SMART
ANALYSIS

ANALYSIS OF WINE COLOR WITH THE CIELAB METHOD

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WHAT IS COLOR?

Color is a feeling, that is, a sensory perception due to a light stimulus that affects the eye and which is then processed and interpreted by the brain, generating the feeling of red, green, purple, etc. To see and recognize a color, several aspects are involved::

- Physics: how light interacts with objects generating a particular light stimulus;
- Physiology: how the human eye transforms the light stimulus into electrical pulses that are decoded by the brain;
- Psychology: how the brain responds to the stimulus by generating the feeling of perceived color.

This is why the perception of "color" is a totally subjective feeling! Each individual perceives color differently, because there are no equal eyes (from man to man *physiology* changes) and the brain interpretation to the stimulus is different (from man to man *psychology* changes). An example of this are people with color blindness, who due to a particular physiology have an altered perception of colors (in some cases they see black and white, because they are unable to perceive any color).

Moreover, even the same individual perceives the same color in a different way if, for example, he looks at the same object in the sunlight, or on a cloudy day or inside a room illuminated by artificial light (think, for example, of how the same photograph changes if you set the mode "sunny", "indoor", "cloudy" etc.). As already mentioned, the perceived color depends on the light that illuminates the observed object: different illuminations generate different light stimuli (from illumination to illumination *physics* changes) which are therefore interpreted differently by the brain.

How the color can be measured?

Colorimetry is the science that studies those branches of *Physics*, *Physiology* and *Psychology* involved in the perception of color, to create standards that allow to speak and discuss about colors without the possibility of error. Hence, **Colorimetry transforms color into something objective**, defining standard to measure, describe and represent color in an unequivocal way. Some of these standards are well known, such as the CMYK standard for printers, RGB for digital images or the pantones for defining the colors of paints and varnishes.

Whenever there is a need to standardize something, a responsible entity is created that decides the methods to do this. For color, this entity is the **CIE** (*Commission Internationale de l'Éclairage*, http://cie.co.at/), the International Commission on Lighting, which has been active since the early 1900s.

What is CIELab color analysis?

We focus here on the "**CIELab**" color analysis method, which is the latest chronologically International standard introduced by the CIE in 1976 for the representation of color, that can be used for both solid objects and liquid matrices.

CIELab is the standard for color representation that most of all approaches the feeling perception of colors that men have on "average"; in other words, it is the method that best approximates human vision and for this reason it has become one of the most used standard in many professional fields.

CIELab is a color measurement system based on *Tristimulus*. In CIELab the whole spectrum of the visible light is used, hence all the wavelengths (i.e. all the colors) that man is able to see. *Tristimulus* systems are based on the *Physiology* of the human eye: in the eye, there are 3 types of nerve cells (hence the term *Tristimulus*), called "cones", each of which is able to "see" only one slice of the visible spectrum, around the red (R), green (G, green) and blue (B) color, respectively. The brain takes the signals coming from the three cones R, G and B and mixes them creating in our mind the color perceived. Similarly, the *Tristimulus* color analysis system processes the visible spectrum measured with a colorimeter or a spectrophotometer in a very similar way to what the 3 types of cones do, generating 3 numerical parameters that allow you to define and uniquely represent all the visible colors. In addition, the CIELab method standardizes the type of lighting and represents each color as if it were seen in "daylight".

The 3 parameters (in more precise terms, the 3 coordinates) that are measured in the CIELab method are:

- ***L* (Lightness):** represents how clear, or bright, a color is compared to black and white. White has $L = 100$, while black has $L = 0$. All other colors have L between these two extremes.
- ***a*:** indicates the amount of *red* or *green* in the color. Values of $a > 0$ indicate the dominance of red, while values of $a < 0$ indicate the dominance of green.
- ***b*:** indicates the amount of *yellow* or *blue* in the color. Values of $b > 0$ indicate the dominance of yellow, while values of $b < 0$ indicate the dominance of blue.

These 3 parameters allow to represent the color in a 3D graph, a sort of sphere, as shown in Figure 1, where the *Lightness* is the vertical axis, while *a* and *b* identify the perpendicular plane to *L*.

