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Chapter 16

Wine Lees: Traditional and Potential Innovative Techniques for their Exploitation in Winemaking

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Additional information is available at the end of the chapter

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Abstract

Aging of wine on lees enhances the sensorial characteristics of wine. Only a small part of the lees produced in winemaking are used in traditional aging. Most are collected and then distilled or processed to obtain low quality wine. For these reasons, lees are currently an undervalued by-product of winemaking. A new technique was tested on an industrial scale to provide wine from lees of different origin. After racking, the lees were collected in an innovative steel system and processed by cycles of mixing in controlled condition of temperature and micro-oxygenation. The processing technique contributed to improving the chemical characteristics of wine from the lees. Wines obtained from the treated lees were characterized by color intensity, total polyphenols and total polysaccharides significantly higher compared to those from not treated lees, used as control. The addition of small quantities of wine from lees to a base wine led to a significant decrease of astringency and increase in body, overall aroma, olfactory intensity, and sweet sensation. The obtained results indicate that the proposed method could be an effective tool to exploit lees on a winery scale.

Keywords: lees, wine, colour, astringency, body, aroma

1. Introduction

Wine lees are defined as 'the residue that forms at the bottom of vessel containing wine, after fermentation, during the storage or after authorized treatments, as well as the residue obtained following the filtration or centrifugation of this product' (EEC regulation No. 337/79). The word 'lees' is used also to define the heterogeneous matrix that is deposited during pre-fermentative decantation of white must. Over the course of winemaking, the lees are progressively depleted of their constituents due to decantation phases and their composition varies

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depending on the origin (grape variety, vinification step and type of operation). A scheme of lees origin during both red and white winemaking processes is shown in **Figure 1**.

