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Research Article

Physicochemical and Sensory Characterization of Malvasia Wines from Different Mediterranean Areas

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The identity of different Mediterranean Malvasia wines from Lipari (Aeolian Islands), Sardinia, Crete, and the Canaries by correlating sensory attributes with physicochemical parameters was determined. The Malvasia wines from Lipari had a wide and harmonic aromatic profile with floral, fruity, and exotic fruit aromas in addition to honey, fruit, and raisin flavors. The similarity of sensory characteristics between the Lipari and Crete samples may have originated from the geographic proximity and from the frequent cultural exchanges between Southern Italy and Greece. The Sardinian Malvasia wines had their own identity based on the prevailing citrus aroma, wood aroma and flavor, high alcohol content, and distinctive color parameters. The Canary Malvasia wine was characterized by high clearness and acidity without particular aromatic attributes.

1. Introduction

The old presence of vines in the Aeolian Islands is due to the colonization from Cnidus (Greece 588 B.C.), where sweet and aromatic wines were produced. Although many claim that the varieties found in the Aeolian Islands are Malvasia and Corinto Nero wines, it is difficult to demonstrate [1]. The diffusion of these vines in the entire Mediterranean area began when the Venetian ship owners, returning from the Fourth Crusade (1202), spread the Malvasia cultivar grown in Greece in Dalmatia, Istria, France, Spain, Balearic Islands, Corsica, and Sardinia. Consequently, differentiation of the wines occurred due to the different pedoclimatic and technological conditions [2].

Among the Sicilian Islands, Lipari and Salina in the Archipelago of the Eolies are dedicated to viticulture, contributing to the Malvasia wine production. The Denomination of Controlled Origin (DOC) "Malvasia of Lipari" [3] is produced in three typologies (natural, sweet, and liqueur) and is considered the most pleasant wine to combine with Sicilian confections among the dessert wines of Southern Italy. The sweet typology, called "passito," is a wine obtained from a blend of Malvasia of Lipari (95%) and Corinto Nero (5%–8%) grapes with an alcohol content of 20% (v/v). The grapes are generally harvested in September and exposed to sunlight on rush mats for approximately 10 to 15 days. The dehydration process increases the sugar content in the grapes to approximately 300 g/L. This type of wine is usually produced by natural fermentation induced by autochthonous yeasts and other components of the oenological microflora, which are the result of a natural selection developed by numerous factors linked to the environment (climate and soil), ripeness, local traditions, agronomic management, and winery practices [4]. The complex microbiology of this winemaking process determines typicality and it has a role in the characterization of the specific flavor pattern [5]. Sicilian Malvasia wines have high levels of natural phenolic compounds (stilbenes and flavonoids) that represent a potential preventive antioxidant factor [6].

Another wine product is the Malvasia of Bosa DOC, which is obtained from the Malvasia vines of Sardinia with a maximum tolerance of 5% for different vines in the vineyards. Sardinia has an old tradition in the wine industry and producers high-value wines from red and white grapes. The production of white wines is concentrated largely in the central and northern part of the island [7]. The traditional typology of this wine is characterized by an alcohol content higher than 15% and biological aging, similar to that of Spanish sherry and Italian Vernaccia of Oristano, in partially filled barrels (1/3 to 1/5 of the volume) for two to five years with the presence of flor yeasts including *Saccharomyces cerevisiae* and *Saccharomyces bayanus* species, which are able to colonize the wine surface forming a biofilm [8]. According to the DOC regulations, Malvasia wine has to be obtained using grapes from vines situated in the Sardinia area (Planargia). These aromatic berries completely ripen at the beginning of October. The wine-making process is traditionally performed with brief maceration to allow the aromatic compounds to diffuse in the must. Some wine constituents belonging to the fermentative stage (ethanol, glycerol, and acetic acid) are transformed by flor yeasts during the oxidative stage into volatile compounds (mostly acetals and esters), which confer unique characteristics to the wine.

The Malvasia wines elaborated in the Canary Islands were very important in the 14th century, and the Canary Islands are currently the first region of Spain in cultivated area of this variety. Malvasia wine production has extended to all of the islands within the Canaries starting at Lanzarote and La Palma and spreading to Tenerife [9].

