PAPER

EVOLUTION OF MECHANICAL VARIABLES OF WINEGRAPES FOR ICEWINE PRODUCTION DURING ON-VINE DRYING

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ABSTRACT

The evolution of some mechanical properties of the berry skin and pedicel during on-vine drying of wine-grapes was studied, in order to assess the suitability of two alpine cultivars, Becuét and Fumin, for the production of icewines. This overripening process on the vine, which lasts until complete freezing of the grapes, results in marked changes in the mechanical characteristics of the grapes.

During grape dehydration, the skin thickness increased in both cultivars (Becuét +73 μm, Fumin +85 μm). The skin hardness also increased, particularly in the Becuét berries, in which the break skin force and break skin energy values increased of 0.148 N and 0.823 mJ, respectively. In contrast, the peduncle detachment force decreased during the drying process; in Becuét grapes, this occurred after only 15 days. While the two cultivars have different mechanical properties, both proved to be suitable for the production of icewines ("Vini del ghiaccio"); the changes that occur during on-vine drying do not preclude the resistance of the berries to shattering and of the berry skin to splitting.

- Key words: berry skin, grape dehydration, grape withering, peduncle, texture analysis -

INTRODUCTION

Many varieties of wines world-wide are produced by partial or total use of overripe and/or dehydrated grapes. Among these wines, there are those characterized by the absence of sugar ("dry"), and other, ("sweet" or dessert wines), which contain the presence more or less elevated levels (10-250 g/L) of residual sugar. The latter are generally very well-known and are commercially more important. These include the "Passiti" wines, the "icewines", the Sauternes, the Tokaij and the Jerez, as well as many other lesser known wines that are produced in almost all viticultural areas of the world (BARBANTI *et al.*, 2008, SOLEAS and PICKERING, 2007; GENOVESE *et al.*, 2007; MIKLÓSY *et al.*, 2000).

Various withering procedures are used in the production of these wines. Dehydration of harvested grapes (off-vine grape drying) can be performed directly in the sun, as in the production of Passito di Pantelleria or in sweet Greek wines (ASTORINO and DI STEFANO, 2003; KARAGIANNIS *et al.*, 2000), or indirectly in ventilated rooms, tunnel-dried (BELLINCONTRO *et al.*, 2004) with or without use of ventilation systems and/or thermohygrometric control (artificial overripening). On-vine grape drying is the withering technique that is used in the production of Sauternes and icewines (RIBÉREAU-GAYON *et al.*, 2000).

The various withering techniques influence the evolution of many compounds such as glycerol, aromatic substances (BAILLY *et al.*, 2006; COSTANTINI *et al.*, 2006), and polyphenols (AMATI *et al.*, 1983; FRANGIPANE *et al.*, 2007) that contribute directly to the sensory characteristics of the wine, as well as to the development and selection of the microflora present on the grapes (CHAMBERLAIN *et al.*, 1997; RIBÉREAU-GAYON *et al.*, 2000; URSO *et al.*, 2008). While the chemical and microbiological knowledge is available in the scientific literature, information about the evolution of the mechanical behavior of wine-grapes during the different withering processes is very limited. In particular, there are no studies related to on-vine grape drying. Knowledge of the evolution of some mechanical variables such as the ease of pedicel detachment, or the hardness and thickness of the skin, is important because these aspects are directly related to the phenomena of shattering, resistance to splitting and plant diseases (GABLER *et al.*, 2003; LANG and DURING, 1990).

Canada, Germany and Austria are the main icewine producers followed by many other European countries including France, Hungary, Slovenia and Switzerland. Icewines ("Eiswein") are produced according to strict production standards and regulations. Harvesting and wine-making are monitored by public and/or private institutions. In Canada the grapes must be naturally frozen on the vine at -8 °C or colder and this temperature must be maintained throughout the pressing process without artificial refrigeration (CLIFF *et al.*, 2002; NURGEL *et al.*, 2004). According to German regulations grapes must be frozen naturally at -7°C or lower and the must is required to have an Oechsle value of 125 degrees (ZIRALDO, 2000). The Vidal, Riesling, Traminer, Chardonnay and Muscat Ottonel cultivars are traditionally used to produce icewines, but some countries use local cultivars.