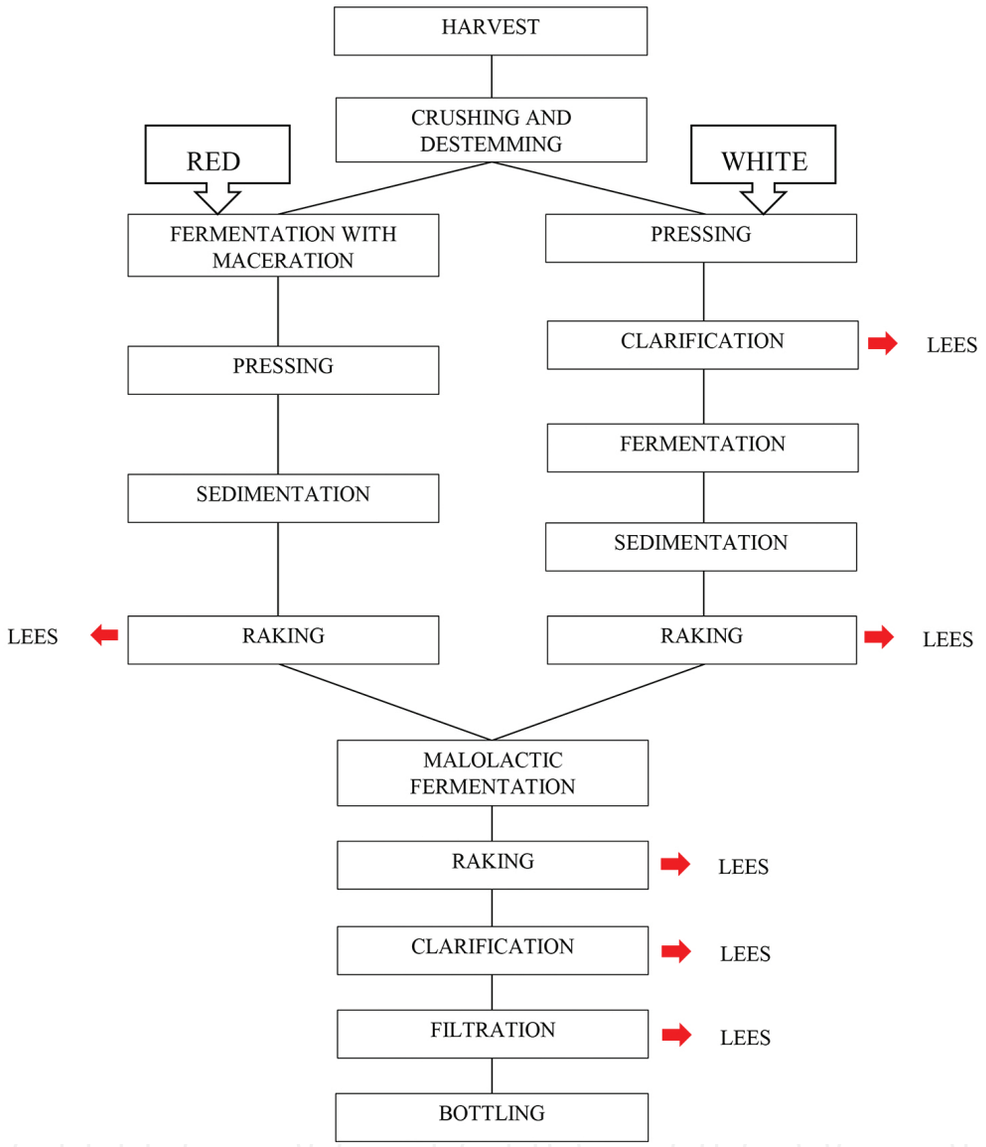


Figure 1. General scheme of lees origin during red and white winemaking processes. The lees come from several steps of racking and other operations of the production chain in which they are separated from the wine and treated as a by-product.

In Tuscany alone, in the past 2 years, the mean production of wine before lees separation was more than 2 million hectolitres and we estimate that about 5% of this volume is lees. The majority of lees produced at industrial level are collected at the wineries after racking and other operations and then disposed of. Most of the lees are sent to distilleries but this practice is currently not convenient for farms. From a financial standpoint, European support for distilleries is reduced at the production level. Alternative destinations—agronomic and energetic—are now authorized to tentatively solve the problem of lees disposal, but they could

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generate new problems of sustainability in the long term [1, 2]. Only a small portion of lees from winemaking processes are used in traditional practice of wine aging. It is known from several studies about wine aging on lees that this matrix is complex and rich of wine active compounds and its application in winemaking improves wine characteristics. For these reasons, lees are currently an undervalued by-product of the winemaking industry.

The oenological practice of aging wine on lees is traditionally performed with lees originated after alcoholic fermentation and some racking operations. In general, these lees are a low density matrix, mainly composed of microorganisms (yeasts and bacteria) related to the winemaking process. Tartaric acid and inorganic matter are a minor part of lees composition. Some particular types of wine are left in contact with their lees during aging. For example, sparkling wine elaborated through a classic method is aged on lees after foaming. Currently, this technique is used still in wine, more widely in white than in red. The major effect of aging on lees in white wine is the reduction of oxidative phenomena of colour and aroma [3]. In red wine, colloids of lees prevent the precipitation of complexes that are formed between tannins and anthocyanins, and the practice of aging on lees can lead to a better stability of wine colour [4]. Contact with lees produces a less astringent wine, with slightly less colour intensity. Body and roundness of the wine are enhanced by contact with lees. The aromatic and phenolic fraction is deeply modified during the aging due to the complex interactions between lees and wine compounds. In general, traditional ageing of wine on lees is described as a technique that enhances the sensorial characteristics of wine. The oenological potential of lees originates in their complex composition and properties exploited by a traditional approach [5]. During aging, autolysis of yeast cells modifies the composition of lees in terms of wine active compounds [6, 7]. Indeed, mannoproteins, polysaccharides, lipids, volatile compounds and enzymes are released by yeast into the wine during post-fermentative contact.

Despite the positive effects described above, some problems can arise during aging on lees. Sulphur odours and off-smell can appear in wine during aging on lees, primarily due to oxygen consumption by dead yeasts and development of spoilage microorganisms. Lees can be responsible for the presence of precursors and enzymes that, under favourable conditions, can lead to the synthesis of biogenic amines [8]. These compounds are responsible for commonly reported disagreeable odours and are also a risk for consumers due to their physiological effects [9]. On the other hand, lees are described as a matrix that can play a role in the removal of undesirable compounds of wine such as volatile phenols and residues form treatments [5]. Over the course of traditional aging, lees are periodically re-suspended by stirring (a practice of French origin called 'batonnage') to increase the amount of macromolecules extracted into the wine. To prevent the appearance of reduction notes in wine, aging on less is traditionally performed in oak barrels. The micro-oxygenation technique, which consists in the addition of small and controlled doses of oxygen to wine aging in steel tank, may be an effective way to manage this practice. The use of adequate doses of sulphur dioxide is useful to prevent microbiological alterations.

The traditional technique of aging wine on lees involves a considerable demand of winery resources, a potential disadvantage. Indeed, long times of wine storage, frequent 'batonnages'

and close monitoring of the evolution of the product are required during aging on lees to achieve positive results.

With the aim of improving the efficiency of aging wine on lees, several techniques were previously investigated. Enzyme-assisted and physical treatments, such as ultrasound and microwave, were employed during on lees processing to maximize the extraction of wine active compounds from yeast cells [10, 11]. The results of these studies concern the improvement of traditional technique by the addition of lyophilized yeast cells at different doses. The exploitation of the large amount of lees generated by winemaking processes still remains an unsolved problem.

