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Digital image analysis in determining the color number of vegetable oils

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***Abstract*—Digital color transfer technologies allow a more accurate and more sensitive visual analysis of the chromaticity of objects in various fields of science and practice. The quality and composition of agricultural raw materials and food products is often evaluated by appearance and color. The article substantiates the use of digital image analysis in the analysis of vegetable oils to determine their color number. The use of mathematical models for digitizing color images while measuring a color series was analyzed. The comparison of the results of colorimetric tests conducted by visual and digital measurements of color characteristics is given. The fundamental possibility of using in digital image analysis of mobile Android devices is shown on the example of measuring the color number of unrefined and refined vegetable oils. A parameter for assessing the degree of refining vegetable oils is proposed. This parameter characterizes the color of vegetable oil.**

***Keywords*—digital image analysis, digital technologies, vegetable oils, color number**

I. Introduction

The basis of digital image analysis is a comparison of the color characteristics of an object with a reference sample. This type of analysis is widely used in the printing, textile, glass, food industries, in the field of computer and television equipment, etc. The level of development of digital technology currently allows to obtain color coordinates by measuring the overall function of the addition of colors. The prevalence and availability of digital technology makes colorimetric measurements simple, allow computer processing of the data, reduce metrological errors of visual observation, and conduct instrumental non-destructive analysis of technological and agricultural facilities in production and field conditions [1-8].

In the monograph [1], the authors conduct a theoretical assessment of the development of color scales for visual test analysis. The authors substantiated, by comparing digital measurements and visual observations of a large number of respondents, an interval of color scales, which makes it possible to most accurately visualize the color of objects. These studies are extremely important for semi-quantitative test analysis based on a color reaction.

The review authors [2] review literature data on the use of digital colorimetry in: chemical analysis. This is used, for example, in determining the content of cations of toxic metals [3]; pharmaceutical analysis of biologically active substances; food chemistry in the analysis of amino acids [4], vegetable oils [5] and vegetable syrups.

The relevance of the use of digital technologies in the food industry is shown in [6–8] as in the analysis of products of plant and animal origin.

Vegetable oils contain pigments that cause their color. Yellow color is associated with the presence of carotenoids in oils. Carotenoids can be divided into two main groups of carotenes and xanthophils. Carotenes are hydrocarbons. Moreover, the number of cycles and the structure depend on their type. There are three types of α-; β- and γ- carotenes, oxygen-containing carotene derivatives are called xanthophiles. Vegetable oils mainly contain β-carotene. [9]

Green oil gives pigment chlorophyll. Chlorophyll consists of two substances of blue-green chlorophyll A and yellow-green chlorophyll B. For vegetable oils, the presence of chlorophyll B is typical in most cases. The ratio of carotenoids and chlorophyll in vegetable oils is not the same. So, in the amaranth and sunflower oil carotenoids predominate, and they betray the yellow color of the oil. Olive, linseed, mustard and rapeseed contain more chlorophyll which gives a greenish tint to these oils. In addition, the intensity of oil color depends on the technological parameters of its extraction. Often the forpress oil has light shades, and the color of the expeller oil, on the contrary, is more intense. Extraction oils contain more pigments as compared to press ones, since in the extraction process hexane and other solvents perfectly dissolve the pigments and convert them to miscella, and as a consequence, the intensive coloring of the extraction oils. [10].

In the process of alkaline neutralization, only an insignificant change in the color of the oil occurs and, mainly, due to sorption of pigments by means of soap stock. In the process of bleaching (adsorption refining) of diatomaceous clays, the color of the oil decreases dramatically due to the sorption of carotenoids and chlorophyll on the surface of diatomite. Bleaching is an important technological operation that improves the quality of vegetable oils, not only to lighten but also to stabilize its properties [11].

The color of the oil is characterized by such an indicator as the color number (CN). It gives an idea of the quantitative and qualitative composition of the pigment complex and is an important indicator characterizing the qualitative changes at the stage of adsorption refining or bleaching of vegetable oils. CN is the number of milligrams of free I_2 contained in 100 ml of 1 cm thick standard solution of iodine, which has the same color intensity as the test oil itself. This indicator allows you to monitor the process at all stages, to regulate the amount of sorbent, temperature and other parameters of bleaching, as well as to form the necessary quality characteristics of the finished product. [10].

The color number of light oils refers to organoleptic characteristics and is determined by visually comparing the color of the filtered oil with the color scale of standard substances (aqueous solutions of iodine in potassium iodide) or by colorimetric method using photocolorimeters or tintometers. These methods involve fixed discrete measurements. Experimenters face difficulties in assessing chromaticity in the case of very light or very dark oils, as well as oils with a greenish tint, such as olive, canola, linseed, etc.

