ASSESSMENT OF GRAPEVINE MATURITY USING A NEW PORTABLE SENSOR: NON-DESTRUCTIVE QUANTIFICATION OF ANTHOCYANINS

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Abstract

Aim: Premium wine production can only be made from quality grapes. The determination of harvest date and the assessment of grape maturity need to be as accurate as possible. Therefore, technological and phenolic ripenings are monitored during grape maturation, taking into account environmental factors. The objective of this study was to calibrate and compare to standard analytical procedures a recently-introduced hand-held optical sensor based on the epidermal screening of fruit chlorophyll fluorescence. Anthocyanin, flavonol and chlorophyll contents on intact berries and bunches are simultaneously monitored.

Method and result: Wet chemistry and optical sensor (Multiplex®) measurements were performed on berry samples and whole bunches from several plots of Pinot meunier, Pinot noir and Chardonnay in the Champagne region. The two methods gave similar results for the evaluation of anthocyanin content in berries. Moreover, kinetics of anthocyanin, flavonol and chlorophyll contents were monitored on whole bunches and berry samples, during the whole season.

Conclusion: Wet chemistry and Multiplex® data were well correlated and enabled us to monitor the ripening of the studied plots. Furthermore, the new in vivo spectroscopic method based on chlorophyll fluorescence was validated for the non destructive monitoring of anthocyanins accumulation.

Significance and impact of study: The rapid and non-destructive nature of the Multiplex® measurement would contribute to solve three main problems of maturity assessment: the necessity of analysing a very large number of samples, up to the whole crop; the possibility to follow the same bunches during the whole season; the use of climate variations to study the impact of environmental factors on grape maturity.

Key words: Flavonoids, chlorophyll fluorescence, kinetics of grape ripening, Vitis vinifera L. cv. Pinot noir and Chardonnay, Multiplex®

Résumé

Objectifs : Un vin de haute qualité ne peut être obtenu qu’à partir de raisins de qualité. Pour en obtenir de tels, la détermination de la date de vendanges et l’estimation de la maturité du raisin doivent être aussi précises que possible. C’est dans ce but que les maturations technologiques et phénoliques du raisin ont été suivies pendant le mûrissement des grappes, en considérant l’influence des paramètres environnementaux. L’objectif de cette étude était de calibrer un nouveau capteur optique portatif basé sur l’effet d’écran de l’épiderme sur la fluorescence des fruits et de le comparer aux méthodes analytiques standards. Les teneurs en anthocyane, flavonol et chlorophylle ont été suivies de façon simultanée, aussi bien sur baies intactes que sur grappes entières.


Conclusion : Les données Multiplex® sont bien corrélées avec les données chimiques et ont permis de suivre la maturité des parcelles étudiées. De plus, cette nouvelle méthode spectroscopique in vivo basée sur la fluorescence chlorophyllienne pour le suivi non-destructif de l’accumulation des anthocyanes a été validée.

Signification et impact de l’étude : Les mesures Multiplex®, rapides et non-destructives, pourraient contribuer à résoudre les trois principaux problèmes rencontrés dans l’évaluation de la maturité du raisin : la nécessité d’analyser un très grand nombre d’échantillons jusqu’à la vendange complète ; la possibilité de suivre les mêmes grappes durant toute la saison ; l’utilisation des variations climatiques pour étudier l’impact des facteurs environnementaux sur la maturité du raisin.

Mots clés : flavonoïdes, fluorescence chlorophyllienne, cinétique de maturité du raisin, Vitis vinifera L. cv. Pinot noir et Chardonnay, Multiplex®
INTRODUCTION

The accurate assessment of grape maturity and the determination of the optimal harvest date are essential for premium wine production. The optimal harvest date is still difficult to predict: it is dependent on the climatic conditions of the year. Anthocyanins (ANTH) and other phenolic compounds, mainly tannins, can influence colour, flavour and structure of the produced red wine. The maximum content of ANTH is therefore sought after, and, with the estimation of total phenolic compounds (PHEN) content, is named phenolic maturity. Unfortunately ANTH and PHEN quantification by spectrophotometrical analysis upon extraction is time-consuming and very dependent on berry sampling (Krstic, 2003).

