# FIRMNESS OF THE GRAPES. MECHANICAL TESTS AND DEFINITION OF INDICES. STUDY OF THE EVOLUTION OF BERRY SKIN RESISTANCE DURING ALCOHOLIC FERMENTATION

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## Abstract:

**Context and purpose of the study:** The mechanical strength or firmness of a fruit is considered an important parameter to characterize its state of maturity or conservation, as other parameters such as sugar level or color. The mechanical resistance of grapes influences the integrity and sanitary quality of the harvest. In this study, the mechanical characteristics of grapes berries are studied at harvesting time in order to determine their properties of firmness and the resistance of the berry skin during the alcoholic fermentation. Special indices are defined measuring the energy needed to crush 50% of the initial diameter of the berry. We applied these indices to different varieties and get different results either for the entire berry firmness or for the skin resistance.

**Material and methods :** To evaluate the firmness of grapes, INRA has developed a tool specifically adapted to measure the skin resistance of the grapes (Penelaup Robot, patented). We used here two grape varieties: Grenache Noir and Carignan Noir.Firmness of the entire berries were measured at harvesting. Right after, the fermentations were conducted at 21°C, in low volume tanks (<1kg) using "French Press" coffee plunger with similar and standard conditions. 1 kg of berries were crushed and poured in the tank. Lalvin ICV OKAY yeast (20 g/hL) and $SO_2$ (250 µL of a 8% solution) were added simultaneously. Cap management was carried out every day during alcoholic fermentation (AF) by submerging pomace with the plunger. The decrease of sugar concentration was monitored by measuring the Brix degree and the density. Fermentations were considered done when the density remained stable (7 to 8 days) with density less than 995. At the end of AF the classical wine chemical parameters were determined. Skin resistance measurements were carried out at the beginning and at the end of AF plus several points in between.

**Results:** We defined mechanical indices dedicated to the firmness of grapes. Using these indices, the result of this study shows differences in firmness related to the grape varieties: Grenache Noir and Carignan Noir have different mechanical properties. Similarly, during the alcoholic fermentation, the resistance of the skins highlights different properties of the berries immersed in the fermenting must. This had never measured until now. These results give new information on the mechanical properties of the grapes. It would help the winemaker to better choose the type of fermentation and maceration adapted to his grapes depending on the type of wine he wants to produce.

**Keywords**: grapes, firmness, rheology, berry skin, fermentation.

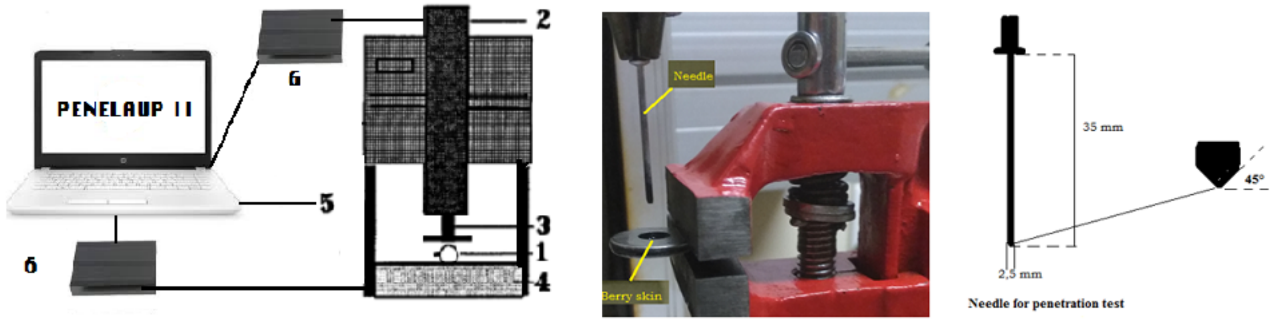
## 1. Introduction

Softening is an important physiological change during the onset of ripening in fruits (Robin *et al*, 1997; Castellarin *et al*, 2016). So, firmness is an essential quality parameter of wine grapes (*Vitis vinifera* L) but also for table grapes (Balic *et al*., 2014). The relationships among major events during softening in grape (*Vitis vinifera* L.) have previously been investigated by quantifying elasticity in individual berries. It is possible from the results provided by the Penelaup rheometer to discriminate varietal, vintage and even environmental effects (Robin *et al*., 1997). If we take into account the resistance of the grape skin, changes in pectins and hemicelluloses in primary cell wall polysaccharides, and alterations in the interactions of these polymers, have been proposed as the primary causes for texture changes that result in a decrease of firmness during the ripening of different fruit (Brummell, 2006). After ripening, and during wine processing, polyphenols, among other molecules, are extracted from the grape skin. During the fermentation, several parameters are modified in the must/wine matrix: the ethanol concentration increases in parallel to a sugar concentration decrease, but very few is known about the evolution of the parietal structures during the vinification. According to previous studies, skin resistance seemed to be correlated with anthocyanins extractability for Shiraz (Rolle *et al*, 2009) and for Nebbiolo (Rolle *et al*, 2012). The goal of this study was to check this hypothesis for other varieties and to investigate the possible changes of the mechanical behaviour of grape skins during fermentation and assess if they can be related to possible structural changes.