Recently, a new technique was tested on an industrial scale for the management of liquid lees collected after the first and second racking during the winemaking process to obtain high-quality wine [12, 13]. The achievement of this objective allows wine producers to develop an efficient and sustainable strategy for the exploitation of lees at the winery.

2. Materials and methods

2.1. Processing system

An innovative vertical tank (under patent) was used (**Figure 2a**). It is made of stainless steel (25 hL capacity), designed to maintain the temperature by means of cooling bands that cover 75% of the outer surface and insulation (60 mm) on the entire surface. Inside the system, there are several mixing means splined to a shaft. Movement of the means on the shaft puts the system into action. Each mixing mean includes two coplanar agitators. The first agitator moves the oenological matrix downward while the second moves the oenological matrix upward, producing a gentle swirl. Depending on the work phases, the speed of rotation is variable and the direction of the mixing means can be either clockwise or counterclockwise. The system is equipped with several accessories for the optimization of loading, draining, pump-over, micro-oxygenation of the product and discharge of semi-solid residue. During the process, a device automatically controls operations and product temperature. The processing system is suitable for the innovative lees management technique and for traditional oenological practices such as pre- and post-fermentative maceration, clarification and storage. Trials were conducted in 2012, 2013 and 2014. A semi-automatic prototype was used in 2012.

2.2. Lees

At the winery, lees of different origin were collected after fermentation and used for the trials. Test A was performed with lees from Sangiovese (80%) and Cabernet Franc (20%) red grapes, vintage 2012. Lees from Sangiovese grapes (100%) were used for the test C, vintage 2013. In 2013, several varieties of red and white grapes (Cabernet Franc, Syrah, Merlot, Montepulciano, Cabernet Sauvignon and Viognier) were vinified separately, and the collected lees were used to perform test F. In 2014, lees derived from different winemaking processes of white grapes

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(Chardonnay, Viognier, Bellone and Incrocio Manzoni) were collected at the winery and then processed with the aid of the processing system.

