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Application of Image Processing in Colorimetry of Soy-Enriched Bread Crust

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Abstract

In the current research, application of image processing in colorimetry of medium-sized soya-enriched bread crust is discussed. For this purpose, loaves of bread enriched with soy flour at 4 levels (0, 4, 8 and 12%) were produced. Image processing for extraction of colour parameters from 96 pictures was carried out in L*a*b COLORSPACE and color space transformation was conducted in a two-stage procedure with Image J software. Statistical analysis showed that enrichment of bread with different levels of soy flour will lead to a significant effect on mean values of L, a, and b components, and standard deviation of L and b.

Keywords: soya flour (soybean flour or soy flour), colorimetry, image processing

INTRODUCTION

Among physical characteristics of foods, color is known as the most important apparent feature in perception of quality. The customers tend to correlate color to flavor, safety, durability, and nutritional properties. Satisfaction level is influenced by color thanks to strong correlation with physical, chemical, and sensory assessment of food qualities [4]. Color is the most significant property of image because of embracing main information of pictures, similar to human's vision. In fact, all the contents of image are color components stored in image pixels. As such, each color can be reconstructed by combining the three main colors. Colorimetric information of images can be extracted through emplacing pictures in different colorimetric conditions and calculation of mean value and standard deviation of color intensity in image pixels [5]. Vision machine is the technology of preparation and analysis of images of a real scene using computer in order to acquire information or control a process. Vision machine is a non-destructive and scientific technique for evaluation of color pattern in non-uniform colorimetric levels. Food industry is the evident instance of image analysis application; the major elements include visual evaluations and description of foods in images whose properties can be extracted and expressed as quality index (5). Conventional methods of sensory assessment are widely used in determining quality of foods. But, such methods are time-consuming and costly. These factors lead to motivation for developing alternative techniques which can evaluate key characteristics of products in shorter time and higher precision. It was proved that application of image processing in assessment of qualitative characteristics is one of the most promising areas of research [3]. Color is an effective parameter for evaluation of objects in images of different foods including variety of fruit, vegetable, cereals, and meat. This parameter is used for grading variety of fruits. More ever, researchers have deployed diverse methods for evaluating maturation degree of tomato. Colorimetric evaluation is applied in meat industry for automatic analysis and grading of meat treatment and improving objectivity of process. Color images have been used for analyzing defects and diseases of birds' meats [1].

In a paper, SUN et al. [2006] investigated the recent studies for qualitative evaluation and inspection of food products using image analysis techniques. They analyzed four aspects of image processing application in qualitative assessment including color, size, shape, and texture [5]. Pedreschi et al. (2006) have used image analysis in L*a*b model for evaluating chips color. In his research, he transformed the images obtained in RGB model to L*a*b color space using a program of MATLAB software with artificial neural network (4).

Briones et al. (2004) used image processing for tracking color variations of milk chocolate crust during preservation period. Milk chocolates were placed under intensified conditions for fat migration and evaluated in different time intervals. These researchers first converted captured RGB images to CIE XYZ model and then into CIE L*a*b model using MATLAB software. They also studied the correlation between colorimetric values acquired from image processing with values measured by HUNTERLAB machine [2]. In his paper, TAN (2003) collected results of researches conducted during the recent years on using image processing in meat quality assessment and prediction of its qualitative degree [7]. YUM et al. (2003) introduced novel method of image processing based on imaging with digital camera by means of PHOTOSHOP software. They utilized this software for determining L*a*b values and colorimetric distribution of images [9]. SUN et al. (2002) reviewed the research works in the field of assessment and grading of agricultural and alimental products using image processing [6]. TAN et al. (2000), employed color-based image processing for grading pieces of muscle meats. Mean and variance of colorimetric values are evaluated using two models, namely RGB and HIS in the current research. Artificial neural network modeling and statistical methods for final values will be used for prediction and evaluation.

MATERIALS AND METHODS

Bread Baking

Soya flour was bought from local stores in URMIA city. Flour, salt, liquid oil, yeast dough, sugar, and supplementary additives were the raw materials for baking the medium-sized bread. Bread baking procedures were as follows: after mixing the raw materials of formula and making dough for 20 minutes in low-speed rotation of the special instrument, the dough was relaxed for two minutes, and then, kneaded for one minute at low speed. The resulting dough was again relaxed for 10 minutes. The dough was relaxed for another 1 minutes after dividing the product into round shapes. his step as follo ed by shaping the dough and transferring the trays into proof. he trays ere placed under ater steam in the proof. he dough was baked in oven at initial and secondary temperatures of in presence of ater steam for minutes. The medium-sized bread was made in four soya levels (zero, four, eight, and twelve percents of soya which replace the wheat flour in the formula). The tests were carried out 12 and 36 hours after the bread baking. These tests were replicated three times.

