CHEMICAL ENGINEERING TRANSACTIONS

VOL. 58, 2017

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Remigio Berruto, Pietro Catania, Mariangela Vallone

ISBN 978-88-95608-52-5; **ISSN** 2283-9216

DOI: 10.3303/CET1758047

Acceleration Assessment During Mechanical Harvest of Grapes Using a non Commercial Instrumented Sphere

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The use of the harvesting machine for grape wine has the limit of the production of must coming out from the detachment of the berries that could reflect negatively on the quality of the final product. It depends on many factors including grapes variety, ripeness and frequency of the harvesting machine shakers. The shaking frequency generally adopted is the one that achieves the maximum harvest efficiency, that means high work capacity and low grape juice production. In this paper, the authors present a new system to measure the accelerations received by grapevine during mechanical harvest with the aim of evaluating the influence of the shaking frequency on the quality of the must obtained. The device is an instrumented sphere designed and implemented by the Agricultural Mechanics Section of the Department of Agricultural and Forest Sciences, University of Palermo, Italy. It contains a triaxial Micro Electro-Mechanical Systems (MEMS) sensor capable of acquiring acceleration from a few mg to 400 g (where g is the gravitational acceleration). The field tests were carried out in September 2015 on Viognier and Grillo grapes. They allowed to measure the accelerations on the plants during mechanical grape harvest with three different shaking frequencies: 7.6, 7.9 and 8 Hz, and then to evaluate their influence on the main quality characteristics of the musts obtained. The results showed that the number of vibrations on the plants linearly increases with the increasing frequency. With reference to the quality of the musts obtained, polyphenols and catechins increased as the shaking frequency increased both for Viognier and Grillo varieties.

1. Introduction

Mechanical harvest of grapes is today an essential task in the modern vineyards management mostly to promptly intervene at the optimum harvest time and to overcome the problems of lack of manpower (Catania et al., 2013; Penisi et al, 2015). Mechanical harvest affects the quality of the future wine, and the shaking frequency during mechanical harvest above all. This parameter is responsible for the must production that is generated during mechanical harvest because of the energetic action of the shakers against the bunches to allow the separation of grape berries (Morris, 1998). The stresses transmitted by machine to plants during mechanical harvest are fundamental to efficiently perform harvesting without compromising the product quality and the vineyard.

Many systems are available today to register accelerations through a device which represents a given fruit: impact recorder device (IRD) sensor (Arazuri et al., 2010), the Danish made PTR 200 instrumented sphere (Canneyt et al., 2003), the instrumented spheres by Techmark inc. (Ferreira et al., 2006, Valentini et al., 2009) and other customized devices (Oliveira et al., 2015; Roa et al., 2015; Yu et al., 2012) .

The authors designed a non commercial small size instrumented sphere in order to study the stresses and shocks suffered by the fruit from harvest to processing, described in Catania et al. (2015). This device, equipped with a triaxial accelerometer, was applied to the vineyard in order to study the accelerations distribution on the plants and correlate them to the quality of the musts obtained.

Please cite this article as: Vallone M., Alleri M., Bono F., Catania P., 2017, Acceleration assessment during mechanical harvest of grapes using a non commercial instrumented sphere, Chemical Engineering Transactions, 58, 277-282 DOI: 10.3303/CET1758047

Therefore, this study aims at measuring the accelerations transmitted on grapevine by a self propelled harvester in order to evaluate the influence of the shaking frequency of the machine on the quality of the product.

2. Materials and methods

2.1 Vineyards and grape harvester

The trials were carried out in two 10-year vineyard plots located in the province of Trapani (Sicily, Italy) in September 2015, cv. Grillo and Viognier, both white grapes. The vineyards were hedgerow trained and Guyot pruning, with planting layout respectively 2.50 × 1.50 m for cv. Grillo and 2.60 × 1.20 m for Viognier.
The self propelled harvester Braud 9060L was used to mechanically harvest the grapes. It has a 111 kW, 6-cylinders, Fiat Powertrain common rail electronic engine. The harvesting head is composed of curved SDC (Shaking Driver Control) shakers, laid out in two vertical series (maximum 14 + 14). The shakers are fixed on plates mounted on the two sides of the shaking head, by means of a rubber sleeve and two terminals. Driven by eccentrics moved by a hydraulic motor, these plates are equipped with a cyclical movement synchronized in phase. The grapes interception and transport system is called NORIA system; it is made up with two series of 63 polyurethane baskets, ensuring a full respect of the vines and reduction of ground loses. The machine is provided with two stainless steel hoppers (2,600-3,200 L) and four centrifugal fans for cleaning the product, two located next to the area of grape detachment and two above the hopper inlet.
The machine was equipped with IntelliView™ III, an integrated Intelligent Management System, with touch screen monitor, that provides full access to all the key harvester functions.

