Influence of grape transport and destemming systems on the quality of Chardonnay wines

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Abstract: The winemaking technology plays a very important role in enology as it directly influences the characteristics of wine. In particular, grape transport and destemming are critical steps in winemaking for the wine quality. The aim of this study was to compare two different processing lines of Chardonnay grapes to evaluate their effects on the quality of the final product. In particular, grapes receiving, transporting and destemming were performed using different machines in order to evaluate their influence on the quality of Chardonnay wines. The use of a receiving hopper equipped with a belt conveyor, followed by a destemmer equipped with partially coated rubber beaters, allowed to obtain Chardonnay wines of overall higher quality than using a receiving hopper equipped with a screw conveyor, followed by a destemmer equipped with steel beaters. The results were supported by chemical analyses on musts and wines and by the sensory analysis of the wines.

Keywords: belt conveyor, destemmer, screw conveyor, winemaking

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1 Introduction

In Italy, as well as globally, the wine industry is known as a growing industry. Several investments aim today at enhancing the quality of wines and the technology used by the wine industry is constantly improved (Catania et al., 2011; Catania et al., 2013).

The winemaking technology plays a very important role in enology as it directly influences the characteristics of wine. The types of machine used in the winemaking process and their regulation strongly affect the quality of the resulting wine (Boulton et al., 1996; Darias-Martin et al., 2004; Parenti et al., 2015). Many studies have been conducted on the effect of winemaking techniques to incorporate more flavor, character and uniqueness, however, in white wines they mostly concern fermentation (Medina et al., 2013; Orlic et al., 2007; Varela et al., 2012).

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The production plants in use in wine-cellars for the extraction of must from white grapes range from grape harvest, gravity tipping into the receiving hopper, transporting with conveyor, destemming, crushing, pressing, to the gentle extraction of juice to be sent to the fermentation tanks. The conveyor allows to feed the destemming and crushing machine with a continuous and constant flow of grape avoiding supercharging or underfeeding with consequent overloading of the machines and reduction of their work capacity (Nardin et al., 2006). To the best of our knowledge, no studies have been published on the different grape conveyor systems that can be used to bring the product from the receiving hopper to the destemmer.

Destemming is one of the critical points revealed by Christaki and Tzia (2002) in winemaking both for the quality and for the safety of wine. The role of destemming is to separate grape berries from the stalks and other vegetable matter. Stems removal before crushing reduces the excessive uptake of phenols and lipids from vine parts; stem phenol produce more astringent and bitter tastes than phenols released by seed and skin. The effect of different juice pressing conditions was studied by Tian et al. (2013) obtaining that destemming and crushing before pressing improve juice yield and the extraction of proteins and phenolics into juice. Benitez et al. (2005) studied the effect of grape destemming on the polyphenolic and volatile content of Fino sherry obtained that a different degrees of destemming did not affect the wine quality due to the short time that musts and stems were in contact.

The aim of this study was to compare two different processing lines of Chardonnay grapes to evaluate their effects on the quality of the final product. In particular, grapes receiving, transporting and destemming, which represent the early stages of processing, were performed employing machines that treat the product in a different way in order to evaluate the influence of the processing technology on the quality of Chardonnay wines.

2 Materials and methods

2.1 Plant material

The trials were carried out in a winery located in the province of Palermo (Sicily, Italy) in September 2014.The grapes came from a 10-year vineyard sloped between 3% and 10% and set at 420 m above sea level. The Chardonnay vineyard was hedgerow trained with 4000 plants/ha (planting layout 2.50 × 1.00 m) and Guyot pruning. Chardonnay is considered a vigorous variety with a moderate grape yield, a very versatile variety that can adapt to different climates and soils, as evidenced by the varied sites and conditions where it is cultivated (Winkler et al., 1974). Its berry clusters are small, cylindrical, and winged and can range from well-filled to compact, and usually contain only one seed (Kerridge and Antcliff, 1999).

2.2. Experimental tests

Grapes were manually harvested according to a randomized block design in order to realize three replicates, and conferred at the winery. Two batches per replicate were identified, 5 t each, and processed under the conditions identified as tests T1 and T2 (Figure1) which differ exclusively for the grape transport and destemming systems.

