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Varietal Relationship between Skin Break Force and Off-Vine Withering Process for Winegrapes

S. Giacosa#, F. Torchio#, S. Río Segade, A. Caudana, V. Gerbi, and L. Rolle

# These authors contributed equally to the study

University of Turin, DIVARA - Food Technology sector, Via L. da Vinci, 10095 Grugliasco, Turin, Italy.

Contact information for Corresponding Author

Corresponding author: Susana Río Segade

Email: susana.riosegade@unito.it

Tel.: +39 11 6708558

Fax: +39 11 6708549

ABSTRACT

This paper presents a detailed study on the influence of the winegrape variety, skin hardness of fresh berries and withering thermo-hygrometric conditions on the dehydration kinetics of the grape. Although some works already published are focused on the changes in the weight loss rate during grape dehydration under different environment conditions for several varieties, the effect combined of the skin mechanical properties and the thermo-hygrometric conditions has not been previously considered. The skin break force was confirmed as varietal marker. Furthermore, its role in the selection of the withering conditions was also assessed. The fresh grape berries were classified in two groups (soft and hard) according to the skin break force, and four off-vine withering conditions were evaluated. The softer skins facilitated the dehydration process increasing the weight loss rate but significantly only at low temperatures. The increase in temperature and/or the decrease in relative humidity favored the grape dehydration process. A weight loss of about 50% after 12 withering days was achieved at air temperature of 28º C and relative humidity of 40%. At the same dryer environment conditions, certain varietal effect in the dehydration kinetics was observed because a faster weight loss occurred for those grapes characterized by lower values of the skin break force. These results suggest that the grape dehydration rate, influencing the quality of dessert wines, should be planned considering the skin hardness of fresh berries and the withering conditions. The skin break force represents a new variable that should be considered in modelling the withering process and in selecting, prior to harvest, which is the most appropriate vineyard to elaborate the dessert wines desired.

Keywords: *winegrape varieties; off-vine dehydration kinetics; skin hardness; thermo- hygrometric conditions.*

INTRODUCTION

Instrumental texture analysis is a rapid and low-cost analytical technique that is acquiring a great interest in the oenological sector. This success is attributable to its increasing recognition as a powerful routine tool for monitoring the winegrape quality.[1] In fact, the efficiency of the berry skin mechanical properties for the differentiation of varieties, production areas and even vineyards has been recently assessed. The skin break force allows the differentiation of red winegrape varieties,[2,3] it being likely to be a varietal marker. Moreover, variations inside the same cultivar can be imputed to clone differences and viral status of the vine.[1]

Within the same variety, the growing area heavily influences the skin break force, which becomes an effective tool to discriminate vineyards located in different zones[4,5] and even subzones.[6] Most of authors suggest that environmental factors play a dominant role in the characterization of the skin texture attributes with respect to the sugar accumulation. On the other hand, the skin mechanical characteristics are seasonal dependent.[2] The influence of annual variations in climate on the skin hardness has been recently investigated for colored and white winegrape varieties using different climatic indices.[7] As a consequence of the genotype-environment interaction, seasonal temperature parameters, particularly absolute maximum temperature, are significantly correlated with the skin break force.[7,8] Furthermore, the influence of the production area was also evaluated in the same season, precipitation parameters being the best ones correlated with this skin texture parameter.[7]

The behavior of the skin break force close to harvest could limit the choice of this mechanical parameter as a ripeness indicator in grape berries.[1,4] The changes occurred in the skin mechanical properties during the grape ripening process are more related to the densimetric heterogeneity of the berries harvested than to the harvest date.[1]

Since the grape phenolic composition has a notable repercussion on the wine quality, the potential of the skin break force as a reliable predictive index of the skin anthocyanin extractability has been assessed.[9,10] Furthermore, the berry skin break force also affects the extraction kinetics of individual anthocyanins.[9]

During whole fruits dehydration, as in the case of grapes, the skin acts as a semipermeable membrane that control the water transfer rate from the fruit to external medium[11] and, therefore, the skin texture parameters have been already considered efficient indicators of the winegrape suitability for on-vine withering.[12,13] Moreover, the skin break force of fresh berries influences the dehydration kinetics during the off-vine withering process under controlled conditions as demonstrated in a preliminary study.[14] The softer skins facilitate a quicker berry weight loss, particularly for higher sugar contents. In fact, there is a correlation for the riper grapes between the skin break force of fresh berries and the weight loss observed for different withering days.