## 2. Materials and Methods

We used here two grape varieties: Grenache Noir and Carignan Noir. They were harvested on the experimental unit of INRA Pech Rouge (Gruissan, France), on August 22nd[nd] 2018 and September 5th[th] 2018, respectively. Berries were first sorted according to their size (volume plus or minus, noted V+ and V-), then each batch was sorted according to their density (D+ or D-). The decrease of sugar concentration was monitored by measuring the Brix degree and the density. Fermentations were considered finished when the density remained stable (7 to 8 days) with density less than 995. At the end of AF the classical wine chemical parameters were determined: pH, % vol , glucose / fructose and volatile acidity. Total pigments (TP) and total polyphenol Index (TPI) were measured as the absorbency at 520 nm and 280 nm after a 100 fold dilution in 1 M hydrochloric acid, measured in a 10 mm cuvette at the beginning (T0) and at the end (T3) of AF. A spectrophotomer UV-visible was used with three replicates at each T time. Skin resistance measurements were carried out at the beginning (T0) and at the end (T3) of AF plus two points in between, corresponding roughly to half (T1) and ¾ (T2) of the fermentation.

To evaluate the firmness of the grapes and the skin resistance, we used a device developed by INRA and CTIFL (Abbal and Planton, 1990). This device (Penelaup robot, serisud@yahoo.fr) automatically determines the physical characteristics such as the dimensional characteristics and / or the firmness of a product. It consists of a support, a measuring rod whose end is designed to support a part intended to come into contact with the sample (Figure 1). This tool is either a flat tool to measure the berry firmness or a needle-like tool to measure the berry skin resistance (Penelaup II). The sample is placed on a measuring sensor support. The control of the system consists of a computer (PC Windows 10 TM) connected to several microcontroller modules specifically developed for performing commands and processing analog signals coming from the sensors. For each measurement, the robot supplies the mass, the diameter as well as the stress curve (Newtons) of the product according to the % of crushing, chosen by the user. Given the very high accuracy of this device, the user can work in the superficial areas of the bay (a few %) or otherwise seek to the bursting of the berry. The recorded measurement curve can be used with Microsoft Excel.




1. grape: 2. column and servo screw moving system
3. mandrel and crushing tool 4. sensor
5. Computer 6. electronic control modules

Skin resistance tool - Penelaup II TM

**Figure 1 : Penelaup device**

In this work, we defined and calculated specific indices to quantify the firmness of the berries and the resistance of their skin. These indices could be used for other fruit.

Let's call p the percentage of desired deformation, D the diameter of the berry (mm), M the weight of the fruit (g);

If the deformation curve has for equation y = f (x), the area under the curve is A = ∫ f (x) d x. In physics, the area is the integral A = ∫ f (x) d x while the x and y coordinates represent physical magnitudes of different dimensions. If x represents the displacement of the tool and y a force, the area is the graphical representation of the total energy of the process (x expressed in meters, y = f(x) in Newtons, A in Joules).

**A=** $\int_a^b f(x)\mathrm{d}x$ if a = 0 and b = D * p we can define **A1(p) =**$\int_0^{D*p} f(x)\mathrm{d}x$ (first Abbal index)

A1(p) is the index of absolute firmness (joules) for p % deformation of the initial diameter D of the fruit.

Using equation A if we calculate A/M= $\int_a^b f(x)\mathrm{d}x$ / M with a = 0 and b= D * p we can define

**A2(p) =**$\int_0^{D*p} f(x)\mathrm{d}x$ **/ M** ( second Abbal index) . A2(p) is a second index of firmness (joules / kg), taking into account the weight of the fruit for a p % deformation of the initial diameter (D) of the berry.

