

## A NEW, LOW-COST, ON-LINE RGB COLORIMETER FOR WINE INDUSTRY BASED ON OPTICAL FIBERS

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**Abstract** – This paper presents a new kind of colour sensor based in measurement the three channels of RGB colour space, using bifurcated optical fibres to conduct light from illuminant to liquid under test and from liquid to photo sensor. This kind of colorimeter can be applied to wine industry in despite of using different colour space in relation to traditional methods.

This paper shows a brief description of colour measurement process, a prototype implementation and several experimental results to compare their results to colour data from commercial equipment, and to verify its applicability to wine industry.

**Keywords:** colour sensor, optical fibre, illuminant

### 1. INTRODUCTION

Colour contributes to the organoleptic attributes of a wine and depends on some parameters such as the grape composition, winemaking techniques and several reactions that take place during wine storage. The composition of wine colour changes continuously during winemaking and storage, with associated changes in sensory characteristics.

Usual colour analysis for grape juices and wines is that made by measurements at three wavelengths in blue, green and red spectrum areas: 420, 520 and 620 nm [3].

There are several methods to measure the chromatic parameters in all wines types, such as the method based on the CIE (*Comission Internationale de l'Eclairage*) [1] or the OIV (*Office Internationale de la Vigne et du Vin*) [4] method to determine the wine colour. These methods uses two very similar processes to obtain colorimetric values of wine samples that they are the following ones: transmittance and absorption measures because the colours sensation feels because the wine absorbs the radiation incident, or transmits the one that not absorbed. In both cases, the objective of each one is to obtain three colorimetric values to situate each wine in one point of the specific colour space in each method [4].

Both methods have quite similar characteristics, including their high cost, because they use spectrometers, very expensive and delicate equipment, and other subsystems like special illuminants.

In addition, final colour read-out involves a complex procedure, not allowing on-line operation; this limitation reduces the use of these colorimeters in winemaking process.

On-line requirements and low-cost condition force to explore new methods of colour measurement, able to provide on-line chromatic values without punishing the cost, that is: they can be used within the control system of winemaking processes [2].

This paper presents a new design that uses another colour space – RGB – a specific sensor and takes advantage of optical fibre like transmitter that is, high noise immunity, and measurement to long distance and great reliability as much electrically as mechanically.

### 2. SYSTEM DESCRIPTION

Finished wines are very transparent liquids, therefore, when they are illuminated with a light source, they reflect a little amount of light, and the rest is transmitted due to turbidity value very low.

The wine colour must be evaluated with transparency measures, that is, observing the transmitted light or the absorbed light. In any case, light cross the wine, and will be collected. An observer receives the collected light, and calculates the chromatic values of wine as is shown in Fig. 1.

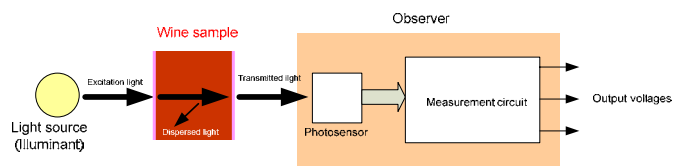


Fig. 1. Measurement principle for wine color estimation.

In order to simplify the procedure to conduct the light from illuminant to wine and from wine to observer are introduced some modifications in initial system displayed in Fig. 1: a bifurcated optical fibre bundle is used in addition to a reflective surface. Thus, light from source (illuminant) reaches the wine by optical fibre, is transmitted into wine, reflected in the surface and returns to fibre across wine (see Fig. 2). Optical fibres has been used to avoid external interferences, disturbances and uncontrolled attenuation along the air path of light as it usually happens in a standard colorimeters, where the light reaches the wine sample from illuminant and comes to observer through a long air path. These problems could produce noise and uncertainty in the measurement process, reducing the performance of instrument.

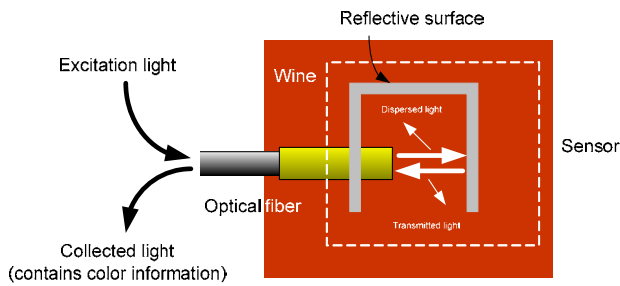


Fig. 2 Diagram of wine colour determination by transmittance when bifurcated optical fibres are used such as light transmission path.