Since the skin break force might be an interesting instrumental texture parameter to optimize the withering conditions and to obtain dried grapes with certain desirable characteristics, the aim of this work was firstly to compare the skin break force among different grape varieties from the same growing area at the same sugar content, and secondly to study the influence of the withering conditions on the off-vine dehydration kinetics for grape berries of the same variety with different values of the skin break force. Finally, the response of different grape cultivars under the same withering conditions was also assessed according to the skin hardness.

MATERIALS AND METHODS

Grape Samples

Grape samples of 28 black and 11 white cultivars (*Vitis vinifera* L.) were harvested at the technological maturity from an experimental vineyard located in Piedmont (North-West Italy) in 2010. Each sample consisted of about 3000 grape berries with attached pedicels, which were randomly picked from different plants. The grape berries of each cultivar were separated according to their density (total soluble solids), which was estimated by flotation in different saline solutions (from 130 to 160 g/L sodium chloride) so that the difference in total soluble solids of two consecutive batches of berries was about 17 g/L sugar (1 % potential alcohol).[15,16] This densimetric separation permits to obtain more homogeneous samples and to minimize the effect of different ripening stages of grape berries. One sugar content was only studied (215 ± 8 g/L) for all winegrape varieties. The floating berries were washed with water, visually inspected before dehydration and those with damaged skins were discarded.

Instrumental Texture Analysis

For each cultivar, the skin hardness was assessed by a puncture test carried out by an Universal Testing Machine (UTM) TAxT2i® Texture Analyzer (Stable Micro System -SMS, Godalming, Surrey, UK) equipped with a HDP/90 platform, a SMS P/2N needle probe (stainless steel cylinder of 2 mm of diameter with a conical needle bit) and a 5 kg load cell.[2] The test speed was 1 mm/s and the penetration applied was 3 mm. All of the data acquisitions were made at 400 Hz, and data were evaluated using the Texture Expert Exceed software version 2.54 for Windows 2000. Before the test, the instrument was calibrated for force and distance.

A set of 40 berries was randomly sampled and they were individually placed on the metal plate of the UTM, with the pedicel in a horizontal plane, in order to be consistently punctured in the lateral face. The skin hardness is assessed by the maximum break force (F_{sk}), which is expressed in Newton (N). It corresponds to the skin resistance to the needle probe penetration. The use of needle probe allows the only estimation of this skin mechanical characteristic, minimizing the possible interferences caused by the pulp firmness on the results. For dehydration purposes, the micro-hole caused by the needle probe penetration was closed with a micro-drop of natural resin to avoid interferences on the withering process.[14]

Dehydration Process

For Erbaluce cultivar (non-aromatic white grape variety commonly used in Italy for the production of *"Passito"* dessert wines),[17] two sets of 200 berries were selected according to their skin hardness (soft, S and hard, H), and eight sub-samples of 25 berries were randomly selected from each set. Two sub-samples were subjected in a controlled chamber to the same withering conditions of temperature and relative humidity (RH). The first two sub-samples were subjected to 15º C and 55% RH (withering conditions A). The second ones were treated at 18º C and 75% RH (withering conditions B). The third ones were dried at 28º C and 40 % RH (withering conditions C). Finally, an uncontrolled natural dehydration process, carried out at environment conditions in an open room, was applied to the last ones (D). On the other hand, five winegrape varieties (three black and two white) with different skin hardness were subjected to the same withering conditions. For each variety, three sub-samples of 50 berries were randomly selected, and they were dried in a chamber at 16º C and 60% RH. In any case, the withering conditions were fixed by the winery, which can be correctly controlled in the chamber. The air speed used was always 0.9 m/s.[14]

In all of withering experiments, grape berries were located on appropriate metallic supports with meshes of 0.64 cm^2 (0.8 × 0.8 cm) for a correct aeration. Fresh berries were weighed for each sub-sample before their introduction in the withering cell. The weight was measured during the entire withering process at intervals of three days by means of a technical balance (Gibertini E1700, Modena, Italy) and the weight loss percentage (WL%) was calculated as: [100 - (weight of withered samples × 100 / weight of fresh sample)].[14] The day number that the process was monitored depended on the cultivar and withering conditions.