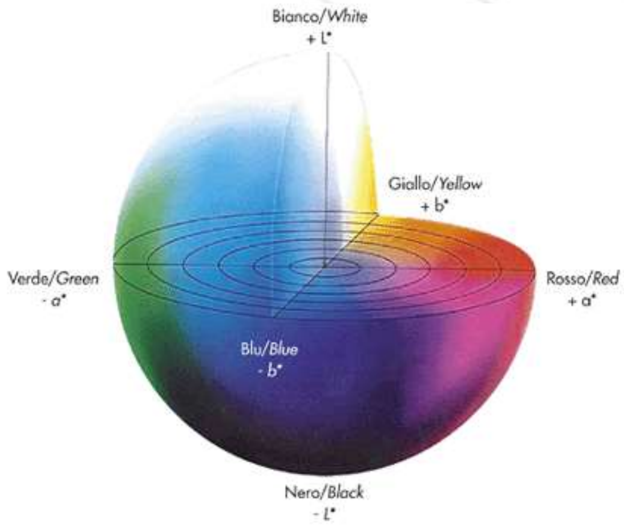


Figura 1. Representation of the color space defined by the CIELab standard.

From the coordinates *a* and *b* two other parameters can be derived, that are much more useful in practice:

- ***H* (Hue):** represents the color that is perceived (red, yellow, purple, etc …). The hue is an angle and is measured in degrees.
- ***C* (Chroma):** represents the *saturation* of the color, hence how intense the color is. The larger *C*, the more intense the color, the smaller *C*, the weaker the color. White, black and the whole grayscale has $C = 0$, as they are achromatic colors (they have no *Hue*). The only thing that sets them apart is *L*.

The two quantities *C* and *H* are also called *CIELab polar coordinates*, because they allow each color to be represented as a point on a 2D polar graph, where *C* is the distance of the point from the center of the graph, while *H* is the angle that the point forms with the horizontal axis of the graph. In particular, the polar graph is obtained by slicing the sphere represented in Figure 1 horizontally. This representation facilitates the interpretation and above all the comparison between the colors. An example is shown in Figure 2.

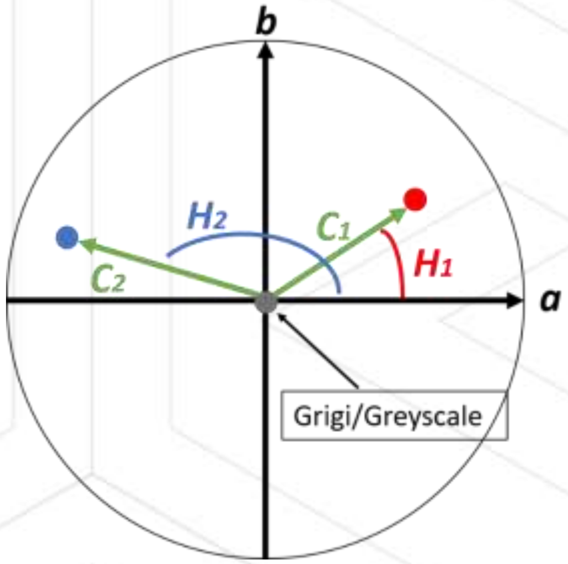


Figura 2. Representation of the Chroma (C) and the Hue (H) of the CIELab standard in 2D polar graph.

Another fundamental characteristic of CIELab analysis that has favored its enormous diffusion in many professional fields is the following: **this is the first standard for color representation that allows to measure the difference between colors very similarly to how man perceives it**. This made it possible to define the minimum thresholds of difference below which man is unable to distinguish two colors: men see them identical even if in reality they are different. In this way, for example, color tolerance standards have been introduced in the textile, plastics, printing industries, which define the maximum difference that two different objects must have to be considered the same color.

The simplest formula to evaluate the difference in colorimetric terms between 2 colors, indicated with the symbol dE_{ab}, is the following:

$$dE_{ab} = \sqrt{(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2}$$

E There are also other formulas to calculate the difference in color, more complex than this, introduced in recent years, but in which we will not go into detail. Both for the color analysis of wine and for beer dE_{ab} is used.

CIELAB COLOR ANALYSIS WITH SMART ANALYSIS

Color measurement is performed differently on solids and liquids. To measure the color of solid objects, the reflection colorimeters are used, which illuminate the object with their internal lamps and measure the light reflected from the surface of the object to calculate the CIELab coordinates (or of other color representation standards).