If the reflective surface has a good reflectance, total effects is equivalent to transmit the light along two times the distance between the end of fibre and reflective surface. It is made of a stainless steel, type INOX 304 or 316 with appropriate surface is a robust solution for wine industry.

A commercial-grade halogen lamp 12V/20W has been used as illuminant with a full-stabilized power supply that allows us a constant value of applied voltage. Thus, filament temperature is also constant, causing a constant emission spectrum; moreover, this lamp has enough light intensity to obtain a high value of signal-to-noise ratio.

The observer, which receives the collected light, is a multiple photodiode type from Hamamatsu Photonics model S9032-02 with specific sensible areas for each colour.

Finally, a measurement circuit to transform the colorimetric information to voltage signals becomes necessary. Three similar channels with two stages constitute this circuit: a current-to-voltage converter and an additional gain step as it is shown in Fig. 3.

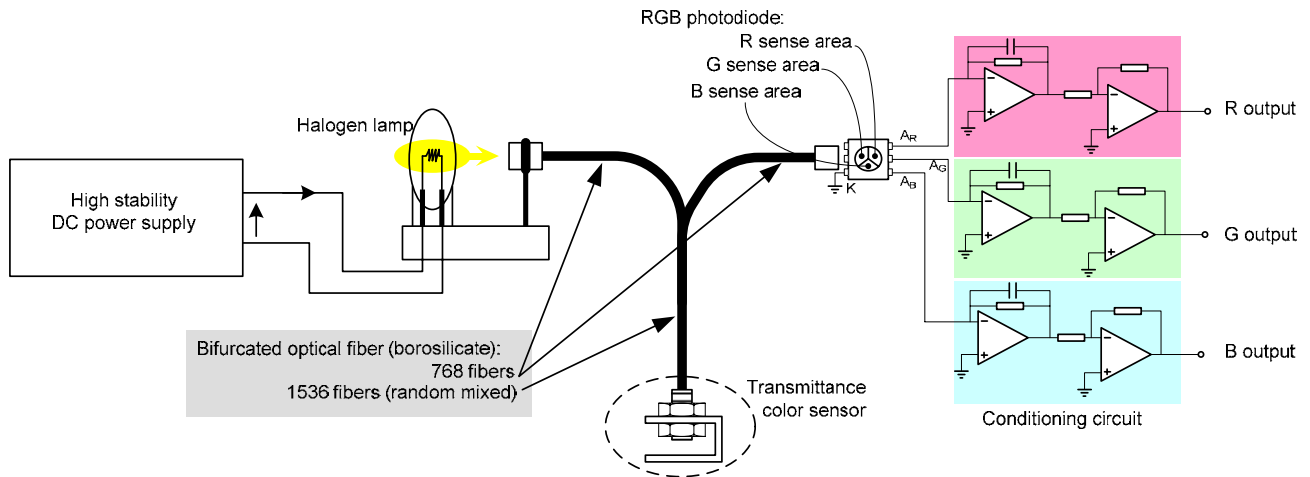


Fig. 3 Complete system including illuminating and observer constituted by a RGB photodiode and three similar channels for conditioning.

### 3. EXPERIMENTAL RESULTS

The objective of the experimental tests has been to verify the designed system process using a commercial spectrophotometer such as reference and several finished wines such as liquid under test. The results of reference

workbench for liquid colour measurement will be compared with results provided by RGB-colour measurement system presented in this paper. The same illuminant was used in both cases.

Colour reference measurements of wines were done by an Ocean Optics HR2000CG-UV-NIR spectrophotometer, working at 400-700 nm spectral area and bifurcated optical fibres such as transmission path. Several wines have been used – red, rosé and white wines – without specific containers or recipients for sampling: a traditional wine glass was used and the sensor will be placed inside. The Fig. 4 shows this reference workbench, constituted by a spectrometer USB port -connected to PC, a halogen light source and a bifurcated optical fibre bundle with the colour sensor.