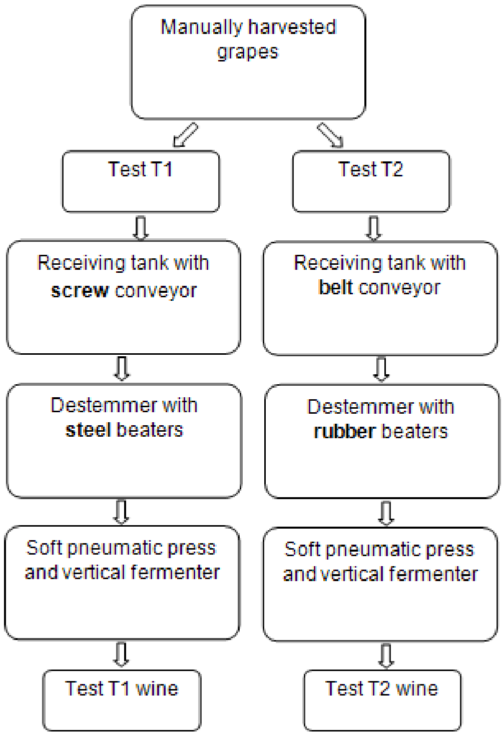

Figure 1 Stages of the Chardonnay wines production: manual harvest, gravity tipping into the receiving hopper, transporting with conveyor, destemming and crushing, pressing, fermentation

In test T1 a receiving hopper equipped with a screw conveyor was used, followed by a destemmer equipped with steel beaters. The conveyor is constituted by a supporting steel frame and by a steel hopper with trapezoidal section welded to the frame with inclined side walls to facilitate the conveying of the product. A steel rotating screw is placed at the bottom of the hopper, housed inside a U-shaped channel, which ensures the transport of the grapes. The machine is 3 kW powered, 5000 mm long, 2400 mm wide, 3000 mm high; the discharge height is 1100 mm and the discharge mouth is 1000 mm long. The external diameter of the screw is 400 mm, equal to the pitch.

The screw flow Q [kg/s] was calculated as:

$$Q = k \cdot \rho \cdot \frac{\pi\left(D_e^2 - D_i^2\right)}{4} \cdot p \cdot n$$

where:

k is a reduction coefficient (0.3÷0.4) assumed equal to 0.35according to the grape variety that is characterized by compact clusters;

ρ is the density of the conveyed material, equal to 1000 kg/m^3;

De is the screw diameter, equal to 0.4 m;

Di is the diameter of the shaft where the spiral is welded, equal to 0.1 m;

n is the r/min, equal to 60;

p is the pitch, equal to 0.4 m;

It was obtained a theoretical flow Q equal to 30 t/h. The true measured value was equal to 27 t/h.

In test T2 a receiving hopper equipped with a belt conveyor was used, followed by a destemmer equipped with partially coated rubber beaters. The conveyor has the same steel structure of the previous one but is characterized by the presence of a plastic conveyor belt at the bottom of the hopper, equipped with transverse cleats 0.40 m spaced. The belt is wound in a loop around two pulleys, one neutral and the other acting as the towing moved by an electric motor via geared motor unit; the pulleys are placed at the two ends of the conveyor, forming a continuous transport system. The machine is 4 kW powered, 5000 mm long, 2400 mm wide, 2000 mm high; the discharge height is 1100 mm and the discharge mouth is 1000 mm long.

The belt conveyor flow Q [t/h] was calculated as:

$$Q = v \cdot A \cdot \rho \cdot 3.6$$

where:

v is the conveyor speed, equal to 0.35 m/s;

A is the average section of the layer of material on the conveyor, equal to0.0189 m^2;

ρ is the density of the conveyed material, equal to 1000 kg/m^3.

The average section A of the layer of material on the conveyor was calculated as:

$$A = B \cdot h \cdot 0.6$$

where *B* is the conveyor width, equal to 0.63 m; *h* is the transverse cleats height, equal to 0.05 m and 0.6 a reduction coefficient relating to the level of filling.

It was obtained a theoretical flow Q of 19 t/h. The true measured value was equal to 18 t/h.

