Colour Study in CIELAB Space on Natural Colorants from Vaccinium Vitis-Idaea Fruits

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It is very important for food industry to use ecological additives and adjuvants such as natural dyes extracted from plants. The present paper presents a study regarding colour and colouring properties of the natural, non-toxic dye extracted from fresh fruits of cranberry (Vaccinium vitis-idaea) water extracted. Colours were measured in CIELAB system using a standard white specimen. The samples are different regarding their dye concentration. Experiments comprising more samples sets used three different illuminators. The hue, luminosity and saturation are discussed. The phenomenon of dichroism was also studied.

Key words: natural dyes, colouring power, dichroism

For food industry it is very important to use ecological products as additives and adjuvants. So, it is desirable that the natural colorants extracted from plants to be widely used instead of synthetic alimentary colorants, which can show a toxic effect. Nature is rich in color and the majority of plant pigments are not widely exploited for the coloring of food.

Anthocyanins are a chemical class of red to blue pigments that are commonly found in mature fruit (e.g. strawberries, blueberries, cherries, cranberries, and grapes), vegetable (e.g. onions, cabbages), seeds and flowers. They are used as natural food colorants for a long time and are therefore regarded as safe.

Cranberries (Vaccinium vitis-idaea fruits) are natural sources of non-toxic dyes. The extraction of such a dye and its use as coloring additive for different food products are subject of intensive research [1-10].

The coloring power shows the relative ability of a pigment to modify the color of another coloring agent to which it is added. For this reason, the colored pigments are observed in mixture with white pigments, usually titanium dioxide, in different ratios.

Color may be described using more color systems such as XYZ, RGB, CMYK, CIELAB etc., which quantify in different manners the three attributes of color perception: hue, saturation and luminosity [11-21].

The present paper presents the data referring to the color measurements in the CIELAB system. The measurements were done after applying the fruit extract of Vaccinium vitis-idaea onto a cellulosic support varying the concentrations. Experiments comprising more samples sets used three different illuminators. The results were presented in tables 2 and 3.

The spectrophotometric determinations were done using a Minolta 3220d spectrophotometer.

The experimental program was developed using three standard illuminants:
- illuminant D65 (daylight simulator, color temperature ~ 6500 K);
- illuminant A (incandescent bulb simulator, color temperature ~ 2856 K);
- illuminant F2 (cold fluorescent white simulator).

For each sample we determined the rectangular coordinates L', a', b', and the saturation (C) and tonality (h) were measured.

Results and discussions

In order to have a general view over the colors obtained after the application on the cellulose support of the 5 samples, coloring measurements in the CIELAB system have been carried out. The results were presented in tables 2 and 3.

Table 2 presents the values of reflectance both for the dye samples and the standard white specimen.

Reflectance is a physical measure that depends on the incidence angle, the polarization of the radiation and the refraction index of the materials that form the separation surface. From the data obtained we can observe that the reflectance depends on the wavelength and respectively on the colorant concentration. Thus, for the sample with the greatest concentrations in anthocyanins the reflectance is the smallest at a certain wavelength. For all cases as for the standard the reflectance grows with the wavelength.

Table 3 presents the values of the color measurements in comparison with the white base for the M1 – M5 samples for the three illuminants.

The data in table 3 show that light sources affect the color. The spectral composition of the emitted light and the reflectance of objects surfaces determine changes in

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Table 1

<table>
<thead>
<tr>
<th>Sample</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthocyanins content (mg/mL) $10^3$</td>
<td>9.67</td>
<td>4.45</td>
<td>2.80</td>
<td>2.15</td>
<td>1.46</td>
</tr>
</tbody>
</table>

In table 1 the spectrophotometric determinations were done using a Minolta 3220d spectrophotometer. The experimental program was developed using three standard illuminants: illuminant D65 (daylight simulator, color temperature ~ 6500 K); illuminant A (incandescent bulb simulator, color temperature ~ 2856 K); illuminant F2 (cold fluorescent white simulator). For each sample we determined the rectangular coordinates $L'$, $a'$, $b'$, and the saturation (C) and tonality (h) were measured.
color perception. The apparent change of color perception with the light source is a type of dichroism. The dichroism is obviously undesired in the food industry. The fluorescent light in a supermarket, the yellowish bulb light in a restaurant and so on, can modify the color of soft drinks, dairy products or food, in general. This effect might be subject of interpretation by the consumers. The change of color might be associated with the alteration of the product.

The difference of color for the cranberry extract, DE*, is expressed by the relationship (1):

\[
\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}.
\]

The analysis of the data in Table 3 can lead to the following:
- \(\Delta E^*\) influences the color perception only if its value is higher than 0.5;
- \(\Delta L^*\) is not very significant since the values of luminosity are very close for all three illuminants;
- \(\Delta a^*\) is important for the illuminant A. In this case the sample seems more red;