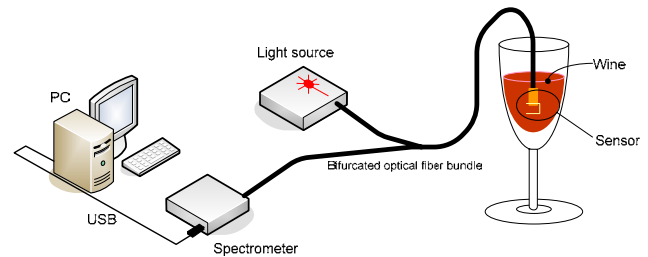


Fig. 4. Commercial equipment used like reference in the tests.

Data processing was carried out with Spectrometer analysis software to get the spectral response of liquid under test (wine). In order to minimize disturbances introduced by light path attenuation and other uncontrolled causes, all measured spectrum are referred to ultra-pure water spectrum; thus, disturbances and attenuation are cancelled and obtaining spectrum curves that have not dependence of

any uncontrolled agent. These ratiometric spectra are shown in Fig. 5 for several wine types.

Proposed colorimeter for wine application will provide three values of RGB color space to characterize each wine; then, results from spectrophotometer and designed colorimeter will be compared to determine the expected relationship. Fig. 6 shows the designed colorimeter.

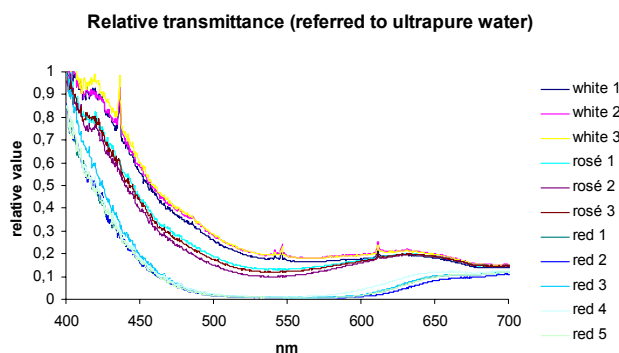


Fig. 5 Relative spectra of the wine (commercial equipment).

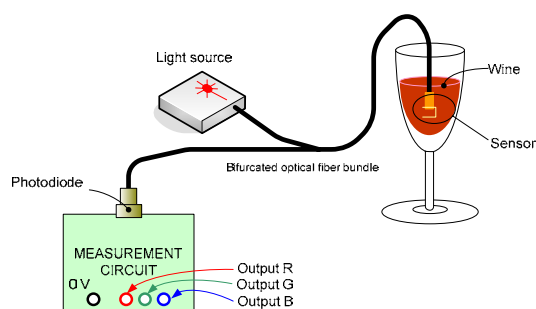


Fig.6. Designed colorimeter for wine application includes a halogen illuminant, a bifurcated optical fibres bundle, a transmittance sensor, and measurement system.

Table 1 includes voltage values obtained of each RGB channel from proposed colorimeter; each value is the average of six consecutive measurements (higher and lower values are rejected and the average is calculated for four-intermediate values). As we can see, there are differences between wine types (white, rosé and red) and between wines.

Table 1. Values [mV] provided by RGB colorimeter for each type of wine. Wine numbers are according to Fig. 5.

WINE TYPE		GRAPES	R	G	B
White	1	Airen	1980	1190	591
	2	Chardonnay	2020	1220	589
	3	Parellada	2000	1210	598
Rosé	4	Plurivarietal	1860	705	385
	5	Plurivarietal	1920	886	441
	6	Tempranillo	1890	823	420
Red	7	Tempranillo	86	75	142
	8	Tempranillo	87	120	162
	9	Tinta de Toro	90	68	140
	10	Tinta de Toro	83	74	142
	11	Plurivarietal	88	73	144

To compare the provided data by spectrometer with values obtained from designed equipment it is necessary to process the spectrum results. Due to excessive resolution of spectrophotometer (0.44 nm, that would cause, noise problems if a single spectrum point were used), it is necessary to calculate an average value around 420 nm, 520 nm and 620 nm, by taking a  $\pm 10$  nm interval, that is, a smoothed spectrum. Thus, a single value for each wavelength is obtained and it can be correlated to values of each RGB channel provided by the proposed system. A high correlation between both methods can be observed in the Fig. 7, 8 and 9 where relationships between values provided by spectrophotometer and values from the proposed colorimeter for each colour are shown.