This variety was harvested overripe in order to obtain a natural sweet wine [10]. The wine-making industry in the Canary Islands is rapidly growing and has two peculiarities. Firstly, the climate is different from the Mediterranean climate in which the vines were first grown [11]. Secondly, the Canaries are a group of islands, which has permitted the conservation of some grape varieties introduced from Europe prior to the phylloxera epidemic. The new configuration of the high-quality parameters found in the vine growing and wine sector in the Canary Islands and the ecological and socioeconomic importance of this agricultural subsector demand considerable knowledge. Moreover, the application of this knowledge to vine growing is important for the oenological and marketing potential of wine made with the malmsey grape variety.

In literature, there are no researches regarding the Malvasia of Crete. The island of Crete (Greece) is located in the southeastern part of the Mediterranean region. Agriculture is an important source of income for the region of Crete, and in particular grapevines are also important sources of income for farmers. Grapevines cover 8.9% of the total cultivated area [12].

With regard to Malvasia wines, many studies have been carried out including studies focusing on postharvest drying in dehydration rooms [13], phenolic compounds [14], and the interesting aromatic components in these wines obtained by the modern production techniques [10, 15–17]. Few researchers have considered the sensory characteristics that determine the identity of Malvasia wines with different geographic origins, unlike other wines such as Riesling wines [18], Sauvignon blanc wines [19], or Malbec wines [20]. The information reported in the literature on Malvasia delle Lipari wine are limited: Lanza et al. [21] and Muratore et al. [22] have reported a first research on sensory characteristic, while a successive research has characterized this wine determining the aromatic volatile compounds and the sensory profile and then correlating these data [23]. This study aimed to further contribute to the creation of an improved sensory profile for 21 Malvasia wines from the Mediterranean area and to develop appropriate sensory terminologies that are more descriptive than the few sensory descriptors established in the Malvasia DOC disciplinary (color yellow golden-amber, characteristic odor, and sweet taste reported for the Malvasia delle Lipari) by correlating the descriptors to physicochemical parameters: pH, alcohol content, titratable acidity, volatile acidity, reducing sugars, and CIELAB parameters (L^*, a^*, and b^*).

2. Materials and Methods

2.1. Wine Samples. The samples were provided by the wineries. The following 21 commercial samples of Malvasia DOC wines were collected and analyzed in triplicate: 10 from Salina in the Aeolian Islands (from L1 to L10), 6 from Sardinia (from S1 to S6), 3 from Crete (Cr1, Cr2, and Cr3), and 2 from the Canaries (Ca1 and Ca2), which were stored in the winery of the department (12–16°C, UR 60–70%). The harvest year of wine samples L2, L3, L4, L6, L9, S2, S3, S5, Cr1, and Ca1 was 2015, while for the other wine samples it was 2016. The different number of samples among the geographical areas studied was due to the limited number of producers, resulting in difficulty in obtaining wine samples.

2.2. Physicochemical Analyses. Ethanol content, titratable acidity, volatile acidity, reducing sugars, and pH were determined according to the official methods of the Office International de Vigne et du Vin [24]. The color of the wines was objectively assessed by tristimulus colorimetry from their transmittance spectra, according to procedures recommended by the International Commission on Illumination, updated in 1986. Within the uniform color space CIELAB, two color coordinates, a^* and b^*, as well as L^* are defined. The coordinate a^* takes positive values for reddish color and negative values for the greenish ones, while b^* takes positive values for yellowish color and negative values for the bluish ones. L^* is an approximate measure of lightness, which is the property that allows any color to be regarded as equivalent to a member of the grey scale, between black ($L = 100$) and white ($L = 0$). Color measurement was performed in a 1 mm path length coupling cuvette using a Varian Cary 1E Spectrophotometer (Varian Inc., Melbourne, Australia) equipped with Cary Color Calculation software to record the L^*, a^*, and b^* values. All analyses were performed in triplicate.