To measure the color of liquids, instead, a spectrophotometer able to acquire all the visible wavelengths, from 380 nm to 780 nm, must be used. Once the absorbance (or transmission) spectrum of the liquid sample has been acquired, i.e. the part of light that is absorbed (or that passes through) the liquid, the CIELab parameters must then be calculated or by creating spreadsheets (in excel, ad example) and setting all the necessary accounts (not at all simple) or purchasing the appropriate software, which typically are not included in the basic versions of the spectrophotometer software.

If you need to measure the color of your liquid product (wine, beer, vinegar, fruit juices, etc.) because color is a parameter defined by a specification, it is an important characteristic for your customer that influences its purchases or because you want to standardize production batches, but you don't have a traditional bench spectrophotometer or you don't have the right software**, then Smart Analysis is the perfect solution because it is the only one that allows you to immediately use the most recent and the best standard never created by the CIE to measure and compare colors.**

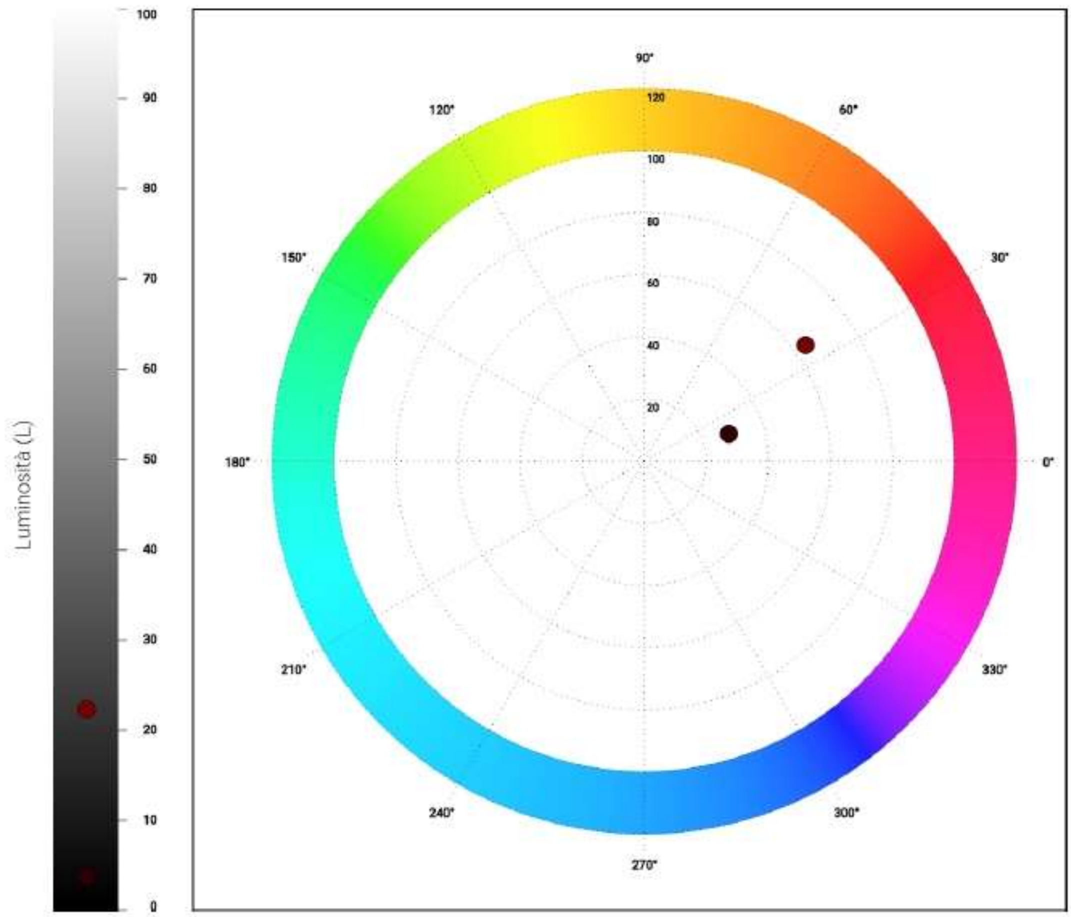
In fact, the Smart Analysis platform allows anyone to perform the color analysis of liquid samples with the CIELab method quickly, without the use of reagents and above all to use this analysis in a practical and effective way even if you are not expert in colorimetry, because:

- The optical device is a **spectrophotometer** (patented) that meets all the specifications defined by the CIE to measure color accurately and correctly with the CIELab method;
- The APP interface software performs all the calculations and returns the CIELab values and polar coordinates without any user intervention, which only needs to insert the sample into the device and start the analysis from the APP;
- The APP software automatically represents colors of the samples measured on the polar graph making the interpretation of the numerical data and above all the comparison between different samples totally intuitive.