In Italy the climatic conditions for producing icewines ("Vini del ghiaccio") are only present in mountainous grape-producing environments. This study was conducted on two cultivars, Becuét and Fumin, that are mainly distributed in the Western Alps in Europe (SCHNEIDER *et al.*, 2001). These cultivars can adapt to a shorter growing season and freezing temperatures in those areas. One of the key factors in the economic development of viticulture and the wine industry in mountainous areas is the exploitation of ancient, local grape cultivars. In this context, the production of icewines could provide a major opportunity for companies operating in alpine regions. The climatic conditions suitable for the production of these wines are only found in such areas.

The purpose of this study was to assess the evolution of some mechanical characteristics during withering on the vine of different wine-grapes cultivars used to produce icewines.

MATERIALS AND METHODS

Grapes, sampling and chemical analyses

Two red grapes varieties were studied: Becuét and Fumin. The university experimental vineyard is located at 750 m asl on the sun-exposed side of the Susa Valley in the Province of Turin (Piedmont, Italy). The study was carried-out in 2007.

Four hundred berries, with attached pedicels, were sampled for each cultivar on six dates, in a random manner, during the overripe period (20 September-to 19 December), according to the sampling method described by CARBONNEAU *et al.* (1991). Cluster fragments were randomly picked in the middle part of the cane or cordon; the first rows of the vineyard were excluded.

The climatic conditions (temperature, relative humidity, rain) in the vineyard were monitored by a Vantage PRO2 weather station (Davis Instruments, Hayward, CA, USA).

For each sampling date, the analytical variables of grape ripeness (soluble solids concentration, titratable acidity, pH) were estimated using EEC methods (1990). Malic acid was monitored by HPLC (SCHNEIDER *et al.*, 1987).

Texture analysis

The mechanical properties of grapes were measured on sub-samples of 30 berries each from the 400 berries described above, for each cultivar and for each test. The remaining berries were used for chemical determinations.

To avoid any alteration, the tests were performed on the day that the berries were picked. Prior to testing, the berries, arranged in a single layer, were thermally conditioned at 20°C in a thermostat.

A Universal Testing Machine TAxT2i Texture Analyzer (Stable Micro Systems - SMS, Surrey, UK) equipped with a HDP/90 platform (with and without perforations) and a 5 kg load cell was used. All the acquisitions were made at 400 Hz; data were evaluated using the Texture Expert Exceed software package (vers. 2.54 in Windows 2000). The test conditions applied, the probe and the mechanical parameters measured (Table 1), were based on previous work (LETAIEF *et al.*, 2008a,b; ROLLE *et al.* 2007).

Statistical analysis

Analysis of variance (ANOVA) was applied to all the variables studied. Statistical analyses were performed using the statistical software SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). All statistical analysis results are reported in Table 2.

RESULTS AND DISCUSSION

After 90 days of withering on the vine, both cultivars reached the sugar level required for the production of icewines in Europe (Fig. 1). The early-morning temperatures (from -7° to -14°C) met the icewine production requirements. The sugar concentration increased regularly throughout the period of overripening in parallel with berry dehydration and relative weight loss (Fig. 2).

The decrease in acidity during slow dehydration is also observed in long-term drying under uncontrolled environmental conditions and has been attributed to malic acid depletion (BELLINCONTRO *et al.*, 2002). This aspect was particularly evident in Fumin grapes in which the titratable acidity and malic acid concentration decreased markedly (Fig. 1).

Fig. 3 shows the evolution of the berry skin mechanical variables. The F_{sk} and W_{sk} values, in spite of the elevated dispersion of the data, increased progressively during grape overripening on the vine, while E_{sk} showed the opposite trend which was more evident in the Becuét grapes than in the Fumin ones. Throughout the period of drying on-vine the Becuét berry skin was characterized by higher values for both skin break force and skin break energy. These factors are important because they allow the grapes to resist fungal diseases, as well as strong winds.

In parallel with the hardening of the skin tis-

Table 1 - Operating conditions used in the texture analysis of Becuét and Fumin grapes.

Test	Probe - Platform	Test speed	Force	Mechanical properties
Berry skin hardness	SMS P/2N Needle; HDP/90 platform	1 mm s^{-1}	compression 3 mm	F_{sk} = Berry skin break force (N) W_{sk} = Berry skin break energy (mJ) E_{sk} = Skin Young's modulus (N/mm)
Berry skin thickness	SMS P/2 Ø 2 mm; HDP/90 platform	0.2 mm s^{-1}	-	Sp_{sk} = Berry skin thickness (μm)
Peduncle detachment resistance	SMS A/PS modified with rigid arm; HDP/90 perforated (Ø 5 mm) platform	1 mm s^{-1}	traction 10 mm	F_{ped} = Peduncle detachment force (N) W_{ped} = Peduncle detachment Energy (mJ)

Table 2 - Statistical analysis results. Latin letters (a, b, c) in the same column are used to compare the influence of overripening time within each cultivar. Greek letters (α, β) in the same column are used to compare the cultivar differences. Means values followed by the same letter are not significantly different (P≤0.05).

