individual factor map revealed the Sangiovese wines grouped for denomination; and the group representation revealed the correlation between group of variables. In the first dimension (Dim1) ($p < 0.05$) the variables herbaceous OD, floralOD, herbaceousAR, bitter and astringent were positively projected, correlated with TS wines. Sapid and fruityAR were negatively correlated with Dim1, on which the MS category was projected. The second dimension (Dim2) was positively correlated with balsamicOD, 3MH, and woodyAR, which characterized CC wines, while spicyAR and woodyOD characterized the CH denomination. The variable "designation" was highly correlated with the "volatiles" one, projected on Dim2. According to this, wines differed mainly

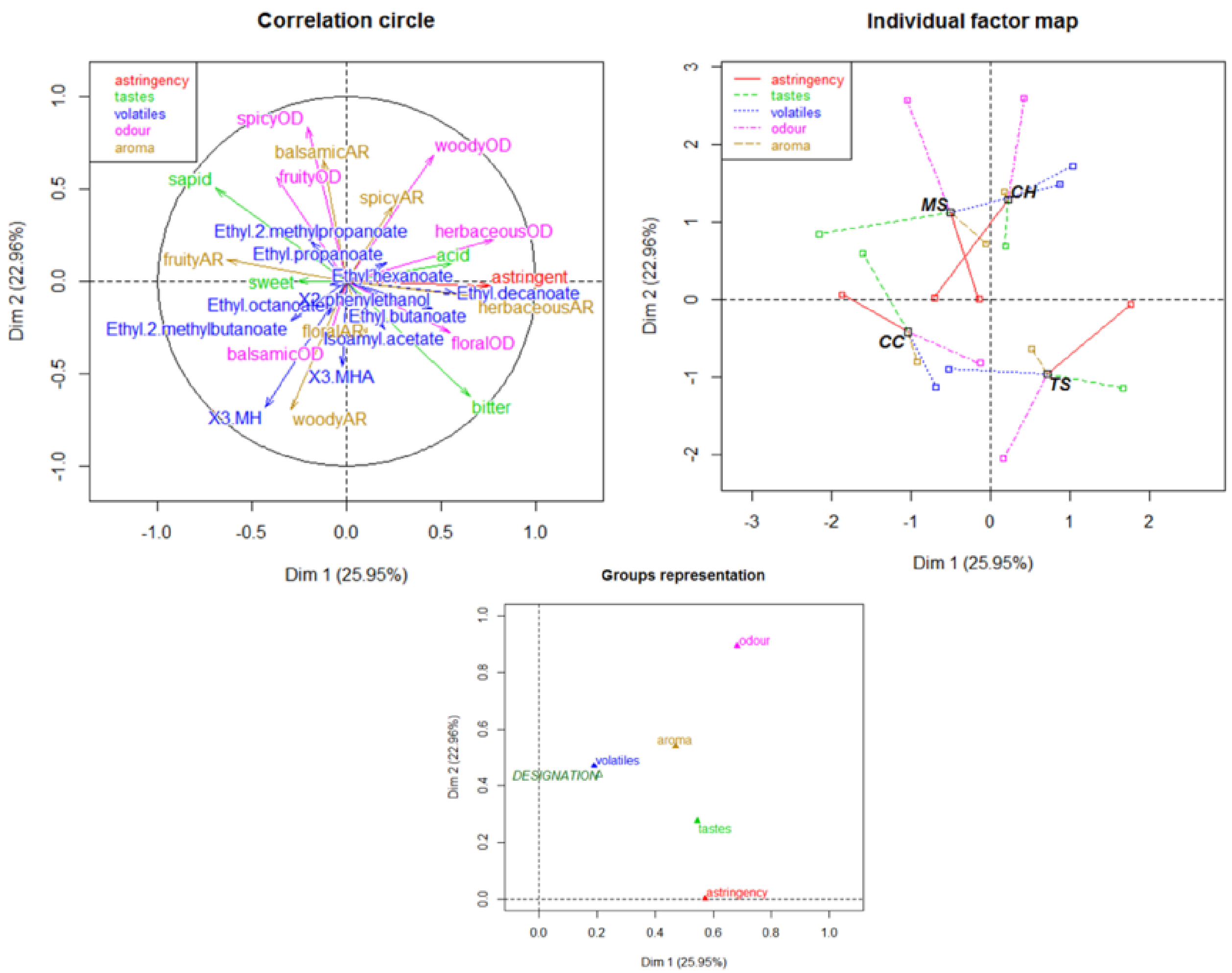

FIGURE 3. Sensory differences of Tuscan Sangiovese wines by denomination.

