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AESTHETICS APPRECIATION OF WOOD COLOUR AND PATTERNS BY COLORIMETRY. PART 1. COLORIMETRY THEORY FOR THE CIELAB SYSTEM

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ABSTRACT

The colorimetry theory for the CIELab system today allows us to compute the chromatic coordinates of the raw timber colour along the wood - chain industry. The wood industry is nd strongly behind in such areas. Progress in the wood appearance description by means of colour and pattern characteristics would be suitable to classify the wood. It would also help to match pieces of wood in furniture and inside the houses, to study the wood colour change in wood ageing by photodecoloration or by drying operations, and to improve wood colour variability.

Keywords: wood colour; colorimetry theory

INTRODUCTION

The wood industry is behind in the field of measuring wood colour appearance and in managing wood colour data if we compare it with the food, clothing, car, cosmetics, architecture industry and technology.

The Marketing valuation of the wood colour as raw material to make decorative panels, parquet, furniture, fine marquetry and joinery, and decorative beams for houses can contribute to increase its economical performance.

In the future, wood cannot be only considered for its mechanical resistance (Dilem, 1992), its conservation against injury, or its physical properties (shrinkage or density), but also for its Aesthetic aspect (Janin ,1994). It plays an important role among people due to its fair and fashionable patterns and colours.

The sustainable problem of the productive forest cannot only be considered taking into account the target production of the wood cubic meters / ha, but also in the bio-diversity of species yielding wood with pleasant figures and colours (Goncalez , 1993).

Then, after the use of genetic improvements with the aid of the heritability, a large range of wood patterns and colours can be produced.

If we consider how attractive wood has become for people buying furniture and wooden houses , it is very important to take into consideration the external appearance (Mazet and Janin, 1990) because it may become the most important criteria at the moment of buying .

The appearance can be evaluated by looking at the texture,figure and colour of the wood surface. These wood characteristics can be included in the concept of aesthetic aspects of wood.

Wood appearance in furniture is very important the moment of buying it. Most of the time it is even more important than the nature, the provenance or geographic origin of the wood (i.e.: name of a species, native country etc) or the commercial name of the species.

Therefore we want to propose that scientific appreciation and evaluation of the Aesthetic characters can help to understand better the reasons for which the prices of precious hardwoods are so high and which is a reason for final customers to buy a certain piece of furniture or a wooden decoration for the house.

The questions for the research in that area are:
How to determine wood colour ,texture and figure?
How to appreciate the motivation and the attraction of people for wood?
How to maintain the best colour related to the same species?
How to better understand, describe and explain wood quality and Aesthetic (surface pattern features and colour)?

Through which means can wood research and industry improve the utilization of wood in the market?

Man, wood colour and appearance

Colour is a psychosensation and an answer of man to a visual stimulus. It is an emotion that transmits a sensorial subjectivity of man related to the different objects that he sees during the day.

The effects produced by a colour on a person are connected to a certain extend with the personal fineness of the visual perception and with the individual interpretation of the brain. These sensations are under physiological control and they depend on the psychological and educational background of the people involved..

Wood and wooden objects are found everywhere, in flats or houses,etc. They are part of people's environment : wood-panels, furniture, stairs, chairs, sculptures or handicrafts. They help to create a special sensitive atmosphere due to the nature of the wood and its different appearance.

Moreover, the sensations perceived by man considering colour reveal the ability and e capacity to appreciate and evaluate the aesthetic impressions created by the scenery that the person is looking at, and also characterize its relative position in the field of the theoretical and practical knowledge of the world of the colour and colorimetry.

We will explain how the quantitative colorimetry of wood, the opinion-poll techniques applied to the users of the wood chain industry and the means of the forestry improvement (selection and heritability) can respond to those challenges.

Colour and colorimetry theory.

The quantitative colorimetry theory and technique consist in transforming the sensorial impressions into numbers. Then these numbers can be treated as objective data and information concerning the colours studied.

