An Application of Image Analysis and Colorimetric Methods on Color Change of Dehydrated Asparagus (*Asparagus maritimus* L.)

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Summary

Shape and color are key factors in quality evaluation of fresh asparagus *(Asparagus maritimus* L.*)*. Typical green color of asparagus comes from the chlorophyll, pigment which has been degradated during drying process. The aim of this paper was to compare color changes of asparagus dried in laboratory tray drier equipment at different temperatures (40 °C, 50 °C, 60 °C and 70 °C) at airflow velocity of 2.75 ms^{-1}. Color changes were obtained by digital image analysis in RGB color model and by chromameter in $L^*a^*b^*$ color model. Basic elements of image analysis system were low voltage halogen lamps with reflector, digital camera and programs for image pre-processing and analysis.

Mean values of color parameters, color changes and correlation coefficients for asparagus were calculated for both color models. An analysis showed statistically significant influence of drying temperature on hue angle and total color change for both chosen color models of dehydrated asparagus. Represented results show that there was no statistically significant difference according to color changes between drying at 50 °C and 60 °C. Calculated correlation coefficient between color changes for used models was found to be 0.9167.

Key words

image analysis, color, asparagus, dehydration

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Received: October 23, 2008 | Accepted: March 4, 2009

ACKNOWLEDGEMENTS
This work was financially supported by Ministry of Science, Education and Sports of the Republic of Croatia, projects 113-0000000-3497 and 113-1130471-0592.

Introduction

Fresh asparagus is gaining popularity due to its unique texture and flavor (Lau et al., 2000) but also it is an extremely perishable vegetable. Freshly harvested asparagus deteriorates rapidly leading to a short shelf life (An et al., 2008). The very short shelf life of asparagus is mainly related to its high respiratory activity which continues after harvesting (Albanese et al., 2007). Dehydration, i.e. drying, of asparagus provides long term conservation and marketability of this product.

In recent years, much attention has been paid to the quality of dried foods. For the food technological properties such as color, shape (shrinkage) and rehydration capacity are determinant for the quality of the dried product (Fernandez et al., 2005). Similar to other vegetables, changes in color, chemical and textural properties of asparagus occur during thermal treatment such as drying. Color is an important quality attribute of fruit and vegetable which occurs in the interaction among light, observed object and observer (Yam and Papadakis, 2004). To define and display color it is necessary to select a color space which is a mathematical representation of a set of colors. The three most common color spaces are: RGB (used for television, computer screens, scanners and digital cameras), CMYK (used by the printing industry) and the CIE Lab space (used in laboratory colorimeters) (Fernandez et al., 2005). Colorimeters measure color parameters on small rounded area and give non-objective results of colored samples with bigger different color area than measured area. Image analysis method can be applied on total area of analysed samples to ensure more objective results because almost 100 % of total surface is captured in an image. Color changes measured in RGB color model can be separated in color channels with intensity values for red, green and blue color from 0 to 255 (Magdić and Dobričević, 2007).

Several studies have been carried out to investigate the drying characteristic of the *A. officinalis* (Strahm and Flores, 1994; May et al., 1997; Nindo et al., 2003). Generally, in available scientific papers, there seems to be no published work on the color behaviour of dehydrated rare wild species of asparagus (*Asparagus maritimus* L.).

The objective of this investigation was to determine and compare color changes observed by image analysis system in RGB color model and chromameter in $L^*a^*b^*$ color model of asparagus dried at four different temperatures.

Materials and methods

Material

Raw wild asparagus (*Asparagus maritimus* L.) was obtained in May 2008, from the coastal area of the Adriatic Sea and stored at +4 °C. After stabilization on room temperature, the asparagus was cut into 10 cm long slices before drying and analysis. Moisture content and color of all samples were measured before and after drying.

Drying

Asparagus samples were dried in a pilot plant tray dryer (UOP 8 Tray Dryer, Armfield, UK). The dryer enables the control of temperature and airflow velocity. The drying temperatures of asparagus samples varied from 40 °C, 50 °C, 60 °C and 70 °C (±0.5 °C). The dryer was operated at constant air velocity of 2.75 ms^{-1}. The air flowed parallel to the horizontal drying surfaces of the samples. The drying process was started when the required drying conditions were achieved. The fifty asparagus samples were arranged on trays and placed into the tunnel of the dryer, at which point the measurements were started. Dehydration lasted until the required moisture content of around 9% (wet base) was achieved.