Figure 1: The self propelled harvester Braud 9060L used in the tests (left side) and view inside the harvesting head (right side, curved shakers and NORIA system).

2.2 The non-commercial instrumented sphere

The non-commercial instrumented sphere used in the tests was developed at the Agricultural Mechanics Section of the Department of Agricultural and Forest Sciences, University of Palermo, Italy as described in Catania et al. (2015) (Figure 2). It is made up of a sensor node, 20 mm diameter, with a MEMS (Micro Electro-Mechanical Systems) sensor inside (a triaxial accelerometer) able to record acceleration from ±1g to ± 400 g (where g is the gravitational acceleration). The device is equipped with an internal microcontroller with a crystal in which the software developed for the specific application is loaded. The sampling rate of the acquisitions is managed by a microcontroller and set via the software interface through the master to load and download commands and device data and to change parameters such as data acquisition frequency. In this study, it was assumed equal to 200 Hz.

Figure 2: The non-commercial instrumented sphere used in the tests while positioned on the first wire of the hedgerow.

The sensor node was inserted inside a foam sphere, waterproof by means of a Teflon cover, having 3.5 cm diameter and a total weight of 6 g, and then firmly fixed on the first wire of the hedgerow. The instrumented sphere was positioned at the center of a row, so that the Y axis of the reference system corresponded to the shaking direction of the machine, the X-axis with the direction of the row and the Z axis orthogonal to the X-Y plane.

2.3 Experimental tests

The harvesting tests were performed using three different increasing shaking frequencies of the machine, respectively F1 = 7.6, F2 = 7.9 and F3 = 8 Hz keeping constant the other parameters of the machine, i.e. forward speed, equal to 3 km h^{-1}, seven shakers per side, working height adjusted according to the canopy. The shaking frequencies values were selected depending on the structural characteristics of the vineyards and precisely: canopy thickness, bunches size and position, etc. Each test was performed on a 120 m long row in triplicate, according to a randomized block scheme.

For each test a sample of mechanically harvested grapes was taken, put in a hermetically closed plastic jar and then in an insulated bag to be transferred to the laboratory. In addition, a sample of must was added with potassium metabisulfite, in order to block catechins oxidation during the transfer to the laboratory, with the aim of assessing the influence of the shaking frequency on eventual catechins oxidation. A sample of manually harvested grapes was taken for each test and used as control.

In the laboratory, the samples were manually pressed in order to obtain the must for chemical analyses. The must samples were analyzed by Foss Integrator WineScan™, (FOSS Italia S.p.A.) to determine the following qualitative parameters: total dry extract (g / l), pH, sugars (g / l), titratable acidity (g / l), malic acid (g / l), catechins (mg / l) and polyphenols (mg / l).

2.4 Statistical Analysis

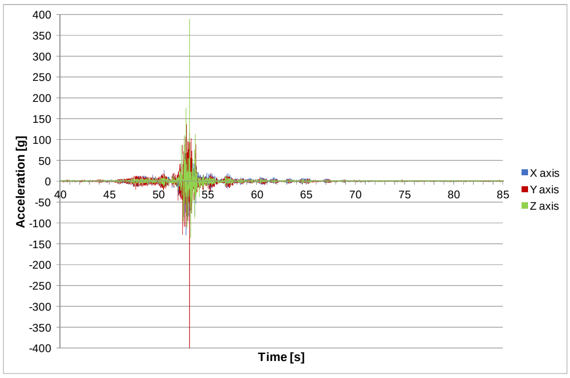
To test differences in total dry extract, pH, sugars, titratable acidity, malic acid, catechins and polyphenols of the different tests for grapes cv. Grillo and Viognier, the analysis of variance (ANOVA) was applied. The experimental design consisted of 12 observations for each cultivar; in total we therefore had 24 observations. The experimental factors were the shaking frequency, called F factor, and the cultivars, Grillo and Viognier . The F factor had 4 different levels, three different shaking frequency levels applied to the machine and a control referred to manual harvest. The parameter cultivar is the grape variety which consisted of two levels: Viognier and Grillo.

Seven two-way ANOVA models were considered, one for each of the analytical parameters observed. The analysis was performed using Stata 14. statistical software.