The three main points of the summarized Quantitative Colorimetry theory to compute colour numbers are:

-the energy of the light illuminant used along the visible spectrum of the wavelength is between 400 and 700 nanometers,
-the object light reflectance curve
-the human eye sensibility according to the *CIE 1931 standards observer definition (*Commission International de l 'Eclairage), along the visible spectrum.

The illuminant energy and the light nature.

The colour and colorimetry world utilizes all the notions of the physics of the light source energy: the illuminants. The illuminant nature is the energy distribution for each wavelength along the visible region spectrum, and the effects of the physics rules derived from low or high energy level of the light sources , polychromatic or monochromatic, flicking luminous signals, on the vision neurophysiology at the eye, retina and brain level.

The definition of light sources is related to the large wavelength spectrum ,ranging from U-V, blue, yellow-red to infrared .

Each light source has an established colour temperature in **K** (Kelvin absolute temperature scale), which is the temperature level reached by the black body emitting the same spectrum.

The illuminants.

The illuminants derive from the light sources. Each of them contains a particular energy distribution along the wavelength spectrum in the visible region ranging between 400 and 700 nm. They also have a colour temperature expressed in **K** (λ).

The most commonly illuminants used are:

Illuminant A:

- it is the light source distributed by the lamp with a tungsten filament, at 2855 **K** . It displays most of its energy in the red part of its spectrum, above 550 nm.

Illuminant C:

- It represents almost day light, with a low energy level in the blue part. Its colour temperature is 6770 **K** . It is rarely used nowadays.

Illuminant D 65:

- It is thus called because it has a colour temperature at 6500 **K** and it is the most commonly used illuminant. It is called the (D_{65}), D stands for Day Light and 65 (instead of 6500 **K**), with a large acceptation throughout the world.

In order to compare the energy distribution among all the illuminants, an energy reference for each of them is recorded at 560 nm .Its value at this point is considered as 100 on the energy distribution curve , in a comparative scale of relative energy. Thus we can rapidly compare the energy distribution for any illuminant (see Figure 1).

