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RED PEPPER POWDER COLOR MEASUREMENT BY USING AN INTEGRATING SPHERE AND DIGITAL IMAGE PROCESSING

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ABSTRACT. A home made integrating sphere and a commercial digital camera were used to calculate the color characteristics of 16 pepper powder samples. Similar data for the samples were calculated from reflectance spectrum data measurements too, as reference ones. The color parameters calculated with the two methods agree within the experimental errors.

Keywords: *red pepper, color, integrating sphere, CIELa*b*, RGB, digital image*

INTRODUCTION

Different varieties of pepper (*Capsicum annuum* L.) are largely grown plants for human alimentary consumption. The fruit of the plant is consumed as fine grounded powder, called paprika, added to different foods. The young fruits are green, during the ripening their color gets red due to the deterioration of the chlorophyll and formation of red, orange and yellow colored pigments. About thirty different pigments contribute to the paprika color, mainly from the class of carotenes (β-carotene, α-carotene, lycopin) and oxygenated carotenes, also known as xanthophylls (capsanthin, capsorubin, zeaxanthin, violaxanthin, β-cryptoxanthin). The predominant carotenoid in paprika is capsanthin, exclusive to *Capsicum* species [1,2]. Paprika powder as well as the concentrated paprika extract, called oleoresin, is used mainly as natural colorants added to the foodstuffs, in cosmetics and less as spice or vegetable [3,12]. Since paprika is used as a coloring agent, its market value depends partly on the red color, the color being considered the main quality factor of it. More intensive the red color more valuable the powder.

The paprika red color and tone depend on many factors such as: the pepper brand [4], the growing conditions (soil, temperature, light and humidity), the processing and storage conditions (harvest, milling, dehydration, heat, light, packing etc.)[5,6,10]. On the other hand, during processing and storage, carotenoids are susceptible to degradation, oxidation and isomerization, due to the influence of light, temperature, heat, oxygen, enzymes, metals, etc. fact, which led to the color change, mainly to the redness loss of the powder [7-9,11,12].

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The color of the peppers can be evaluated from three different aspects: surface color, extractable color and carotenoids profiles, the first two being the standard quality evaluation in the spice industry. The surface color measurements are used to specify colors perceived by the human eye. The visual evaluation of the color depends to a great extent on the individual's eye color perception and training level, the evaluator momentary state of mind, the physical conditions of the observation (light source, illumination and background conditions, etc.). So, each person for the same sample and observation condition will interpret the described color a little differently, the verbal descriptions could be difficult, imprecise and sometimes confusing. In order to avoid the subjective, peculiar color assessment several optical instruments, systems and techniques were developed for objective color determinations of different objects, including pepper, either fruit or grinded powder. The early instruments measured the reflectance of the uniformly illuminated samples (at three different wavelengths or in the whole visible spectral domain) and the RGB and CIELa*b* values were calculated from the reflectance data [13-15]. The data allow the precise calculation of the color parameters of the sample, but only the average ones. Meanwhile many attempts were made in order to replace the classic illumination and detection system. These consists in the replacement of the integrating sphere with a light source which allows diffuse, uniform illumination (as new type of discharge tubes, halogen tungsten lamps with diffuser and multidirectional illumination etc.) as well as the replacement of the vacuum photo detectors with calibrated CCD cameras [16-21]. The use of such camera has several advantages over the vacuum tube detectors, as: eliminate the use of the monochromators or filters, allows the determination of color parameters of each individual point of the surface, the digital image could be easily saved and processed by proper PC software programs.

In principle other digital optical devices, as webcams or still cameras, could be used as photo detectors, their use are not come yet into general use. To our best knowledge the use of commercially available digital camera for determination of the color parameters of foods, including pepper powder, was not reported. The aim of our work is to evaluate the features of an integrating sphere and digital camera as photo detector system for the determination of color characteristics of grounded pepper powder.

