Impact analysis of different chemical pre-treatments on colour of apple discs during drying process

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Summary

The main purpose of this study was to compare colour changes of chemically pre-treated dried apple discs. Changes were observed by chromameter in $L^*a^*b^*$ colour model by using Minolta chromameter CR-400 and by image analysis system in RGB colour model. Apple discs variety "Gold Rush" were pre-treated and dried in laboratory tray drier at drying temperature 70 °C and at airflow velocity of 1.5 ms^{-1}. Different chemical pre-treatments were applied on apple discs (dipping in 0.5% ascorbic acid solution; 0.3% L–cysteine solution; 0.1% 4–hexyl resorcinol solution and 1% sodium metabisulphite solution). Mean values of colour parameters, colour changes and correlation coefficients for apple discs were calculated for both colour models. The analysis showed statistically significant influence of pre-treatment method on total colour changes for both chosen colour models of dried apples. Calculated correlation coefficient between colour changes for used models was found to be 0.894. According to colour characteristics the best results were achieved when samples were pre-treated with 0.5% ascorbic acid solution. According to calculated results it was found that image analysis method as well as colorimetric method can be used to observe the colour changes on dried apple discs.

Keywords: Pre-treatment, Colour, RGB, $L^*a^*b^*$, Gold Rush

Introduction

In the past few years' computer vision was rapidly developed and image processing method today has an important role in the development of food quality assessment (Jelinski et al., 2007). In comparison to earlier used traditional methods, using a digital camera and software for images processing proved to be an ideal combination for quickly, cheaply and accurately colour measure of various food products (Yam & Papadakis, 2004). The most often used model is the RGB colour model. At this model each sensor separately captures the light intensity of the red (R), green (G) and blue (B) colour channel respectively (Katherine Leon et al., 2006). These technique can be applied on both sides of apple (reddish and greenish) and gives more objective results than chromameter because almost 100% of apple surface is captured in an image (Magdić & Dobričević, 2007).

Colour change is mostly caused by the phenomenon called browning. Good knowledge of the browning reaction offers lots of ways to prevent these reactions or to slow the same one down (Gonzalez–Aguilar et al., 2004; Fernandez et al., 2005). According to legal issues of food industry, ascorbic acid is a good substitute for sulphites to prevent browning of fruits and vegetables (Son et al., 2001). Along with ascorbic acid good results in preventing browning provided the sulphur that containing amino acid groups. Cysteine, the colourless conjugate compounds, is the best known representative of these groups. It reacts with quinone and thus preventing enzymatic browning (Son et al., 2001; Guerrero–Beltran et al., 2005). Among the recently discovered substances that prevent enzymatic browning, it is necessary to point out the 4-hexyl-resorcinol which has been known as a very successful PPO inhibitor, especially with the apple products (Son et al., 2001; Iyidogan & Bayindirli, 2004; Guerrero–Beltran et al., 2005).

The aim of this investigation was to determine and compare colour changes of dried apple discs after different pre-treatment methods using image analysis system and chromameter in RGB and $L^*a^*b^*$ colour model, respectively.

Materials and Methods

Materials

Apple variety "Gold Rush" was harvested at the small local family farm and stored at +4 °C. After approximately 20 minutes stabilization at the ambient temperature, apples were hand peeled and cut into discs, 20 mm diameter and 5 mm height.

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Drying method

Drying was performed in a pilot plant tray dryer (UOP 8 Tray Dryer, Armfield, UK). The dryer (Fig. 1) is equipped with controllers for controlling the temperature and airflow velocity.

Air was drawn into the duct through a diffuser by a motor driven axial flow fan impeller. In the tunnel of the dryer there were carriers for trays with samples, which were connected to a balance. The balance was placed outside the dryer and continuously determined and displayed the sample weight.
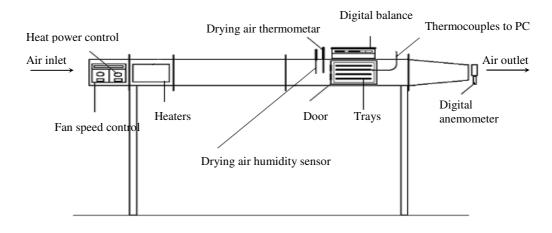

Fig. 1. Laboratory dryer used for convective drying

The drying temperature was 70 °C for both, non-treated and pre-treated apple discs and the dryer was operated at air velocity of 1.5 ms^{-1}. Before drying apple discs series were treated by dipping for five minutes with different solutions respectively as follows: 0.5% ascorbic acid solution; in 0.3% L–cysteine; 0.1% 4–hexyl resorcinol and 1% sodium metabisulphite. After five minute dipping in particular solutions discs were removed out and excess liquid was left to dry naturally. Apple discs on trays were placed into the tunnel of the dryer and the measurement started from this point. The "Testo 350" probes, placed into the drying chamber, were used to measure drying air temperature. The digital balance (Ohaus, Explorer, USA) and the digital anemometer (Armfield, UK) were used for recording weight loss of samples and airflow velocity in the five minutes interval during drying process. Dehydration lasted until a moisture content of about 12% (wet base) was achieved.