For skin resistance measurements, the test consists to measure the energy needed to push a needle through the berry skin for a displacement of L = 10 mm. The needle is 35 mm long and 2.5 mm thick and the bottom has a V shaped (Figure 1). In the experiments described below, we used A1(p) index with X=10 mm for the grapes skins (penetrometry) and A2 with p=50% for the entire berries (firmness). To illustrate the use of these indices, we used the two grape varieties previously described: Grenache Noir and Carignan Noir. Firmness of the entire berries was measured at harvest with 50 berries samples for each variety. At the same time, 20 berries of each variety randomly sampled were prepared for skin resistance measurements. Skin resistance measurements were carried out at the beginning (T0) and at the end of AF (T3) plus two points (T1, T2) in between using 20 samples for each measurement.

## 3. Results and discussion

The fermentations were monitored through the measurements of °Brix and densities, with three replicates for each. At T0, firmness was measured with the Penelaup robot on 20 berries of each modality, for both variety. Indices A1 and A2 were calculated as previously described. These experiments were previously conducted in 2017 leading to the same conclusions. At T0, T1, T2, T3, the skin resistances were measured on 20 skins for each modality. Results are presented on Figure 3.Since the differences between the modalities are not significant compared to the varietal differences, we have grouped all the modalities and therefore we have considered the average of 80 measurements.. Upon visual and tactile examination, the skins did not seem damaged. **For the two varieties studied, skin resistance remains stable during fermentation.**

Studies were performed in parallel in our group, on how phenolics diffuse through the skins to the must during fermentation, showed that the main differences in composition between these two varieties are related to their composition in anthocyanins (Abi Habib et al., 2019), the **Carignan variety being roughly 4 times richer in anthocyanins**. This results in large differences observed when measuring the total pigments/total polyphenol index on the final wines (Figure 2), with Carignan wines having a higher absorbency at 520 nm. However, other parameters may play a role in the final composition, such as the polysaccharide and protein composition of insoluble cell material (Abi Habib *et al.*, 2019).

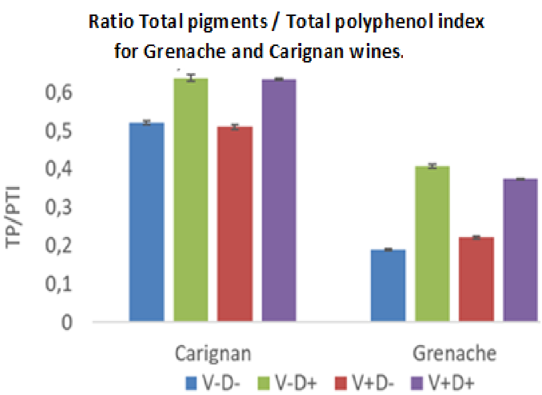



**Figure 2**

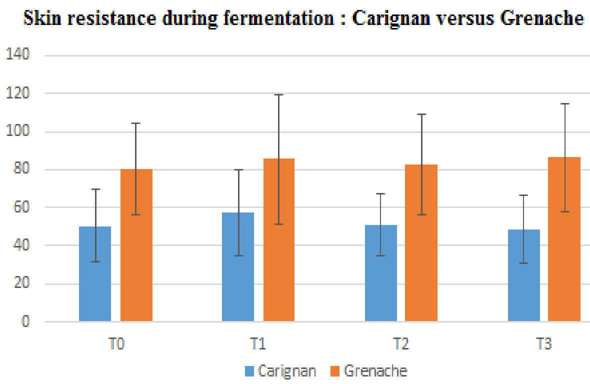



**Figure 3**

## 4. Conclusion

The main results of this work are:

- the skin resistances of the Carignan grapes and of the Grenache grapes remain stable all along the fermentation process and the skin resistance is significantly higher for Grenache versus Carignan.

- the ratio total pigments / total polyphenols is significantly higher for Carignan versus Grenache.

The grape berries used in this study were chosen to be very different according to their composition in phenolics and their supposed skin resistance. They effectively gave wines with different phenolic compositions. There seems to be a correlation between the phenolic composition, the skin resistance and the wine final composition, however the causality is unclear and further work has to be done in order to understand if Carignan gives wines richer in anthocyanins because the grapes are richer in anthocyanins, or because their skins are softer and the extraction easier.

Studies on more varieties, which would be different in several parameters, such as skin hardness and phenolics, should be performed to use these new indices of firmness as indicators of polyphenol extractability.

Anyway, these measurements would already help the winegrower (a hard skin resistance is better suited for mechanic harvesting) and the winemaker (carbonic maceration) to better choose the type of fermentation and maceration adapted to his grapes depending on the type of wine he wants to produce:

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