Grape maturation and the associated changes in its constituents depend strongly on environmental factors: irradiance, temperature and water availability. ANTH are particularly sensitive to temperature and its diurnal variations (Spayd et al., 2002; Yamane et al., 2006) while flavonols (FLAV) are more influenced by sun exposure (Price et al., 1995; Spayd et al., 2002). Furthermore, the severity and the length of water deficit during the maturation can have positive or negative effects on the phenolic content (Ojeda et al., 2002; Kennedy et al., 2002). A simultaneous assessment of different berry constituents during grape maturation compared to meteorological data would thus help us to better understand these influences.

Recently, a rapid in vivo spectroscopic method was developed based on the screening of chlorophyll fluorescence by phenolics present in berry skin (Agati et al., 2007). A portable optical sensor based on this method was also introduced (Cerovic et al., 2008) following the new trend in non-destructive analysis of grapes based on chlorophyll fluorescence (Kolb et al., 2006; Lenk et al., 2007). This active fluorescence sensor, named Multiplex, is insensitive to ambient light. Hence the optical signals can be used to follow berry samples representative of plots in the laboratory as well as whole bunches in the vineyard. The aim of this work was threefold: 1°) to calibrate the Multiplex index related to the anthocyanin content in berry extracts; 2°) to evaluate the usefulness of non-destructive measurements on samples from commercial vineyards; 3°) to follow the kinetic of grape maturation in the field during the whole season.

MATERIALS AND METHODS

1. Grape sampling and meteorological data

The study was conducted in 2007 during the maturation of grapes from veraison to harvest in Epernay, Champagne (49° 02’ 25” Nord, 3° 57’ 36” Est, France). Three experiments were conducted in parallel on several commercial vineyards belonging to Moët & Chandon and at the experimental plot Fort Chabrol: (1) The Multiplex® was calibrated for the red varieties of the
Champagne region, Pinot meunier (PM) and Pinot noir (PN); (2) Multiplex® data were compared to anthocyanins extraction on 200-berries samples in the laboratory; (3) Kinetics of the phenolic maturation and of the chlorophyll content of whole bunches have been performed in the field at Fort Chabrol.

(1) For the calibration of the Multiplex®, fifty bunches of PM and PN were sampled at six dates during August at Fort Chabrol. Nineteen berries were randomly sampled from each bunch for Multiplex® measurements. They were frozen at -20 °C and then at -80 °C until anthocyanins extraction was performed.

(2) For the comparison of Multiplex® measurements and anthocyanins extraction of berry samples in the laboratory, two hundred berries per plot were sampled from seventy plots of PN and PM twice per week (August 2nd - August 31st) - according to Carbonneau et al. (1991). For the technological maturity in Fort Chabrol, fifteen to twenty bunches were sampled twice per week (July 30th - August 27th).

(3) For the kinetics at Fort Chabrol with the Multiplex®, sixteen east-exposed bunches of each variety were marked at pré-veraison and followed from July 27th to August 27th 2007. Daily precipitations (mm), global daily irradiation (MJ/m²) and daily mean temperature (°C) were measured each day by a meteorological station located on the plot.

2. Monitoring of the technological maturity

Berry or bunch samples were pressed and the obtained juice analysed for sugar content measured by refractometry or densitometry (aerometer) for the Moët & Chandon plots and the Fort Chabrol plot, respectively. Berry juice pH was measured with a pH-meter.

3. Anthocyanins extraction and their quantification

a - Berry samples

The 200-berries samples were ground in a kitchen blender (high speed, 1 min). Fifty grams of the slurry was then heated at 70 °C in a water bath during 30 min. After standing 30 min at room temperature, the sample was centrifuged for 10 min at 4,000 rpm. The supernatant was diluted, 0.4 ml was added to 4 ml of an acidified aqueous solution (H₂O/HCl; 98/2; w/w) and then centrifuged again for 10 min at 6,000 rpm. The latter supernatant was used for spectroscopic estimation of the anthocyanin content (absorbance at 520 nm).