Over ripening days	Berry weight		F_{sk}		W_{sk}		E_{sk}		Thickness		F_{ped}		W_{ped}	
	Becuét	Fumin	Becuét	Fumin	Becuét	Fumin	Becuét	Fumin	Becuét	Fumin	Becuét	Fumin	Becuét	Fumin
0 (20 sept)	a	a	b,α	a,β	b,α	b,β	a,α	a,α	c,α	d,α	a,α	a,α	ab,α	ab,α
14 (4 oct)	a	a	ab,α	a,β	ab,α	b,β	b,α	b,α	b,α	bc,α	b,β	a,α	a,α	ab,α
29 (19 oct)	ab	ab	b,α	a,β	b,α	b,β	b,β	ab,α	ab,β	a,α	b,α	ab,α	bc,α	b,α
48 (7 nov)	ab	ab	ab,α	a,β	ab,α	a,β	c,α	c,β	ab,α	cd,α	b,β	ab,α	c,β	ab,α
66 (25 nov)	b	b	ab,α	a,β	ab,α	a,β	d,α	c,α	a,β	a,α	b,β	ab,α	bc,β	a,α
90 (19 dec)	b	b	a,α	a,β	a,α	a,β	d,α	c,α	a,α	ab,α	b,β	b,α	bc,β	a,α

