A revolutionary device for predicting grape maturity based on NIR spectrometry

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Abstract:

Near Infrared spectrometry can be used for measuring the evolution of fruit quality traits. The main characteristics that can be measured are sugar content but also in some case acidity. In conjunction with IFV (institute of Vine and wine), Cemagref research centre and Pellenc SA company have conducted long term researches to get accurate measures of grape sugar and acidity in field conditions, without destroying the fruits. The aim of this collaboration is also to design and build a reliable and low cost portable apparatus. First issues to cope with were the highly variable environmental conditions (temperature, sun light…). Second issues were to find an appropriate design to reduce costs. Until now, more than five prototypes have been developed and tested either in Europe or in Australia, on several varieties and in various conditions. This paper presents the results obtained with this revolutionary device. The calibrations and predictions have been carried out on sugar content (R^2= 0,95 and SECV= 1,12 Brix), on acidity (R^2= 0, 84 and SECV= 1,35g H_2SO_4/l) and on water content (R^2= 0,8 SECV= 1,89 on red grape). This system will be commercialized soon by PELLENC SA.

Key words: Near Infraread Spectroscopy, Wine Grapes, Maturity Monitoring, Portable Device.

1 Introduction

In the field of oenology , grape composition and harvest quality are important factors to determine harvest date and the wine-making process [6, 9, 2]. Thus, there is a need for monitoring various ripeness parameters of grapes before harvest (such as sugar content, total acidity and total anthocyanin concentration). These parameters are usually measured at laboratory though destructive measurement.

During the last decades, extensive research has been carried out on the development of nondestructive sensors, especially in Near Infrared (NIR) spectroscopy [3]. This technology provides quick non-destructive measurement of many chemical compounds in various fruit and vegetable products [13, 14, 15] including analysis of grapes and wine [11, 7, 8, 5, 10, 12]. Moreover, thanks to technology improvement, NIR spectroscopy can be transferred to the field with portable applications. Nevertheless, there are many constrains to design an efficient portable NIR sensor : among others, the sensor must have a small size, a low cost, and deliver robust measurement values.

The portable device, developed jointly by PELLENC and Cemagref, uses NIR spectrophotometry in the visible-NIR range (400 - 1100 nm). Light interactance is directly measured on the grape surface. Experiments, calibration and ripeness monitoring were performed with several grapes varieties in various environmental conditions. Indeed, tests were conducted in vineyards located in France (Languedoc Roussillon and Champagne) and Australia (Adelaide area) during 2008. This paper introduces this revolutionary tool and gives the results obtained in 2008.

2 Materials and Methods

2.1 low cost portable apparatus design

The spectrophotometer module records data in the 400 – 1100 nm range. The measurement setup is designed for collecting light from interactance on the grape surface. A major constraint to obtain NIR spectra, with limited noise, was to avoid direct light from specular reflection to enter into the sensor.

The challenge was to increase the signal capture (e.g. large capturing surface, high light power) and to reduce the noise (e.g. miniaturized and meticulous electronic conception). Moreover, the design has also been optimized to make a really portable sensor ; all components (battery, spectrophotometer, light source, microcontroller) are contained in a small case.

The final system weighs less than 800 g. This case was developed especially for field use (i.e shockproof, waterproof). A dedicated Software was also developed to manage whole's entities. The latter controls the measuring process (e.g check spectra) and logs measured data. The interactance data (T) are computed into absorbance (A) using Lambert Beer's law ($A=long_{10}T^{-1}$).

2.2 Calibration

Calibration sample sets were composed from spectra of grapes batches collected daily during two months, between ripening and a few days after harvest (from July to September 2008 in France and from January to March in Australia 2008). Each grapes batches were picked up randomly in each plot for each variety. The following varieties were studied : Shiraz, Merlot, Cabernet, Pinot and Chardonnay. The bunches were brought back to the laboratory and measured both with the sensor and by destructive analysis. Approximatively 3 batches of 2 or 4 grapes for each variety were measured daily. The batch size was dictated by the quantity of grape juice necessary to test both method the same batch.

Ten spectra were acquired directly on different side of the grape batches with the sensor. The aim was to gather a maximum quantity of information for each batch. Various destructive measurements were applied on the same batches to compare reference values for the component measurements, i.e. the analysis of sugar content, the total acidity, the anthocyanin index and the percentage of water content. Sugar content was obtained by digital refractometer readings Brix (Atago, Japan). Total acidity and anthocyanin were measured by standard procedures of IFV. Water content was obtained by difference between fresh and dry weight (grape crushing 24 h at 60 °C).