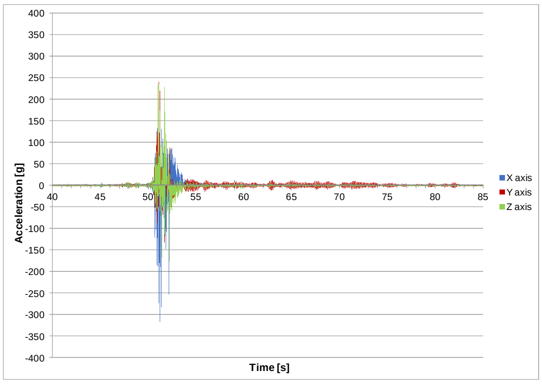
3. Results and discussion

3.1 Accelerations measured by the instrumented sphere

The accelerations measured in the three tests conditions (F1 = 7.6, F2 = 7.9 and F3 = 8 Hz) on X, Y and Z axes for the two grape varieties are shown in Figure 3 (mean of three replicates). As the shaking frequency increases, the accelerations increase and consequently the energy transmitted from the shakers of the harvesting head to the plant. This is most of all evident in the tests performed adopting F3, where accelerations reach values higher than 300 g, according to Pezzi and Caprara (2009). Furthermore, Y axis is the most stressed as it coincides with the principal direction of the vibration.

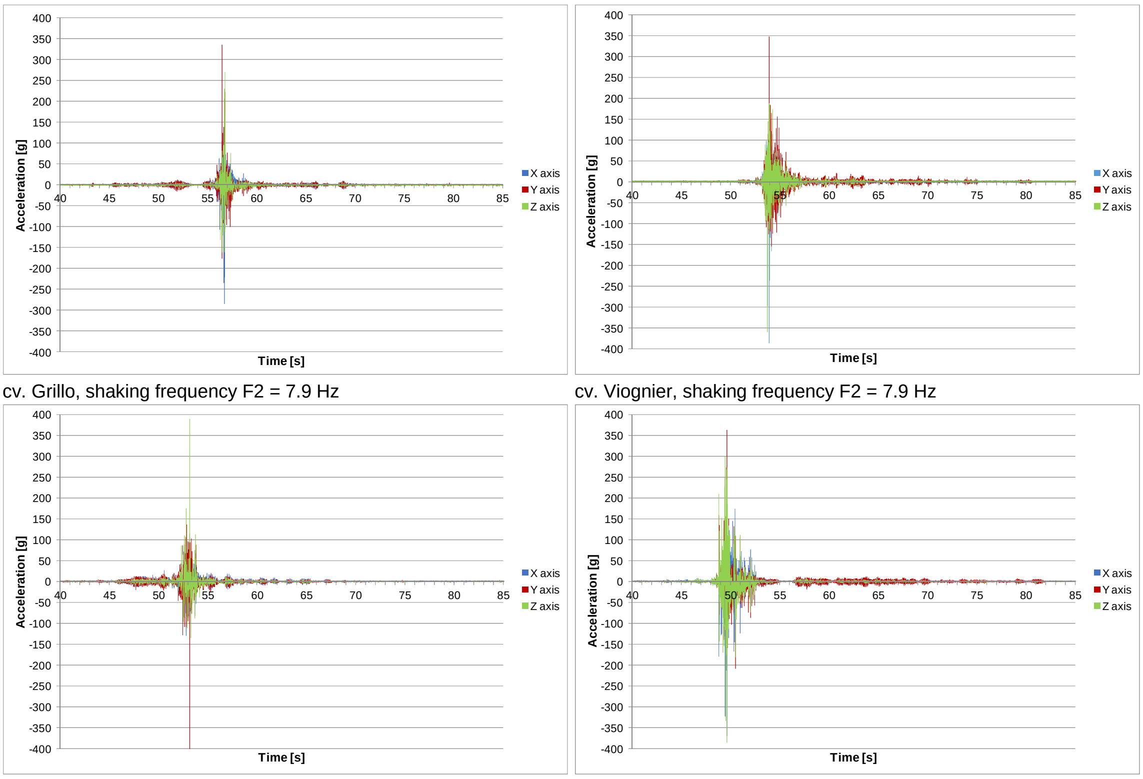


cv. Grillo, shaking frequency F1 = 7.6 Hz



cv. Viognier, shaking frequency F1 = 7.6 Hz

Figure 3: Accelerations measured by the non-commercial instrumented sphere in the three tests conditions (F1 = 7.6, F2 = 7.9 and F3 = 8 Hz) for the two grapes varieties. (continue)



cv. Grillo, shaking frequency F2 = 7.9 Hz | cv. Viognier, shaking frequency F2 = 7.9 Hz

cv. Grillo, shaking frequency F3 = 8 Hz | cv. Viognier, shaking frequency F3 = 8 Hz

Figure 3: Accelerations measured by the non-commercial instrumented sphere in the three tests conditions (F1 = 7.6, F2 = 7.9 and F3 = 8 Hz) for the two grapes varieties.