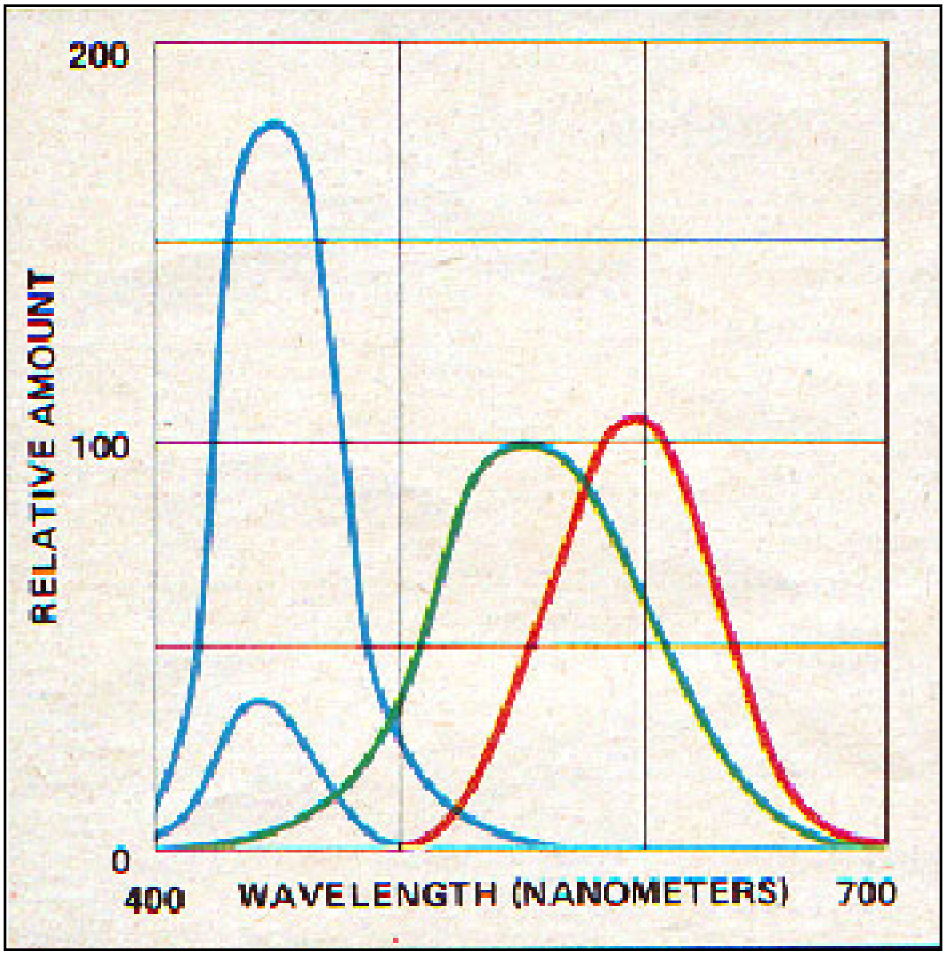

FIGURE 1. Curves of sensibility of the CIE 1931 standard observers (Course: Hunter, 1975)

Considering the energy curve of one illuminant we can conclude that its most interesting use along the wavelength is between 400 and 700 nm.

For instance the utilization of the illuminant A, can be more suitable to measure the dark reddish coloured wood because it is richer in the red region, and thus the reflectance can be higher.

The energy distribution along the spectrum can also be moved according to the selected object and the light must be adapted to the illuminant.

The CIE 1931 standard observers.

The sensibility of the human eye is widely spread. In 1931 the CIE , after examining dispersion among many people chose the most convenient Standard Observers.

The sensibility curves of the human eye along the wavelength of the visible spectrum were established for 2º and 10º respectively. These are the special vision angles on the vision on the central fovea of the retina with an experimentation concerning three primary colours of three different light sources.

The three primary colours are non-monochromatic with a dominant wavelength of:

- in the blue part 465 nm,
- in the yellow-green 545 nm
- in the red part 640 nm

The denomination of the corresponding curves for 2^0 and 10^0 standard observers are :

for the red cone cells:

$\bar{x}_2(\lambda)$ and : $\bar{x}_{10}(\lambda)$

for the green-yellow cone cells:

$\bar{y}_2(\lambda)$ and: $\bar{y}_{10}(\lambda)$,

for the blue cone cells:

$\bar{z}_2(\lambda)$ and : $\bar{z}_{10}(\lambda)$

Theses curves show the sensibility of the human eye along the visible spectrum, for the CIE standard observers 2^0 and 10^0 (see Figure 2)