INSTRUMENTATION

The experiments were carried out with a home-made integrating sphere by casting of gypsum cubic block, with a spherical inner hole having a diameter of 26 cm (Fig. 1).

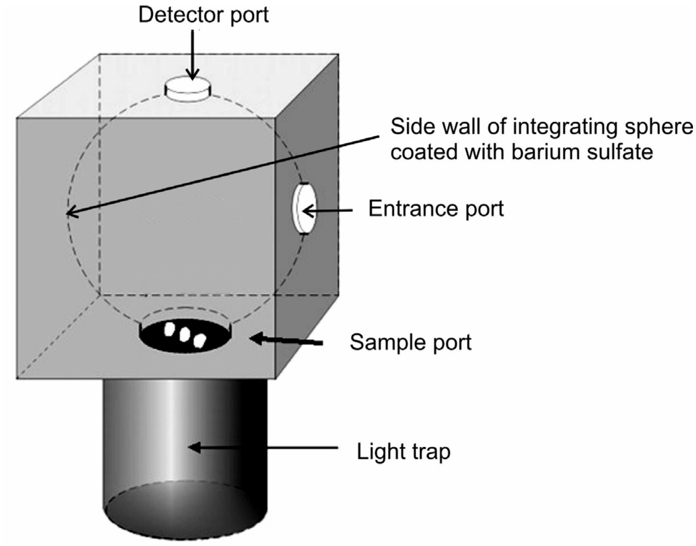

Figure 1. The schematic drawing of the integrating sphere

The inner wall was covered with $BaSO_4$ powder (used as white reference material for reflectance measurement). The sphere was provided with 3 ports, of diameter of 5. 9 cm, each perpendicular to other. The port on the upper side served as observation hole for camera. In the horizontally disposed entrance port was fixed the box of the light source with a 20 W / 12V halogen tungsten lamp provided from a Specol 20 spectrophotometer (Carl Zeiss, Germany), used as stabilized power source too. The third port, on the lower side, and face to face with the first, served for sample introduction. The samples were put on a plastic tray, and lifted upwards till they reach a tangential position to the sphere. Below the tray a light trap was mounted (a black painted plastic pipe, its lower end covered with black velvet). The tray has three vertical holes, which communicate with the light trap disposed beneath the block, serving as the black reference. The photo detector was a commercially available digital camera SONY DSC-H1. The shots were carried out in the automatic adjustment mode of the shutter speed and aperture. The digital image, of 5. 3 megapixels, was saved as . jpg file and transferred to the Pentium III PC for processing. As white reference surface a $BaSO_4$ tablet was photographed together with each pepper sample.

The SFA-01 VIS spectrophotometric module (ICIA, Bucharest, Romania) with a concave diffraction grating and a CCD detector was used for the plot of reflectance spectra of the samples in the spectral domain of 400-700 nm, and $45/0^{o}$ geometry. The spectrum was recorded in 512 points and saved as a . txt file. The color parameters were calculated from these data and served as reference values for comparison.

CONVERSION OF COLOR SPACES

From the reflectance (R) data the CIE XYZ tristimulus value, the CIELa*b* color coordinates and C, h* color attributes have been calculated [22]. The RGB values of each camera pixel were converted into device-independent CIE XYZ tristimulus values, using a conversion matrix as shown in Equation1.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} p_1 & p_2 & p_3 \\ q_1 & q_2 & q_3 \\ r_1 & r_2 & r_3 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

Using a set of paired RGB and CIE XYZ values obtained with the digital camera and reflectance measurements, a cost function was defined and then minimized to obtain an optimized conversion matrix for our system (Fig. 2) [23].