The destemmers used in the experimental tests were equipped with a destemmer section and a crusher rollers section. The machine consists of a rotating steel drum with funnel holes which act like a sieve and a beater shaft that rotates inside the drum coaxial to it. The rotation of the drum and the beater shaft is in the same direction. The beater shaft is fitted with pins arranged in a spiral around the shaft that contribute to beat the berries from the stems. The grapes are projected against the drum, and the berries and the must can pass through the holes. The stems remain behind and discharge at the other end of the drum. The stems expulsion is favored by the warped shape of the beaters. Drum dimensions, holes dimensions, pins number and orientation were the same in the two machine used.

The destemmer used in test T1 was equipped with steel beaters. This model is largely used in the winemaking process for the good durability of the beaters and the low maintenance requirements. The destemmer used in test T2 was equipped with steel beaters partially coated with rubber to limit the grapes maltreatment. The work capacity of the machine was 35-45 t/h. The regulating parameters adopted for both the destemmers were: rotation speed of the beater shaft 400 r/min and rotation speed of the drum 40r/min, respecting the ratio of 1:10.

The crushing section of the machine used in tests T1 and T2 was formed by two contra rotating rollers in alimentary rubber, with longitudinal grooves, which carry out the crushing of the grapes without inducing lacerations of the skins.

The grapes of the two batches were then separately pressed with a soft pneumatic press and transferred to a vertical winemaker equipped with automatic pumping system. The winemaking process was conducted following the same protocol for both tests.

2.3 Analyses on grapes and must

Chemical analyses were performed to determine sugar content, pH and acidity of the grapes. A portable refractometer (Milwaukee, MR32ATC) was used to determine the sugar content (Callejón-Ferre et al., 2009); acidity was determined with NaOH titration and pH was measured using a portable pH meter (multimeter MM40, CRISON)(Corrales et al., 2012). Analyses were performed in triplicates.

Samples of must were taken in three points of the grapes processing, identified as A, B and C, in order to perform the turbidity meter analysis.

Point A corresponds to the draining of the free run juice during the pneumatic press loading. Point B is located in correspondence of an intermediate step of the pressing process (0.6-0.8 bar). Point C is the storage tank of the product after the first decant.

A portable turbidity meter was used to determine the turbidity of the musts (model HI 93703, Hanna Instruments Company), with a scale from 0 to 1000 NTU, calibrated at two points, 0.0 and 10 NTU (Cassano et al., 2007). Analyses were performed in triplicates.

2.4 Analyses on wines

The common white wine making process was followed to turn the must obtained from grape processing into wine. The vinification lasted about one month and took place within stainless steel tanks; at the end of the process, the wine was filtered through a pre-coat filter with diatomaceous earth.

Alcohol, pH, total and volatile acidity, sugars, total polyphenols, density, were determined in triplicate on the wine samples with the WineScan^{TM}(Foss, Denmark).

Volatile organic fractions in wine samples were extracted by SPME (Solid Phase Micro Extraction) with a polydimethylsiloxane/divinylbenzene (PDMS/DVB, 65 mm) coated fiber purchased from Supelco Sigma Aldrich. The extraction was carried out after having mixed 10 ml of wine with 0.75 g of NaCl in a 40 ml glass headspace vial with PTFE/ Silicone septa and a magnetic stirring bar. The vial was gently heated and magnetically stirred for 20 min at 40℃ to allow equilibrium. Then, the SPME fiber was inserted through the septum and exposed to the vapor phase above the sample for 10 min. The fiber was then retracted and introduced on the GC (gas chromatograph) injector and held for 3 min to allow the desorption of the analytes onto the column. Analysis of organic volatile compounds was carried out using a gas chromatograph and mass-spectrometer (GC-MS) system (HewlettPackard 5890 and 5973 MS). The column used was a HP5-MS (5% diphenyl- 95% dimetilpolisiloxano 30 m × 0.2 mm, 0.25 μm film, J&W Scientific, Folsom CA, USA). The oven temperature was maintained at 40℃ for 5 min, then raised 2℃/min to 260℃ and held for 10 min. Helium was used as carrier gas with a flow rate of 1 ml min; injection mode was splitless. The injection port temperature was 280℃. MS full-scan method was used and the electron impact ionization spectra were obtained at 70 eV, recording mass spectra from m/z 42 to 550 UMA. The compounds' mass spectra were compared with those of data bank MS NIST 05 and the identifications were confirmed by using standard products (all 99% purity – Fluka, Sigma-Aldrich Chemie GmbH, Switzerland). Blank samples were run after conditioning the fiber at the manufacture's recommended temperature in order to characterize possible contaminants from the fiber or chromatographic system.