All analysis data is automatically saved in the APP archive and can be sent to your own *Reserved area* of the **Smart Analysis Cloud,** accessible via web. In this way it becomes immediate to build your own historical archive of analyzes, to search the results of the color analysis of samples measured even months or years before, and to compare, through the graphic functions present in the Cloud, the colors of samples measured in different periods to maintain a certain standardization in the color of your product.

Below is an example of how the APP reports the CIELab data measured both in a numerical table and on the polar graph. In the graph, each point represents a sample and the color of the point reproduces the color of the sample itself. The distance of the points from the center is the chromaticity *C* of the sample, identified by the concentric circles with chromaticity 20, 40, 60 etc., while the angle that the point forms with respect to the horizontal axis is the *H* color, identified by the rays starting from the center. The crown of colors around the graph indicates which hue corresponds to the specific angle and makes it easier to read the graph. In the example shown, this allows us to say that the sample with greater chromaticity, the "Sangiovese 4", has a color that tends more to orange than the sample "red 5" which has shades tending more to purple. Finally, the vertical bar on the left of the graph represents the Lightness *L* of the samples.

Nome	Chroma	Hue	L	a	b
Rosso 5	28.24	14.32	4.3	27.34	7.09
Sangiovese 4	61.43	33.8	22.8	50.95	34.32



CIELAB WINE COLOR

The first characteristic that a wine consumer has the opportunity to evaluate, right from the bottle if the color of the glass allows it or in the glass when pouring the wine, is the color. Although probably the majority of consumers do not use objective evaluations and do not have the bases to use the color of what they are going to drink as a qualitative parameter, they still associate the color of the wine with its quality and, consequently, are influenced by the color in purchasing decisions. Whether it is right or not, they are the ones who buy and the color impacts their decision!

There is a scientific explanation for this. In fact, it has been shown that the color of wine also impacts and changes the olfactory perceptions ... yes, you got it right ... the color changes the olfactory perceptions! An experiment conducted by researchers from the University of Bordeaux in collaboration with the IRNA research center and published in the scientific journal Science Direct, has shown that the color of wine is really capable of changing the olfactory perception of that wine due to a perceptual illusion [https://www.sciencedirect.com/science/article/abs/pii/S0093934X01924939]. In the experiment, a white wine artificially colored red with an odorless dye was described from the olfactory point of view as a red wine by a panel of 54 tasters.

Color is therefore a very important qualitative parameter of wine that deserves the same dignity and attention in the control of all the other parameters (sugars, malic, total acidity, pH, etc ...). On the other hand, it is the first parameter that is evaluated in the tasting phase in competitions [disciplinary research where color is regulated]. So why don't you analyze it? Or if so, why do you do it with obsolete methods?

As for all other wine quality control analysis parameters, the OIV (International Organization of Vine and Wine) has defined the standards for measuring and evaluating the color of wine in an objective way. The recognized standards are two:

- "Chromatic characteristics" (OIV-MA-AS2-07B). Method type IV. http://www.oiv.int/public/medias/2475/oiv-ma-as2-07b.pdf
- "Determination of the chromatic characteristics with the CIELab color space" (OIV-MA-AS2-11). Method type I. Http://www.oiv.int/public/medias/2949/eno-01-2006-it.pdf

The type I methods of the OIV are the methods considered unique and best, as there are no other methods to obtain that type of value for the parameter in question. In other words, there are no other systems other than that based on the CIE standard for determining the color of wine according to the CIELab method. Type IV methods, on the other hand, are defined as "auxiliary" methods, that is, they are conventionally used when "higher" grade methods, such as type I, cannot be used.