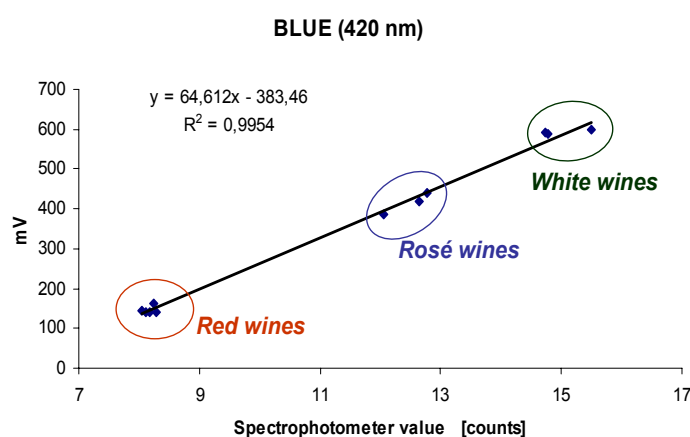


Fig. 7. Comparison of results from the commercial spectrophotometer and proposed colorimeter (BLUE channel). As we can see, different wine types can be easily separated in blue channel. For the same wine type, Rosé and white wines provide different colour values but all red wines produce similar response.

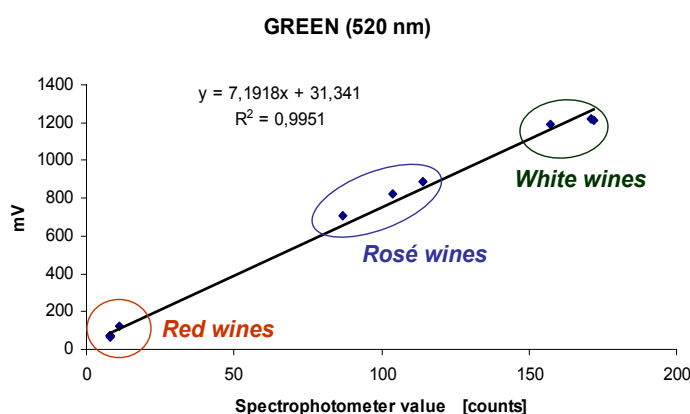


Fig.8. Comparison of results from the commercial spectrophotometer and proposed colorimeter (GREEN channel). As we can see, different wine types can be easily separated in green channel as occurred for blue channel. For the same wine type, each individual Rosé and white wines provide different colour values but all red wines produce similar response.

The obtained results can be plotted by means of different axes. These new axes are defined by the red-to-green ratio and the yellow-to-blue ratio. The value of yellow component

was not measured, but it can be obtained – estimated – by addition of blue and green channels:

$$Y = G + B \quad (1)$$

where G and B are the obtained values of green and blue channels for the developed system (Fig. 6), and Y is the estimated value for yellow channel.

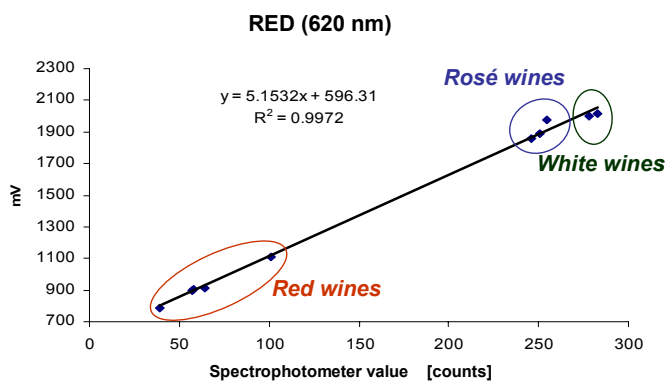


Fig. 9. Comparison of results from the commercial spectrophotometer and proposed colorimeter (RED channel). For this colour, rosé and white wines produce similar values. However, there is enough sensitivity to separate responses for each type of red wine.

Fig. 10 shows the position of each wine tested (Table 1) in the coordinates system R/G – Y/B. As we can see, red and rosé wines coordinates are separated and they can be identified easily but, all white wines have similar coordinates and they cannot be separated.

