IUFoST 2006
DOI: 10.1051/IUFoST:20060337

Grape skin and seeds hardness assessment by texture analysis

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Abstract

In order to optimize wine quality it is important to first characterize grape phenolic maturity and to determine the extractability of phenolic compounds during winemaking. The choice of harvest date is therefore very important but nevertheless still empirical. Previous works showed the interest of grape texture measurement as factor of grape maturity characterization.
This work proposes to focus on berry skins and seed texture properties of three grapevine varieties: Cabernet sauvignon, Pinot noir and Nebbiolo from different growing areas and during two vintages, using a Universal Testing Machine TaxT2i Texture Analyzer. For the measurement of berry skin hardness, a needle probe was used, whereas for seed hardness a flat P/35 cylinder probe was used until a 50% deformation was reached. Tests were performed at 1mm.s^{-1}. Every test gave a force-deformation curve indicating the applied force at the skin and seed rupture point and the involved rupture energy.
The first part of the study concerned the validation of the method used for grape skin and seed hardness measurements. The second part was dedicated to the importance of grape skin and seed hardness for the varietal differentiation The collected data showed that since there is a significant difference between varieties, berry skin and seed hardness represents a meaningful parameter for varietal characterization and differentiation. In both years 2004 and 2005, Nebbiolo was the variety with the toughest seeds (55,8N and 58,9N), but with the weakest berry skins (0,46N and 0,35N), in comparison to Pinot noir, which had the weakest seeds (35,9N and 41,3N) but the toughest berry skins (0,57N and 0,50N). Cabernet sauvignon showed a medium hardness for berry skins (0,51N and 0,46N) and seeds (44,5N and 43,4N).

Key words Grape, texture analysis, hardness

Introduction

The texture analysis is a surveying analytical technique for the definition and the control of food physical properties (Bourne, 2002). It is nowadays more and more applied in food sector because it is able to supply objective results. The first Texture Analysis studies on grape have been made on table varieties (Bernstein e Lustig, 1981). The assessment of pulp compactness and berry skin consistency is important for customer acceptance of the product (Sims e Halbrooks, 1986; Laszlo e Saayman, 1991; Mencarelli et al., 1994; Sato et al., 1997; Sato e Yamada, 2003).
There is little experience with Texture Analysis application on wine grapes. The scientific contributions are concerned principally with the study of some

Article available at http://iufost.edpsciences.org or http://dx.doi.org/10.1051/IUFoST:20060337

modifications concerning mechanical properties, like hardness evolution during ripening (Liang et al., 1990; Abbal et al., 1992; Robin et al., 1996; Robin et al.,1997; Rolle et al., 2006b; Ruiz Hernandez, 1996).
The knowledge of texture indices like berry skin thickness and hardness, as well as seed ripening degree, can present some fundamental qualitative information for the oenologist during the planning and management of pressing and maceration processes.
The assessment of technological maturity by sugar and acid measurements is not sufficient to completely predict the grapes oenological potentialities (Failla et al., 2005). Different studies aiming for the characterization of grape phenolic substances (Saint-Criq et al., 1998a,b; Moutounet et al., 1996; Cheynier, 2001; Borsa et al., 2002, Gerbi et al. 2003) and their evolution during the ripening (phenolic maturity) highlighted important grape quality indices (Glories e Augustin, 1993; Venencie et al., 1997; Saint-Criq et al., 1998c; Cayla et al., 2002; Crespy, 2002; Mattivi et al., 2002; Cagnasso et al., 2003).
Sensory analysis has also been favorably used to evaluate grape ripeness (Rousseau e Delteil, 2000; Rousseau, 2001; Martinez, 2002).
This work proposes to focus on berry skin and seed texture properties of three grapevine varieties: Cabernet sauvignon, Pinot noir and Nebbiolo from different growing areas and during two vintages.

Materials and Methods

Sampling

During the 2004 and 2005 vintages, Cabernet sauvignon, Pinot noir and Nebbiolo grapes from different vineyards in Piedmont (North West Italy) were analyzed .
At harvest, a randomised sample of 30 to 50 clusters of each variety was collected from each vineyard.
From each cluster sample, three sub-samples of 20 berries were taken randomly from three different positions: shoulder G1 (front and back), middle G2 (front and back) and bottom G3 of the cluster. See Figure1. The sub-samples were taken without detaching the pedicel and all tests were performed the same day the berries were picked.