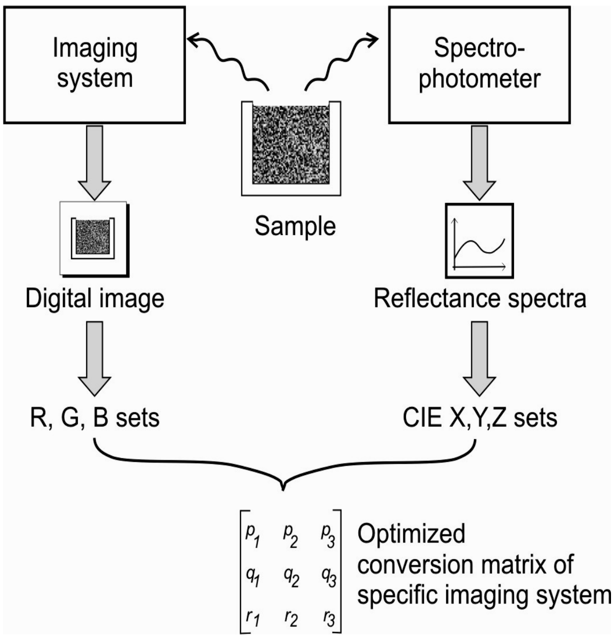

Figure 2. The optimization scheme of the conversion matrix

The cost function for ***p*** :

$$(\boldsymbol{p}) = \sum_{i=1}^{n} ((RGB)_i (p_1 \ p_2 \ p_3)^T - X_i)^2 \quad (2)$$

The solution, which minimizes this function, is:

$$(p_1\ p_2\ p_3)^T = K^{-1}\gamma \tag{3}$$

Where:

$$K = \sum_{i=1}^{n} (RGB)_i^T (RGB)_i$$

$$\gamma = \sum_{i=1}^{n} X_i (RGB)_i^T$$

Similarly, we calculated the optimized second and third row vectors, ($q_1\ q_2\ q_3$) and ($r_1\ r_2\ r_3$), respectively.

SAMPLING AND SAMPLE HANDLING

Thirteen different blend and origin of packed red pepper powders were purchased from the commerce and three samples from individual farmers. The powders were used as purchased, about 0. 5 g was introduced into a small plastic cup, gently pressed in order to obtain a compact smooth surface. The sample cups were introduced in the spectrophotometer and the spectrum has been drown, than it was placed in the integrating sphere and the digital photo was taken. The brand (as indicates the label on the original package) and the appropriate code used in this paper are presented in the Table 1.

Table 1. The pepper samples brand and codes

Nr.	Brand / origin	Code
1	Kalocsai - Csemege	PS1
2	Szegedi - Rózsa	PS2
3	Házi arany - Édesnemes	PS3
4	Fuchs – Édesnemes	PS4
5	Fuchs – Boia de ardei iute	PS5
6	Fuchs – Boia de ardei dulce	PS6
7	Galeo - Boia de ardei iute	PS7
8	Kotányi – Boia de ardei dulce	PS8
9	Cosmin – Boia de ardei dulce	PS9
10	Clever – Boia ardei dulce	PS10
11	Apahida – Boia de ardei dulce	PS11
12	Echom – Boia de ardei dulce	PS12
13	Home made-1 – Boia de ardei dulce (Gheorgheni-area)	PS13
14	Home made-2 – Boia de ardei dulce (Războieni- area)	PS14
15	Home made-3 – Boia de ardei dulce (Cluj-Napoca area)	PS15
16	Kamis Chili – Boia de ardei iute	PS16
17	Idem 1	PS17
18	Idem 1	PS18

PROCEDURE

First the white, the black and the color values of the digital image was corrected by using the ColorPilot 4. 80. 01v software package (Two Pilots™, USA, Germany, Russia). The corrected image was then processed with the ImageJ 1. 37v software program (Wayne Rasband, National Institute of Health, USA), the RGB parameters of the selected area were determined. Then the tristimulus values of XYZ and the CIELa*b* chromatic coordinates and of C, h* color attributes have been calculated.

RESULTS AND DISCUSSION

DETERMINATION OF THE PEPPER POWDER COLOR PARAMETERS BASED ON THE REFLECTANCE SPECTRA

The typical reflectance spectra of five selected pepper samples are represented in the Figure 3.