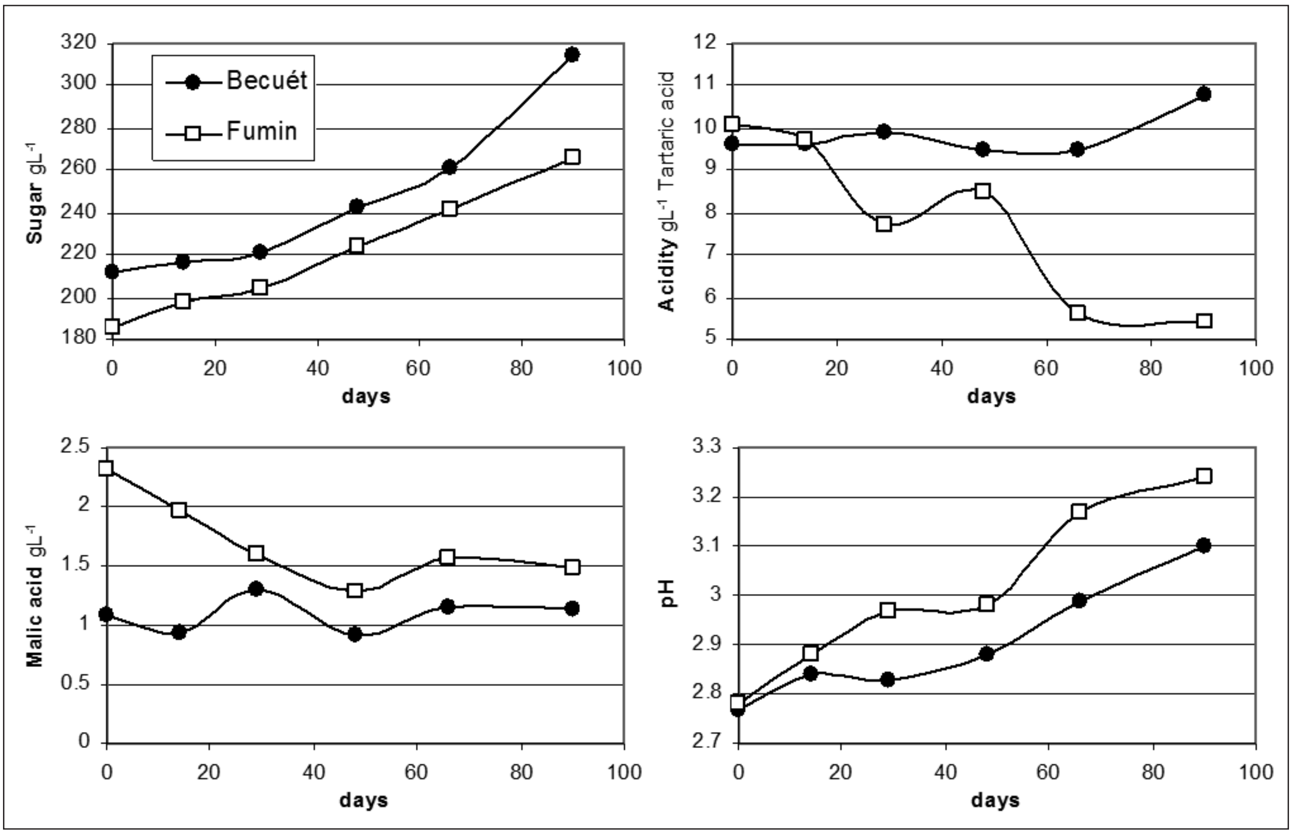

Fig. 1 - Monitoring variables used for assessing overripening of grapes on the vine for the Becuét and Fumin cultivars.

sues, the average skin thickness also increased (Fig. 4), which partially explains the higher F_{sk} and W_{sk} values discussed above. The increase in thickness was particularly rapid in the first 30 days. At the end of the withering period, the skin thickness in both cultivars had increased about 35%. There were no differences between Becuét and Fumin with respect to Sp_{sk}, although the latter generally had higher average values.

On 1 November 2007, there were 32 mm of rainfall in the vineyard after a prolonged period of drought (75 days). Some of the abnormal data related to Sp_{sk}, and the titratable acidity in the Fumin grapes on 7 of November can be attributed to this rainfall. During the rest of the experimental period there was no rain, but 30 cm of snow fell on 12 December. At the time of the last sampling (19 December), the clusters carried a considerable amount of snow, the weight of which could have caused a significant loss of grape berries if the detachment force was low. The evolution of the strength and energy of detachment of the pedicel showed that the Becuét grapes had a greater propensity to fall during the entire wither-

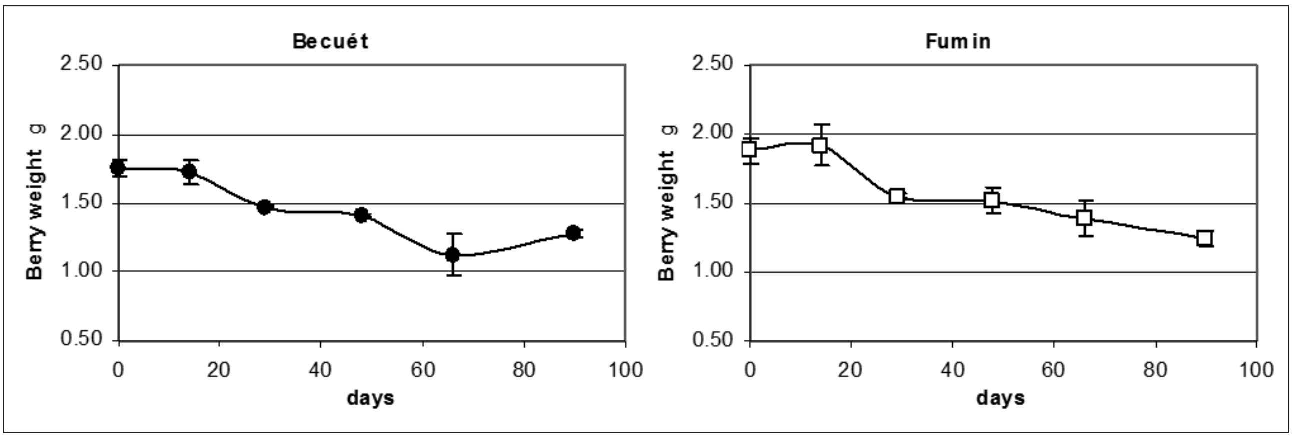

Fig. 2 - Evolution of Becuét and Fumin grape berry weight (g) during overripening on the vine. Average value ± standard deviation (*n*=30).