The method of evaluating the color according to the "Chromatic Characteristics" standard is known to all and certainly the most used still today. It is based on the spectrophotometric reading of Absorbance (or optical density D.O.) at the three wavelengths 420 nm, 520 nm, 620 nm, from which the Intensity is then calculated, adding the D.O. of the 3 wavelengths, and the Tone, making the relationship between the D.O. measured at 420 nm and 520 nm. Historically, it was born and is still used today because the analysis can also be performed with poorly performing instruments, such as old spectrophotometers or simple photometers. In addition, they do not require special software because the calculations to be made are simple (a sum and a ratio).

This method of measurement, however, is extremely approximate and largely insufficient to describe the overall color of the wines, or rather, it does not describe the color of the wine at all but approximates only some of its properties. For this reason, in 2006, the OIV replaced this standard with the use of CIELab which describes the color as it is perceived by man, using 80 wavelengths, which cover the whole spectrum of the visible, rather than just the 3 wavelengths of the previous method.

Although 14 years have passed since the introduction of this standard in the world of wine, it is still not widespread in daily practice because only a few external laboratories provide this analysis and because until recently it was difficult to find tools (and especially software) that would allow to bring this analysis to the cellar! Until recently, in fact ... now there is Smart Analysis.

The Smart Analysis platform allows to analyze the color of the wine with the CIELab method quickly (the analysis lasts a few seconds) directly in the cellar, and above all to use the information of the analysis in a practical and effective way, even if not one is an expert in "colorimetry".

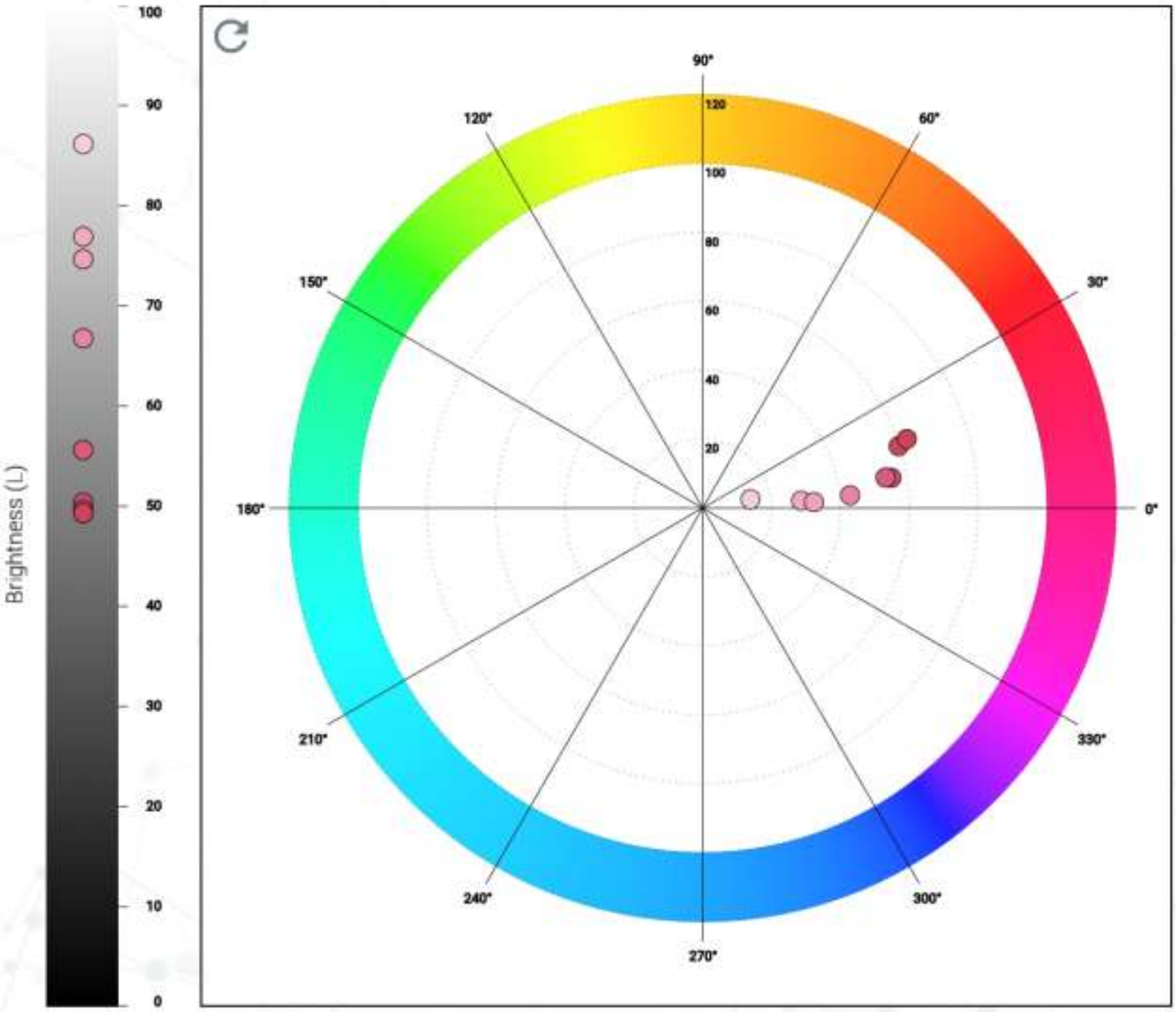
Together with the CIELab parameters, the Smart Analysis APP calculates the Intensity and Tone values according to the old "Chromatic characteristics" method. With a single analysis you therefore have both methods defined by the OIV available. This way you can easily start using the CIELab system, always keeping an eye on the data with which you are used to reasoning. Below is an example of how the results of the analyzes are reported.