b - Multiplex® calibration

The upper half (flower scar side) of each one of the frozen nineteen berries sampled for calibration was peeled. Frozen skins were ground in liquid nitrogen and then stored at -80 °C until further extraction by the method of Pirie and Mullins (1977). Powder (15 to 30 mg per sample) was transferred to 9 ml of acidified extraction solvent (MeOH/H₂O/HCl 12N; 50/49/1; v/v/v) on a nine position stirrer (Model 509, PMC Industry Inc., San Diego, USA) for 45 min, at stirring level 6, at room temperature. The choice of the respective proportion of methanol and water was strengthened by the recent study of Downey et al. (2007). Absorbance spectra were measured immediately upon extraction on a spectrophotometer (HP 8453; Agilent, les Ulis, France) from 200 to 1,100 nm. Anthocyanin content was expressed in equivalents of malvidin-3-O-glucoside (oenin) using the molar absorptivity at 530 nm of 28,500 m⁻¹ cm⁻¹, after subtraction of a residual absorbance at 780 nm (Agati et al., 2007).

4. Multiplex® fluorescence measurements

The Multiplex® is a non-contact hand-held optical sensor based on plant fluorescence produced by Force-A (Orsay, France). The prototype version which was used for this study (Cerovic et al., 2008) has three LED-matrix light sources: 375 nm (UV-A), 530 nm (G) and 630 nm (R). There were three synchronised detectors for fluorescence recording: yellow, red (RF) and far-red (FRF). One measurement consisted of 500 individual excitation flashes and associated fluorescent signals that were averaged. The measurement took less than one second. Although nine signals were available (three excitations x three emissions) for each measurement, this study focused only on the signals ratios linked to phenolic maturity and chlorophyll content, based on FRF_UV, FRF_R, RF_R (FRF excited by UV light; FRF and RF excitations x three emissions) for each measurement, this was averaged. The measurement took less than one second. 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Figure 2 - Time course of technological (sugar — and pH - - -) maturity.
(a) Average of 35 plots per variety, 200-berries sample per plot (Moët & Chandon). (b) For comparison, average of 35 plots per variety for ANTH content measured by wet chemistry. (Error bars are 95% confidence intervals).

Figure 3 - Multiplex monitoring of 200-berries samples at Moët & Chandon during the maturation period in 2007.
Sixteen plots (1 curve = 1 plot) of PM (a) and eighteen plots of PN (b) were followed. Bold curves are means of all plots shown for each component and grape variety (Error bars are 95% confidence intervals.).
b - Berry samples

For each sampling date and each plot, 200-berries samples were scanned with the Multiplex®. Three to five positions (increasing with the berry size along the grape maturation) were measured on a non-fluorescent tray. Berries were then randomised twice and the measurements repeated two more times. So, berries samples were represented by a mean of twelve to fifteen measurements.

c - Monitoring of phenolic maturation at Fort Chabrol.

For each variety, the bunches marked at pré-veraison were measured weekly, two measurements per bunch, the first on the sun-exposed face and the second on the hidden face.

RESULTS

1. Calibration of the Multiplex

Groups of 19 berries were sampled to cover a range of anthocyanin content as large as possible. Anthocyanin content was represented by the average of six Multiplex measurements per 19-berries sample, the average of four Multiplex shots for whole bunches and the average of three repetitions for the extracts. Extraction gave anthocyanin values between 0 to 26 nmol/mg of skin fresh weight (Figure 1a).

A satisfying exponential fit links Multiplex data and anthocyanin content of the extracts for both PM and PN varieties (cf. in Figure 1a the common exponential fit for PM and PN). Exponential fits for each individual variety do not differ significantly (not shown). Multiplex measurements performed on bunches and on the corresponding 19-berries samples are well correlated as expected (figure 1b; linear fit, $r^2 = 0.84$). The calibration equation is:

$$\text{ANTH (Multiplex)} = 1.26 \times (1 - e^{-0.0608 \times \text{ANTH (extract)}})$$

2. Monitoring of grape ripening in commercial vineyards

In parallel to the estimation of anthocyanin content, sugar content and pH were measured during the whole season. Figure 2a presents the accumulation of sugar and the increase of pH during maturation for the 200-berries samples.