Statistical Analysis

Statistical analyses were performed using the SPSS software version 17.0 for Windows (SPSS Inc., Chicago, IL, USA). One-way analysis of variance (ANOVA) was used to establish statistical differences in the skin hardness and in the WL% experienced during the grape dehydration process. The effects of withering temperature, RH and F_{sk} on the withering kinetic rate was assessed by means of multiple linear regression.

RESULTS AND DISCUSSION

The berry skin hardness, expressed as F_{sk}, for all of the black and white winegrape varieties studied was shown in Fig. 1. As can be observed, the values ranged from 0.964 N for Malvasia di Casorzo to 0.295 N for Pollera in black varieties, and from 0.854 N for Moscato giallo to 0.338 N for Cortese in white varieties. This comparative study was performed on grape berries harvested from the same vineyard and calibrated according to density to minimize variations related to environmental and ripening effects. Therefore, the variations observed among grape varieties *confirm that the skin break force is likely to be a varietal marker. Its decisive contribution to the varietal differentiation of red winegrape varieties has been previously assessed.[2,3,18]*

The skin plays a key role in the dehydration process of the grape, regulating gas exchange between the berry and the surrounding environment, serving as a protective barrier against fungal disease and protecting the grape from UV light and physical injuries.[19,20] Likewise, some authors have already considered the skin texture parameters as efficient indicators of the winegrape suitability for on-vine withering.[12,13] Particularly, the skin hardness increased significantly during on-vine withering. The texture degradation of thermally processed biomaterials is closely related to enzymatic and non-enzymatic changes in the cell-wall pectin.[21]

Respect to raisins process,[22,23,24] in a withering process, winegrapes are not chemically or physically pretreated to remove the cuticular wax layer on the berry skin. This sample pretreatment overcomes the low moisture diffusivity because of the hydrophobic nature of the waxes during grape drying.[25] Consequently, moisture diffusion coefficients for withered grapes are lower (1–2 orders of magnitude) than those found in literature for dried grapes, and they increase with increasing temperature and decreasing RH, similarly to the changes occurred in the moisture content.[26]

In scientific literature, the effects of the skin mechanical features of fresh berries on the dehydration kinetics during the off-vine withering process under controlled conditions have been previously studied.[14] Since kinetics is also generally affected by the dryer environment conditions,[26,27] the influence of air temperature and relative humidity (RH) was now assessed on the off-vine dehydration kinetics for Erbaluce grape berries with different skin hardness. Table 1 shows average, minimum and maximum values of the skin break force determined for the eight berry groups used in the withering trial (AS, AH, BS, BH, CS, CH, DS, DH), as well as the average values for each one of the replicates analyzed. The skin hardness of the four groups established for either soft fresh berries or hard ones was in agreement ranging from 0.372 to 0.675 N, or from 0.681 to 1.233 N, respectively.

Fig. 2 shows the evolution of the weight loss (WL%) due to the grape dehydration experimented through the off-vine withering process at three controlled environment conditions (A, B, C) and under uncontrolled conditions (D). The withering conditions C that correspond to the higher temperature (28º C) caused a faster WL% (about 49.3% in 12 withering days). Fresh grapes lost 41.6% of their weight in 54 and 42 days at the withering conditions B and D, respectively. On the other hand, significant differences in WL% were only found among soft and hard fresh berries at the withering conditions A. The soft berries (AS) are characterized by significantly higher values of WL% than hard ones (AH) from 42 days onwards and, therefore, the dehydration rates decreased with increasing berry skin hardness and the number of withering days under these environmental conditions. Particularly, values of WL% of about 41.3% were observed in 48 withering days for hard berries, whereas for soft ones were 46.6%.