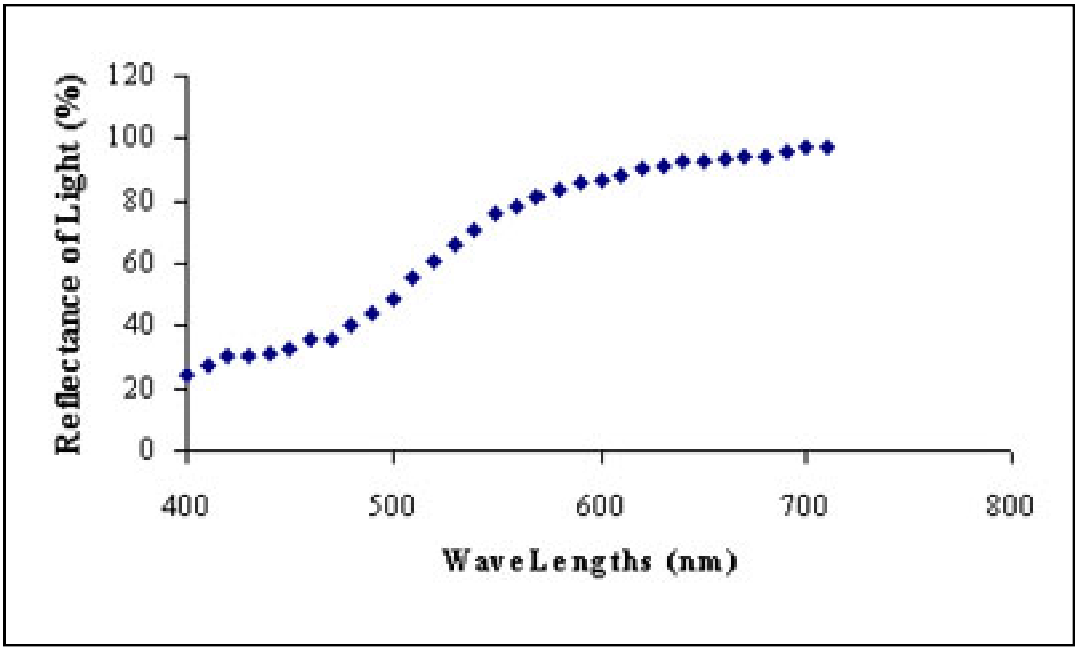

FIGURE 2. Curve of reflectance of the object: “invariant”.
(Course: Hunterlab, 1995)

The 2^0 and 10^0 are the solid angles on which a person sees an object. It means that on the retina only the cone cells are concerned with colour interpretation in the central area of the fovea for both angles. The rod effects are eliminated .

The 2^0 is used for precise hue determination (i.e.: the hue angle on the colour circle), and the 10^0 is utilized for the quantitative chromatic coordinate determination thus measuring the differences among many colours.

The objective and quantitative Colorimetry

The technique of the quantitative Colorimetry itself is the transformation of sensorial impressions into numbers: L*,a* b* with the aid of the CIELab 1976 system or L*,C, h in the CIELCh system, which define each point of the colours of an object in the colour solid L, a* and b*(Figure 3).This is the well known energy nature of the utilized light, the "invariant " or object reflectance in the CIE 1931 standard observer sensibilities .