Determination of dry matter content

Dry matter content of the asparagus samples was determined by drying the milled samples (~10 g) at 105 ±0.5 °C to a constant mass. Analyses were done in duplicate and the average dry matter content (w_{db}), expressed in percents (%), was calculated using the following equation:

$$w_{db}(\%)=\left(\frac{m_2}{m_1}\right)\cdot 100 \qquad (1)$$

where m_1 is the mass of asparagus samples before drying (g) and m_2 is the mass of asparagus samples after drying (g)

Color measurement

In this paper color of raw and dehydrated samples was measured using digital image analysis system and chromameter CR-400 (Minolta). The asparagus slices were milled in a coffee grinder to obtain fine and homogeneous powder. Analyses of color values were done twenty times for each raw and dehydrated asparagus sample.

RGB color measurement

Color changes in RGB color model were followed by image analysis. Basic elements of image analysis system shown in Figure 1 were lightening chamber with low voltage halogen lamps with reflector (provided illumination of sample area of 760±5 Lux), background from which picture of sample was taken with digital camera (Panasonic Lumix DMC-FZ30) and software for image pre-processing and analysis (IrfanView, Adobe Photoshop®, Global Lab Image/2). Samples for imaging were placed at 60 cm distance from camera (which has the following settings: Aperture F/5, Exposure Time 1/5 sec).

Images were stored in bitmap (BMP) graphic format with 8-bit Windows System pallet (2^8 = 256 colors) and after that were processed and analyzed. This graphic format stores information about colors in RGB-triplets for every pixel on the image where red (R), green (G) and blue (B) are intensities of mentioned colors in range from 0 to 255. Program Global Lab Image/2 calculated mean values of percentage for red (R), green (G) and blue (B) color on a sample area. The hue angle defined as (Preucil, 1953)

$$h^{\circ}_{RGB}=60^{\circ}\cdot\left(1+\frac{R-B}{G-B}\right) \text{ if } G>R\geq B \qquad (2)$$

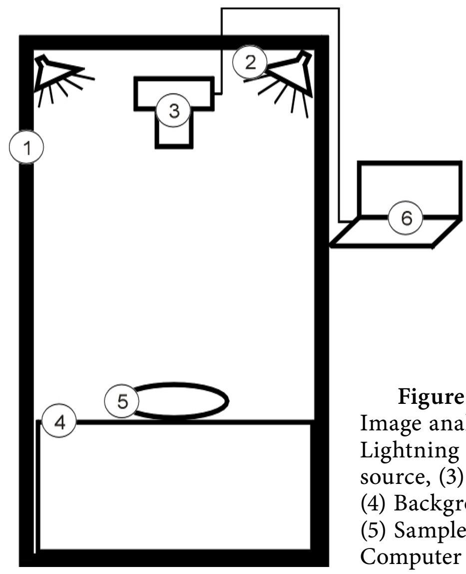

Figure 1.
Image analysis system (1) Lightning chamber, (2) Light source, (3) Digital camera, (4) Background for sample, (5) Sample for analysis, (6) Computer

was calculated from R, G and B values and expressed in degrees: 0° (red), 60° (yellow), 120° (green), 180° (cyan), 240° (blue) and 300° (magenta). An average share of each color on sample surface was presented as the final result. Color changes in RGB color model were defined as:

$$\Delta E_{RGB}=\sqrt{\left[(R-R_0)^2+(G-G_0)^2+(B-B_0)^2\right]} \quad (3)$$

where R_0, G_0 and B_0 indicate color parameters of raw asparagus samples.

L*a*b* color measurement

Three parameters, L^* (lightness), a^* (redness) and b^* (yellowness), were used to study color changes in the $L^*a^*b^*$ color model. L^* refers to the lightness of the samples and ranges from black ($L^* = 0$) to white ($L^* = 100$). A negative value of a^* indicates green, while a^* positive one indicates red-purple. Positive b^* value indicates yellow and negative b^* blue.