Wine color (OIV-MA-AS2-07B)

Name	A_{420}	A_{520}	A_{620}	Intensity	Tone
Sample 1	0.159	0.25	0.063	0.472	0.636
Sample 2	0.265	0.478	0.085	0.828	0.554
Sample 3	0.29	0.543	0.09	0.923	0.534
Sample 4	0.421	0.779	0.118	0.318	0.54
Sample 5	0.763	1.353	0.241	2.357	0.564
Sample 6	0.663	1.187	0.184	2.034	0.559
Sample 7	0.869	1.597	0.242	2.708	0.544
Sample 8	0.901	1.691	0.229	2.821	0.533

CIELab features (OIV-MA-AS2-11)

Name	Chroma	Hue	L	a	b
Sample 1	14.624	249.24	86.626	14.582	1.114
Sample 2	28.633	81.93	77.378	28.624	0.719
Sample 3	32.18	29.79	75.132	32.179	0.29
Sample 4	42.245	170.74	67.232	42.187	2.204
Sample 5	54.084	426.85	50.8312	53.625	7.03
Sample 6	52.495	446.33	56.093	52.012	7.104
Sample 7	57.84	909.28	50.113	55.637	15.81
Sample 8	60.554	978.04	49.762	57.887	17.772



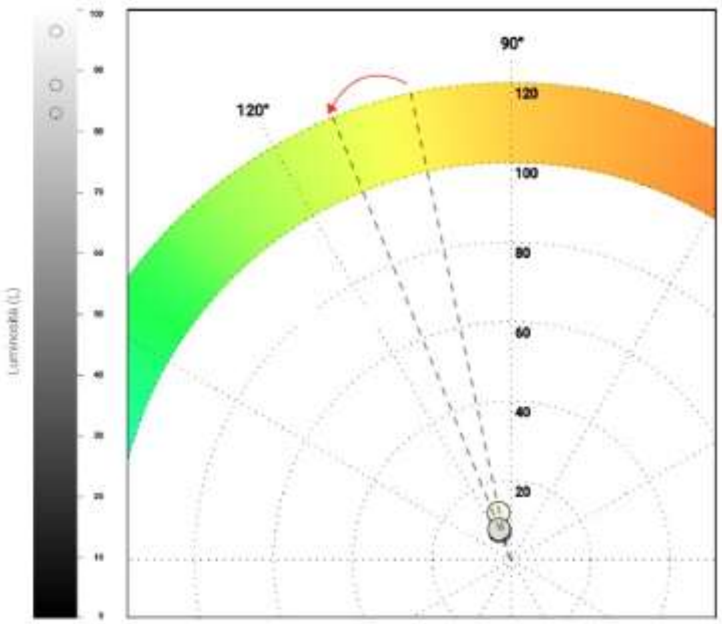
The color analysis done with Smart Analysis does not require the use of reagents, but you just need to pour the wine (properly filtered and degassed if necessary) in the empty cuvettes with the optical path of 10 mm, if the wine is white or pink, or 1 mm, if the wine is red, as indicated by the OIV. During the analysis, the APP allows you to select the optical path you are using, in order to automatically perform the necessary calculations.

