

Figure 1. Validation of Dualex and Multiplex optical sensors. Absorbance of extracts and skin contents of both Pinot Noir and Pinot Meunier are compared to anthocyanins measured by Dualex ANTH™ (A) flavonols measured by Dualex FLAV™ (B) and anthocyanins measured by Multiplex™ (C).

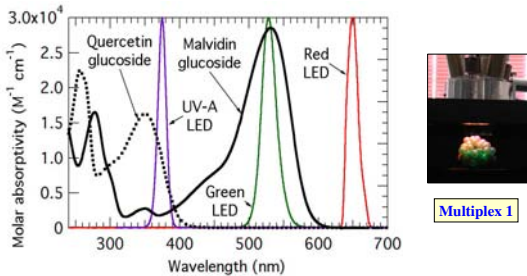


Figure 2. Spectra of the main berry skin absorbers compared to the light source used in Dualex FLAV™, Dualex ANTH™ and Multiplex™.

M&M Each week from mid July to the end of September 2005 two bunches of grapes (*Vitis vinifera* L.) of three varieties, Pinot Noir, Pinot Meunier and Chardonnay, were sampled from the CIVC experimental vineyard Fort Chabrol in Epernay, France. The Dualex™ (FORCE-A, Orsay, France) technology, was described by Goulas et al. [4]. In the new Dualex ANTH™ the original UV-A LED is replaced by a green sampling LED emitting at 528 nm, and is therefore dedicated to the measurement of ANTH (Fig. 2). At véraison, caps were cut from berries chosen to cover different grades of red colour, and measured with Dualex ANTH™ and Dualex FLAV™. The juice of the remaining berry part was used for total soluble solids (TSS) measurements expressed in °Brix. The caps were extracted in acidified 50% methanol as described in Agati et al. [1]. The Multiplex prototype is a hand-held optical sensor controlled by a computer. It has three LED-matrice light sources: UV-A (UV), green (G) and red (R), pulsed at 3.3 kHz, and three synchronised photodiode detectors protected by interference filters for fluorescence recording: blue-green (BGF), red (RF) and far-red (FRF). Each grape bunch was measured twice on the two sides of two bunches, so each point in Fig. 3 is a mean of 8 measurements. After Multiplex measurements, six berries were sampled individually for their sugar content and the result averaged.

References: [1] Agati G., Meyer S., Matteini P. and Cerovic Z. G. (2007) Journal of Agricultural and Food Chemistry 55: 1053-1061. [2] Bramley R. (2005) Australian Journal of Grape and Wine Research 11: 33-42. [3] Gishen M., Damberg R. G. and Cozzolino D. (2005) Australian Journal of Grape and Wine Research 11: 296-305. [4] Goulas Y., Cerovic Z. G., Carletat A. and Moya I. (2004) Applied Optics 43 4488-4496.

Optical methods are particularly appropriate for **precision viticulture** because the optimal grape sugar content and acidity are attained at different times in vineyard blocks. The grape phenolic maturity is even more heterogeneous and is attained later than technological maturity. Selective harvesting has been proposed as a solution to this problem based on zonal vineyard management and on-the-go quality sensing [2]. The assessment of grape quality inside the zones has relied mostly on destructive laboratory analysis, although optical techniques based on near infrared spectroscopy are emerging [3]. More recently, a new optical method was proposed, based on the **screening of fruit chlorophyll fluorescence** (ChlF), that allows both flavonol (FLAV) and anthocyanin (ANTH) contents of intact berry skin to be assessed [1, 4]. Here we present preliminary results obtained with two commercial devices, **Dualex FLAV™** and **Dualex ANTH™**, and a prototype, **Multiplex**, all based on this new method.

Dualex ANTH™ gave a very good estimation ($r^2 = 0.98$) of the skin ANTH content (Fig. 1). FLAV was also measured reliably by Dualex FLAV™ ($r^2 = 0.91$) showing tendencies towards saturation at higher skin contents. This is due to the three-fold smaller molar absorptivity for FLAV at their measuring wavelength compared to ANTH (cf. Fig. 2). Thanks to their low absorptivity in UV-A, ANTH will not interfere much with the measurements of FLAV. The FLAV do not contribute to absorbance at 530 nm at all (Fig. 2).