Finally, aroma and flavour sensory profile of the wines obtained from tests T1 and T2 were assessed by the implementation of a sensory panel consisting of wine industry professionals (n=8) with a minimum of two years' experience. The evaluation followed an established protocol with 50ml samples being poured into black ISO XL5 glasses. The wines were served at ambient temperature, 15℃-20℃, and water was provided. The panelists were given defined attributes to evaluate the wines. The attributes were obtained from the literature (Ough 1969;Gambetta et al., 2014). For scoring of the sensory attributes, a ten-point scale was implemented, with 0 representing non-existent and 10 representing extreme.

2.5 Statistical analysis

The data obtained on musts and wines were subjected to one-way analysis of variance; the student "t" test was used for mean comparison. The analyses were performed with the statistical software package Statgraphics centurion, version XV, Statpoint Inc. (Warrenton, Va., 2005).

3 Results and discussion

3.1. Analyses on grapes and must

The sugar content of the grapes was equal to 19 g/L, pH was 3 and acidity 6.30.

Table 1 shows the results of the turbidimeter analysis performed on the must samples.

Table 1 Results of the turbidimeter analyses performed on the must samples for tests T1 and T2 in different points of grapes processing (A = draining of the free run juice during the pneumatic press loading; B = intermediate step of the pressing process with 0.6-0.8 bar; C = storage tank after the first decant)

	T1			T2		
	mean	st.dev.		mean	st.dev.	
A	220.10	4.03	a	182.58	2.64	b
B	640.32	1.56	a	629.46	1.66	b
C	30.09	0.91	a	30.04	1.04	a

Note: Data are reported as means and standard deviations of the three replicates. Values in the row having different letters are significantly different at $p < 0.05$.

The must taken in point A in test T1 (draining of the free run juice during the pneumatic press loading) was significantly more turbid than the one in test T2. In the next phase of grapes processing, in correspondence of an intermediate step of soft pressing, the difference of turbidity between the two tests decreases with statistically significant differences. No differences were found between the samples taken in point C, namely in the storage tank of the product after the first decant. The values obtained in point C agree with Berger (1991) in the definition of musts of quality with turbidity between 50 and 150 NTU.

3.2. Analyses on wines

Sugars determined on T1 (1.38 g/L)and T2 (1.80 g/L) wines were statistically different (Table 2) while density did not show statistically significant differences between the two tests. Total acidity was 6.90 in test T1 and 6.27 in test T2, so the wine obtained using the belt conveyor was slightly acid than the one processed using the screw conveyor. No statistically significant differences were obtained for volatile acidity values in the two tests.

Table 2 Results of the analyses performed on wines from tests T1 and T2

	Sugars [g/L]	Density	Total acidity [g/L]	Volatile acidity [g/L]	Total Polyphenols [mg/L]
T1	1.38±0.06 b	0.913±0.004 a	6.90±0.07 a	0.21±0.02 a	248±6.51 b
T2	1.80±0.04 a	0.912±0.010 a	6.27±0.10 b	0.20±0.02 a	263±6.11 a

Note: Data are reported as means and standard deviations of the three replicates. Values in the column having different letters are significantly different at $p < 0.05$.

Total polyphenols were lower in T1 than T2, probably due to the mechanical action of the screw on the grapes that tore the skins more than the belt conveyor causing the polyphenols oxidation.

The number of aroma compounds determined in both wines did not show significant differences between the two experimental set up (Figure 2). In fact, acids, terpenes and alcohols were detected using the previous described analytical method. Decanoic and octanoic acid were the most represented compounds. Moreover some differences have to be reported between the two samples considering the aldehyde compounds, such as nonanal, produced by the theoretical breakdown of oleic acid hydroperoxide (9/10-OOOH), which is represented in T1, and heptanal produced by the theoretical breakdown of linoleic acid hydroperoxide (11-LOOH) that show the lower concentration in the same sample.