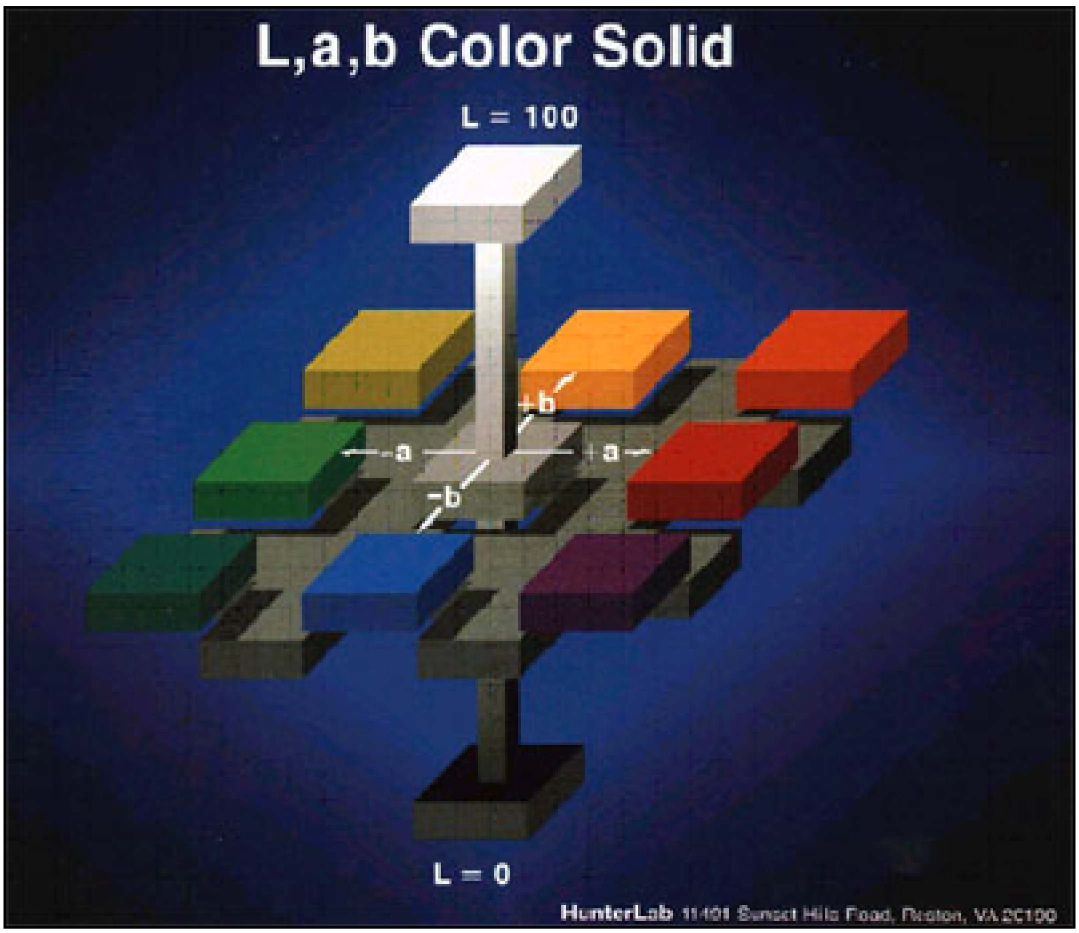

FIGURE 3. Hunterlab color solid L*, a*, b* (Course: with permission Hunterlab, 1995)

Then all objects can be described by :

L * lightness level along the black-white (z) axis, and a* (x) of the green - red axis and b* (y) of the blue - yellow axis in three-rectangular chromatic coordinates in the volume of the CIELab (1976) colour solid representation (see Figure 3)

The numerical representation value can be completed also by the cylindrical values: of the L* lightness, C saturation and h the hue angle on the colour circle around the Lightness axis in the CIELCh representation .

To obtain such characteristic numbers for colour, the technique of the computing colorimetry needs the concepts described below :

-the light energy distribution under which the object is placed for observation (figure: 2) ,
- the "invariant" of the point of the colour choices on the surface of the object observed and measured which is the reflectance (Figure 4)
- the sensibility of the CIE 1931standard observers that is the adapted response of the different chemical constituent of the three types of conal cells of the retina for specific orientation 2 ^{0} or 10^{0} of the observation (Figure 2).

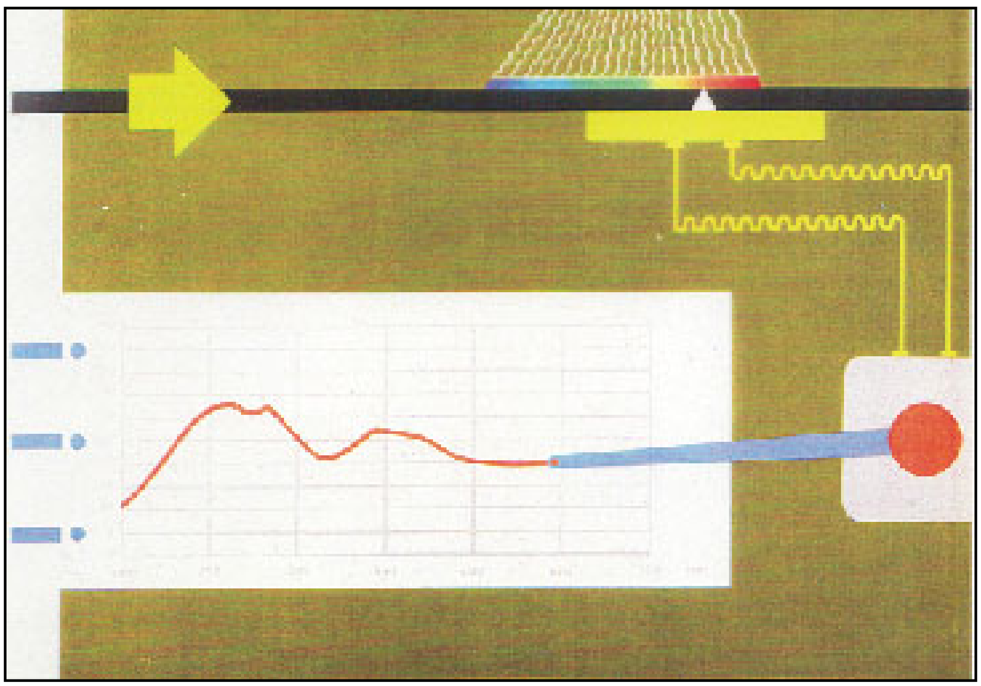

FIGURE 4. Distribution of the energy along the wavelengths for an illuminant
(Course: Janin, 1994)