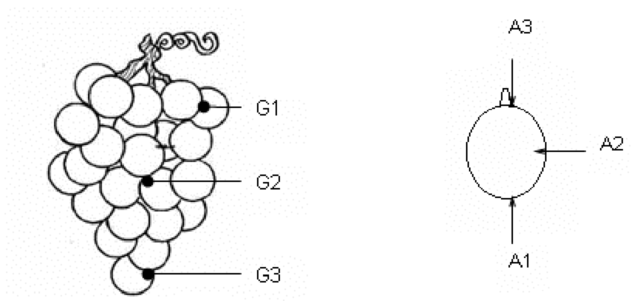

Figure1 On the left, berry sampling positions in the cluster (G1 shoulder, G2 middle, G3 bottom). On the right, berry skin puncture test positions (A1 top, A2 side, A3 bottom)

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Analysis

The analytical parameters of technological ripeness (%Brix, total acidity, pH) were estimated with official methodologies CE.
For the appraisal of grape mechanical properties, and for each individual berry, two different tests were made: berry skin and seeds hardness.
The measurements were made using a Universal Testing Machine TAxT2i Texture Analyzer (Stable Micro System, Godalming, Surrey, UK) equipped with a HDP/90 platform and a 25 Kg load cell. The acquisitions were made at 400 Hz, using Texture Expert Exceed software version 2.54 working in a Windows environment. The operative conditions applied for the tests' execution are resumed in Table1 (Uys, 1996; Grotte, 2001).

Table 1 Operational Parameters for the tests execution of the berry skin and seeds hardness

Test	Probe	Test speed (mms^{-1})	Compression	Mechanical properties
Berry skin hardness	Needle	1	3mm	F_{sk} = berry skin break Force (N) W_{sk} = berry skin break Energy (mJ)
Seed hardness	P/35, Ø 35mm	1	50%	F_s = seed break Force (N) W_s = seed break Energy (mJ)

Preliminary beery skin hardness test

In previous works on table and wine grapes, the berries used for the berry skin analysis were placed on the horizontal metal plate of the Texture analyzer with the pedicel in a horizontal plane (Lee and Bourne, 1980; Rolle et al., 2006a,b).
This preliminary berry skin hardness test was carried out on Cabernet sauvignon and Pinot noir sub-samples from the 2005 harvest, in order to compare three puncture positions on the berry (top, side and bottom), and find out which of these positions leads to the most reproducible results. See Figure1.

Statistical analysis

The data elaboration was made using the Statistica Software version 7.0 (StatSoft Inc., Tulsa, OK, USA).

Results and discussions

Table2 reports the technological ripeness parameters of Cabernet sauvignon, Pinot noir and Nebbiolo at the two harvest seasons 2004 and 2005.

Table2 Technological ripeness of Cabernet sauvignon, Pinot noir and Nebbiolo grapes at harvest seasons of 2004 and 2005. The data is the mean of vineyards

	2004			2005		
	Brix %	Total acidity (g/L tartaric acid)	pH	Brix %	Total acidity (g/L tartaric acid)	pH
Cabernet sauvignon	23,8	5,7	3,12	22,4	7,5	3,18
Pinot noir	20,3	7,6	3,08	21,0	9,9	3,03
Nebbiolo	23,8	7,0	3,10	24,6	6,7	3,12

DOI: 10.1051/IUFoST:20060337

Figure2 shows a typical Force-time (or deformation) curve obtained with the berry skin puncture test. The berry skin hardness is assessed either by the maximum break force (Fsk) or by the break energy (W_{sk}). The first parameter corresponds to the skin resistance to the probe penetration while the second parameter is represented by the area under the curve, which is limited between the 0 point and F_{sk}.