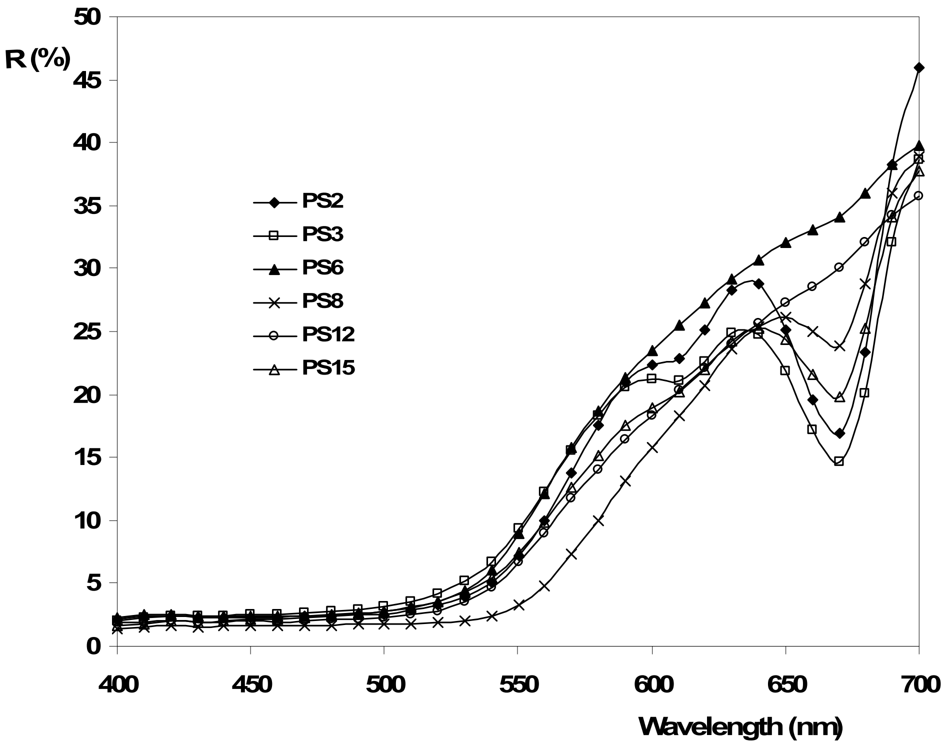

Figure 3. The reflectance spectra of five selected pepper samples

The samples reflect the light only over 500 nm. A group of spectrum (samples PS3 and PS6) exhibits a continuous, monotone increase of reflectance versus the wavelengths. For the other group of spectra (PS2, PS8, PS12 and PS15) the presence of local maxima and minimum are the characteristic feature of the increasing reflectance values versus the wavelength.

The local maxima appear at ~ 600 nm and at ~ 640 nm, respectively, the minimum appears at the 670 nm, despite of the pepper brand. In the later cases, the spectra look like a superposed molecular spectrum of three different colorants in the 530 – 700 nm spectral domain. This fact suggests the presence of three, yellow and red, colorants in the pepper powder in higher concentrations.

Based on the reflectance data the calculated color characteristics of the samples are summarized in the Table 2.