The effect of the skin break force on the grape dehydration kinetics for the dryer environment conditions A (15º C and 55% RH) agreed with the one previously reported,[14] who suggested that the softer skins of Erbaluce fresh berries facilitate a quicker WL%, particularly for average sugar contents of c.a. 240 g/L. In fact, a negative correlation was found between the skin break force of fresh berries and the WL% observed for different withering days when the conditions of the chamber were set to 16º C and 60% RH. This seems to indicate that the dehydration kinetics of grapes, at low temperatures, is influenced by the skin hardness.

A daily average WL% of about 4.1, 1.0, 1.0, 0.9 and 0.8 corresponded to the withering conditions C, D, AS, AH and B, respectively. The higher temperature could justify the higher daily average values of WL% for the dryer environment conditions C. Instead, the higher the relative humidity associated with the withering conditions B, the lower the daily average values of WL%, and more withering days were required to reach WL% of 40. It is due to the smaller gradient of the water vapor pressure between grapes and air humidity. In any case, the decrease in the berry weight as a function of withering time was quite linear, indicating that the dehydration rates were constant for each environment conditions and berry skin hardness. This linearity, also found in other studies,[27] was very evident for the faster WL% (withering conditions C), which was expected as the dehydration rate usually slows with time.

The effects of temperature (T, ºC), RH (%) and F_{sk} (N) (independent variables) on the withering kinetic rate (daily WL%, dependent variable) was described by the following equation:

Daily WL% = 0.269 + 0.197 T – 0.039 RH – 0.153 F_{sk} (R^2 = 0.998, $p < 0.001$)

Temperature and RH coefficients were of different order of magnitude and opposite, whereas the temperature coefficient was of similar order of magnitude but opposite to the one of F_{sk}. This confirmed that an increase in temperature resulted in an increased withering rate, whereas an increase in RH and/or F_{sk} caused a reduction of the withering rate. The skin break force is likely to be a new variable that should be considered in modelling daily WL%.

Since the growing area heavily influences the skin break force within the same variety,[4-6] this skin mechanical property could be an effective tool to select, prior to harvest, which vineyard gives the best grapes to elaborate the dessert wines desired.

Table 2 shows average, minimum and maximum values of the skin break force determined for five winegrape varieties in a single withering trial. In this case, a great number of berries were analyzed to obtain a more representative sample of each variety. The softer berries corresponded to Moscato bianco variety with an average value of the skin hardness of 0.468 N whereas the one ranged from 0.784 to 0.859 N for all of the remaining varieties. Fig. 3 represents the curve pattern of WL% regarding the grape dehydration experimented through the off-vine withering process under controlled conditions (16º C and 60% RH) for the five varieties.

Moscato bianco grapes lost 36.0% of their weight in 21 days, whereas Erbaluce ones lost 30.0% in 30 days. It signifies a daily average WL% of about 1.7 and 1.0, respectively. The results obtained agreed with that reported in a previous work,[14] where the evolution of the WL% for Erbaluce and Moscato bianco varieties during the off-vine dehydration process under these last controlled conditions was also studied. Fresh grapes with similar characteristics than in the work now developed were used, particularly sugar concentration and skin break force. Corvinone and Corvina varieties showed a WL% of 20.1 and 23.3 in 30 withering days, respectively, whereas Freisa grapes lost 31.9% of their weight in 27 days. It supposed a daily average WL% of about 0.7, 0.8 and 1.2, respectively.

As can be seen, the dehydration kinetics depended on the variety because a faster WL% was found for Moscato bianco grapes, which have lower skin break force, particularly the maximum value. However, the skin hardness permits to explain the varietal effect on grape dehydration only partially. In fact, Freisa grapes, although characterized by higher skin break force (0.859 N) than Corvinone grapes (0.784 N), showed a relatively faster dehydration kinetics. This aspect induces to investigate also on other mechanical properties such as skin thickness, which probably concur to determine the speed of the withering process.