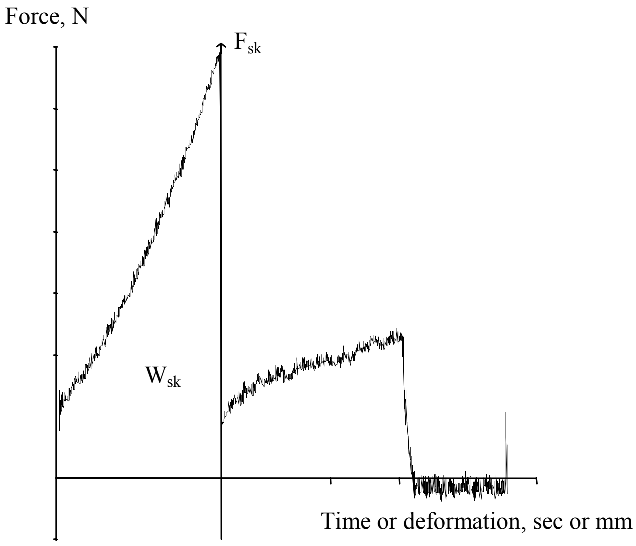

Figure2 Force-time (deformation) curve corresponding to the berry skin puncture test

The Force-time curve, related to the seed hardness test, is reported in Figure3. Break Force (Fs) corresponds to the first peak, while break energy (W_s) corresponds to the area under the curve which is limited by the 0 point and the break point. D1 represents the break distance. E_s is a measure of the material's resistance to axial deformation. It represents the stiffness of the material to an applied load. The larger the stiffness, the higher the force or stress needed to cause a given deformation or strain. Its value is calculated as the slope of the stress-strain curve in the linear section (Vargas et al., 2001).

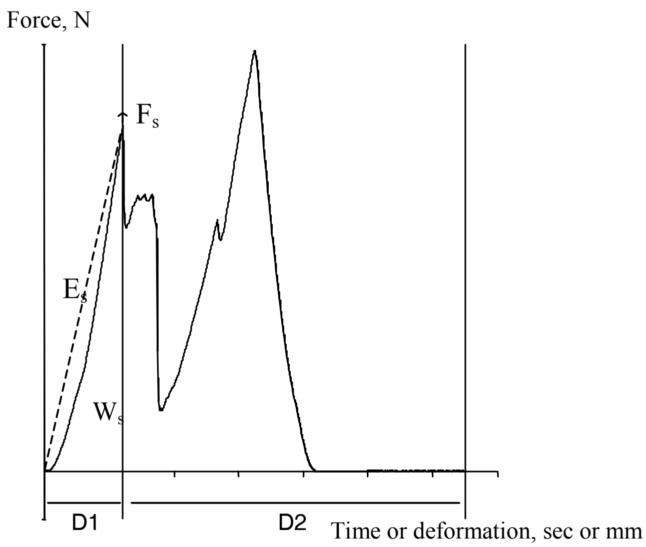

Figure3 Force-distance curve related to the test for seed hardness determination

DOI: 10.1051/IUFoST:20060337

The results of the preliminary berry skin hardness tests are reported in Table3. Results show a significant difference between the three puncture positions (A1, A2, A3) whereas there is no significant difference between the berries picked from different positions of the cluster, as shown in Table4. It is therefore possible to underline that the berry skin hardness test is not affected by the sub-sampling position because whether the berries are picked in the top, the middle or the bottom of the cluster, they still have the same skin mechanical properties. In contrast, the test is affected by the positioning of the berry on the horizontal metal plate of the Texture Analyzer: with the pedicel in horizontal (A2) or vertical plane (A1 and A3).
The differences according to the berry puncture position between the two vineyards of Cabernet sauvignon and Pinot noir are shown in Table5 and Table6. For Cabernet sauvignon, there is no significant difference between the vineyards if the puncture test is carried out in A1 or A2 points, whereas the difference is significant ($p<0,05$) when the puncture point is A3. The same comparison between Pinot noir vineyards showed that there is a significant difference if the test is made in A2 and A3 points ($p<0,001$) while there is no significant difference if the puncture position is A1. The results given by A2 are therefore more reproducible than A1 and A3 and consequently, it is considered the best position for the puncture test and supports the methods of Lee and Bourne (1980) and Rolle et al. (2006a,b) for grape puncture tests.