Representation of the correlation circle, the individual factor map, and the group representation variables on the first two dimensions of the multiple factor analysis performed on sensory data (astringency, taste, odor, aroma), and the volatile compounds of Tuscan Sangiovese wines grouped for designation (CH, Chianti; CC, Chianti Classico; MS, Morellino di Scansano; TS, Toscana).

for volatile compounds. It was possible to assign sensory properties to the different categories by MFA. Chianti Classico (CC) was highly characterized by the varietal thiol 3MH and by the ethyl-2 methylbutanoate ester, by a balsamic (pot herbs) odor, woody and floral aroma and basically a sweet taste. Toscana (TS) was astringent and highly bitter in accordance with the higher values of BSA-rt and flavans, nevertheless this category resulted in a tasting characterized by a herbaceous, floral aroma and by a floral odor, as also indicated by the higher concentrations of ethyl decanoate and 2-phenylethanol. Chianti (CH) showed a woody odor with cherry (ethyl propanoate) and green apple (ethyl hexanoate) notes. The aroma of CH was mainly spicy. The Morellino di Scansano (MS) was characterized mostly by the ethyl 2-methylpropanote (strawberry), fruity and spicy in odor, and fruity and balsamic in aroma, sapid in taste. "Volatiles" was the variable that better differentiated Sangiovese wines, accounting for 49 % of total variance. The floral odor, which was due to the high content in 2-phenylethanol, seemed to differentiate the Toscana wines from the others Sangiovese designations. In addition, the thiolic compound 3MH was able to discriminate CC and CS, which resulted mainly in fruity aroma compounds. However, due to the limited number of analyzed wines, further studies are necessary to evaluate the incidence of these compounds on the fruity and floral aroma of Sangiovese wines.

4. Effect of bottle aging on Sangiovese wine perception

The sensory perception of the same Tuscan wines was carried out after 20 months of bottle aging by evaluating the odor, aroma, taste, astringency intensity, and subqualities (RATA). Only the variables significantly correlated ($p < 0.05$) were loaded in PCA, together with "denomination" (CC, CH, TS, MS) as supplementary variable, as shown in Figure 4.

Principal component analysis (PCA) on significant sensory attributes of Tuscan Sangiovese wines after 20 months of bottle aging. Intensity of astringency, astringency subqualities (*dry, adhesive, corduroy, hard, pucker, rich, soft velvet*), odor (-OD) and aroma (-AR) (fruity-, floral-, spicy-, balsamic-, woody-, oxidized-) tastes (acid, bitter) were the active variables, and denomination