Table 2. The CIE color attributes based on the reflectance data

Sample	Color characteristics							
	X	Y	Z	L	a	b	C	h
PS1	11. 665	9. 401	2. 442	36. 74	21. 36	34. 27	40. 38	58. 07
PS2	14. 440	10. 738	2. 515	39. 14	29. 39	37. 84	47. 91	52. 16
PS3	14. 137	11. 309	2. 767	40. 10	23. 36	37. 64	44. 30	58. 17
PS4	7. 357	4. 998	1. 509	26. 73	29. 11	25. 41	38. 64	41. 11
PS5	8. 210	5. 874	1. 554	29. 09	26. 87	29. 01	39. 54	47. 19
PS6	15. 929	11. 953	2. 635	41. 14	29. 62	40. 40	50. 10	53. 75
PS7	12. 665	9. 326	2. 039	36. 60	28. 88	37. 33	47. 20	52. 27
PS8	10. 462	7. 041	1. 732	31. 90	33. 39	32. 05	46. 28	43. 83
PS9	8. 608	6. 095	1. 751	29. 65	27. 98	27. 99	39. 58	45. 01
PS10	14. 911	11. 032	2. 564	39. 63	30. 11	38. 32	48. 74	51. 84
PS11	14. 660	11. 020	3. 660	39. 61	28. 68	31. 04	42. 26	47. 26
PS12	12. 586	9. 300	2. 135	36. 56	28. 55	36. 43	46. 28	51. 91
PS13	16. 938	11. 932	2. 288	41. 11	35. 48	43. 01	55. 75	50. 48
PS14	17. 550	11. 921	2. 310	41. 09	38. 90	42. 81	57. 84	47. 74
PS15	12. 839	9. 859	2. 305	37. 59	25. 80	36. 81	44. 95	54. 97
PS16	15. 970	12. 397	2. 861	41. 84	26. 85	39. 99	48. 17	56. 12
PS17	13. 322	10. 801	2. 893	39. 24	21. 85	35. 29	41. 50	58. 23
PS18	12. 480	10. 078	2. 628	37. 98	21. 69	35. 00	41. 18	58. 21

DETERMINATION OF THE PEPPER POWDER COLOR PARAMETERS BASED ON THE DIGITAL IMAGE

In this case, only the color corrected pictures were taken into the consideration, the pixels representing the sample surface points on each photo was processed further. RGB values of each camera pixel were converted into device-independent CIE XYZ tristimulus values using a conversion matrix as shown in Equation1. The calculated color characteristics of the samples based on the digital image are summarized in the Table 3.

Table 3

The CIE color attributes calculated based on the digital image

Sample	Color characteristics										
	R	G	B	X	Y	Z	L	a	b	C	h
PS1	116.80	36.68	16.90	12.223	9.822	2.748	37.52	21.89	33.33	39.87	56.70
PS2	135.58	35.77	15.18	14.184	10.842	2.773	39.31	27.01	36.24	45.20	53.30
PS3	125.79	42.44	14.74	14.229	11.539	2.944	40.47	22.29	37.05	43.24	58.97
PS4	89.89	13.24	13.17	7.432	4.998	1.559	26.73	29.81	24.87	38.82	39.84
PS5	89.71	17.39	13.03	7.981	5.711	1.708	28.67	26.58	26.71	37.68	45.14
PS6	144.85	40.36	15.70	15.534	12.016	3.025	41.24	26.87	37.82	46.39	54.61
PS7	121.81	27.42	9.78	12.895	9.458	2.175	36.85	29.32	36.59	46.89	51.29
PS8	114.91	15.28	9.69	10.701	7.067	1.672	31.96	34.91	32.73	47.86	43.15
PS9	95.85	15.63	9.32	9.055	6.218	1.548	29.96	30.46	30.55	43.14	45.08
PS10	140.32	34.01	11.34	15.154	11.296	2.599	40.07	29.65	38.81	48.84	52.63
PS11	136.72	32.72	14.82	13.965	10.431	2.654	38.61	28.69	35.87	45.94	51.35
PS12	122.63	28.19	9.88	13.051	9.616	2.213	37.14	29.10	36.78	46.90	51.65
PS13	162.40	33.69	8.98	17.624	12.667	2.645	42.26	34.25	42.24	54.38	50.96
PS14	164.13	26.97	9.48	16.814	11.549	2.423	40.49	37.42	40.87	55.41	47.52
PS15	119.67	30.58	9.88	13.087	9.872	2.283	37.61	27.32	37.01	46.00	53.57
PS16	134.97	36.37	10.16	15.198	11.584	2.61	40.55	27.87	39.55	48.38	54.82
PS17	117.59	36.29	11.33	13.348	10.541	2.536	38.80	23.92	37.08	44.13	57.18
PS18	113.23	32.57	10.56	12.614	9.795	2.34	37.47	24.77	36.32	43.96	55.71

The CIELa*b* characteristics and C, h* color attributes (Fig. 4) show that the data are close to that obtained from the reflectance spectrum, as reference data. The differences are within the error of determinations. We can conclude, that the use of integrating sphere and digital still camera is suitable system for the precise determination of the color characteristics, and based on it, the quality assessment of different pepper powder brands.