Table3 Berry skin hardness parameters of Cabernet sauvignon and Pinot noir measured in different puncture positions. Sign = significance; ***p< 0.001, **p<0.01, *p<0.05, ns = not significant

		Fsk (N)				Wsk (mJ)			
		A1	A2	A3	Sign	A1	A2	A3	Sign
Cabernet sauvignon 1	G1	$0,39^{b}$ ± 0,09	$0,41^{b}$ ± 0,09	$0,29^{a}$ ± 0,04	***	$0,19^{b}$ ± 0,09	$0,22^{b}$ ± 0,08	$0,10^{a}$ ± 0,03	***
	G2	$0,36^{b}$ ± 0,06	$0,42^{c}$ ± 0,08	$0,29^{a}$ ± 0,06	***	$0,18^{b}$ ± 0,05	$0,22^{b}$ ± 0,08	$0,11^{a}$ ± 0,05	***
	G3	$0,38^{b}$ ± 0,07	$0,43^{b}$ ± 0,06	$0,29^{a}$ ± 0,06	***	$0,19^{b}$ ± 0,06	$0,24^{b}$ ± 0,06	$0,12^{a}$ ± 0,06	***
Cabernet sauvignon 2	G1	$0,36^{b}$ ± 0,055	$0,44^{c}$ ± 0,06	$0,29^{a}$ ± 0,05	***	$0,19^{b}$ ± 0,07	$0,25^{c}$ ± 0,06	$0,11^{a}$ ± 0,04	***
	G2	$0,37^{b}$ ± 0,08	$0,41^{b}$ ± 0,06	$0,26^{a}$ ± 0,05	***	$0,18^{b}$ ± 0,06	$0,23^{c}$ ± 0,06	$0,09^{a}$ ± 0,03	***
	G3	$0,36^{b}$ ± 0,06	$0,41^{b}$ ± 0,05	$0,26^{a}$ ± 0,05	***	$0,18^{b}$ ± 0,06	$0,22^{b}$ ± 0,05	$0,09^{a}$ ± 0,03	***
Pinot noir 1	G1	$0,39^{a}$ ± 0,10	$0,53^{b}$ ± 0,08	$0,41^{b}$ ± 0,06	***	$0,19^{a}$ 0,08	$0,31^{b}$ ± 0,07	$0,18^{a}$ ± 0,04	***
	G2	$0,43^{b}$ ± 0,08	$0,57^{c}$ ± 0,05	$0,38^{a}$ ± 0,05	***	$0,22^{b}$ ± 0,07	$0,31^{c}$ ± 0,05	$0,19^{a}$ ± 0,06	***
	G3	$0,42^{b}$ ± 0,07	$0,56^{c}$ ± 0,08	$0,35^{a}$ ± 0,07	***	$0,22^{b}$ ± 0,06	$0,29^{c}$ ± 0,08	$0,19^{a}$ ± 0,06	***
Pinot noir 2	G1	$0,41^{b}$ ± 0,10	$0,46^{b}$ ± 0,06	$0,35^{a}$ ± 0,06	***	$0,19^{a}$ ± 0,08	$0,26^{b}$ ± 0,05	$0,16^{a}$ ± 0,05	***
	G2	$0,40^{a}$ ± 0,11	$0,50^{b}$ ± 0,09	$0,35^{a}$ ± 0,05	***	$0,20^{a}$ ± 0,09	$0,30^{b}$ ± 0,06	$0,16^{a}$ ± 0,05	***
	G3	$0,43^{b}$ ± 0,11	$0,48^{b}$ ± 0,08	$0,35^{a}$ ± 0,04	***	$0,24^{b}$ ± 0,10	$0,27^{b}$ ± 0,08	$0,16^{a}$ ± 0,04	***

Table4 Berry skin hardness parameters of Cabernet sauvignon and Pinot noir sampled from different positions in the cluster. Sign = significance; ***p< 0.001, **p<0.01, *p<0.05, ns = not significant