In digital technology for the mathematical description of the color characteristics of the object, the following models are used: RGB, CMYK, XYZ, HSB and CIELab. One of the most common is the RGB model, whose name is made up of the first letters of the English names of the basic colors: red (R), green (G) and blue (B). The RGB digital model is additive and characterizes the color by the sum of three components with zero black color (0, 0, 0). The base white color (255, 255, 255) consists of the components: R (255, 0, 0), G (0, 255, 0), B (0, 0, 255) [1].

CIELab color space is most accurate for calculating color characteristics. Equal distances between points, corresponding to different colors, in any parts of this coordinate system are related to visual perception. This allows you to enter a convenient measure for quantifying color differences. The color gamut of CIELab is very wide and includes RGB and CMYK, and other colors not represented in previous models. When converting to CIELab all colors are saved. This color model is most important for printing. It is convenient for determining contrast, sharpness and other tonal characteristics, and that is why it is used when transferring images from one color model to another, between devices and even between different platforms [1, 2].

Detection of color characteristics can be carried out using modern digital technology (digital cameras, scanners, etc.). Subsequent processing of digitized images using graphic editors allows you to obtain information about the content of colored substances in the object [1, 2, 7, 8].

II. Materials and Methods

The comparison of the results of visual observation of the color of samples of unrefined vegetable oils with the results obtained by digital fixation of color characteristics in a 10 mm thick quartz cell on a white background was carried out. RGB color characteristics were detected using the Color Picker application for the Android operating system. The measurement parameters used in the Color Picker application were: maximum pixel for a sample of 1024, preview size 1280 × 720, refresh rate 250 ms. The resolution of the camera of the smartphone is 12 megapixel, the correction of the photoexhibition is 750 ISO, the flash is off, the lighting is incandescent 100 lx. The grading of CN results was obtained for a series of standard aqueous solutions of iodine.

Preparation of calibration solutions of iodine. 0.26–0.27 g of double-sublimated iodine were weighed in a glass. Double the amount of potassium iodide and dissolved in 10 cm^3 of bidistilled water. The solution was transferred to a measuring flask with a capacity of 250 cm^3, diluted to the mark with water, capped and stirred. The exact concentration of the prepared iodine solution was determined by titration with sodium thiosulfate solution with a concentration of 0.01 mol / dm^3 (0.01 N) in the presence of starch as an indicator. After adjusting the concentration, bidistilled water was added to the prepared solution in such an amount that 100 mg of this solution contained exactly 100 mg of iodine per 100 cm^3. The primary standard was used to prepare solutions with a lower concentration by pipetting [10].

III. Results and Discussion

To select the color model that underlies the CN measurements, the functional dependence of the intensity of the color components R, G, B (on the RGB model) and L, a, b (on the CIELab model) for the calibration iodine solutions was evaluated. Fig. 1 shows the results of colorimetric measurements, the standard deviation was 1.45%. The greatest contribution to the color characteristic of solutions according to the RGB iodine model is made by the components R and G (Fig. 1a). Component B is almost independent of the iodine content in the solution, but plays a significant role in the color of iodine solutions with a high concentration. This observation leads to the conclusion. For a correct digital description of a color, it is impossible to neglect its components; therefore, to construct a calibration dependence, we used the integral parameter RGB Σ, which is the sum of the intensities of the color components R, G and B (Fig. 1a). For the CIELab color model, the correlation of the intensity of the components and their integral characteristic Lab Σ with the value of the color number was not observed (Fig. 1b). Therefore, the RGB color model was used to measure CN of vegetable oils.

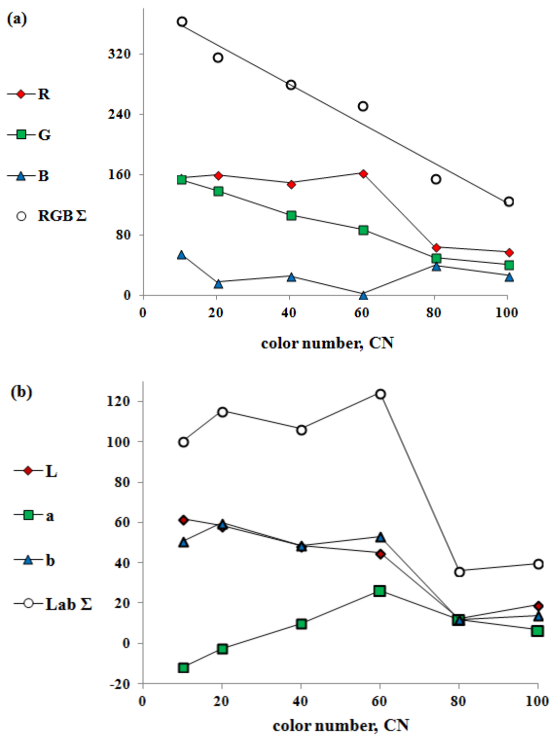


Fig. 1. The dependence of the intensity of the color components on the color number (CN) for the RGB (a) and CIELab (b) color models.