The computation of the chromatic coordinates: L* a* b*, C and h, by the aid of X, Y,Z tristimulus values.

Obtention of the tristimulus values X,Y,Z.

To compute the colours characteristic we need the energy contribution of the reflected light by the object in the blue, green-yellow, and red part of the visible spectrum. These contributions are named "the tristimulus": X for the red, Y for the yellow-green, and Z for the blue.

The tristimulus values X, Y, Z, are the numbers representing the contribution of the retina cone cells of the eye in the red, green-yellow, and blue region.

They are computed by utilizing the all ready mentioned notions of light nature E(λ), the "invariant" or reflactance curve of the object R (λ), and the sensibility of the CIE 1931 standard observers.

The expressions for each value are:

X : the contribution of the red cones to the red perception region by the eyes,
Y : the contribution for the yellow-green,
Z : the contribution in the blue,

Thus:

$$X = \int_{400}^{700} \left[E(\lambda) . R(\lambda) . \bar{x}(\lambda) . d\lambda \right] \quad (1)$$

$$Y = \int_{400}^{700} \left[E(\lambda) . R(\lambda) . \bar{y}(\lambda) . d\lambda \right] \quad (2)$$

$$Z = \int_{400}^{700} \left[E(\lambda) . R(\lambda) . \bar{z}(\lambda) . d\lambda \right] \quad (3)$$

Where:

E (λ) = is the energy distribution of the incident light
R (λ) = is the object reflectance ("invariant")

$\bar{x}$ (λ), $\bar{y}$ (λ) , $\bar{z}$ (λ) , = are the sensibility of the human eye in the red, green-yellow and red part, for the 2^0 or 10^0 standard observers respectively.

dλ: are the wavelength interval choices to compute colour data (usually :dλ =10 nm). All the above parameters are considered along the spectrum of the visible wavelength (λ).

X_0 , Y_0 , Z_0 , are the tristumulus values for white standard tile considered as reference in the calibration of the spectrocolorimeter.

The value of each chromatic character is given by the theory:

For lightness (L*):

$$L^* = 116 \, (Y / Y_0)^{1/3} - 16 \qquad (4)$$

For the Green - Red axis:

$$a^* = 500 \, [(X/X_0)^{1/3} - (Y / Y^0)^{1/3}] \qquad (5)$$

For the blue - yellow axis:

$$b^* = 200 \, [(Y / Y_0)^{1/3} - (Z / Z^0)^{1/3}] \qquad (6)$$

For the CIELCh system of the colour representation, C: is the colour saturation and h: is the hue angle on the colour circle.

The determinations are:

-the saturation

$$C = \sqrt[2]{a^{*2} + b^{*2}} \qquad (7)$$

the saturation represents the right distance between the z-axis to the point of the colour in the Hunter color solid ,

$$h = \text{arctang} \, (b^*/a^*) \qquad (8)$$

-the hue angle can be expressed in radiant, degrees or grades on the trigonometric circle:

$$\hat{h} \, (en \; radiant) = arctangente\left(\frac{b^*}{a^*}\right) \qquad (9)$$

$$\hat{h}\left(en\ degrés\right) = arctangente\left(\frac{b^*}{a^*}\right).\frac{180}{\pi} \qquad (10)$$

$$\hat{h}\left(en\ grades\right) = arctangente\left(\frac{b^*}{a^*}\right).\frac{200}{\pi} \qquad (11)$$

the hue angle is a position of the colour point under the colour circle. Depending on the value and the sign of + or - a* on the x green-red axis and + or - b* on the y blue - yellow axis, the h angle can move its value around the colour circle from 0^0 and 359^0 from red to violet -red following the trigonometric direction.