3.2 Analyses on musts

The fixed effects F (shaking frequency) and cultivar are significant in all the models (except for catechins where the cultivar effect is not significant). The interaction between F and cultivar is significant for all the parameters, except pH and catechins.

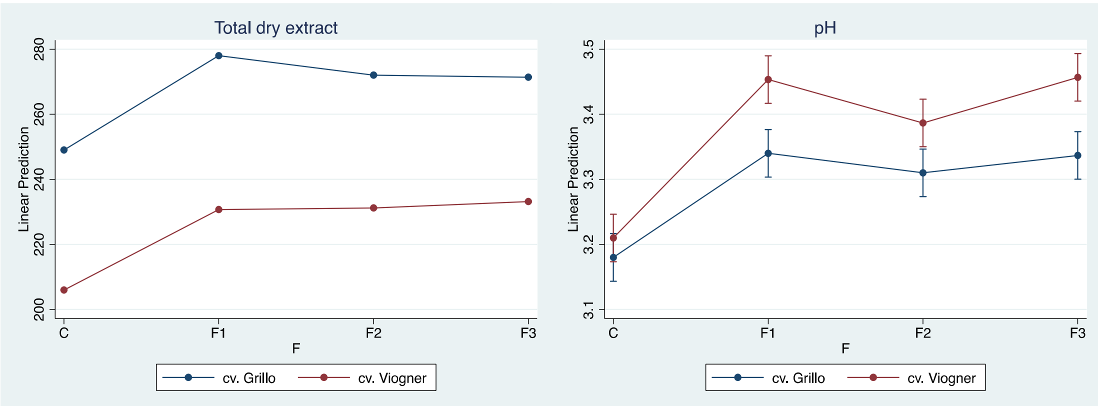


Figure 4: Predictive margins for F (shaking frequency) with 95% confidence intervals in the two grape varieties for total dry extract and pH.

Figure 4 shows that total dry extract for both grapes varieties significantly increases between the control and the mechanically harvested samples. This parameter does not significantly vary as the shaking frequency increases.

The parameter pH shows higher confidence intervals on the predicted values for different shaking frequencies. Overlapping confidence intervals show means that do not differ significantly. The mean pH values for manual harvested samples (C = control) show no significant differences between the two varieties. Furthermore, pH is not affected by the shaking frequency increase for both varieties but it is always lower in the control than the samples corresponding to F1, F2 and F3. The variety Viognier has pH mean values significantly higher than Grillo in F1 and F3.

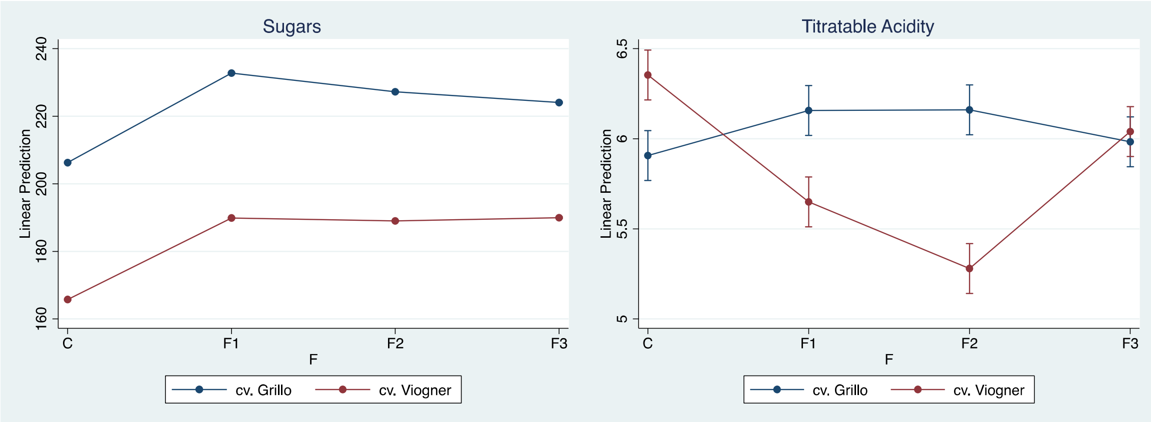


Figure 5: Predictive margins for F (shaking frequency) with 95% confidence intervals in the two grape varieties for sugar and titratable acidity.