The hue angle, defined as (Little, 1975; McGuire, 1992; Voss, 1992):

$$h^\circ_{L^*a^*b^*} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \text{when } a^* > 0 \text{ and } b^* \geq 0,$$
$$h^\circ_{L^*a^*b^*} = 180 + \tan^{-1}\left(\frac{b^*}{a^*}\right) \text{when } a^* < 0 \quad (4)$$

was calculated from a^* and b^* values and expressed in degrees: 0° (red), 90° (yellow), 180° (green), 270° (blue). The total color difference (ΔE) was calculated as follows (Hunter, 1975):

$$\Delta E_{L^*a^*b^*}=\sqrt{\left[\left(L^*-L^*_0\right)^2+\left(a^*-a^*_0\right)^2+\left(b^*-b^*_0\right)^2\right]} \quad (5)$$

where L^*_0, a^*_0 and b^*_0 indicate color parameters of raw asparagus samples. Raw asparagus samples were used as the reference and a higher ΔE represented bigger color change.

Mean values of color and color changes of asparagus samples were calculated for both color models.

Statistical analysis

One-way analysis of variance (ANOVA) and multiple comparisons (*post-hoc* LSD) were used to evaluate the significant difference of the data at $p < 0.05$. Data was expressed as means ± standard deviation. Experiments were replicated five times for statistical purpose.

Results and discussion

Tables 1 and 2 show the results of the color measurement of raw and dehydrated asparagus samples for both RGB and $L^*a^*b^*$ color model. Statistical analysis (ANOVA, *post-hoc* LSD, $p = 0.05$) showed that drying temperatures had statistically significant influence on all parameters and color values on dehydrated asparagus samples for both color models, while only parameter a^* ($L^*a^*b^*$ color model) of dehydrated asparagus samples did not show statistically significant change.

Table 1. RGB color parameters of raw and dehydrated asparagus samples

Sample		R		G		B	
Raw		139.81 ± 7.58	a	188.37 ± 1.94	a	106.63 ± 8.93	b
dehydrated	40 °C	143.70 ± 2.88	ab	168.86 ± 0.69	b	98.82 ± 3.65	c
	50 °C	148.93 ± 0.70	b	161.41 ± 4.08	c	97.45 ± 2.21	c
	60 °C	141.36 ± 0.28	a	159.19 ± 3.67	c	92.18 ± 3.08	c
	70 °C	183.80 ± 5.21	c	183.22 ± 5.10	a	115.84 ± 3.07	a

a , b , c - groups which differed statistically significant from one to another according to drying temperature

Table 2. $L^*a^*b^*$ color parameters of raw and dehydrated asparagus samples

Sample		L^*		a^*		b^*	
Raw		21.42 ± 1.04	a	-2.77 ± 0.28	a	6.28 ± 0.43	a
dehydrated	40 °C	24.48 ± 0.31	b	-2.52 ± 0.27	b	6.95 ± 0.28	b
	50 °C	30.53 ± 2.25	c	-2.47 ± 0.84	b	8.48 ± 1.32	c
	60 °C	31.00 ± 1.20	c	-2.45 ± 0.36	b	8.49 ± 0.64	c
	70 °C	33.63 ± 0.34	d	-2.51 ± 0.10	b	10.57 ± 0.26	d

a , b, c, d - groups which differed statistically significant from one to another according to drying temperature

Figure 2 shows the total color changes of dehydrated asparagus samples at different drying temperatures for both color models. An ANOVA analysis showed the existence of three groups which differed significantly from one to another ($p = 0.05$; *post-hoc* LSD), one of them corresponding to samples dried at 40 °C, another for the samples dried at 50 °C and 60 °C, and third one corresponding to 70 °C. Calculated correlation coefficient between color changes for used models was found to be 0.9167.

Color change from green to olive green or yellow green, is the result of the conversion of chlorophyll to pheophytin,

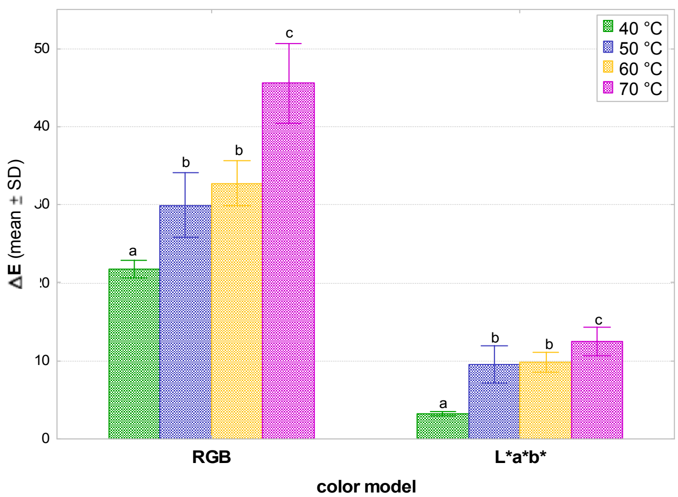

Figure 2. Total color changes (ΔE) of dehydrated asparagus samples at different drying temperatures for both color models