2.3. Sensory Analysis. In the present study, the sensory profile [25] was constructed using a panel of eight trained judges (three males and five females, 20–32 years old) who were students in the Di3A (Department of Agriculture, Food, and Environment) of the University of Catania (Italy). Judges were selected for experience with wine sensory education, availability, interest in the study, being nonsmokers, being regular wine drinkers, and being of good health. To train the judges [26] and to develop a common dictionary for the generation of the descriptors, the Malvasia samples

Table 1: Mean values and standard deviation of the physicochemical parameters.

Samples	pH	Titratable acidity (g/L tartaric ac.)	Volatile acidity (g/L acetic ac.)	Reducing sugar g/L	Alcohol content (vol. %)	L^*	a^*	b^*
L1	3.46 ± 0.04	0.56 ± 0.00	0.69 ± 0.03	41.87 ± 1.45	11.73 ± 0.00	96.84 ± 0.20	−4.06 ± 0.03	19.90 ± 0.01
L2	3.45 ± 0.06	0.49 ± 0.01	0.61 ± 0.04	88.03 ± 1.06	14.65 ± 0.00	90.61 ± 0.03	−0.18 ± 0.02	37.11 ± 0.04
L3	3.63 ± 0.06	0.57 ± 0.01	0.94 ± 0.05	54.79 ± 0.00	13.30 ± 0.00	94.53 ± 0.08	3.49 ± 0.03	23.91 ± 0.06
L4	3.40 ± 0.05	0.61 ± 0.00	0.48 ± 0.02	91.96 ± 0.00	19.84 ± 0.09	94.50 ± 0.02	−3.14 ± 0.02	24.69 ± 0.07
L5	4.10 ± 0.06	0.58 ± 0.01	1.28 ± 0.03	65.20 ± 1.17	14.29 ± 0.00	92.83 ± 0.04	3.96 ± 0.02	32.08 ± 0.01
L6	3.81 ± 0.01	0.49 ± 0.01	0.98 ± 0.07	20.52 ± 0.57	15.66 ± 0.37	96.21 ± 0.10	−4.54 ± 0.04	21.48 ± 0.00
L7	3.96 ± 0.01	0.61 ± 0.01	1.35 ± 0.07	93.64 ± 3.41	15.25 ± 0.42	85.13 ± 0.17	0.19 ± 0.08	49.14 ± 0.14
L8	3.39 ± 0.02	0.60 ± 0.02	0.93 ± 0.04	33.44 ± 0.43	10.36 ± 1.72	96.40 ± 0.00	−2.55 ± 0.16	15.80 ± 0.03
L9	3.77 ± 0.01	0.56 ± 0.02	0.79 ± 0.02	51.69 ± 2.53	14.00 ± 0.00	83.44 ± 0.19	0.05 ± 0.02	49.16 ± 0.38
L10	3.81 ± 0.00	0.49 ± 0.01	0.98 ± 0.06	20.53 ± 0.47	15.66 ± 0.30	96.21 ± 0.08	−4.54 ± 0.03	21.48 ± 0.00
S1	3.30 ± 0.05	0.59 ± 0.01	0.57 ± 0.01	23.41 ± 0.00	16.26 ± 0.33	96.50 ± 0.16	−3.15 ± 0.05	15.45 ± 0.05
S2	3.26 ± 0.01	0.59 ± 0.01	0.53 ± 0.00	10.51 ± 0.30	17.84 ± 0.61	82.94 ± 0.23	2.97 ± 0.12	49.73 ± 0.29
S3	3.28 ± 0.01	0.58 ± 0.00	0.54 ± 0.01	3.08 ± 0.03	17.28 ± 0.05	74.98 ± 0.07	2.53 ± 0.00	38.17 ± 0.15
S4	3.52 ± 0.02	0.52 ± 0.01	0.86 ± 0.02	3.87 ± 0.06	17.42 ± 0.19	91.90 ± 0.12	−2.96 ± 0.13	26.45 ± 0.04
S5	3.74 ± 0.01	0.50 ± 0.00	1.10 ± 0.02	6.48 ± 0.04	18.12 ± 0.14	65.31 ± 0.70	3.81 ± 0.03	38.69 ± 0.37
S6	3.42 ± 0.07	0.53 ± 0.01	0.73 ± 0.01	2.61 ± 0.03	14.98 ± 0.60	90.76 ± 0.12	−1.33 ± 0.06	34.07 ± 0.04
Cr1	3.70 ± 0.07	0.65 ± 0.00	1.00 ± 0.02	23.50 ± 0.05	15.50 ± 0.20	90.17 ± 0.50	−0.62 ± 0.04	33.16 ± 0.05
Cr2	3.65 ± 0.02	0.60 ± 0.02	1.03 ± 0.05	25.25 ± 1.30	16.40 ± 0.02	91.22 ± 0.15	−0.69 ± 0.01	32.20 ± 0.22
Cr3	3.60 ± 0.05	0.50 ± 0.00	1.10 ± 0.03	25.00 ± 0.07	16.00 ± 0.10	89.10 ± 0.07	−0.60 ± 0.15	33.13 ± 0.01
Ca1	3.30 ± 0.01	0.73 ± 0.01	0.70 ± 0.00	69.65 ± 1.54	12.50 ± 0.00	98.41 ± 0.35	−1.17 ± 0.20	5.34 ± 0.33
Ca2	3.34 ± 0.05	0.68 ± 0.02	0.50 ± 0.02	8.31 ± 0.00	12.30 ± 0.00	99.61 ± 0.96	−1.52 ± 0.08	5.51 ± 0.30