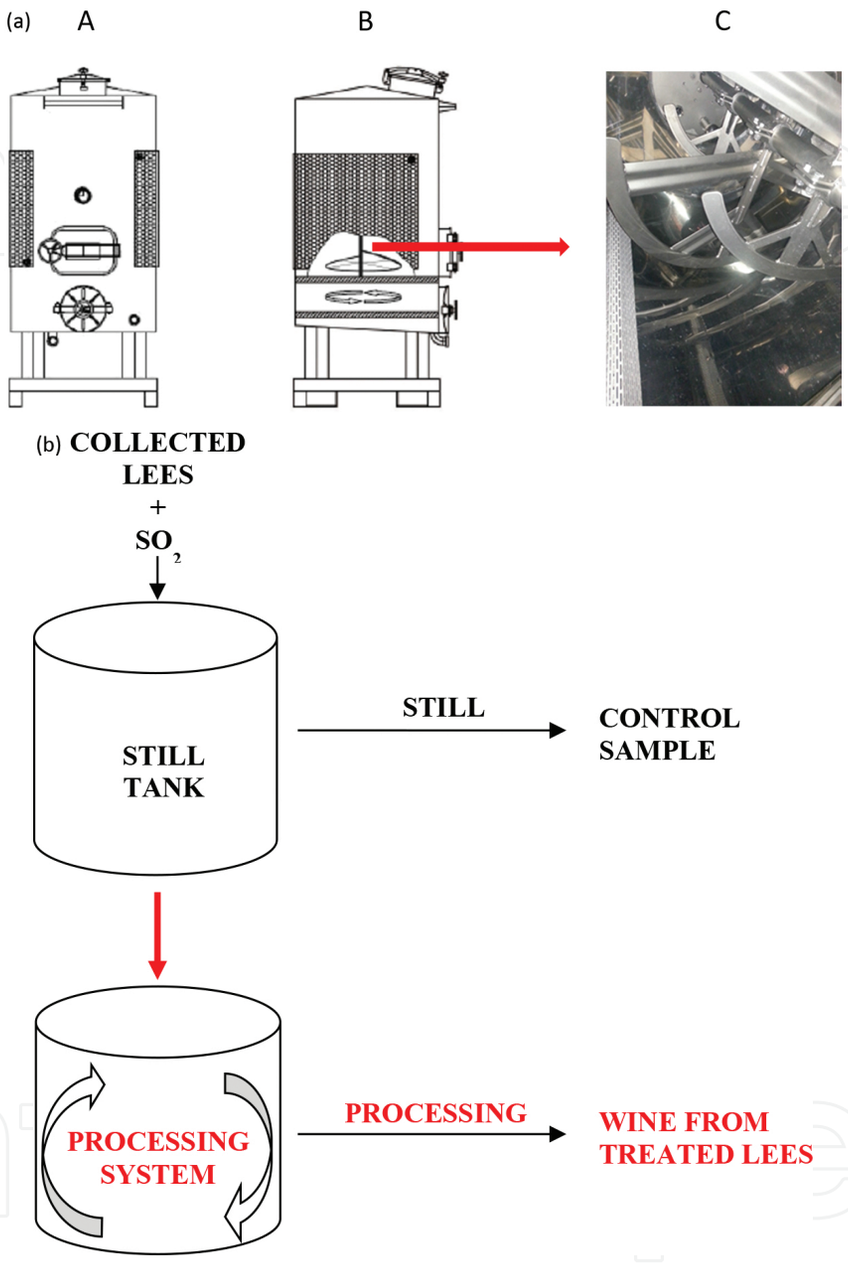


Figure 2. (a) Processing system (front view A; side view B) used to perform treatment and a particular (C) of the inside with stirring device. (b) Scheme of the processing technique conducted using the innovative processing system. A β-glucanase commercial preparation was added at the dose of 10 g/hL directly into the system for tests C and F. Samples C and F were micro-oxygenated at the dose of 3 mg/L/month.

2.3. Processing techniques

The red grapes were harvested at maturity in excellent health and vinified depending on the winery protocol. After completion of alcoholic and malolactic fermentations, the wines were

kept in a tank for sedimentation and then racked. A scheme of the processing technique is shown in **Figure 2**.

The lees were collected in a steel tank and added with SO_2 (60 mg/L). The lees, with density varying from 1.1 to 1.4 g/L, were pump-overed for 30 min and transferred to the processing system. All tests were performed at 22°C. For test A (vintage 2012), the lees were processed for 30 days by stirring every 2 days for 30 min. For the analyses, samples were taken at the beginning and at the end of treatment, immediately after mixing. In 2013, the lees were stirred every 8 h for 10 min for 7 days (tests C and F) and micro-oxygenated at the dose of 3 mg/L/month. Then, the lees were kept still at 20°C, with micro-oxygenation (3 mg/L/month) until 30 days. Samples were taken from the system at the beginning (0), after 3 and 7 days, immediately after mixing and 1 month later (30 days). A β-glucanase commercial preparation (10 g/hL) was added to the lees at the beginning for tests C and F. Control samples CA, CC and CF were obtained from the tanks where lees were maintained still at 20°C, without providing O_2 and analysed after 30 days (**Figure 2**). Analysis of wine from the lees was performed on clear supernatant after centrifugation of the samples for 10 min, at 7000 rpm at 4°C.

In 2014, white grapes of different varieties (Chardonnay, Viognier, Bellone and Incrocio Manzoni) were harvested at maturity and vinified separately, according to the winery protocol. After the end of fermentations, the wines were decanted and then racked. The lees, collected in a steel tank, were added with SO_2 (60 mg/L) and transferred to the processing system. The lees were stirred every 8 h for 10 min for 15 days at 22°C and 3 mg/L/month of O_2 were provided. The lees were then kept still inside the system at 20°C for sedimentation. After racking, the obtained wine was aged in oak barrels for 6 months and then used to blend a white wine.

2.4. General analyses

Reducing sugar, total acidity and pH of wine were evaluated according to the official or usual methods recommended by the International Organization of the Vine and Wine (OIV) [14]. Analyses were performed in duplicate.

2.5. Phenolic indexes and wine colour

The total polyphenol index (TPI_{280}) was determined by measuring the absorbance at 280 nm of a 1:50 dilution of wine using a 10-mm quartz cuvette [15]. Total flavonoids (TF), total anthocyanins (TA) and total flavanols (TFn) were estimated on an acquired spectrum between 230 and 700 nm of the wine diluted 50-fold in acidic ethanol solution (ethanol:H_2O:HCl = 70:30:1), according to the method described by Di Stefano et al. [16]. Wine colour at 420, 520 and 620 nm was measured in cuvettes with 1 mm of optic pathway; colour intensity (I) was calculated as the sum of A420, A520 and A620 and hue (H) as the ratio A420/520 and expressed as absorbance unit (Au) [17]. The contribution of co-pigmented anthocyanins to the total wine colour at pH 3.6 (Copig %), the degree of anthocyanin polymerization (Pol %), the monomeric anthocyanins (Mon %) and the estimate cofactors (C) were determined [18]. Gelatin index (G) was evaluated as described by Glories [19]. All measurements of the absorbance values were obtained with a Perkin Elmer Lambda 10 Spectrophotometer (Massachusetts, USA).