		Fsk (N)				Wsk (mJ)			
		G1	G2	G3	Sign	G1	G2	G3	Sign
Cabernet sauvignon 1	A1	0,39 ± 0,09	0,37 ± 0,06	0,39 ± 0,07	ns	0,19 ± 0,09	0,18 ± 0,05	0,19 ± 0,06	ns
	A2	0,42 ± 0,09	0,42 ± 0,08	0,43 ± 0,06	ns	0,22^{b} ± 0,08	0,22 ± 0,08	0,24 ± 0,06	ns
	A3	0,29 ± 0,04	0,29 ± 0,06	0,29 ± 0,06	ns	0,10 ± 0,03	0,11 ± 0,05	0,12 ± 0,06	ns
Cabernet sauvignon 2	A1	0,37 ± 0,05	0,37 ± 0,08	0,37 ± 0,06	ns	0,19 ± 0,07	0,18 ± 0,06	0,18 ± 0,06	ns
	A2	0,44 ± 0,06	0,41 ± 0,06	0,41 ± 0,05	ns	0,25 ± 0,06	0,23 ± 0,06	0,22 ± 0,05	ns
	A3	0,29^{b} ± 0,05	0,26^{a,b} ± 0,06	0,26^{a} ± 0,05	*	0,11 ± 0,04	0,09 ± 0,03	0,09 ± 0,03	ns
Pinot noir 1	A1	0,38 ± 0,10	0,44 ± 0,08	0,43 ± 0,07	ns	0,19 ± 0,08	0,22 ± 0,07	0,22 ± 0,06	ns
	A2	0,53 ± 0,08	0,57 ± 0,05	0,56 ± 0,08	ns	0,31 ± 0,07	0,31 ± 0,05	0,29 ± 0,08	ns
	A3	0,42^{b} ± 0,06	0,38^{a,b} ± 0,05	0,35 ^{a} ± 0,07	**	0,18 ± 0,04	0,19 ± 0,06	0,19 ± 0,06	ns
Pinot noir 2	A1	0,42 ± 0,10	0,40 ± 0,11	0,43 ± 0,11	ns	0,19 ± 0,08	0,20 ± 0,09	0,24 ± 0,10	ns
	A2	0,46 ± 0,06	0,50 ± 0,09	0,48 ± 0,08	ns	0,26 ± 0,05	0,30 ± 0,06	0,27 ± 0,08	ns
	A3	0,35 ± 0,06	0,35 ± 0,05	0,35 ± 0,04	ns	0,16 ± 0,05	0,16 ± 0,05	0,16 ± 0,04	ns

Table5 Berry skin hardness of two Cabernet sauvignon vineyards. Sign = significance; ***p< 0.001, **p<0.01, *p<0.05, ns = not significant.

	Fsk (N)			Wsk (mJ)		
	Cabernet sauvignon 1	Cabernet sauvignon 2	Sign	Cabernet sauvignon 1	Cabernet sauvignon 2	Sign
A1	0,38 ± 0,07	0,37 ± 0,06	ns	0,19 ± 0,07	0,18 ± 0,06	ns
A2	0,42 ± 0,08	0,42 ± 0,06	ns	0,23 ± 0,08	0,23 ± 0,06	ns
A3	0,29 ± 0,06	0,27 ± 0,05	*	0,11 ± 0,05	0,10 ± 0,04	ns

Table6 Berry skin hardness of two Pinot noir vineyards. Sign = significance; ***p< 0.001, **p<0.01, *p<0.05, ns = not significant.

	Fsk (N)			Wsk (mJ)		
	Pinot noir 1	Pinot noir 2	Sign	Pinot noir 1	Pinot noir 2	Sign
A1	0,42 ± 0,09	0,42 ± 0,11	ns	0,21 ± 0,07	0,21 ± 0,09	ns
A2	0,55 ± 0,07	0,48 ± ,076	***	0,30 ± 0,07	0,28 ± ,064	*
A3	0,38 ± 0,06	0,35 ± 0,05	***	0,17 ± 0,05	0,16 ± 0,05	*

The data shown in Table7 is related to the difference among Cabernet sauvignon, Pinot noir and Nebbiolo varieties according to their berry skin and seed hardness parameters. In both 2004 and 2005 there is a significant difference between varieties, therefore berry skin and seed break force and energy are meaningful parameters for varietal characterization and differentiation. Nebbiolo indeed was the variety with the more resistant seeds (55,8N break force in 2004 and 58,9N in 2005) and (14,4 mJ break energy in