The **Multiplex** fluorescence index for FLAV, defined here as $\log(\text{FRF}_R/\text{FRF}_{UV})$ like in Dualex FLAV™, changed little with time. It was negatively but very weakly correlated to the sugar content (Fig. 3B). On the other hand, the FORCE-A Multiplex index for ANTH, defined as an inverted normalised $\log(\text{FRF}_R/\text{FRF}_G)$, and the $\text{BGF}/\text{FRF}_{UV}$ ratio were far more responsive to ANTH accumulation with grape maturation. This is due to the screening of ChlF excitation by the accumulation of ANTH. As FLAV seems to change little during ripening the increase in $\text{BGF}/\text{FRF}_{UV}$ (Fig. 3D) can either be due to an accumulation of ANTH or to a decrease in chlorophyll. The behaviour of Multiplex indices was very similar for Pinot Noir and Pinot Meunier showing good correlation to the grape sugar content (Fig. 3). As expected, ANTH related Multiplex indices changed little in white grapes (Chardonnay).

Flavonols stabilise the colour of **Anthocyanins**. It is therefore important to have a means to assess them in each berry. Dualex can fulfil that need for research on light intensity, temperature, nitrogen and other nutrient effects on accumulation of phenolics. Preliminary tests have shown that Dualex measurements can be performed even on whole berries. The representativity of the sample is the largest problem for maturity assessment. With the multiplex type sensors even total harvest can be sensed through on-line measurement. In addition, for maturation surveys marked bunches, representative of the block, can be followed during the whole season. Finally, optical signals dependent on ANTH could be used as a real-time decision support for selective harvesting.

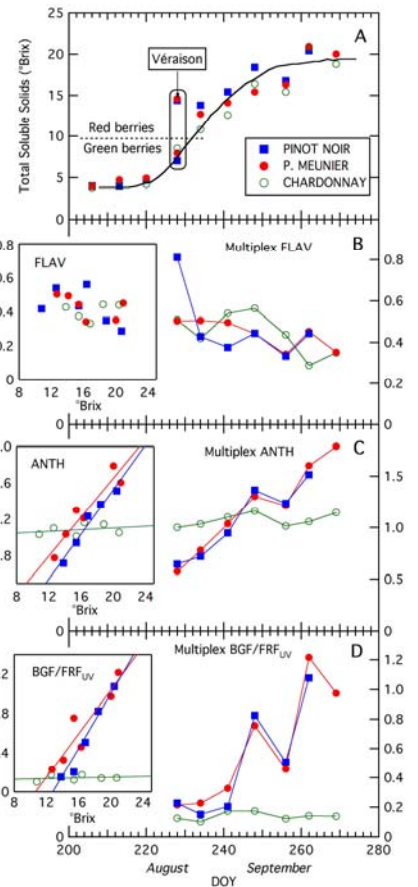


Figure 3. Time course of technological and phenolic maturation during the summer 2005. Fluorescence ratios measured on whole bunches with Multiplex are compared to the sugar content of the berry juice (inserts).

What Next?

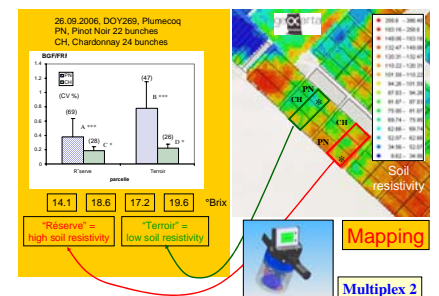


Figure 4. The new version of the Multiplex sensor will be used for mapping of grape maturity in vineyard zones identified by the apparent electrical resistivities of the soil.

In **Conclusion**, the "leaf-clip" type Dualex is inherently more precise and can yield quantitative data on ANTH and FLAV in individual berries. These would be valuable for studies on environmental effects on grape maturation. The non-contact sensor Multiplex, on the other hand, has real potential for **precision viticulture**.