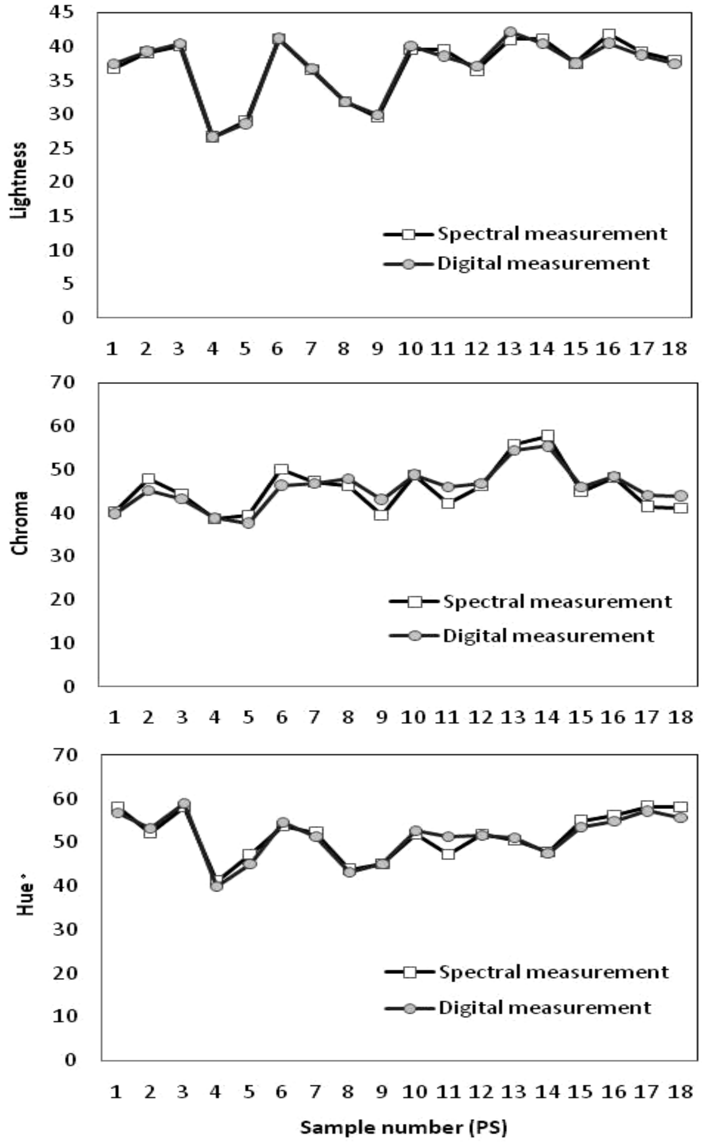

Figure 4. The calculated Lightness, Chroma and Hue values of the pepper samples based on the reflectance spectra and the digital image

CONCLUSIONS

The pepper samples exhibit different color and tone which could be emphasize by measuring the color characteristics. The reflectance spectra reveal the presence of there different colorants in some pepper powders. The differences in the reflectance spectrum appear as a tone change on the digital photo, which appears clearly as a difference in color characteristics. The color parameters calculated with the two methods agree within the experimental errors. As final conclusion, we can reveal, that the use of integrating sphere and digital still camera is suitable system for the precise determination of the color characteristics, and based on it, the quality assessment of different pepper powder brands.

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