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DOI: 10.1051/IUFoST:20060337

2004 and 15,9 mJ in 2005), but with the less resistant berry skins (0,46N break force in 2004 and 0,35N in 2005) and (0,34 mJ in 2004 and 0,18 mJ in 2005). In opposition, Pinot noir had the weakest seeds but the toughest berry skins. Cabernet sauvignon showed a medium hardness for berry skins and seeds.
The high berry skin hardness of Pinot noir could be due to a reduced level of maturity compared to the other two varieties with low sugar content (20,3 % Brix) and high acidity 7,6 g/L tartaric acid in 2004 and 6.8 g/L tartaric acid in 2005, since the berry skin hardness decreases when sugars increase (Lee and Bourne, 1980). It could likewise be the consequence of high berry skin thickness (Rolle et al., 2006b). Berry skin resistance to rupture (splitting) is nevertheless important from the agronomical and phytopathological point of view (Considine, 1981; Lang e During, 1990; Bišof et al., 1994), as well as from the technological point of view, as this characteristic could reduce cell permeability (Cagnasso et al., 2005).
Coombe (1973) reported that the growth of the grape berry is characterized by two successive sigmoid curves, with a plateau in between that corresponds to three stages of development. During stage I, the pericarp and seed cell numbers increase. During this stage the seed approaches its full size. During stage II, the seed embryo develops with a concomitant hardening of the seed coat (Coombe, 1960). Stage III is the ripening stage when sugars rapidly accumulate. The inception of stage III (termed véraison) is characterized by berry softening. By véraison, much of the seed is fully developed but during the third and last grape ripening stage, the seeds mature, turn from green to brown and become hard and desiccated. The high seed hardness of Nebbiolo is therefore an indication of mature seeds whereas the low seed hardness level of Pinot noir could be due to an uncompleted third ripening stage. Therefore such aspect needs to be subsequently investigated.

Table7 Cabernet sauvignon, Pinot noir and Nebbiolo berry skin and seeds hardness. Sign = significance; ***p< 0.001, **p<0.01, *p<0.05, ns = not significant. (Inside the cells, the significance of the difference among the vineyards is reported).

	2004				2005			
	Fsk (N)	Wsk (mJ)	Fs (N)	Ws (mJ)	Fsk (N)	Wsk (mJ)	Fs (N)	Ws (mJ)
Cabernet sauvignon	0,51 ± 0,07 *	0,35 ± 0,13 ***	44,5 ± 6,94 ns	12,21 ± 3,50 ns	0,46 ± 0,05 ns	0,23 ± 0,06 ns	43,4 ± 5,44 ns	11,61 ± 2,42 ns
Pinot noir	0,57 ± 0,12 ***	0,35 ± 0,12 ns	35,9 ± 7,00 *	11,06 ± 3,75 ns	0,50 ± 0,07 ns	0,27 ± 0,06 ns	41,3 ± 8,37 ns	11,65 ± 3,19 ns
Nebbiolo	0,46 ± 0,09 ns	0,34 ± 0,13 ns	55,8 ± 10,66 ns	14,45 ± 5,00 *	0,35 ± 0,06 ns	0,18 ± 0,05 ns	58,9 ± 10,34 Ns	15,91 ± 4,36 ns
Sign	***	ns	***	***	***	***	***	***

Conclusions

Texture analysis proved to be an efficient method for the assessment of wine grape mechanical behavior. The experiment showed a high discrimination between Cabernet sauvignon, Pinot noir and Nebbiolo grapes. The knowledge of texture indices could provide important qualitative information for the

oenologist during the planning and management of the pressing and maceration processes.
In order to acquire wider information it becomes necessary to extend the study to check the possible correlations between data obtained by texture analysis and grape chemical parameters, with a particular emphasis in those related to phenolic maturity, which in the past involved long and expensive methodologies.
Finally, it is interesting to establish some texture analysis tests that are able to integrate human sensorial capacities in addition to furnishing objective evaluations of the mechanical parameters required in some grape sensory analysis cards.

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