2.6. Astringency mucin index

Wine polyphenols were purified as described by Condelli et al. [20]. A 10 g C18 cartridge (Bond Elut C18, Varian) was activated with 25 mL of methanol and 50 mL of distilled water. Ten millilitres of wine was loaded on the cartridge. Carbohydrates and acidic compounds were washed with 10 mL of 0.01% H_2SO_4 solution. Phenolic compounds were eluted with 15 mL of methanol and a rotary evaporator was used to remove solvents. The phenolic extract was dissolved in 10 mL of 1% ethanol.

The astringency mucin index (AMI) was determined by reacting standard protein, mucin from pig stomach (Sigma, Milan, Italy), with phenols dissolved in 1% ethanol according to Monteleone et al. [21]. The AMI was expressed in terms of nephelometric turbidity units (NTU). The phenol-mucin sample (NTUS) consisted of phenolic extracts (2 mL) mixed with 0.5 mL of mucin solution (0.2% w/v, in citrate phosphate buffer, pH 3.5). The mucin solution (0.5 mL) mixed with 1% ethanol (2 mL) and phenolic extracts (2 mL) mixed with citrate phosphate buffer (0.5 mL) were used as control samples (mucin control-NTUM and phenol control-NTUP, respectively). After 1 min of reaction at 37°C, the turbidity value of all mixes was measured by a Hach 2001N Laboratory Turbidimeter (Hach Co., Loveland, CO) in nephelometric turbidity units. Wine sample phenolic extracts were tested in duplicate. The following formula was used to compute AMI: AMI = NTUS – (NTUM + NTUP).

2.7. Total proteins

Proteins were isolated by precipitation with ethanol [22, 23]. Protein content was evaluated on the ethanol extract. To extract phenols, absolute ethanol (30 mL) was added to 10 mL of wine. The sample was kept at 0°C for 1 h, and then it was centrifuged at 12,000 rpm at 4°C for 10 min. The obtained pellet was washed once with ethanol, and the excess of ethanol was gently removed with the aid of a Pasteur pipette and vacuum pump. After drying at 40°C for 1 h, the pellets were re-solubilized in 1.0 mL of distilled water. Proteins were quantified by Protein Assay kit (Bio-Rad, Milan, Italy). The method is based on the absorbance maximum shifts from 465 to 595 nm of an acidic solution of Coomassie Brilliant Blue G-250 when binding to the protein occurs [24]. A standard curve of bovine serum albumin (BSA) was prepared in a range of concentration from 0.2 to 1.4 mg/mL. All assays were performed in duplicate and averaged.

2.8. Total polysaccharides

Total polysaccharide (TP) was evaluated following the method described by Usseglio-Tommaset [25]. Twenty mL of wine was added with 100 mL of absolute ethanol and 1 mL of 37% HCl, diluted 1:1, to avoid tartaric precipitation. Solution was mixed, kept at 4°C for 24 h and then filtered through a previously weighed membrane (pore size of 0.45 μm). Precipitate was washed two times with 20 mL of ethanol. The membrane was dried at 40°C for 1 h, stored in a desiccator for 30 min and then weighed. The amount of total polysaccharides was obtained by subtracting weight of the filter from the weight of filter with the precipitate. All assays were performed in duplicate and averaged. The total polysaccharide content was expressed as milligram per litre of wine (mg/L).

2.9. Sensory analysis

Descriptive sensory analysis was performed following the sensory profile method according to standard ISO U590A1950 (ISO, 1998) by a panel composed of 20 enology and viticulture students from the University of Florence. The descriptors were scored on a scale of 0–10 (0: descriptor was not perceived, 10: high intensity).

2.10. Statistical analysis

Chemical analyses were performed in duplicate, and the data are presented as mean ± standard deviation. Analysis of variance and comparison of treatment means (LSD, 5% level) were performed using Statgraphics Plus 3.1. Principal component analysis (PCA) was performed using Unscrambler X 10.2 software on data of the sensory descriptions to find the dominant sensory attributes of the wines.

3. Results and discussion

3.1. Wine from lees (vintages 2012 and 2013)

Chemical parameters of wine samples A, C and F were used to perform a principal component analysis (**Figure 3**) [13].