were evaluated three times (2 h) a week for four successive weeks (24 h). Reference standards were available to define descriptors and every term was described and explained to remove any doubt [27].

A list of descriptors was selected on the basis of occurrence (%) of the generated terms and the references for every attribute that corresponded to the maximum intensity of the nine-point intensity scale were also used [21].

The final set of descriptors consisted of 21 attributes as follows: 12 attributes for aroma (alcohol, floral, fruity, citrus, apricot, exotic fruit, stewed fruit, honey, yeasty, raisins, spicy, and woody), 2 attributes for taste (acid and sweet), 5 attributes for flavor (fruity, honey, raisins, spicy, and woody), 1 attribute for astringency, and 1 attribute for warm (referring to mouthfeel perception).

Each judge evaluated in twelve sessions six wines at a time using a nine-point scale to quantify the different descriptors. The evaluations were carried out from 11:00 AM to 12:00 AM in individual booths illuminated with white light. The wine samples (30 mL) were served at 22°C ± 1°C (room temperature) in three-digit coded ISO standard wine tasting glasses that were lidded with glass covers to avoid contamination of other samples and the tasting area. Water was provided for rinsing between wines. The order of presentation was randomized for each judge and in each session. All data were acquired by a direct computerized registration system (FIZZ, Biosystemes, ver. 2.00 M, Couternon, France).

2.4. Statistical Analysis. The physicochemical data were submitted to one-way analysis of variance (ANOVA). The sensory data for each attribute were submitted to ANOVA with the following effects: samples (S), judges (J), replications (R), and their respective interactions ($J \times S$, $S \times R$, and $J \times R$). ANOVA was utilized to analyze wine sensory and physicochemical data at the 5% level of significance ($p \leq 0.05$). Data analysis was carried out by statistic software STATGRAPHICS® *Centurion XVI* (Statpoint Technologies, Inc.).

Principal Component Analysis (PCA) was applied to the mean values of the sensory and physicochemical data using UNSCRAMBLER 9.8 (CAMO Software As, Norway).

3. Results and Discussion

The results of the physicochemical analyses are shown in Table 1. The analysis of variance (ANOVA) for the physicochemical data from the wine samples (data not reported) has shown significant differences ($p \leq 0.001$) for every considered physicochemical parameter among the samples. These results anticipate the differences between the samples analyzed, successively confirmed by sensory evaluation, showing a variability within the areas, minimal for Crete samples, probably due to their fewer number.

The analysis of variance for each sensory attribute has shown significant differences for all descriptors except for aroma spicy (Table 2). The F-values for the replications, $S \times R$ interaction and $J \times R$ interaction, were not significant for most of the attributes. These results indicated that the mean scores given by the panel for each attribute of Malvasia wines were satisfactory estimates of their sensory profiles.