Also other works already published showed that the withering thermo-hygrometric conditions affect the dehydration kinetics, but that the same treatment does not induce the same effect on different winegrape varieties.[26,28] So, each grape variety could have different response time to water stress. After 18 withering days at 42% RH and 21º C, the WL% was 50 and 34 for Malvasia and Trebbiano grapes, respectively, whereas it was 20.5 for Sangiovese grapes after 7 withering days.[28] Nevertheless, the WL% ranged from 10.5 to 14 at 65% RH and 21º C for the three varieties. Therefore the lower the relative humidity, the faster the weight loss rate. Barbanti and others[26] also confirmed that the withering kinetics of Corvina, Corvinone and Rondinella grapes, used for the production of Amarone and Recioto wines, increased with increasing temperature and decreasing relative humidity. This agreed with what was described for Erbaluce grapes.

An optimum WL% from 30 to 40 is generally advisable in the production of Italian dessert wines. These values were achieved for Moscato bianco, Freisa and Erbaluce grapes after 18, 24 and 30 days, respectively. Instead, Corvinone and Corvina grapes require longer withering time to achieve this dehydration grade when 16º C and 60% RH were used for storing (Fig. 3). This agreed *with the reported in other work, where these two last grape varieties reached a WL% of 40 after 80 and 25 days at 53% RH if withered at temperatures of 10 and 25º C, respectively.*[26] *Rondinella grapes also showed the same dehydration rate under these environment conditions. Other examples of the varietal effect on the dehydration rates are Gewürztraminer grapes reaching a WL% of 36 in 17 days at 40% RH and 17º C,*[29] *Trebbiano grapes reaching a WL% of 34 in 18 days at 42% RH and 21º C,*[28] *and Malvasia grapes reaching a WL% of 33 in 29 days at 40% RH and 15 ºC.*[30]

The skin consists of an epidermis and six to ten layers of small thick-walled cells.[31] *The number of layers in the skin of grape berries, their size and volume are cultivar specific issues.*[32] *These different tissue characteristics can contribute to explain the differences in the withering kinetics among varieties.*[26,28]

The advantages of fast grape dehydration are the increase in the sugar content, and above all in phenols, anthocyanins and volatile compounds like ethanol, esters and higher alcohols.[27,28,33] *Furthermore, the optimization of the dehydration rate can also be very important to the control of the development of* Botrytis cinerea,[26] *which has opposite effects on the quality of grapes and wines. Therefore, an accurate control of the withering environment conditions could provide a tool to manage the development and/or oxidation of phenolic and volatile compounds.*

CONCLUSIONS

This work highlights the differences in the skin hardness of the grape varieties usually used for the production of dessert wines in Italy, where the production of overripe grapes for special (sweet) wines has a long tradition. Furthermore, the influence of the withering thermo-hygrometric conditions and the skin hardness of fresh berries on the grape dehydration process was evaluated. The increase in temperature favored the grape dehydration process, in contrast to relative humidity, but its kinetics is also influenced by the skin hardness, particularly at low temperatures. The softer skins facilitated the dehydration process increasing the weight loss rate and, therefore, the skin break force represents a new variable that should be considered in modelling the daily weight loss. On the basis of experimental data obtained at the same environment conditions, the dehydration kinetics depended on the grape variety because a faster weight loss occurred for those grapes with lower skin break force. On the other hand, this approach demands further research on histological and histochemical changes in berry skins during grape withering to assess how the physical characteristics of the skin cell tissues affect the dehydration kinetics and, therefore, the quality of dried grapes and dessert wines. The study should be also extended to other winegrape varieties and production areas to validate the relationships found.