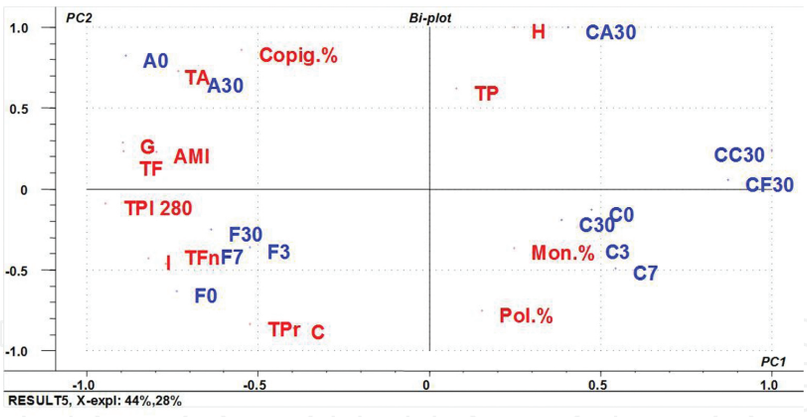


Figure 3. The PCA of the chemical parameters evaluated for the samples A, C and F at the beginning (0), after 3 and 7 days of treatment and 30 days later. CA30, CC30 and CF30 are the controls analysed after 30 days. Colour intensity (I) and hue (H), total polyphenol (TPI_{280}), total flavonoids (TF), total anthocyans (TA), total flavanols (TFn), monomeric anthocyanins (Mon %), polymeric anthocyanins (Pol %), copigmented anthocyanins (Copig %), cofactors (C), astringency mucin index (AMI), gelatine index (G), total polysaccharides (TP) and total protein (TPr).

A large part of the variance (72%) is explained by the first two principal components. Samples grouped according to the vintage, variety of grapes and type of treatment of the lees. Control samples (CA30, CC30 and CF30), analysed after 30 days, were separated from those at the start of processing (A0, C0 and F0) and from the treated samples A, C and F collected during processing. CA30 and CF30 resulted on the opposite side of the graph with respect to the

samples of wine A30 and F30 originating from treated lees. The treated samples were different from the control for most of the chemical parameters measured, which were significantly higher (**Figure 3**). The evolution of colour intensity and hue, total polyphenol index, total polysaccharides, total protein and astringency mucin index during processing of samples A, C and F are shown in **Tables 1–3**.

Sample	I	H	TPI_{280}	TP (g/L)	TPr (mg/L)	AMI
A0	6.2 ± 0.1b	0.8 ± 0.02b	48.1 ± 0.2c	1.4 ± 0.0a	23.2 ± 1.0c	18.2 ± 0.0c
A30	6.4 ± 0.1c	0.7 ± 0.02a	47.5 ± 0.2b	1.7 ± 0.0b	11.9 ± 2.6b	12.4 ± 0.0b
CA30	3.2 ± 0.2a	0.9 ± 0.02c	39.0 ± 0.2a	1.4 ± 0.0a	4.3 ± 1.7a	8.3 ± 0.4a

CA30 is the control sample after 30 days. Colour intensity (I) and hue (H), total polyphenol (TPI_{280}), astringency mucin index (AMI), total polysaccharides (TP) and total protein (TPr).
Data expressed as mean ± SD. Mean values labelled with different letters indicate significant differences among the samples ($P < 0.05$).

Table 1. Chemical parameters of samples A at the beginning (0) and after 30 days of treatment (A30).

Sample	I	H	TPI_{280}	TP (g/L)	TPr (mg/L)	AMI
C0	3.4 ± 0.2b	0.7 ± 0.02b	37.0 ± 0.2b	1.2 ± 0.0a	15.4 ± 2.1e	7.8 ± 0.5d
C3	3.6 ± 0.1b	0.6 ± 0.02a	38.0 ± 0.2c	1.3 ± 0.0b	9.2 ± 1.2d	5.7 ± 0.6bc
C7	3.6 ± 0.1b	0.6 ± 0.02a	40.0 ± 0.3d	1.1 ± 0.1a	4.1 ± 0.8c	5.0 ± 0.7b
C30	5.3 ± 0.2c	0.6 ± 0.02a	41.0 ± 0.2e	1.7 ± 0.0d	1.6 ± 1.7a	6.2 ± 0.4c
CC30	2.8 ± 0.1a	0.9 ± 0.02c	34.0 ± 0.2a	1.4 ± 0.0c	0.8 ± 1.8a	4.3 ± 0.0a

CC30 is the control sample after 30 days. Colour intensity (I) and hue (H), total polyphenol (TPI_{280}), astringency mucin index (AMI), total polysaccharides (TP) and total protein (TPr).
Data expressed as mean ± SD. Mean values labelled with different letters indicate significant differences among the samples ($P < 0.05$).

Table 2. Chemical parameters of samples C at the beginning (0), after 3 (C3) and 7 (C7) days of treatment and 1 month later (C30).