<table>
<thead>
<tr>
<th>(\lambda) (nm)</th>
<th>standard</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>52.06</td>
<td>50.02</td>
<td>50.79</td>
<td>51.33</td>
<td>51.40</td>
<td>51.61</td>
</tr>
<tr>
<td>420</td>
<td>90.00</td>
<td>78.06</td>
<td>81.97</td>
<td>83.55</td>
<td>84.58</td>
<td>85.91</td>
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<tr>
<td>440</td>
<td>92.19</td>
<td>89.68</td>
<td>84.18</td>
<td>85.73</td>
<td>86.93</td>
<td>88.34</td>
</tr>
<tr>
<td>460</td>
<td>92.50</td>
<td>82.68</td>
<td>85.87</td>
<td>87.21</td>
<td>88.56</td>
<td>89.51</td>
</tr>
<tr>
<td>480</td>
<td>92.70</td>
<td>85.10</td>
<td>97.37</td>
<td>88.68</td>
<td>89.86</td>
<td>90.36</td>
</tr>
<tr>
<td>500</td>
<td>92.75</td>
<td>87.02</td>
<td>88.72</td>
<td>89.94</td>
<td>91.37</td>
<td>91.49</td>
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<td>520</td>
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<tr>
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<tr>
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<td>91.64</td>
<td>92.06</td>
<td>92.83</td>
<td>92.92</td>
<td>93.19</td>
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<tr>
<td>700</td>
<td>93.40</td>
<td>92.19</td>
<td>92.27</td>
<td>92.84</td>
<td>92.98</td>
<td>93.24</td>
</tr>
</tbody>
</table>

### Table 2
SPECTRAL REFLECTANCE OF SAMPLES (M1-M5) AND STANDARD SPECIMEN

### Table 3
THE VALUES OF THE COLOR MEASUREMENTS FOR THE M1 - M5 SAMPLES COMPARED TO THE WHITE BASE
- $\Delta b^*$ is significant for the illuminant F2. In this case the sample is more yellow;
- $\Delta C^*$ is important for illuminant F2. In this case the saturation of the color seems to be stronger;
- $\Delta h^*$ is significant since the hues are very close under all three illuminants.

The graphic dependences of the values $L^*$, $a^*$, $b^*$ reported to the white pigment, on the concentration of the colored pigments from the samples analyzed are presented in figures 1, 2 and 3.

![Fig. 1. Variation of $L^*$ with concentration ($C\%*10^3$) of the colored pigments from the samples](image1)

**Fig. 1. Variation of $L^*$ with concentration ($C\%*10^3$) of the colored pigments from the samples**

![Fig. 2. The dependence of the $a^*$ coordinate on the concentration ($C\%*10^3$) of colored pigments in the samples](image2)

**Fig. 2. The dependence of the $a^*$ coordinate on the concentration ($C\%*10^3$) of colored pigments in the samples**

![Fig. 3. The dependence of $b^*$ coordinate and $\Delta E^*$ on the concentration ($C\%*10^3$) of the colored pigments from the samples at illuminant D65](image3)

**Fig. 3. The dependence of $b^*$ coordinate and $\Delta E^*$ on the concentration ($C\%*10^3$) of the colored pigments from the samples at illuminant D65**

Luminosity refers to the quantity of light reflected by the color or it expresses the quantity of black present in the color. As expected, the luminosity decreases for the samples containing a greater amount of anthocyanins. The decrease in luminosity is expected because the concentration of white colorant in the sample increases, the product has a darker color.

The $a^*$ parameter is negative and its value decreases linearly along the increase of the colorant concentration, so the tonality of the color shifts to green.

The power of coloring of the fruit extract of Vaccinium vitis-idaea is a measure of the relative ability of the colored pigments they contain to modify the color of a white pigment to which they are added.

The power of coloring of this extract can be expressed by $\Delta E^*$, which measures the difference of color and depends on the increase of the concentration of the pigments added to the white base, when illuminant D65 is used.

The $b^*$ parameter is positive and we can observe that its value increases with the increase in concentration of the colored pigments. We can draw the conclusion that as the concentration of colored pigments increases, the tonality of the colors shifts to yellow.

Although the concentration of the colored pigments increases dramatically, the color difference towards the white sample increases slightly, so that we can realize that the power of coloring of the cranberries extract is weak. The natural color of the of the cranberry is reddish-black. The hue obtained using cranberries extract in weak concentrations is very weak. In fact, the colors of the samples analysed have different colors ranging from yellow and green.

The color in the $L^*$, $a^*$, $b^*$ space is presented in figure 4.

![Fig. 4. The space $L^*$, $a^*$, $b^*$ for the cranberries extract](image4)

**Fig. 4. The space $L^*$, $a^*$, $b^*$ for the cranberries extract**

**Conclusions**

The study presented above leads to the following conclusions:
- cranberry fruits extract is a natural dye appropriate for food coloring;
- the natural color of cranberry fruits is reddish-black. Added in small concentrations to basic white pigments, the extract can present light colors. The specific hues show different degrees of yellowish white and light greys;
- the coloring power of cranberry extract is pretty weak. This is the reason why very light colors can be obtained;
- the colors are relatively stable to light sources. A slight dichroism phenomenon however occurs;
- luminosity is quite independent of the nature of the standard light source;
- F2 (cold fluorescent white simulator) and A (incandescent bulb simulator) standard illuminants determine small changes of color, which shift slightly to yellow, respectively to red.
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19.*** DIN 53147 Testing of paper; determination of transparency
20.*** DIN 53236 Prüfung von Farbmitteln; Mess und Auswertebedingungen zur Bestimmung von Farbunterschieden bei Anstrichen, ähnlichen Beschichtungen und Kunststoffen
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