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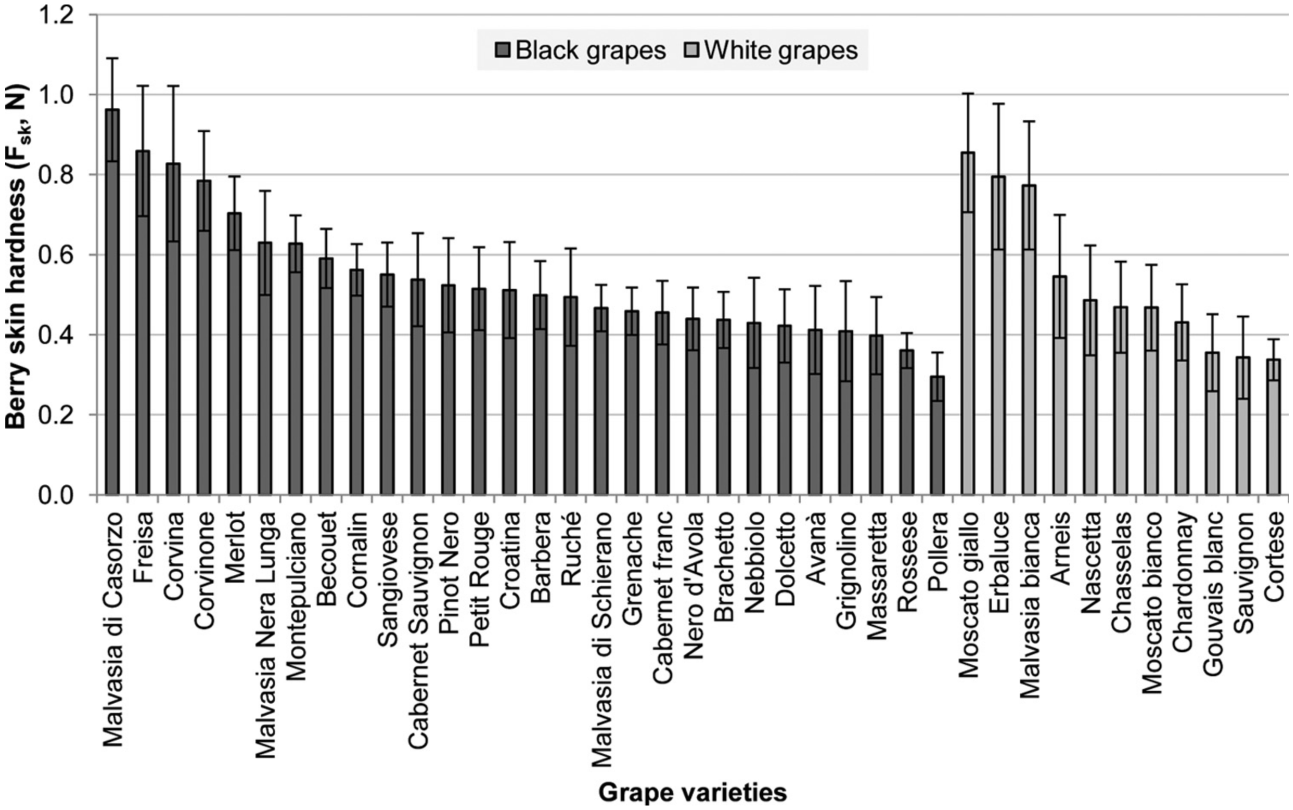

FIG. 1. Berry skin break force (F_{sk}) of fresh grape berries for the black and white winegrape varieties studied.