Image Capturing

In each baking series, 4 breads were randomly selected and 12*25 cm pieces were separated and imaged. To avoid light reflection in the space and preventing from fluctuation in imaging, a chamber having walls covered with black fabric was used for imaging. The images were captured by a Canon camera model Powershot A520 which was connected to computer via USB port. The camera was fixed parallel to and at a distance of 20 cm from samples. Imaging was performed using ZoomBrowser EX 5.0. Other camera specifications are expressed for imaging in table 1. Images were taken in M mode of camera. In this mode, it is possible to adjust shutter speed and Iso-Velocity and AV Aperture. Images were captured from selected pieces of bread samples in 2272*1704 pixel dimensions and resolution of 180 dpi.

Table 1. Camera Settings for Imaging

Flash	Off
Zoom	On
ISO velocity	100
White balance	Fluorescence H
Aperture AV	F/2.6
Macro	On
Shutter speed	1/10 s

Color Spaces

RGB color space

RGB color space is composed of three colorimetric components namely, Red, Green, and Blue, each of which varies in the range 0-255. Every pixel in RGB images has certain values of red, green, and blue components.

L*a*b Color Space

This color space consists of three L* components equivalent for image light which vary in the range 0 (representing black) and 100 (representing complete light reflection). Values of a* is unlimited and the positive and negative values respectively green color. "b*" value is also infinite where positive and negative values are equivalent for yellow and blue colors. This colorimetric system has a performance similar to human's eye. his space is not affected by imaging unlike RGB and HIS spaces. In most cases, L*a*b colorimetric space is sued in research studies of food industries [10].

Image Processing

1000*1000 pixel pieces are cut from the captured images and saved under BMP format. The images were converted into CIE XYZ and then into L*a*b spaces using ImageJ1.40g software and by means of the ImageJ package referred to as " olor_Space_ onverter".

According to the proposed code, two-stage method was applied for converting the information acquired from pixels in RGB into L*a*b color space. In the first stage, RGB parameters were converted into XYZ space in [0 1] domain:

$$[X \quad Y \quad Z] = [r\ g\ b] M \tag{2-5}$$

Where:

$$r = \left(\frac{R+\alpha_1}{\alpha_2}\right)^{\gamma}$$
$$g = \left(\frac{G+\alpha_1}{\alpha_2}\right)^{\gamma}$$
$$b = \left(\frac{B+\alpha_1}{\alpha_2}\right)^{\gamma} \tag{2-6}$$

Where, γ is modifying (fitting) parameter equal to . and M was transform matrix of two spaces determined according to reference point. In this equation, D65 is taken as reference point and M includes:

$$M = \begin{bmatrix} 0.5767 & 0.2973 & 0.0270 \\ 0.1855 & 0.6273 & 0.0706 \\ 0.1882 & 0.0752 & 0.9912 \end{bmatrix}$$

In the second stage, transform was performed from XYZ into L*a*b spaces, where:

$$l = 116 f_y - 16$$
$$a = 500(f_x - f_y)$$
$$b = 200(f_y - f_z) \tag{2-7}$$

And also:

$$f_x = \begin{cases} \sqrt[3]{x_r} & x_r \rangle \varepsilon \\ \dfrac{kx_r + 16}{116} & x_r \langle \varepsilon \end{cases}$$
$$f_y = \begin{cases} \sqrt[3]{y_r} & y_r \rangle \varepsilon \\ \dfrac{ky_r + 16}{116} & y_r \langle \varepsilon \end{cases} \tag{2-8}$$
$$f_z = \begin{cases} \sqrt[3]{z_r} & z_r \rangle \varepsilon \\ \dfrac{kz_r + 16}{116} & z_r \langle \varepsilon \end{cases}$$

$$x_r = \frac{X}{X_r}\ ,\ y_r = \frac{Y}{Y_r},\ z_r = \frac{Z}{Z_r} \qquad (2\text{-}9)$$

Where, (Xr, Yr, Zr) represents reference white.

$$\varepsilon = \begin{cases} 0.008856 & \textit{Actual}\ \text{CIE Standard} \\ 216/24389 & \text{Intent of the CIE Standard} \end{cases} \qquad (2\text{-}10)$$

$$k = \begin{cases} 903.3 & \textit{Actual}\ \text{CIE Standard} \\ 24389/27 & \text{Intent of the CIE Standard} \end{cases} \qquad (2\text{-}11)$$