Sample	I	H	TPI_{280}	TP (g/L)	TPr (mg/L)	AMI
F0	9.4 ± 0.1d	0.6 ± 0.02a	49.3 ± 0.2e	1.1 ± 0.0c	60.2 ± 2.0e	26.9 ± 1.4e
F3	8.8 ± 0.1c	0.6 ± 0.02a	44.9 ± 0.2b	0.9 ± 0.0b	48.6 ± 1.5c	23.1 ± 1.5d
F7	9.3 ± 0.2d	0.7 ± 0.02b	47.2 ± 0.2c	0.9 ± 0.0b	44.8 ± 2.0b	11.4 ± 0.8c
F30	8.1 ± 0.1b	0.7 ± 0.02b	48.4 ± 0.2d	0.8 ± 0.0a	56.8 ± 2.4d	7.8 ± 0.1b
CF30	4.8 ± 0.2a	0.7 ± 0.02b	32.3 ± 0.2a	0.8 ± 0.0a	34.1 ± 0.2a	0.0 ± 0.0a

CF30 is the control sample after 30 days. Colour intensity (I) and hue (H), total polyphenol (TPI_{280}), astringency mucin index (AMI), total polysaccharides (TP) and total protein (TPr).
Data expressed as mean ± SD. Mean values labelled with different letters indicate significant differences among the samples ($P < 0.05$).

Table 3. Chemical parameters of samples F at the beginning (0), after 3 (F3) and 7 (F7) days of treatment and 1 month later (F30).

After 30 days, colour intensity of the processed samples A30 (6.4 Au) and C30 (5.3 A.U) was higher than those of the samples (A0 and C0) analysed at the start (6.2 and 3.4 Au) (**Tables 1** and **2**). On the contrary, sample F30, which maintained a high colour intensity until 7 days (9.3 Au), showed a decrease to 8.1 Au after 30 days. After 1 month, polysaccharide content of samples A and C passed from 1.4 to 1.7 and from 1.2 to 1.7 mg/L, respectively. Conversely, in sample F, polysaccharides decreased from 1.1 to 0.8 (**Tables 1–3**). In all tests, total protein content and astringency mucin index values decreased over the course of processing. The astringency mucin index is a useful tool to predict the strength of perceived astringency, induced by polyphenols of wine [26].

In comparison to the control samples, the intensity of colour of all treated samples after 30 days was higher while hue remained quite stable, indicating that processing contributes to maintaining colour characteristics of the wine (**Tables 1–3**). In all tests, total polyphenol index and protein of control samples analysed after 30 days were at significantly lower levels with respect to the treated samples, indicating a depletion of the wine maintained still on the lees. Total polysaccharides content of the treated samples A and C (**Tables 1** and **2**) was higher than that of the control while it was similar to the control in sample F (**Table 3**). The AMI index of processed samples was always higher compared to that of the control, which was at a very low level. During the treatment, no off-flavours or off-odours arose in wine without further addition of SO_2. Overall results indicated that the processing technique can lead to improving or maintaining the chemical characteristics of wine from the lees.

The release of mannoproteins, parietal polysaccharides of yeast, during aging on lees was previously reported by other authors [5]. Several months were required to obtain a significant increase of these compounds during traditional post-fermentative contact of wine with their lees [5]. With the main objectives of shortening, the aging on lees period and improving the release of polysaccharides from yeast cells, some methods were tested by other authors during traditional processes [10, 11]. The innovative technique described in this work differs from those previously investigated for a general target. Indeed, the new technique aims to exploit most of the liquid lees produced at winery scale by a method of industrial application. Lees with a very high density and complex composition (cells of yeast and bacteria, organic and inorganic matter derived from grapes) were processed. The yield in wine can reach 65% in function of the type of lees processed. The addition of enzymes can improve extraction but the method is efficient also without enzyme addition, as demonstrated by the results obtained for sample A. Extraction of chemical compounds and stability of wine colour can be achieved by means of the type of mixing undertaken by the new processing system and micro-oxygenation of the product.

Our results indicated that the wine from the lees maintained or improved colour characteristics also with enzyme (10 g/hL) addition, contrary to that observed by other authors who used a β-glucanase preparation at the dose of 5 g/hL [10].

Regarding the application of physical treatments to shorten the process of aging on lees, the positive results obtained by ultrasound application on the release of polysaccharides from yeast cells into the wine do not seem related to sensory perception [11]. Moreover, the same

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authors highlighted some problems of active compounds (anthocyanins and volatile) lost and oxidation during the treatment.