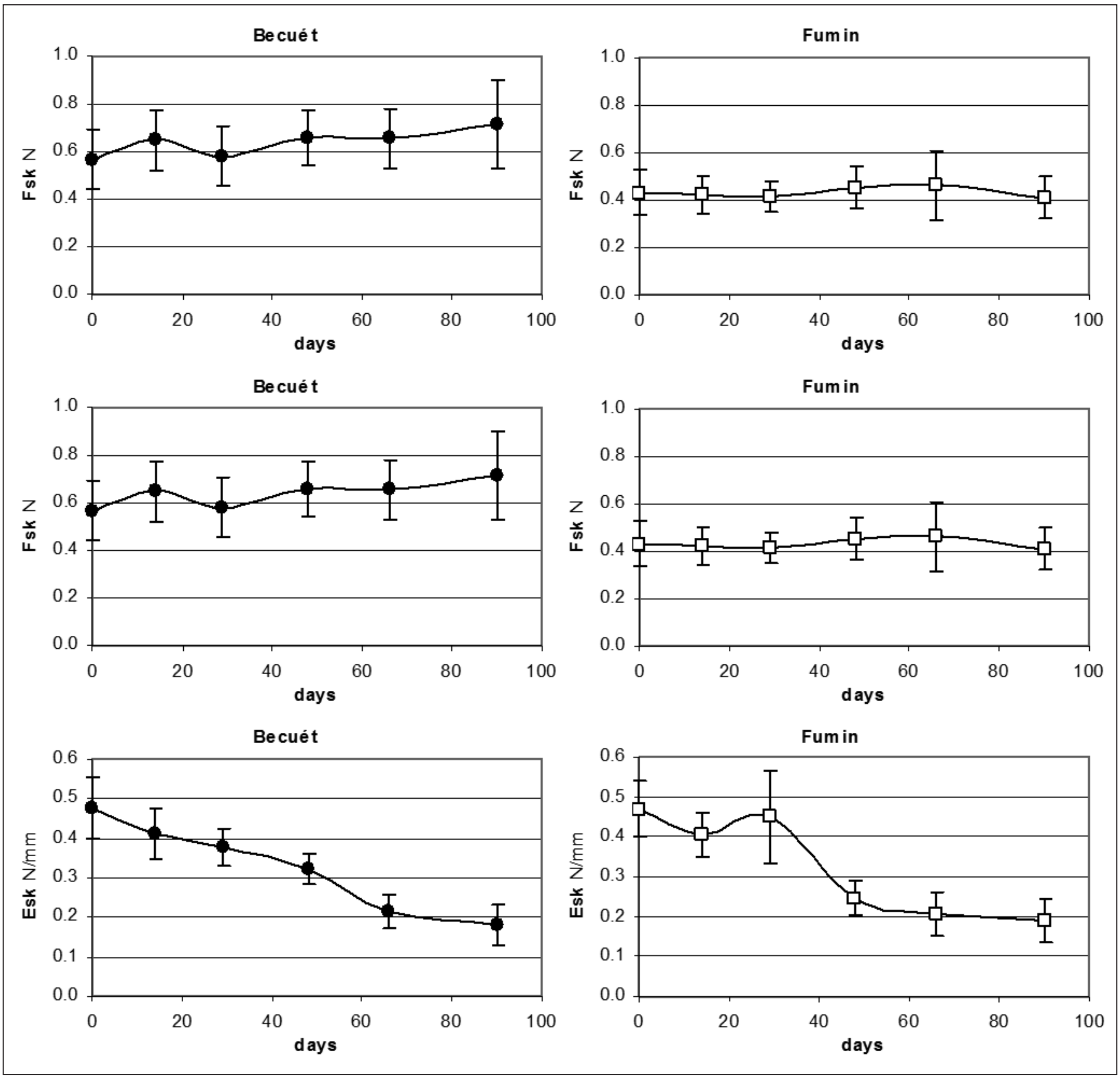

Fig. 3 - Trends in the mechanical properties of Becuét and Fumin grape berry skin during overripening on the vine. F_{sk} = Berry skin break force; W_{sk} = Berry skin break energy; E_{sk} = Skin Young's modulus. Average value ± standard deviation (n=30).