To extract and to generate calibration models, Multiple Linear Regression (MLR) and Leave One Out Cross Validation were used. Standard Error of Cross Validation (SECV) and R^2 were calculated. Before calibration processing, spectra were filtered by Principal Components Analysis (PCA) (95 percent of variance was conserved) and by specific filters to remove outliers. Classical spectral preprocessing techniques (averaging, normalisation, transformation) were applied on the spectral data.

2.3 Validation

Validation sample sets were composed of spectrums collected, such as the calibration database, in the same plots and during the same period. Grapes were not picked up, but directly measured in the field with the sensor. Between 150 and 200 grapes were measured with the same protocol sampling chosen by the grower. Chemicals analysis references was performed on samples collected by the grower.

In order to test models calibration, the latter are used as validation samples. The same preprocessing were applied to spectra before running models.

3 Results and Discussion

3.1 Calibration

Sugar content: After the Australian campaign, first results obtained with the white grapes varieties were unsatisfactory (SECV = 1.63 ° Brix and R^2 = 0.78) whereas results with red grape varieties gave good results (SECV = 1.12 ° Brix and R^2 = 0.95).

Indeed, a major problem to build a good calibration set is to have an homogenous grapes batch . Batches were assembled using grapes color, which is good feature to assess ripeness quickly . But it is hard to assess the changing color for white varieties like chardonnay. Moreover, heterogeneity of white grapes is very large [4, 1].

Consequently, a particular care has been taken during the French campaign for building grapes batches, especially for white varieties. Different results are presented in table 1. They show an improvement in the French campaign with regards to the Australian campaign.

Variety	**SECV**	**R^2**
Shiraz (Australian campaign)	0.92	0.93
Cabernet (Australian campaign)	1.42	0.90
Pinot Noir (French campaign)	1.07	0.88
Pinot Meunier (French campaign)	1.11	0.83
Red varieties (Generic model)	1.12	0.95
Chardonnay (Australian campaign)	1.63	0.78
Chardonnay (French campaign)	1.20	0.83

Table: SECV and R^2 from calibration test

In ordre to illustrated these results, figure 2 shows the scatter plots for red and white varieties obtained white sets calibration. Good calibration was obtained for red and white varieties. If a generic model for red and white varieties was performed, the quality stay fine.

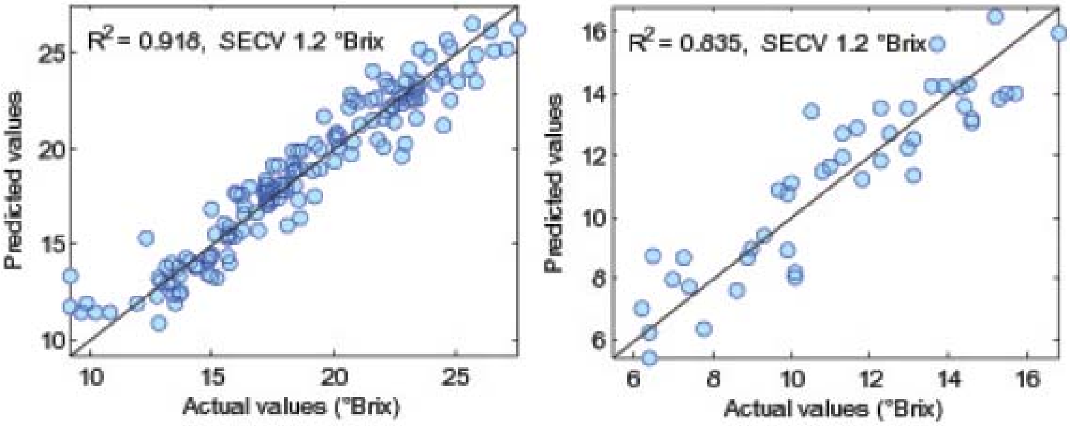

Figure 1: Plots of reference measurements vs predictions from cross validation with calibration sets. (L) Red varieties (R) White varieties

Other components: Figure 2 shows scatter plots for the other components (acidity, anthocyanin and water content) for shiraz variety obtained with sets calibration of French campaign.