Fig. 2 shows the intensity values of the color components of vegetable oils by the RGB model. As with iodine solutions, in the case of vegetable oils, the dominant influence of the red and green color components was observed. A significant proportion of the blue color component in the case of sunflower and amaranth oils was detected. The values of the color number for samples of unrefined vegetable oils (Fig. 2) were determined using the calibration dependence (R^2 = 0.9706, Sr = 0.0145) of the total parameter RGB Σ = -2.62CN + 385 (Fig. 1a).

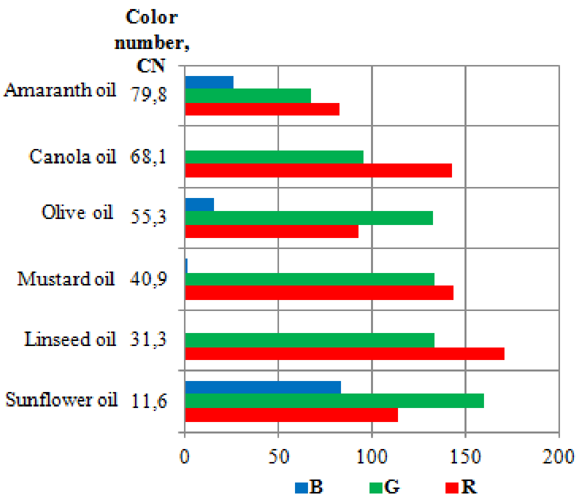


Fig. 2. The intensity values of the color components R, G, B staining unrefined and colored numbers (CN) unrefined vegetable oils.

Color number measurement results by visual observation (method 1) and digital colorimetry method (method 2) are presented in table 1.

TABLE I. COLORED NUMBERS OF UNREFINED VEGETABLE OILS, MEASURED BY VISUAL OBSERVATION (1) AND DIGITAL IMAGE ANALYSIS (2)

Oil sample	Color number, CN	
	Method 1	*Method 2*
Unrefined oils		
Amaranth	90 ± 5	79.8 ± 0.53
Canola	80 ± 5	68.9 ± 0.61
Olive	27 ± 5	55.3 ± 0.61
Mustard	40 ± 5	40.9 ± 0.69
Linseed	32 ± 5	31.3 ± 0.65
Sunflower	12 ± 5	11.6 ± 0.32
Refined oils		
Canola	-	0.95 ± 0.10
Olive	-	3.09 ± 0.20
Sunflower	-	0.82 ± 0.10

After refining, most of the pigments are removed and the color number drops sharply (Table 1). By visual observation, it is impossible to determine the CN of refined vegetable oils, since the difference in the intensity of color of calibration solutions and experimental samples is almost indistinguishable. The authors of the article [5] showed the possibility of using digital image analysis to measure a color number in the region of its low values. In the case of refined oils, the color number was measured using the calibration dependence of aqueous solutions of iodine, corresponding to CN values from 0 to 10. Calibration solutions were prepared by serial dilution of the primary standard.

Fig. 3 shows the dependence of the total parameter RGB_Σ = -15.9CN + 474 (R^2 = 0.9596, S_r = 0.0145) for the range of the color number 0 - 10. The results of the calculation of CN are presented in Table 1.

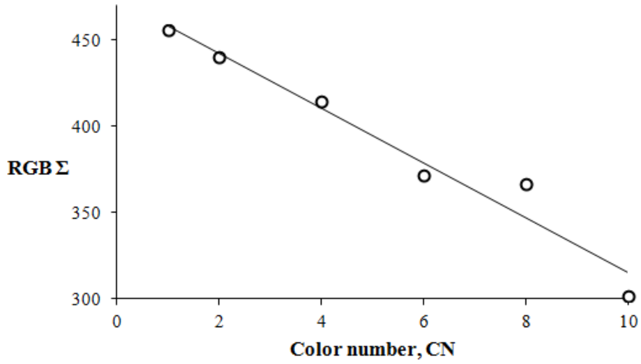
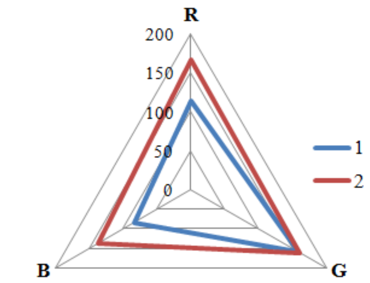
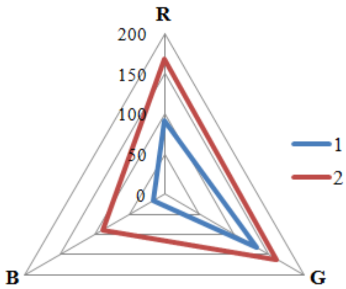