The estimation of anthocyanins accumulation in grapes from veraison to harvest is presented in figure 2b. Data were obtained by the analysis of extracts of 200-berries samples from seventy individual plots.

Just before extractions, the anthocyanins of the same 200-berries samples were measured non-destructively by the Multiplex. In addition, the sensor provided information on flavonol and chlorophyll contents. Each curve in figure 3 represents one commercial plot (Moët & Chandon). The bold curves are the average of sixteen plots for PM and eighteen for PN (figures 3a for PM and 3b for PN). Anthocyanins accumulation measured...
by Multiplex from veraison to harvest was in agreement with the wet chemistry data (figure 2b). Flavonol and chlorophyll contents decreased for all considered plots (figure 3). Chlorophyll degradation during ripening has already been shown for white varieties (Fougère-Rifot et al., 1995; Kolb et al., 2006). Multiplex data presented here confirm this decline for the two red varieties.

Among the plots followed during the season, some of them have been treated with ethylene using Sierra (commercial preparation of Etheflon from Bayer, Puteaux, France) at veraison (SV) or both at flowering and veraison (S). Multiplex data reflected clearly the influence of this treatment on phenolic and chlorophyll contents (figure 4). In addition, figures 3 and 4 show the convergence of plots maturation levels. High disparity of ANTH, FLAV and CHL contents among all the plots at the beginning is progressively reduced during the maturation period until harvest for PM and PN varieties. In figures 3a for PM and 3b for PN, plots shown are composed of 10 PM and 14 PN added to 6 PM and 4 PN Sierra-treated plots. It resulted in the increase of PN average curve by 0.4 Multiplex units, whereas the average for PM remains the same (data not shown). It shows the better success of Sierra treatment for PN than PM.

Thanks to the good correlation between wet chemistry data and Multiplex estimation of anthocyanin content (figure 5), this set of data can also be used as a calibration curve for transformation of Multiplex measurements in units of mg/L: ANTH (Multiplex) = 0.0016 × ANTH (extract); r² = 0.88. Linear fits on the two groups of data, control and Sierra-treated, give the same correlation coefficient (control: r² = 0.882; Sierra-treated: r² = 0.880) and illustrate the robustness of the relationship between Multiplex and wet chemistry data.

3. Kinetics of grape ripening at Fort Chabrol

Measurements for grape monitoring were performed at six dates from July 27th to August 27th (figure 6). Each variety (PM, PN and CH), at each date, is represented by the average of thirty-two measurements performed on sixteen bunches (two shots per bunch). Anthocyanin content increased in PM and PN and remained quite stable for the white variety CH. The small variations observed for CH at later dates could be explained by the changes of berry structure during the season (increase of transparency and of pulp proportion) that influenced its optical properties.

A global decrease of the chlorophyll content was observed for the three varieties (figure 6c). The results are in agreement with the data of 200-berries samples (figure 3) and literature data (Fougère-Rifot et al., 1995; Kolb et al., 2006). Flavonols are known for their sensitivity to sun exposure (Price et al., 1995; Spayd et al., 2002). They globally increased for CH and were more fluctuant for PM and PN during maturation. A succession of decreases (DOY 217-221; DOY 227-234) and increases (DOY 221-227; DOY 234-240) in temperature and irradiation occurred during the season (figure 6d). The periods of decrease are characterized by a slow down of grape maturation and the periods of increase by an acceleration of maturation, as it can be seen on the rates of ANTH accumulation and of CHL degradation.

The apparent decrease in flavonols for the red varieties (figures 4 and 6b) can be the consequence of the signals

Figure 5 - Correlation between Multiplex measurements and ANTH contents in the extracts. Linear fit with 95% confidence intervals, r² = 0.88. ○ Control (untreated) plots, ● Sierra-treated plots, at veraison, at flowering or both.

J. Int. Sci. Vigne Vin, may 2010, 44, special issue Macrowine ©Vigne et Vin Publications Internationales (Bordeaux, France)
Figure 6 - Non-destructive Multiplex monitoring of anthocyanin (a), flavonol (b) and chlorophyll (c) contents for PM, PN, CH bunches at Fort Chabrol (d). Meteorological data: global daily irradiation (MJ/m²) (right scale); daily mean temperature (°C) and daily precipitation (mm) (left scale).