Thus the quantitative and objective numerical values are:

L* , a* and b* or L* , C , h,

They can help to describe the wood colours and all the peculiarities on the surface of wood materials.

The numerical values will be placed in parallel to the advice or choices of the final users detected during the inquiries or opinion-poll for wood quality.

The colours and their effects on the choices can be interpreted after examining the relationships with all the professionals along the wood-chain and comparing them with the opinion polls applied to consumers and users of wood products.

Examples of numerical description of wood colour

There are methods to determine wood colours (Vetter *et al*. 1990) but they are not precise enough and available to compare the wood.

The measurement of the appearance of the following tropical woods can allow us to understand the utility of the determination performed with the CIELab and CIELCh system to compare the flat-sawn wood along the grain for all wood , or to compare the quarter-sawn and end-grain sawn part of the same tree (Table 1).

Table 1 : CIELab and CIELCh colour data of the tropical species

Commercial names	Botanical names	L*	a*	b*	C	h (°)
Ebony	*Diospyros crassiflora*	26,2	0.50	0.80	0.94	58.02
Palissandre	*Dalbergia maritima*	27.80	4.70	2.70	5.42	29.89
Wenge (quarter sawn)	*Milletia laurentii*	31.50	6.20	6.30	8.83	45.48
Wenge (flat-sawn)	*Milletia laurentii*	36.60	7.00	8.40	10	50.22
Ipe	*Tabebuia serratifolia*	40.20	10.20	16.40	19.31	58.15
Niangon	*Tarrietia utilis*	46.70	14.10	21.20	25.46	56.40
Kotibe	*Nesogordonia papaverifera*	47.10	14.30	17.30	22.44	50.45
Satine	*Brosimum rubescens*	53	16	21.70	26.96	53.60
Dibetou	*Lovoa trichiliodes*	57.20	7.90	22.10	23.46	70.37
Peroba Mico	*Aspidosperma macrocarpum*	58.73	14.64	27.94	31,12	59,01
Bilinga	*Nauclea diderichtii*	59.90	17.50	37.70	41.56	65.13
Cedro Apici	*Ocolea scromberghii*	61	11.30	26	28.34	66.54
Lati	*Amphimas pterocarpoides*	69.80	9.10	29.20	30.58	72.73
Guariuba	*Claricia racemosa*	70.40	7.90	40.40	1.16	78.98
Peroba d'Agua	*Rauwolfia paraensis*	69.49	10.81	27.94	31.95	70.20
Amarante	*Peltogyne venosa*	38.1	17.9	3.7	18.2	11.6

The precision of such determination can provide a medium to classify, to match -pair, to join the pieces of the wood in parquet for floor, joinery or in the manufacturing of furniture.

Application of quantitative colorimetry to wood.

The application of the objective and quantitative colorimetry allows us to work with the "numeric chromatic coordinates" of colours to describe the colour of the wood (Charrier *et al*. 1995).

Colour can be natural, or modified by numerous wood treatment after air, drying (Ananías *et al*. 2000; Charrier *et al*., 1992), or thermal treatment (Bourgois *et al.* 1991), finishing by painting or chemical application (bleaching or dyeing) treatment.

The quantitative Colorimetry allows us to obtain the desired information about:

-the definition and the evaluation of wood colour the attraction for its aesthetic value, by the wood end-users along the wood- chain technology (Janin *et al*. 1996),
- the heritability of colour characteristics (Mosedale *et al.* 1996)
- the wood classification by colour differences, in "cluster group"

CONCLUSION

The conclusion of this paper concerns the feasibility of the observation of the different colours among wood and the possibily to speak about colours without the aid of a special word generally used to describe wood colour.

The colour observation of wood is already known by numbers, following quantitative and objective measurement.

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