Table 2: Influence of samples (21), judges (8), and replications (3) on the twenty-one descriptors of wine samples.

Descriptors	F values					
	Sample	Judge	Replication	$S \times J$	$S \times R$	$J \times R$
Aroma						
Alcohol	6.26^{***}	65.61^{***}	$0.61^{n.s.}$	2.98^{***}	$0.99^{n.s.}$	1.93^{*}
Floral	5.23^{***}	68.37^{***}	$2.06^{n.s.}$	3.28^{***}	$0.94^{n.s.}$	$1.13^{n.s.}$
Fruity	3.24^{***}	73.62^{***}	$0.86^{n.s.}$	2.42^{***}	$0.72^{n.s.}$	$1.00^{n.s.}$
Citrus	48.10^{***}	28.60^{***}	$0.07^{n.s.}$	3.34^{***}	$1.01^{n.s.}$	$1.23^{n.s.}$
Apricot	6.76^{***}	106.42^{***}	$0.74^{n.s.}$	2.88^{***}	$0.81^{n.s.}$	$0.86^{n.s.}$
Exotic fruit	6.31^{***}	67.95^{***}	$0.19^{n.s.}$	3.68^{***}	$0.82^{n.s.}$	$0.75^{n.s.}$
Stewed fruit	10.41^{***}	43.51^{***}	$0.01^{n.s.}$	3.19^{***}	$0.98^{n.s.}$	$1.71^{n.s.}$
Honey	9.33^{***}	96.72^{***}	$0.06^{n.s.}$	3.60^{***}	$1.29^{n.s.}$	$1.14^{n.s.}$
Yeasty	4.62^{***}	25.38^{***}	$0.03^{n.s.}$	2.79^{***}	$1.13^{n.s.}$	$0.84^{n.s.}$
Raisins	6.18^{***}	27.28^{***}	4.26^{*}	2.63^{***}	$1.00^{n.s.}$	$1.02^{n.s.}$
Spicy	$1.29^{n.s.}$	109.55^{***}	$0.70^{n.s.}$	3.09^{***}	$0.68^{n.s.}$	$1.16^{n.s.}$
Woody	4.53^{***}	64.15^{***}	$0.51^{n.s.}$	2.67^{***}	$1.33^{n.s.}$	$1.56^{n.s.}$
Taste						
Acid	9.18^{***}	38.63^{***}	$0.01^{n.s.}$	2.99^{***}	$0.97^{n.s.}$	$1.31^{n.s.}$
Sweet	16.35^{***}	35.49^{***}	$2.72^{n.s.}$	2.73^{***}	$1.03^{n.s.}$	$1.21^{n.s.}$
Mouthfeel						
Warm	9.97^{***}	42.95^{***}	$2.71^{n.s.}$	2.74^{***}	$1.20^{n.s.}$	$1.73^{n.s.}$
Astringent	13.39^{***}	30.57^{***}	4.54^{*}	3.05^{***}	$1.13^{n.s.}$	$1.63^{n.s.}$
Flavor						
Fruity	5.50^{***}	78.71^{***}	$0.01^{n.s.}$	2.69^{***}	$0.98^{n.s.}$	$0.30^{n.s.}$
Honey	9.98^{***}	101.64^{***}	$0.43^{n.s.}$	2.68^{***}	$1.01^{n.s.}$	$0.77^{n.s.}$
Raisins	8.90^{***}	35.90^{***}	$1.72^{n.s.}$	3.07^{***}	$1.11^{n.s.}$	$0.89^{n.s.}$
Spicy	1.72^{*}	110.30^{***}	$1.07^{n.s.}$	2.88^{***}	$1.22^{n.s.}$	$1.05^{n.s.}$
Woody	4.80^{***}	38.21^{***}	3.33^{*}	2.48^{***}	$1.09^{n.s.}$	$1.32^{n.s.}$

***Significant difference for $p \leq 0.001$; *significant difference for $p \leq 0.05$; superscript "n.s." indicates no significant difference.