CASE STUDY: HOW TO IMPROVE THE WINE CLARIFICATION AND REFINING PROCESS

Below is an in-depth analysis by the Enologist Dr. Domenico Sebastianelli who explains how the use of Smart Analysis has allowed him to improve his work in the clarification process and in the refinement of wines.

Thanks also to the graphic representation provided, the CIELab color analysis made with Smart Analysis manages to describe in greater detail the color perceived by the human eye, providing important information to be used in the wine clarification phases for the choice of coadjuvants to be use.

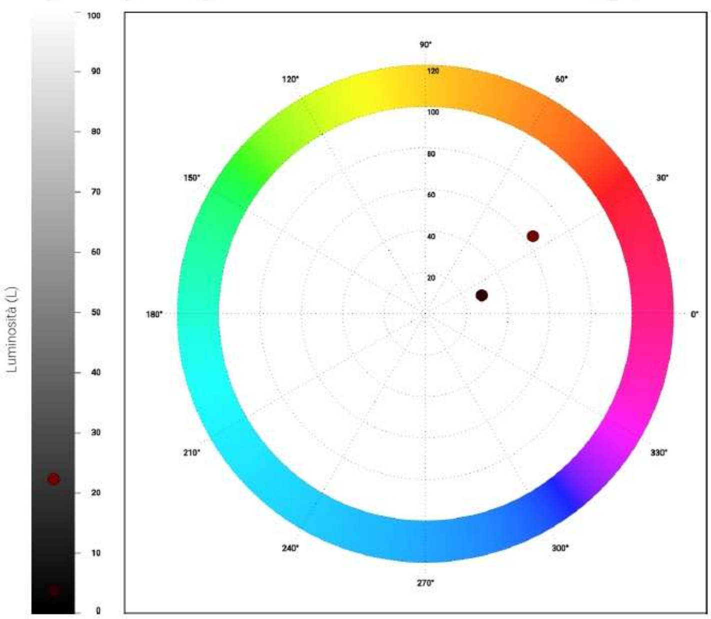
In the photo below you can see a clarification test on Falanghina del Sannio DOC white wine: The lighter colored dot shows the starting sample, while the two at the bottom show two clarification tests with different coadjuvants. Both clarifications resulted in a color tending to straw yellow with some green reflections, compared to the initial sample which tended more to orange color.



READING DESCRIPTION OF RED WINES

The classic readings indicate a similar hue on two distinctly different wines (a Sangiovese and a Montepulciano). The graph manages to make very clear that the Sangiovese sample has a color tending to ruby red (value farthest from the center), while the second red has a color with a greater dark purple component (value closest to the center of the graph).

The value "a" shows how the molecules that give the red color are present in greater quantities in the wine with less color (the Sangiovese), probably because the anthocyanins present are not polymerized with the tannins, therefore they are not stable.



Nome	A_{420}	A_{520}	A_{620}	Intensità	Tono
Rosso 5	4.168	5.864	1.956	11.988	0.711
Sangiovese 4	2.222	2.969	0.681	5.872	0.748

Nome	Chroma	Hue	L	a	b
Rosso 5	28.24	14.32	4.3	27.34	7.09
Sangiovese 4	61.43	33.8	22.8	50.95	34.32

CONCLUSIONS

It can be said that in addition to reading the DOs, the colorimeter indices provide additional information that can be useful by the technician to set, for example, clarification protocols, or to monitor the evolution of the color of a red wine in refinement, etc.

Smart Analysis, in addition to carrying out the basic analyzes in a simple and rapid way, also allows you to evaluate the colorimetric aspects by putting together the information provided by a colorimeter and a spectrophotometer, offering numerical and graphical results of great utility even for small businesses who cannot perform more complex analyzes.

CONTACTS

commerciale@dnaphone.it
matteo.barozzi@dnaphone.it
Office: +39 0521.062397
Matteo mobile: +39 329 9170211
www.dnaphone.it