"k" and "ε" are constants recommended by CIE standard. Following evaluation of colorimetric parameters in L*a*b space, mean and standard deviation values of each parameter were determined using the following equations:

$$m_L = \frac{\sum\sum L(i,j)}{n},\quad m_a = \frac{\sum\sum a(i,j)}{n},\quad m_b = \frac{\sum\sum b(i,j)}{n} \qquad (2\text{-}12)$$

$$v_L = \frac{\sum\sum [L(i,j) - m]^2}{n-1},\quad v_a = \frac{\sum\sum [a(i,j) - m]^2}{n-1},\quad v_b = \frac{\sum\sum [b(i,j) - m]^2}{n-1} \qquad (2\text{-}13)$$

Where (i, j) and "n" respective denote coordinates and number of pixels in each image [1]. Figure 3 demonstrates the converted image.

Statistical Analysis

Completely random plan in factorial block was used for statistical analysis of results. Mean values were compared using Duncan's multi-domain test. Statistical analysis was performed in MstatC software.

RESULTS AND DISCUSSION

Results of variance analysis as presented in table 2 indicate the effect of adding soya flour to formulation of medium bread is significant on L, "a", and "b" colorimetric parameters and also on standard deviation of L and "a" colorimetric parameters in 99% confidence interval. Furthermore, mutual effect of soya flour and preservation time is proved also to be significant on standard deviation of L and "a" colorimetric parameters ($p<0.01$), as shown in table 2. Results of comparison of mean values included in diagrams 1 to 6 show that enrichment of medium-sized bread with soya flour considerably affects crust color of product so that average values of L, "a", and "b" decrease as soya flour percentage increases. Additionally, adding soya flour to bread formulation leads to reduction of variance of colorimetric parameters, and in other words, further uniformity in pixel features of images. Therefore, it can be inferred that application of image processing is a quantitative, precise but simple, and non-destructive method for colorimetric evaluation of bread crust. Due to necessity of bread production (baking) in industrial units, application of this technique enables online automation of production and quality assessment of bread color.

Figure 1. A sample of captured images

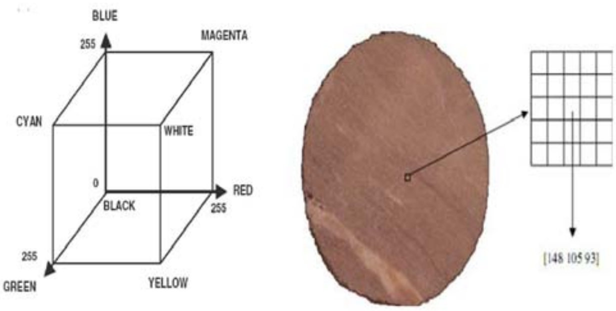

Figure 2. Schematic representation of EGB color space

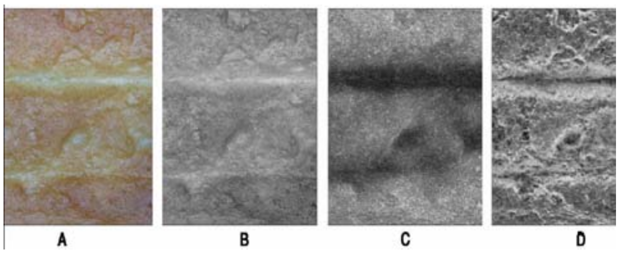

Figure 3. Example of converted image;
A: sample of cut photo B: L* component of image
C: a* component of image D: b* component of image

Table 2. Variance analysis of impact of operational parameters on colorimetric parameters in L*a*b space

		Mean Squares					
Source	Degree of Freedom	ML	Mb	Ma	Std L	Std a	Std b
Soy flour percentage	3						
Preservation Time	1						
Soya flour* preservation time	3						