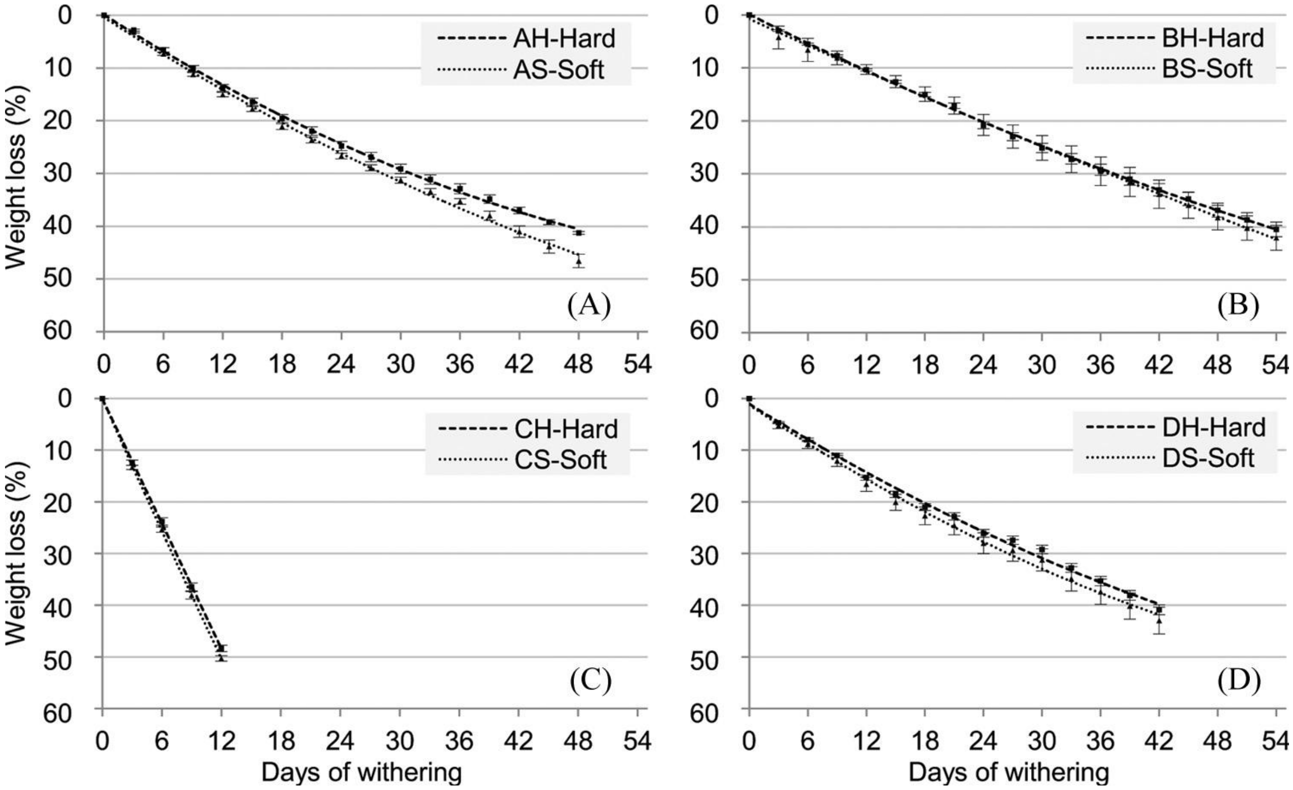

FIG. 2. Dehydration kinetics for Erbaluce grapes with soft (S) and hard (H) skins under three different controlled thermo-hygrometric conditions (A, 15º C, 55% RH), (B, 18º C, 75% RH), (C, 28º C, 40% RH), and uncontrolled conditions (D).