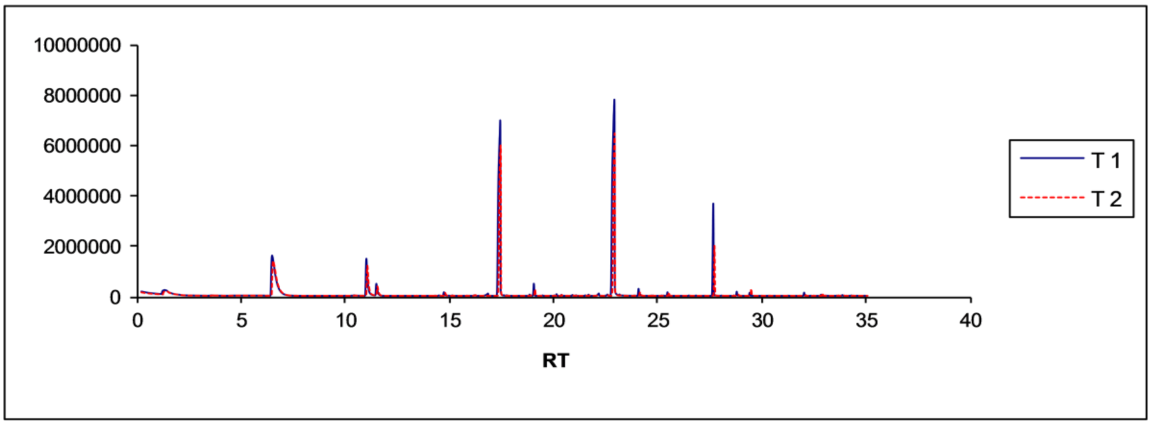

Figure 2 Volatile organic fractions in Chardonnay wines from tests T1 and T2 extracted by SPME (Solid Phase Micro Extraction)

Sensory analysis of the wines as defined by the specified descriptors can be seen in Figure 3. Analysis of variance and t-test at the 95.0% confidence level were used to determine significantly different aroma attributes between the two wines.

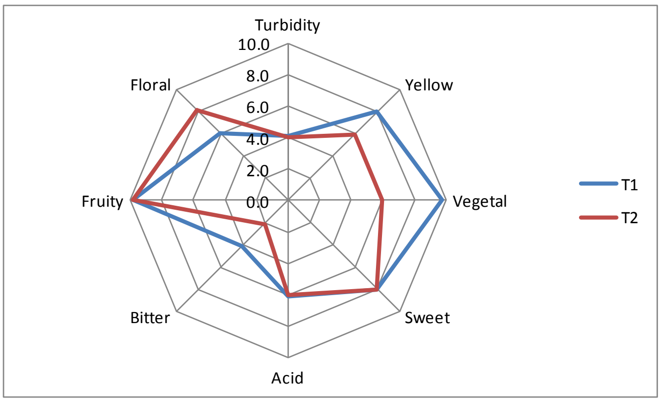

Figure 3 Aroma and flavour sensory profile, as determined by an experienced wine tasting

The wine obtained in test T1 showed a yellow intensity higher than test T2 with statistically significant differences. This is due, probably, to the increased oxidation recorded in test T1 because of the breaking of the berries with a bouquet which tends to enhance vegetable flavors rather than fruity. T1 wine also presents a tip of bitter significantly higher than T2 coming from the lignin of the stalks, to be exclusively attributed to the mode of transportation of the grapes, where the berries skins suffered significant lacerations compared to test T2. Regarding turbidity, however, the two wines are equally limpid and have the same visual turbidity after decanting.

4 Conclusions

This study confirms that the first steps of grapes processing can influence the quality of Chardonnay wines.

In particular, the steel rotating screw conveyor of the receiving hopper causes a preliminary laceration of the berry skins resulting in a greater production of must. The belt conveyor produces less skins maltreatment inducing a lower juice production; it also allows to limit oxidation, with the consequent SO_2 reduction added in the later stages of winemaking, and the decrease of the time for must settling with consequent energy saving in the case of cold settling.

Test T1 allowed to obtain Chardonnay wines of overall higher quality than test T2.

Improving the destemming process is a needed issue for the wine industry as is shown by the use of machines equipped with rubber beaters. The knowledge gained through this study can be applied to improve the existing processes and the development of new technologies.

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