Fig. 3. Calibration dependence of the total parameter RGB Σ on the color number of vegetable oils

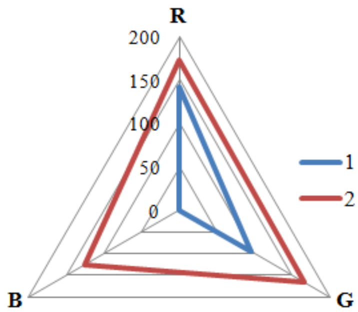
Comparison of the values of the color components R, G and B for vegetable oils before and after refining is important and interesting. The results of the comparison of color characteristics for sunflower, olive and rapeseed oils are presented in the form of diagrams in Fig.4.



(a) Sunflower oil: 1-unrefined, 2-refined



(b) Olive oil: 1-unrefined, 2-refined



(c) Canola oil: 1-unrefined, 2-refined

Fig. 4. Diagrams of the color components of R, G and B vegetable oils before (1) and after (2) refining

In the case of sunflower oil, refining leads to a relatively uniform increase in the values of the R and B components with a constant G component. This trend is characteristic of olive oil (Fig.4a, 4b). However, in the case of rapeseed oil with a relatively small increase in the R and G components, component B was missing in the unrefined sample oil (Fig. 4c). The process of refining significantly affects the composition of the pigment complex. Indeed, the processes of alkaline hydration and, especially, the adsorption purification of unrefined oils are accompanied by a decrease in the number of colored substances with simultaneous equalization of the total RGB Σ. For sunflower and rapeseed oils, after refining, it is 464 units, and for olive oil, 418. This fact suggests the possibility of using the RGB Σ parameter to control the depth of the refining process of vegetable oils.

IV. Conclusion

The use of digital image analysis for the purpose of chemical analysis and semi-quantitative control of the content of various colored components in natural and technological objects makes it possible to reduce the time for performing analysis procedures. The measurement of color characteristics takes 1-2 minutes, and the processing of the received information up to 5-10 minutes. Simplified measurement procedure and reduced its cost. Instead of expensive spectrometers to measure the chromaticity of objects, you can use common mobile devices. Processing digital information can be carried out using different color models. Empirically, we have shown that the RGB color model correctly reflects the change in the composition of the pigment complex of vegetable oils during the refining process. The fact of alignment of the values of the total parameter RGB Σ for various in the nature of vegetable oils after their refining is interesting. This allows us to suggest the use of this parameter to control the degree of purification and removal of the components of the pigment complex during the refining of vegetable oils. The maximum RGB value is $\Sigma = 255 + 255 + 255 = 765$, which corresponds to white color. This value can be used to characterize the degree and depth of the processes of refining and bleaching vegetable oils. Considering this possibility, the degree of refining as a proportion of residual chromaticity relative to white hue, for sunflower and rapeseed oils is $X = 464/765 = 0.605$ or 60.5%, and for olive oil 0.546 or 54.6%.

The correlation of the results obtained by methods 1 and 2 (Table 1) is generally observed. The discrepancy between the visual indicators for olive, canola, amaranth and sunflower unrefined oils with the measured digital method of TsCh can be explained by the complexity of the visualization of color due to the greenish tint of the samples and the difficulty of perceiving differences in shades of dark oils. Therefore, in this case, the application of digital technologies is especially important. Especially valuable is the fact of increasing the sensitivity of the analysis in the field of light tones, for example, in the case of sunflower, canola and olive oils (Table 1), when using digital fixation of color characteristics. This fact suggests the effectiveness of digital image analysis in the refining of vegetable oils for the purpose of techno-chemical control. Analyzing the data obtained, it is possible to state the fundamental possibility of using mobile devices running on the Android operating system in assessing the color characteristics of colored objects.

Digital image analysis techniques are non-invasive. This makes them convenient for use in factory laboratories and field conditions. In addition, the use of mobile communication capabilities allows for analysis remotely.

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