To evaluate the correlations among the studied parameters, two PCA were carried out on the means of the significant sensory attributes and on the means of the physicochemical parameters.

Two multidimensional spaces (biplot) based on the sensory and physicochemical data were obtained.

Considering the biplot based on the sensory data (Figure 1), the variance explained by the first two principal components was 69%.

The first component (PC1), which explained 41% of the variance, divided the samples L6, L7, L8, L10, S1, S3, S4, S5, Ca1, and Ca2 from the other samples. Considering the first component (PC1), the Crete wines (Cr1, Cr2, and Cr3) and four Lipari wines (L3, L5, L9, and L10) were grouped on the right of the PC1 characterized by the following attributes: woody aroma and flavor, alcohol, exotic fruit, yeasty, caramel and citrus aromas, fruity flavor, and warm mouthfeel. The attributes fruity and exotic fruit are due to the high concentrations of acetate, ethyl, and isoamyl esters as reported by Scacco et al. [23].

The second component (PC2), which explained 28% of the variance, distinguished the Lipari wine; in fact the samples L1, L2, L5, L6, and L8 were grouped on the left of PCA, while the others were in the first and fourth quadrant. The second component distinguished the sample S1 from the other Sardinian wine samples.

The wines L7, L10, S3, S4, and S5 and the two samples of the Canaries were grouped in the fourth quadrant characterized by astringency and acid descriptors; these samples were negatively correlated with the sensory attributes.

Considering the biplot based on physicochemical data (Figure 2), the variance explained by the first two principal components was 98%.

The first PC explains 82% of the variance, but in particular the second PC that explains 16% of the variance distinguished the samples of Sardinia and Crete from the other samples, as well as differentiating the Ca1 sample from Ca2. The samples of Lipari are distributed in quadrants 1, 3, and 4.

The samples in the first quadrant were positively correlated to °Brix and b^* and negatively to L^*; the wine samples of the second quadrant were positively correlated to a^* and alcohol content and negatively to all the other parameters. The Malvasia samples of the third quadrant are negatively correlated to all physicochemical parameters, while those

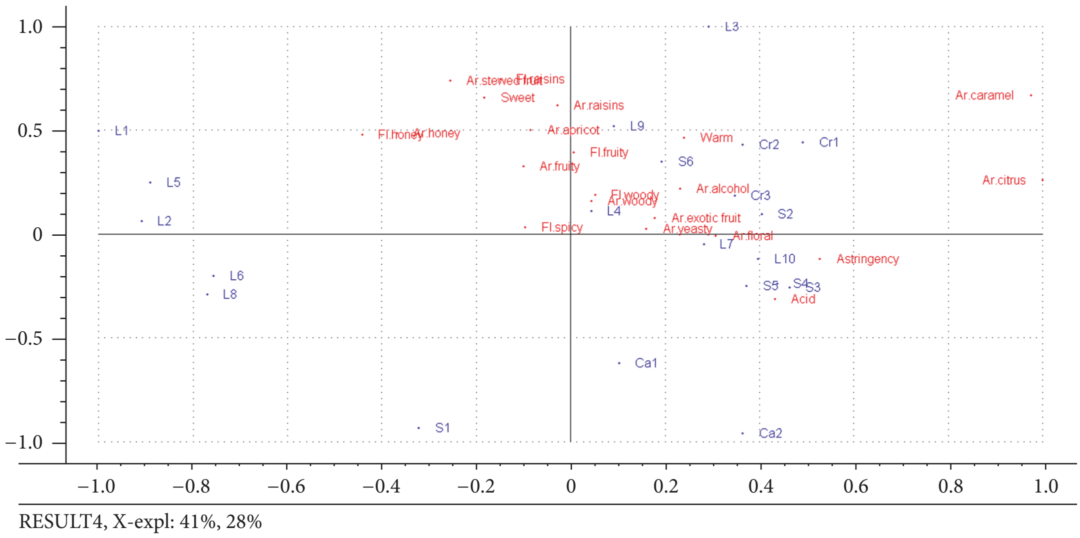

Figure 1: Biplot of wine samples and the significant sensory descriptors.