Figure 7 - Time course of ANTH for PM and PN derived from Multiplex data, in nmol/mg skin. The exponential fit equation of figure 1 was used to transform Multiplex data.

DISCUSSION

1. Multiplex calibration

The Multiplex is a new optical sensor that needs to be calibrated for each particular application. In this study, a complete calibration of the Multiplex was provided for viticulture, at the grape skin, berry sample and intact bunch levels. This calibration was representative of the range of anthocyanin contents observed in the Champagne region for the two main varieties PM and PN. The calibration was performed for a new simple index defined here as \( \log \left( \frac{1}{FRF_R} \right) \).

The \textit{in vivo} measurements can be transformed into skin anthocyanin content (figure 7) using the equation:

\[
ANTH \text{ (in nmol/mg skin)} = -\frac{\ln(1-ANTH \text{ (Multiplex)/1.26})}{0.0608}.
\]

The extraction protocol and the solvent used for this calibration allowed a total extraction of anthocyanins in order to provide an information on skin mass basis, like for example in Downey \textit{et al.} (2007). Alternatively, Multiplex measurements on berry samples from commercial plots were calibrated against the standard wet chemistry procedure used in winery analytical laboratories. Thanks to a good correlation \( (r^2 = 0.88) \), the Multiplex
measurements can be converted to berry anthocyanin content: \( \text{ANTH (in mg/L)} = \text{ANTH (Multiplex)} / 0.0016. \)

2. Differences among varieties

In 2007, the Pinot meunier variety seemed to be ahead of the Pinot noir variety for anthocyanin and sugar contents at the Fort Chabrol experimental plot. In 2005, an earlier study performed on the same plot indicated that PM was more precocious compared to PN for the anthocyanin content but not for the sugar content (Cerovic et al., 2008). Average curves of anthocyanin content have been calculated for ten PM plots and fourteen PN plots among the commercial plots of Moët & Chandon in the same region. On average, higher anthocyanin content was systematically found for PN than for PM at each sampling date. But the plot-by-plot observation shows multiple dynamics and diversified tendencies. Especially, the more frequent treatment of PN plots with Sierra (ethylene) can blur the precocity of the variety. Further studies are also necessary to confirm the general precocity of PM compared to PN.

3. Kinetics of grape ripening and influences of the environment

Thanks to the multiple excitation of the Multiplex sensor, anthocyanin, flavonol and chlorophyll contents could be followed simultaneously, both on whole bunches at Fort Chabrol and on 200-berry samples from commercial plots. For all plots of PM and PN and for the two types of sampling, Multiplex showed the well-known accumulation of anthocyanins. In addition, Multiplex revealed, for the three varieties, the decrease of chlorophyll content due to the degradation of this compound (Fougère-Rifot et al., 1995; Kolb et al., 2006). However, flavonols did not show the same homogeneity among varieties. Chardonnay showed an increase of flavonol content during the whole season. Pinot Meunier and Pinot Noir showed a slight increase from DOY 221 to harvest. The 200-berry samples of PM and PN showed the same decrease from DOY 221 to harvest. But, in both cases, this could come from the influence of anthocyanins on the FLAV index later in the season.

The large number of plots followed in the present study showed an important dispersion from plot to plot in maturation dynamics due to the variations in geographical localization and also local environment. The detailed non-destructive study at Fort Chabrol still revealed the influence of temperature and irradiance on the kinetics of anthocyanins accumulation. In the present study, Multiplex data and meteorological data have been measured at different periods, with a lower frequency for Multiplex. As a consequence, flavonol fluctuations for the three varieties could not be related completely to environmental influences. Thanks to the speed of optical measurements and its non-destructive nature, this type of study can now be repeated with higher frequency.

Acknowledgements: We thank Laurent Paniga, Claire Germain and Ophelie Vigner from CIVC (Comité interprofessionnel des vins de Champagne) and Michel Boulay, Sandrine Toutain and Sophie Bouloumais from Moët and Chandon, for their help and support.

REFERENCES