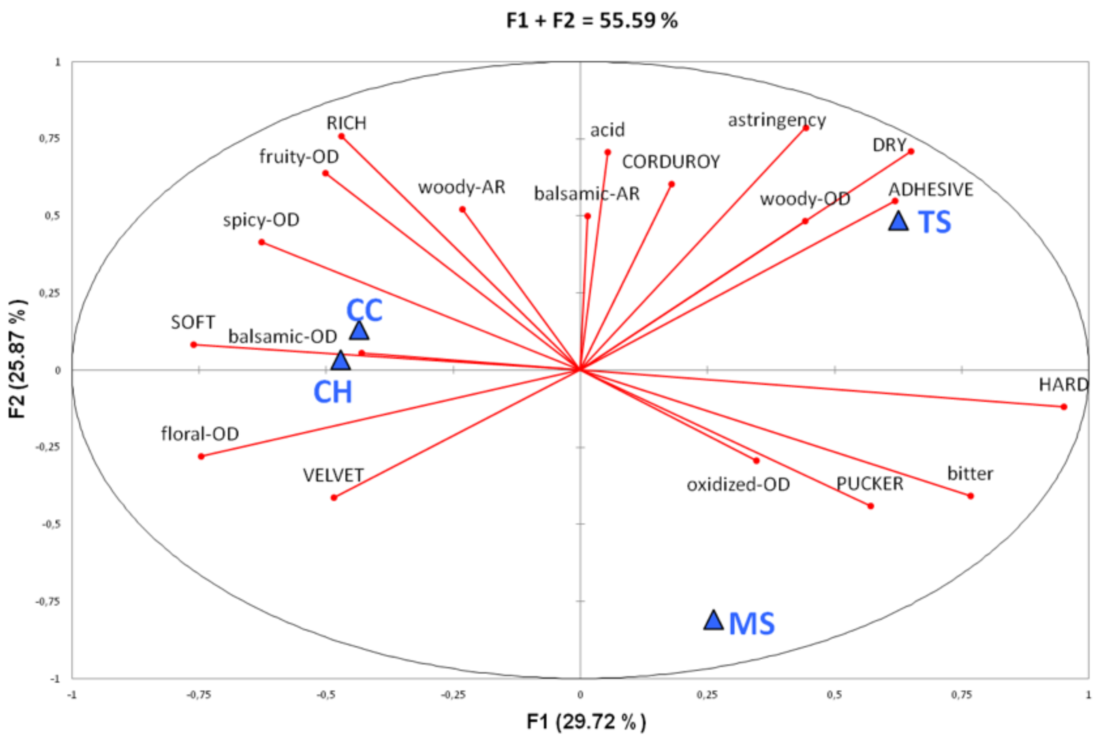

FIGURE 4. Effect of bottle aging on Sangiovese wine perception.
Principal component analysis (PCA) on significant sensory attributes of Tuscan Sangiovese wines after 20 months of bottle aging. Intensity of astringency, astringency subqualities (dry, adhesive, corduroy, hard, pucker, rich, soft, velvet), odor (-OD) and aroma (-AR) (fruity-, floral-, spicy-, balsamic-, woody-, oxidized-) tastes (acid, bitter) were the active variables, and denomination. (Chianti DOCG, CH; Chianti Classico DOCG, CC; Morellino di Scansano DOCG, MS; Toscana IGT, TS) was the supplementary variable.

(Chianti DOCG, CH; Chianti Classico DOCG, CC; Morellino di Scansano DOCG, MS; Toscana IGT, TS) was the supplementary variable.

The two dimensions explained the 55.59 % total variance, which allowed for the categorization of the four denominations. CH and CC were grouped together and mainly differentiated from the others for *soft*, *velvet* and *rich* tannins, with floral, fruity, balsamic and spicy odors and woody aroma. TS wines were highly astringent, characterized by *dry* and *adhesive* subqualities, bitter (*hard*) and with a woody odor. The MS category changed considerably during bottle aging, losing the fruitiness and pleasant aromas which in turn were replaced by odor defects due to oxidation, also associated with an increase in bitterness and *pucker* sensations.

DISCUSSION

Sangiovese represents with its denominations and styles the best-known and high-quality Italian wine in the world. Tuscan Sangiovese wines are often a blend with other red grape varieties of the region, and these can vary according to the production disciplinary of denomination. Very little is known about the sensory characteristics of Sangiovese wines from different denominations and made with different percentages of this grape cultivar. The percentage of Sangiovese had a significant effect on the perception of astringency subqualities of Tuscan wines. Wines obtained with 100 % of Sangiovese grapes were astringent and bitter (*hard*), *aggressive* and *pucker*, but it is also true that this wine typology requires a long aging period and time to fully develop. Conversely, the blend versions of Sangiovese (80-85 %) represented a perfect combination of soft tannins, aroma richness and full-body sensations. Likewise, the most significant drivers of liking for Tuscan Sangiovese wines were related to soft, rich, and mouthcoating tannins, highly appreciated by the expert judges. Wines that are full-bodied and more intense in flavor were highly appreciated by consumers (Niimi *et al.,* 2017).

For the chemical composition, the occurrence of the varietal thiol 3MH enhanced the complexity of the CC Sangiovese flavor. These wines were particularly intense at odor with balsamic notes and a woody aroma. The Chianti (CH) showed a spicy aroma, and significantly differed from the Chianti Classico (CC). In the Toscana denomination, the percentage of Sangiovese can vary from 70 to 100 %; in this study the wines that were all 100 % Sangiovese resulted in the most astringent and bitter, with a herbaceous aroma and a floral odor, highly correlated with ethyl decanoate and 2-phenylethanol compounds. The Morellino di Scansano (MS) was characterized by a high sapidity, and fruity aroma.

However, after around two years of bottle aging the sensory profile greatly differed, especially for MS that lost the fruity character to an odor defect due to oxidation, associated with a bitter taste and a *puckering* sensation. It is likely that MS wines represent a typology of wine which should be drunk within two or three years of production. CC and CH became very similar at tasting, revealing a complex odor and interesting astringency subqualities; however TS remained highly astringent meaning that for 100 % Sangiovese wines, additional years of aging are required.

CONCLUSIONS

A detailed evaluation of the astringency subqualities of commercial Sangiovese wines was made here for the first time. Wines showed different subqualities according to the percentages of Sangiovese and denomination, which were associated with peculiar sensory characteristics. In particular, the occurrence of 3MH varietal thiol highly characterized the Chianti Classico. These results resolve an important query on the difference between Chianti and Chianti Classico, which are two distinct and separate DOCGs, with two different sets of production regulations, production zones and consortiums for the protection of the product. The volatile compounds variable could discriminate the wines with a chemical age of around one to three years according to denomination. After 20 months of bottle aging, the sensory characteristics of Sangiovese wines evolved so that CC and CH highly expressed their aromatic potential in a similar manner, while MS turned to oxidation, and TS was the less involved in the sensory modifications. Considering the aging effect, the astringency subqualities were more able to discriminate wines with a chemical age of three to five years than other variables. Further studies on Sangiovese will be carried out to better investigate the sensory characteristics of one of the best-known and high-quality Italian wine in the world.

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