The parameter sugars show different mean levels between the control and the mechanical harvested samples. No differences were found going from F1 to F3 for both varieties (Figure 5).
With regard to titratable acidity, cv. Grillo does not show any difference between the control and the other tests. Some variability emerges in titratable acidity mean values of Viognier grapes both between the control and the other tests and among the different frequencies applied in the three tests.

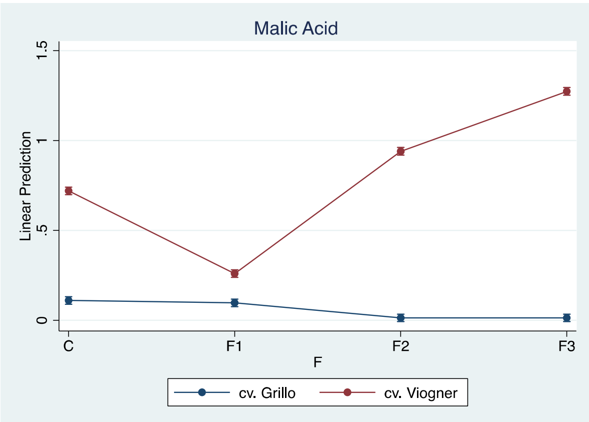


Figure 6: Predictive margins for F (shaking frequency) with 95% confidence intervals in the two grape varieties for malic acid.

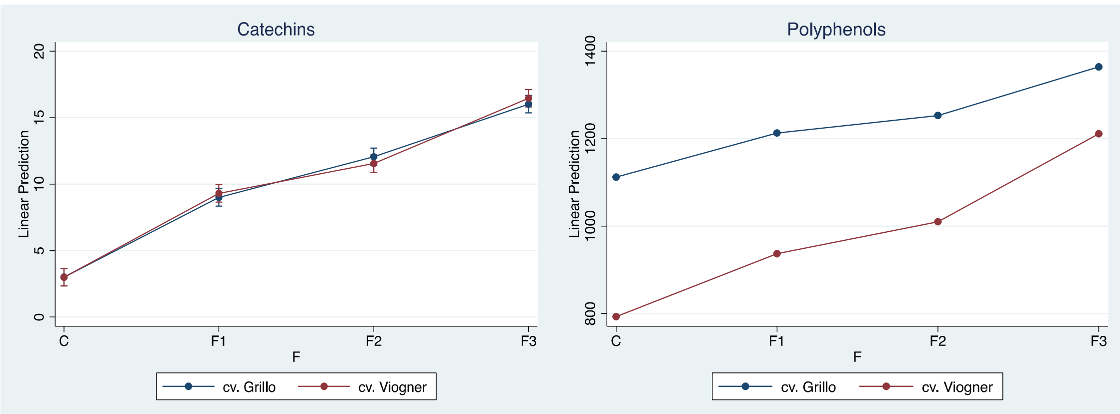


Figure 7: Predictive margins for F (shaking frequency) with 95% confidence intervals in the two grape varieties for catechins and polyphenols.

Malic acid mean values for Grillo grapes do not show statistically significant differences between the control and the other tests. A small reduction is to be noted as the shaking frequency increases. Malic acid values show a higher variability for Viognier grapes both comparing the control with the other tests and among the different frequency levels.

Figure 7 highlights catechins and polyphenols values. Catechins levels are superimposable for the two vareties; they increase as the shaking frequency increases. Neither the cultivar factor nor the interaction between cultivar and F are significant. Catechins vary only depending on the type of harvest (manual or mechanical). Polyphenols show a significant increase going from F1 to F3, especially for Viognier grapes.

4. Conclusions

Our study found that increasing the shaking frequency applied during mechanical harvest of grapes, the accelerations increase and consequently the energy transmitted from the harvesting machine to the plant. This was supported by the data registered using the non commercial instrumented sphere during mechanical harvest of grapes. Furthermore, it is evident that the shaking frequency influences the quality of the grapes directed to the cellar.

Catechins and polyphenols values measured in the must samples showed an increasing trend with the shaking frequency. Catechins have a 82% increase going from 7.6 Hz to 8 Hz for both varieties. Polyphenols have a 35% and 11% increase respectively for Viognier and Grillo grapes.

The results obtained in this study suggest to pay close attention to the choice of the shaking frequency during mechanical harvest in order to protect grapes from alteration, especially for the production of quality wines. With low shaking frequencies, till the limit imposed by the losses of product on the plants, polyphenols and catechins would be negligible in terms of the quality of wines.

Acknowledgments

The authors are grateful to Mr. Salvatore Amoroso of the Department of Agricultural and Forest Sciences technical staff for supporting the tests execution.

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