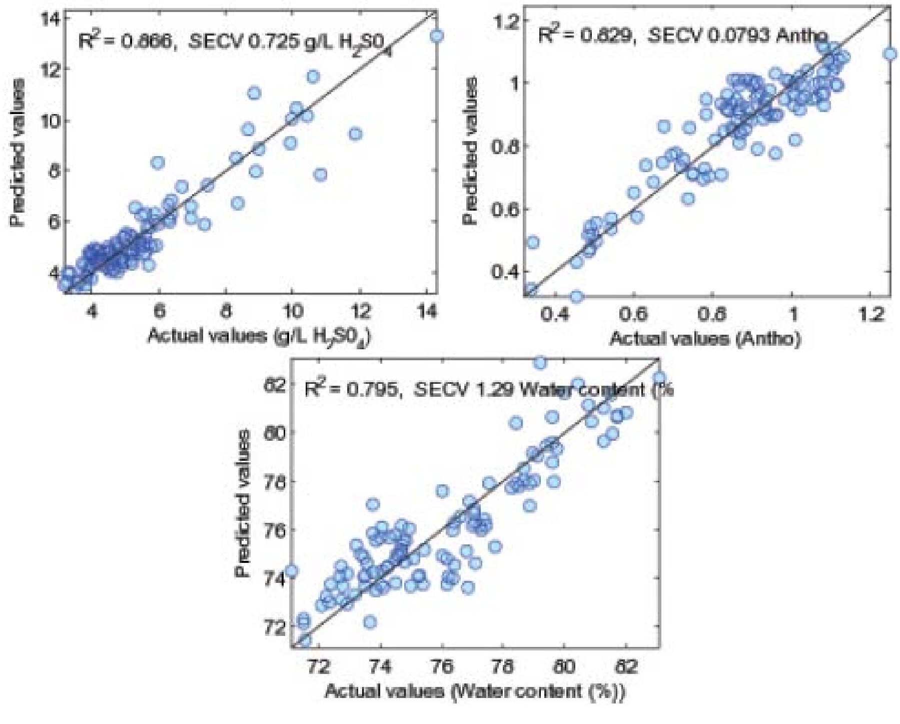

Figure 2: Plots of reference measurements vs predictions from cross validation with shiraz calibration sets. France 2008

Monitoring: The NIR device was applied to monitor the ripeness during the whole season. In that case, the models built in the calibration phase were applied on the validation spectra. Figures 3 and 4 shows monitoring curves obtained for sugar and acidity and the other by those of monitoring conducted by the grower.

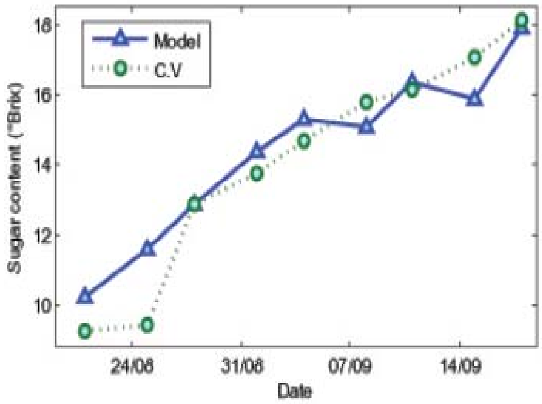

Figure 3: Sugar monitoring of Pinot Noir France 2008. Model : predicts values. C.V : chemical values

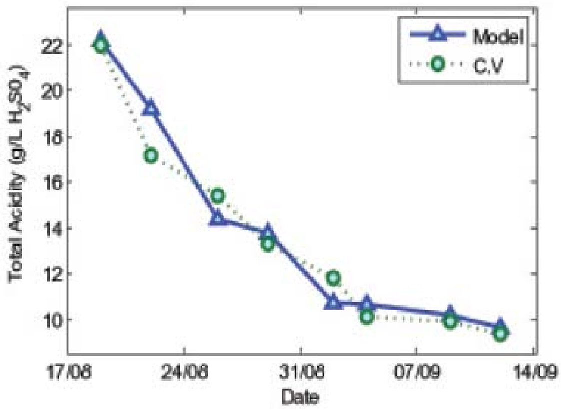

Figure 4: Acidity monitoring of Pinot Noir France 2008. Model : predicts values. C.V : chemical values

4 Conclusion

A low cost and portable sensor using NIR spectrophotometry theory have been designed and tested in field.

Several models have been developed using several varieties. The results show very satisfactory performances with regard to the grape composition and the ripeness monitoring.

Heterogenous distribution of components inside and between grapes was identified as the main problem for calibration.

This generation of new optic sensor showed excellent robustness when used in the field. The influence of different error sources traditionally affecting the performance of spectroscopic systems, such as temperature or humidity, was strangled by the simplicity of the system and spectral preprocessing techniques.

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