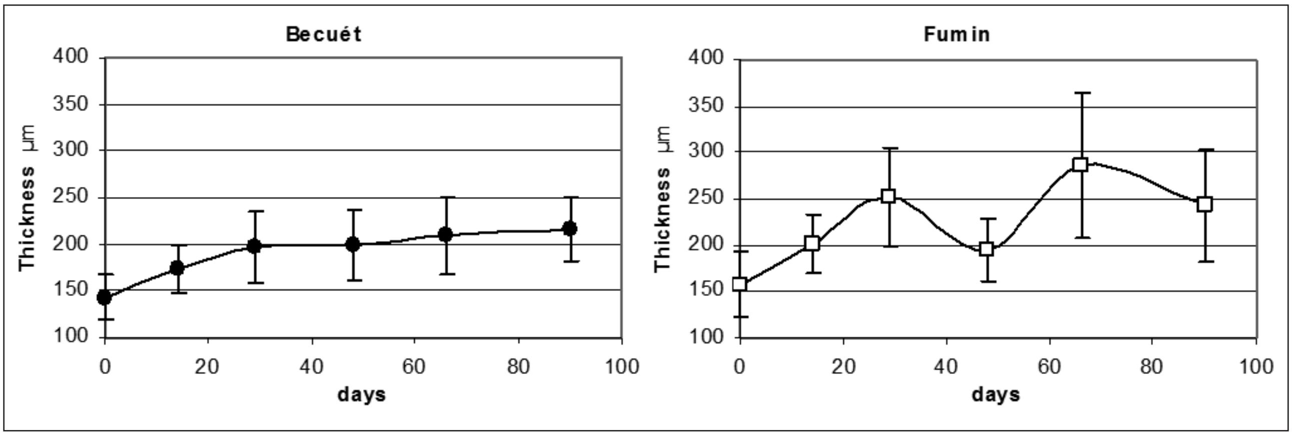

Fig. 4 - Variation of the thickness of Becuét and Fumin grape berry skin (µm) during overripening on the vine. Average value ± standard deviation (n=30).

ing period (Fig. 5). This tendency could already be noted after 15 days of overripening and the lower F_{ped} and W_{ped} values occur when the chance of snow is higher. At the end of the dehydration period, the Fumin grapes had average F_{ped} values that were considerably higher (+57%), and displayed a more gradual decrease during the drying process. This cultivar also showed a progressive W_{ped} increase; during the traction test, before breaking away, the peduncle tends to deform the apical part of the berry and stretches the skin. This increasing elasticity of the Fumin grape skin tissues explains the higher energy of the detachment values that were recorded.

The mechanical characteristics of the grapes showed a high variability which increased for almost all of the variables in the final stages of overripening due to non-homogeneous dehydration of the grapes. Despite this variability, the evolution of the mechanical variables was evident. Even during the normal process of grape ripening from veraison to harvest, some changes in the mechanical properties occur, particularly regarding firmness (LEE and BOURNE, 1980; ROBIN *et al.*, 1997). However, these changes cannot be used as a criterion for determining the time of grape harvest. However, they can be used to discriminate the different production areas (LE MOIGNE *et al.*, 2008). Mechanical properties can also be used to characterize the different cultivars, even if the variables are strongly conditioned by the annual climatic trends (LETAIEF *et al.*, 2008b). The values for many of the variables, including F_{sk}, W_{sk} and F_{ped} differed in the Becuét and Fumin cultivars.

The skin break force is an important technological variable for red winegrapes because it is related to the extractability of phenolic substances from the skin (ROLLE *et al.*, 2008). Regarding the extraction of anthocyanins, there is an interaction between F_{sk} and the stages of ripening (ROLLE *et al.*, 2009). Harder skins lead to a more complete extraction of anthocyanins, but with slower extraction kinetics. F_{sk} and Sp_{sk} are directly related to the cell permeability index (EA%) (RIO SEGADE *et al.*, 2008), which provides information relative to the ease of transfer of these compounds. Higher EA% values indicate a slower dissolution of anthocyanins in the must (CAGNASSO *et al.*, 2008).

In the production of icewines, phenolic compounds are only extracted during the pressing of the frozen grapes because there is no maceration during fermentation. Due to the brevity of contact between the skin and must, varieties with hard skins could have a reduced anthocyanin content in the wine. This aspect is particularly important for cultivars with a low anthocyanin content. The Becuét cultivar, has highest F_{sk} values and is rich in anthocyanins (> 1,300 mg/kg grapes) (GERBI *et al.*, 2005), so even a