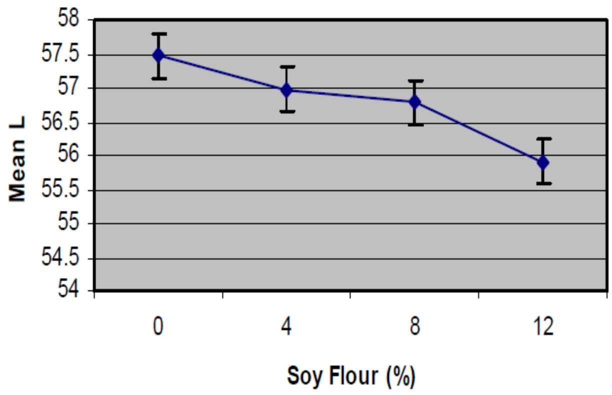

Diagram 1. Variations of mean value of the color parameter L*

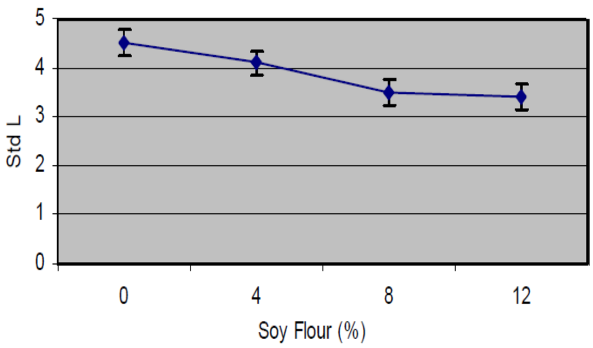

Diagram 2. Variations of standard deviation of the color parameter L*

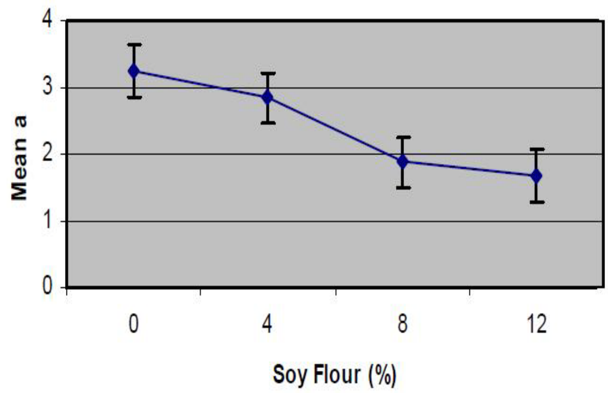

Diagram 3. Variations of mean value of the color parameter a*

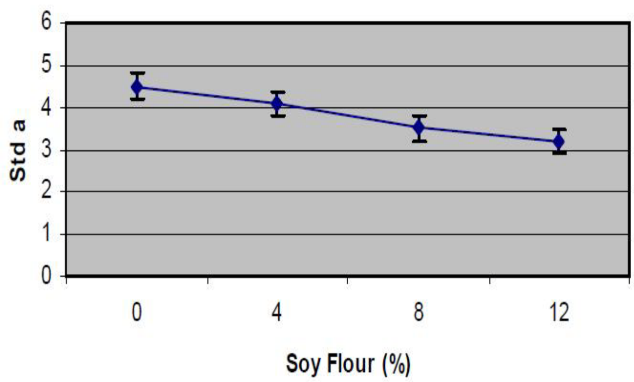

Diagram 4. Variations of standard deviation of the color parameter a*

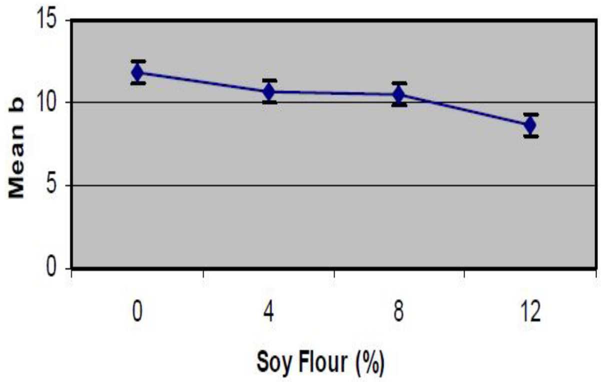

Diagram 5. Variations of mean value of the color parameter b*

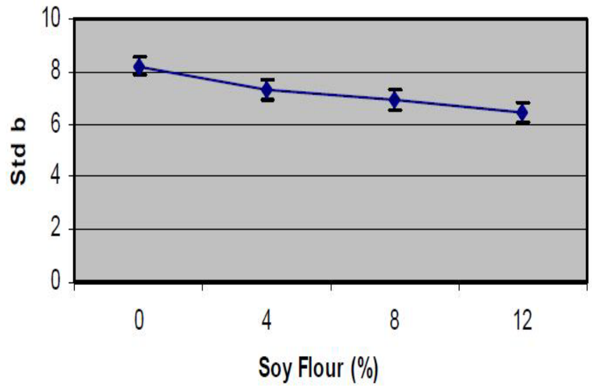

Diagram 6. Variations of standard deviation of the color parameter b*

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