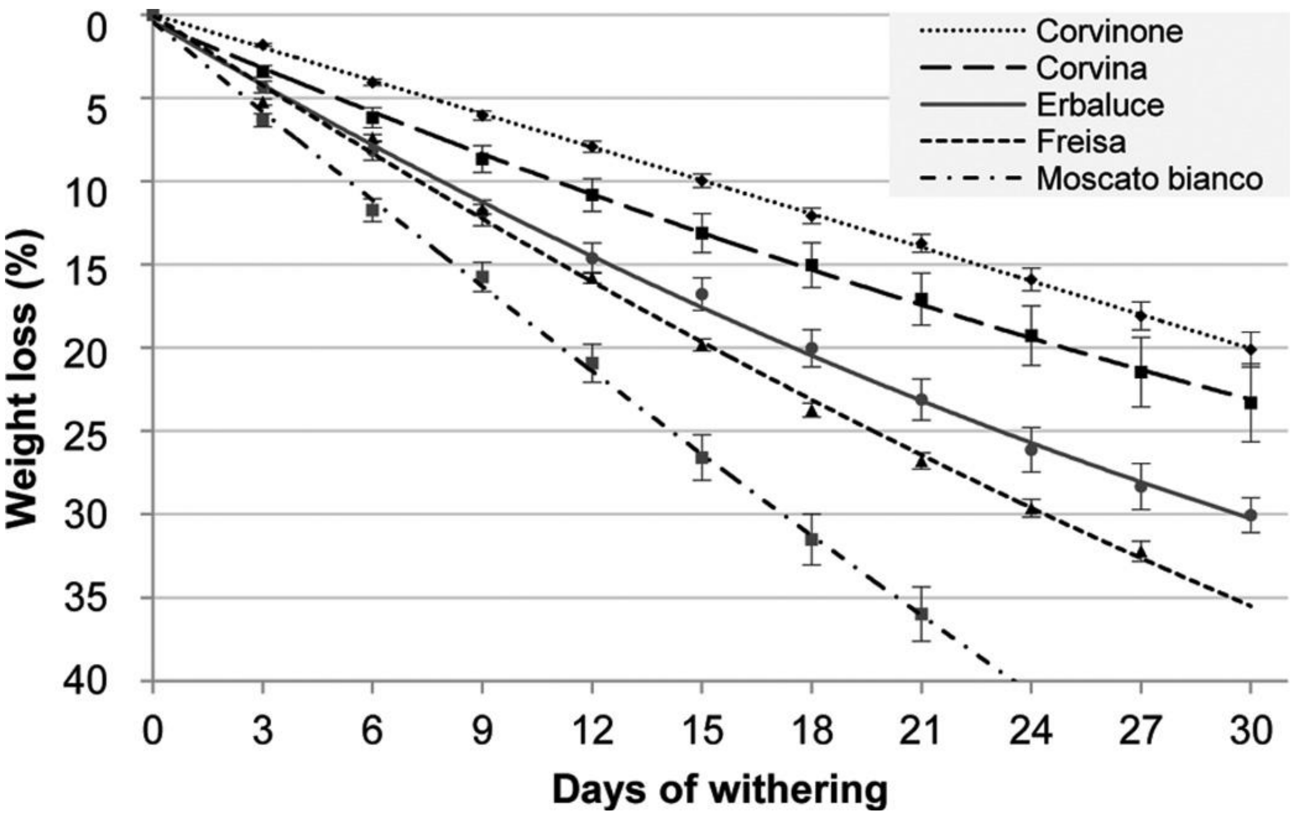

FIG. 3. Dehydration kinetics for five different winegrape varieties at 16º C and 60% RH.

TABLE 1

Average, minimum and maximum values of berry skin break force (F_{sk}), expressed in newtons (N), for the eight groups of Erbaluce grapes used in the withering trial (four withering conditions, soft and hard skins for each condition)

Sample[a]	Average ± SD (*n* = 50)	Minimum	Maximum	Replicates average ± SD (*n* = 25)
AS	0.584 ± 0.065	0.418	0.675	0.531 ± 0.048 0.637 ± 0.023
AH	0.802 ± 0.113	0.683	1.233	0.726 ± 0.030 0.879 ± 0.113
BS	0.580 ± 0.069	0.402	0.674	0.525 ± 0.052 0.635 ± 0.023
BH	0.797 ± 0.106	0.682	1.183	0.724 ± 0.029 0.871 ± 0.103
CS	0.578 ± 0.072	0.372	0.674	0.521 ± 0.057 0.634 ± 0.023
CH	0.792 ± 0.097	0.681	1.148	0.723 ± 0.029 0.862 ± 0.090
DS	0.581 ± 0.068	0.402	0.675	0.527 ± 0.051 0.636 ± 0.023

DH	0.800 ± 0.111	0.683	1.227	0.725 ± 0.029 0.875 ± 0.112

[a]A: 15º C, 55% RH; B: 18º C, 75% RH; C: 28º C, 40% RH; D: uncontrolled conditions; S: soft; H: hard.

TABLE 2

Average, minimum and maximum values of berry skin break force (F_{sk}), expressed in newtons (N), for the grape varieties used in the withering trial (16º C, 60% RH)

Grape variety	Average ± SD (*n* = 150)	Minimum	Maximum
Corvinone	0.784 ± 0.124	0.419	1.237
Corvina	0.827 ± 0.194	0.400	1.361
Erbaluce	0.795 ± 0.182	0.353	1.318
Freisa	0.859 ± 0.163	0.250	1.340
Moscato bianco	0.468 ± 0.107	0.187	0.771