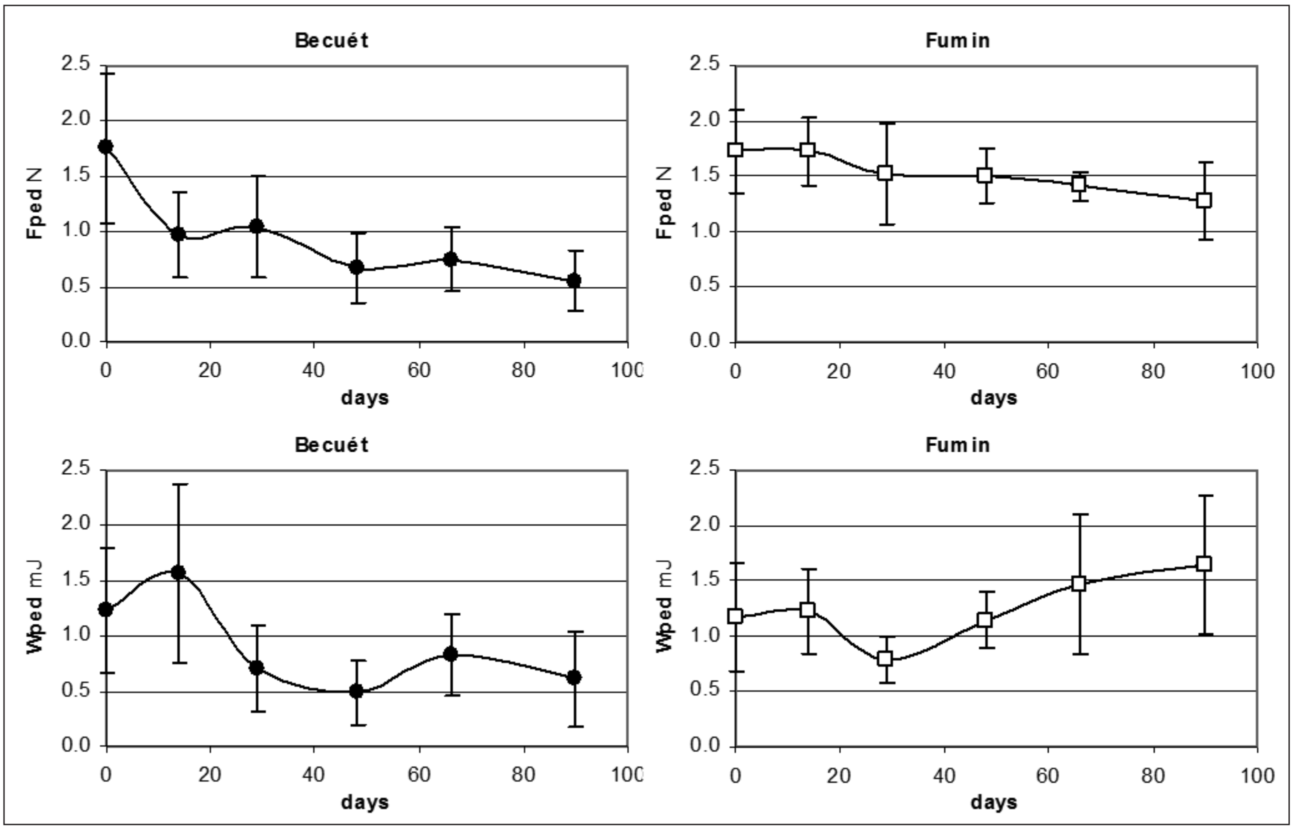

Fig. 5 - Trends in resistance to peduncle detachment in Becuét and Fumin berries during overripening on the vine. F_{ped} = Peduncle detachment force; W_{ped} = Peduncle detach energy. Average value ± standard deviation (n=30).

brief contact time is sufficient to ensure adequate color intensity in the wines.

CONCLUSIONS

The evolution of some mechanical variables of grapes during withering on the vine were shown. Icewines or "Vini del ghiaccio" cannot be produced with grape varieties that do not perform well in the strict environmental conditions required for withering. The main characteristic required is high resistance to shattering and detachment force of the pedicel is an effective parameter for monitoring this characteristic. The hardness and thickness of the skin are important variables for resistance to plant diseases; they also play an important role in must preparation.

The cultivars Becuét and Fumin have different mechanical properties but both proved to be suitable for the production of icewine. In addition to these mechanical variables, cultivars must be carefully selected to ensure that at technological ripeness, the sugar levels are high in order to reduce the time on the vine. To avoid losing the product, the grapes should reach the desired sugar level as early as possible so that harvest of the dried grapes can be carried out as soon as the ambient temperature (<-7°C) permits.

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