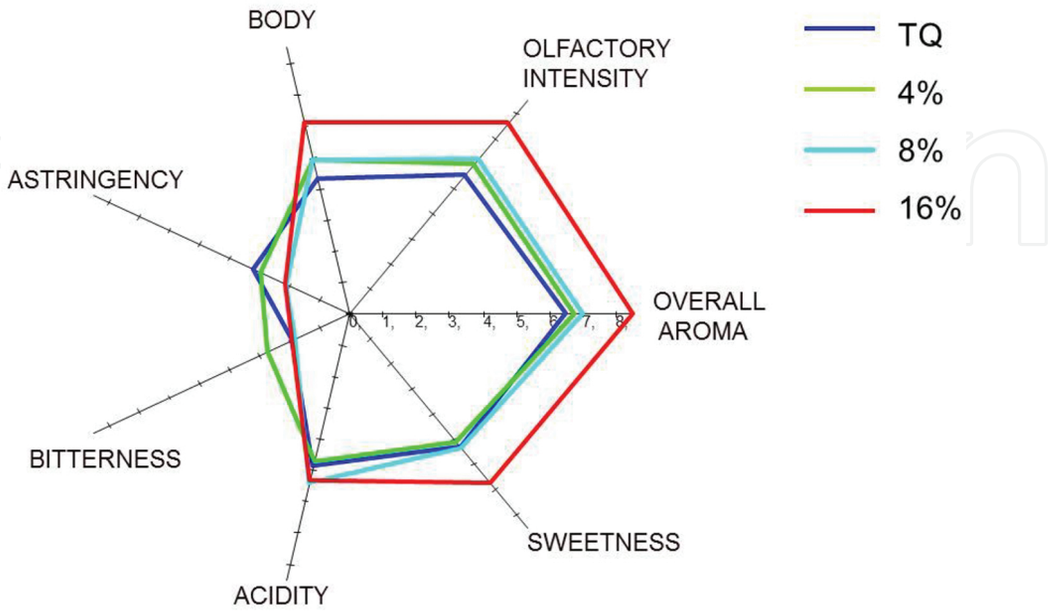


Figure 4. Sensory profiles of a white wine (TQ) and of the same wine added with different percentage of wine from lees.

During processing, chemical analysis of the red wine obtained using the new technique revealed variations in the contribution to wine colour by monomeric, polymeric and co-pigmented anthocyanins. Sensory evaluation showed that in blending with a base wine, the wines obtained with the new technique from white lees could contribute to decrease astringency sensation and enhance body, olfactory intensity, overall aroma and sweet characteristics of the final wine (**Figure 4**). Similar results were also obtained for wine from red lees (data not shown).

The new system proposed in this work has the advantage of its multi-functionality and the proposed technique can contribute to reach the objective of exploiting lees rapidly at the winery. In 2013, with the introduction of the new system, only 7 days of processing led to a significant increase of colour intensity. A decrease of anthocyanins in wines after contact with lees is reported by other authors [5]. Adsorption of anthocyanins on lees is involved in the decrease of these compounds during traditional aging. These phenomena are reversible, and desorption occurs mainly when anthocyanins oxidize or bind tannins. It can be assumed that the increase of colour intensity of wine observed after processing is due to the release of pigments adsorbed on the matrix. The stirring technique and oxygen provided during processing may have contributed to a stabilization of anthocyanins, promoting the reaction with tannins. The reactivity of polyphenols against proteins, measured in terms of AMI, slightly decreased during processing and indicated that the final wine can be perceived as less astringent. However, AMI of the control analysed after 30 days was at a very low level revealing a loss of body of the wine maintained still on the lees [26].

3.2. Wine from lees (vintage 2014)

In 2014, lees originating from vinification of white grapes (Chardonnay, Viognier, Bellone and Incrocio Manzoni) were processed. The obtained white wine was aged for 6 months in oak barrels and then used to blend a base white wine (Viognier, vintage 2013). Wine from the lees showed a total acidity of 5.53 g/L as tartaric acid, pH 3.45 and residual sugar below 1 g/L. Chemical parameters of Viognier were 5.51 g/L total acidity (as tartaric acid), pH 3.35 and residual sugar below 1 g/L. Sensory profiles of Viognier base wine (TQ) and Viognier added with different percentages (4%, 8% and 16%) of the wine from the lees are shown in **Figure 4**.

Astringency of Viognier added with 8% and 16% of wine from lees was significantly lower compared to the Viognier TQ. Moreover, Viognier added with 16% of wine from lees had body, olfactory intensity, overall aroma and sweet sensation significantly higher with respect to the Viognier TQ.

4. Conclusions

The chemical and sensory characteristics of wines obtained from lees following an innovative technique were attained. These characteristics can vary as a function of the type of lees and conditions of processing. Evaluation of the chemical characteristics reveals good quality of the wines from the lees and the sensorial approach confirms and emphasizes this judgment. A high degree of efficiency was achieved by introducing an upgraded industrial system at the winery and optimization of the process (micro-oxygenation and automatic control). In conclusion, the overall results indicate that the proposed method can be an effective tool to exploit the lees on a winery scale.

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