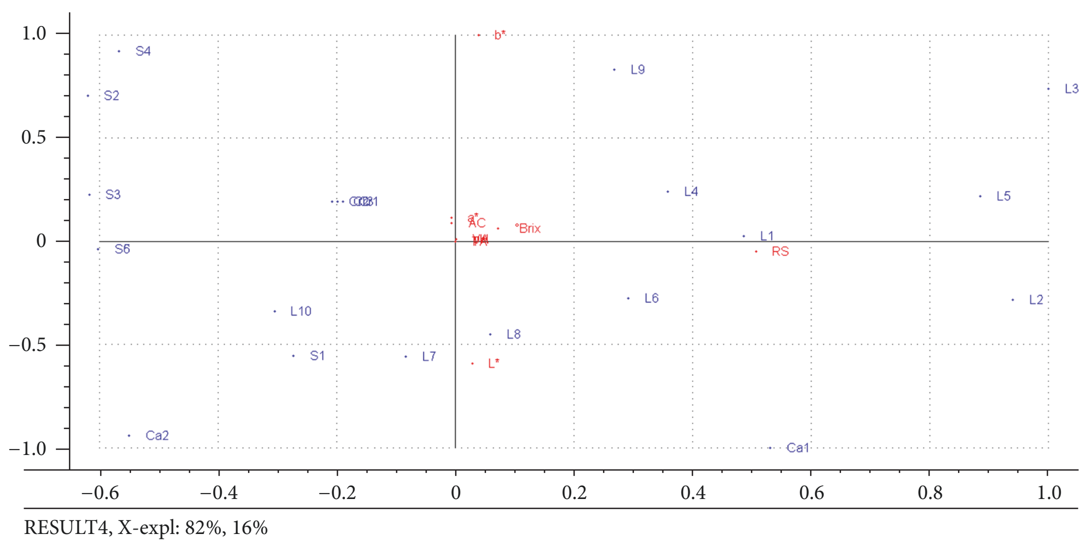

Figure 2: Biplot of wine samples and the physicochemical parameters.

of the fourth were positively correlated to L^* and reducing sugar.

4. Conclusions

There is a renewed interest in the viticulture of the Sicily Islands due to the presence of favourable conjunctures in the international market and wines that are rich in history and that have a dynamic expression of the origin area due to the cultivars, pedoclimatic component, and human action are favoured. The contributive role of such islands is underlined for the production of wines of superior quality, stimulating the production of other DOC and denomination of controlled and guaranteed origin (DOCG) wines in Sicily.

Malvasia wines from Lipari represent a niche production and can be obtained only from a limited area using a special technique of sun-drying, allowing the wine to acquire and concentrate the most peculiar traits of the volcanic environment. The similarity of the sensory characteristics between Lipari and Crete wine samples may have originated from the geographic proximity and from the frequent cultural exchanges between Southern Italy and Greece. The unique identity of Sardinian Malvasia wines was a consequence of the territory characteristics and the scarce contacts with other areas. The Canary Malvasia wines, which were produced geographically distantly from the Lipari Malvasia wines, were unique due to the specificity of territory and production technologies. From the results of the present study, it can be inferred that Malvasia cultivars distributed in the Mediterranean basin for more than 500 years have been modelled by the pedoclimatic environments and growing techniques, which were connected to multiple cultural factors, resulting in each wine developing differently over time. Such interaction has led to products with sensory characteristics that are qualitatively and quantitatively different from each other, contributing to the expansion of Malvasia wine varieties currently available.

Results show in these wines a degree of variability unsuitable for a DOC wine. Apart from reviewing the production rules, the sensory and physicochemical analyses represent essential instruments for improving the standardization of these DOC wines. A classification system of wines solely based on the typology of cultivar would be rather confusing and limited for consumers. In fact, considering the sensory characteristics, the wines differ substantially within the same cultivar, because there are many variations occurring in the viticulture productions (soil type, climate, vintages, enology treatments, etc.) and in the wine-making practices (dehydration process, yeast, aging, etc.). Hence, there is a strong need to study the parameters that influence the wine's composition, the sensory properties, and finally the consumers' preferences.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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