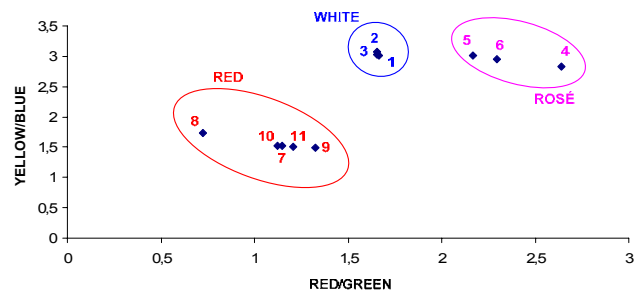


Fig. 10. Wine classification in Y/B-R/G coordinates system.

We can obtain two values of wines similar to the tone and chroma polar coordinates [1]. For do it, it is necessary a change in previous coordinates Y/B-R/G has is shown in Fig. 11.

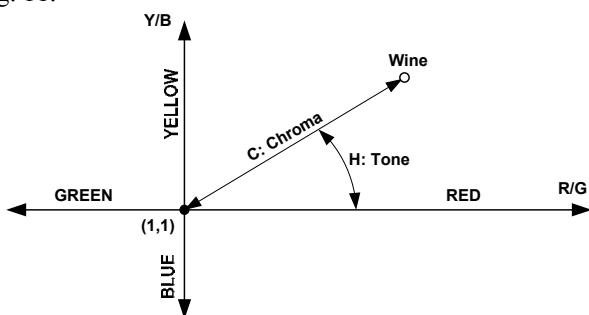


Fig. 11. Calculation of tone (H) and chroma (C) parameters.

The chromaticity values (see Fig. 11), H and C can be calculated as follows:

$$C = \sqrt{(YB - 1)^2 + (RG - 1)^2} \quad (2)$$

$$H = \arcsin\left(\frac{YB - 1}{C}\right) \quad (3)$$

where YB and RG are, respectively, the Yellow-to-Blue and the Red-to-Green ratios. Table 2 shows the C and H coordinates for the tested wines.

Table 2. H and C coordinates of tested wines. Differences are quite significant in rosé and red wines, but it is negligible in white wines.

WINE TYPE		GRAPES	C	H
White	1	Airen	2,12	71,75
	2	Chardonnay	2,17	72,43
	3	Parellada	2,13	72,12
Rosé	4	Plurivarietal	2,46	48,18
	5	Plurivarietal	2,32	59,85
	6	Tempranillo	2,35	56,51
Red	7	Tempranillo	0,55	74,48
	8	Tempranillo	0,79	159,63
	9	Tinta de Toro	0,58	56,33
	10	Tinta de Toro	0,54	76,86
	11	Plurivarietal	0,55	67,94

H and C values can be useful for wine identification in additional to the total absorbance value; In our case, H and C exhibits different values in several rosé and red wines, but they do not provide significant differences for tested white wines.

#### 4. CONCLUSIONS

Optoelectronic techniques have been able to develop an on-line sensor to obtain colorimetric quantification in the wine of a simple, robust and economic form.

The designed equipment has been verified by using several wines (red, rosé and white) and compared with commercial equipment based on spectrometry techniques. Finally, an excellent correlation between the results of both systems can be observed.

Experimental results has demonstrated that RGB colorimeter for wine application can be used to obtain colour differences between same type of wines; thus, blue and green channels provide enough sensitivity to differentiate each rosé or white wine, and red channel can easy differentiate each individual red wine.

In addition, this colorimeter can estimate usual chromaticity parameters such as red-to-green and yellow-to-blue ratios and polar coordinates (tone and chroma). In this case, it is possible to obtain different values for different types of red and rosé wines, but it becomes invalid for differentiation of white wines. In those cases, direct green and blue coordinates provide a better separation. Therefore,

the final solution can be a combination of H-C and G-B diagram to find the differences between all wines from a same type.

As final conclusion, the use of RGB colorimeter with bifurcated optical fibres and reflective sensor can simplify measurement procedures, and is able to work on-line. Consequently, it introduces two types of economic benefits: a decreasing of equipment and procedures costs and, an improvement in final product (wine) because colour can be controlled along winemaking process.

#### ACKNOWLEDGMENT

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