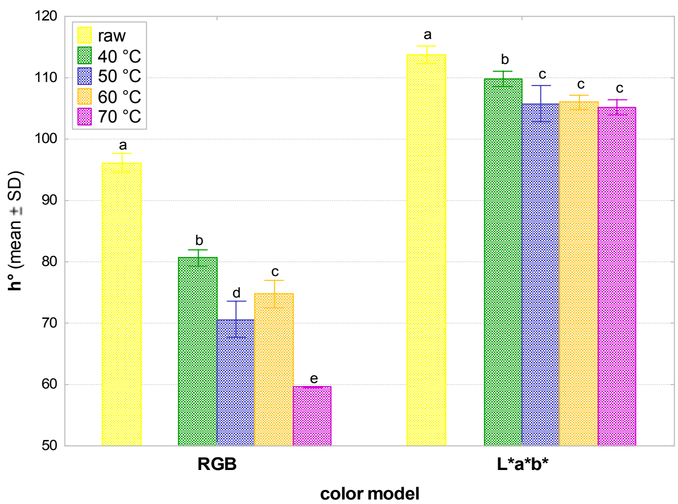

Figure 3. Hue angle (°) of a color of raw and dehydrated asparagus samples at different drying temperatures for both color models

through the magnesium substitution of the chlorophyll by hydrogen (Woolfe, 1979) during heating of green vegetables such as asparagus.

Figure 3 shows hue angle values of a color of raw and dehydrated asparagus samples at different drying temperatures for both color models expressed in degrees. An ANOVA analysis for hue angle of RGB color model showed the existence of five groups which differed significantly from one to another ($p = 0.05$; *post-hoc* LSD) according to different drying temperatures. By $L^*a^*b^*$ color model three groups were found that differed significantly from one to another. Hue values for both used models have transition direction from green to yellow color.

Correlation coefficient between hue angle values calculated for both used models was found to be 0.9413.

Average color value of sample in beginning was in RGB model R = 140, G = 188, B = 107 and in $L^*a^*b^*$ model $L^* = 21.42$, $a^* = -2.77$, $b^* = 6.28$. Mean color changes in RGB color model were $\Delta E_{RGB} = 37.56$, and in $L^*a^*b^*$ color model were $\Delta E_{L^*a^*b^*} = 7.47$.

Conclusion

Statistically comparation of calculated data between color changes of asparagus dried at different temperatures was investigated applying image analysis system in RGB color model and chromameter in $L^*a^*b^*$ model system.

An ANOVA analysis showed statistically significant influence of drying temperature on hue angle and total color change for both chosen color models ($\Delta E_{RGB} = 21.2 - 45.2$; $h_{RGB} = 59.58 - 96.08$ and $\Delta E_{L^*a^*b} = 3.3\text{-}12.5$; $h_{L^*a^*b} = 105.13 - 113.79$) of dehydrated asparagus. Represented results show that there were no statistically significant differences according to color changes between drying at 50 °C and 60 °C. Convective drying at temperatures lower than 45 °C results in higher microbial count (Martinov et al., 2007). It means, the drying temperature should be above this level. Previous studies confirmed that higher drying temperature results in lower energy input (Müller, 1992). Because of this and the very similar color characteristics of material dried at 50 and 60 °C, the optimal temperature in this case is 60 °C.

Consumers select their food in supermarkets based on, primarily, visual perception, and often this is the only direct set of information's received from the product. According to calculated results (high coefficient correlation between chosen color models), it was found that image anaysis method as well as colorimetry method can be used to observe the color changes of dried asparagus samples. During drying it is very important to retain the original color of the asparagus as much as possible, especially if dried asparagus are used, for example, in instant soups or sauces. Furthermore, the influence of drying on other quality characteristics of asparagus, like rehydration characteristics, should be investigated in further studies.

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