Determination of dry matter content

Dry matter content of apple samples was determined by drying 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}) was expressed in percentage (%) and calculated using the following equation:

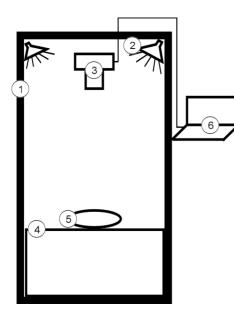$$w_{db}(\%)=\left(\frac{m_2}{m_1}\right)\cdot 100 \qquad (1)$$

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

Colour measurements

The colour characteristics were used as quality parameter of dried apple discs. Colour measurement was done using Minolta CR-400 Chromameter and image analysis system. Data were stored in $L^*a^*b^*$ and RGB colour models and colour changes during this period were evaluated. The total colour difference in $L^*a^*b^*$ colour model was calculated as follows

$$\Delta E_{L^*a^*b^*}=\sqrt{\left[\left(L^*-L_0^*\right)^2+\left(a^*-a_0^*\right)^2+\left(b^*-b_0^*\right)^2\right]} \qquad (2)$$

Parameter L^* refers to the lightness of the samples, and ranges from black (L = 0) to white (L = 100). A negative value of parameter a^* indicates green, while a positive one indicates red–purple colour. Positive value of parameter b^* indicates yellow while negative value indicates blue colour. The Minolta CR-400 Chromameter D65 calibration plate was used for calibration. Experiments were replicated five times for later statistics.

Also, colour changes were followed by image analysis in RGB colour model. Basic elements of the image analysis system shown in Fig 2. are lightening chamber (low voltage halogen lamps with reflector provided illumination of sample area of 760±5 Lux), digital camera (Panasonic Lumix DMC-FZ30) and software for image pre-processing and analysis (IrfanView, Adobe Photoshop, Global Lab Image/2). Apple discs for imaging were placed at 60 cm from camera.

1. Lightning chamber
2. Light source
3. Digital camera
4. Background for sample
5. Sample for analysis
6. Computer

Fig. 2. Image analysis system

All captured images were cropped on the same size (400×400 pixels) and were contained full area of samples. Analysis was done on four samples in every category (360 images in total). Images were stored, processed and analyzed in bitmap graphic format with 8-bit pallet ($2^8 = 256$ colours). This graphic format stores information about colours in RGB-triplets for every pixel on the image where red (R), green (G) and blue (B) are intensities of mentioned colours in range from 0 to 255. Program were calculated average percentage of red (R), green (G) and blue (B) colour on a sample area. An average share of each colour on sample surface was presented as the final result. Colour changes in RGB colour model were calculated as:

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

where R_0, G_0 and B_0 indicate colour parameters of raw pre-treated apple discs. Mean values of colour and colour changes were calculated for both colour models.

Statistic analysis

Statistica 7.0 (Stat Soft Inc., USA) was used for data analyzing. One-way analysis of variance (ANOVA) and multiple comparisons (*post-hoc* LSD) were used to evaluate the significant difference of the data at $p < 0.05$. Mean values and standard deviations were calculated from five replications.

Results and Discussion

Results of the colour measurement of dried apple discs for both $L^*a^*b^*$ and RGB colour model are shown in Tables 1 and 2. Statistical analysis (ANOVA, *post-hoc* LSD) showed that pre-treatment method had statistically significant influence on all parameters and colour values of dried apple discs for both colour models, while only change of R parameter (in RGB colour model) at dried apple was not statistically significant.

Table 1. $L^*a^*b^*$ colour parameters of dried apple discs

sample	L^*		a^*		b^*	
NT	70.64 ± 1.13	[a]	1.94 ± 1.48	[a]	23.12 ± 1.26	[a]
AK	73.70 ± 2.08	[a]	0.26 ± 1.37	[a]	20.20 ± 2.07	[a,b]
LC	73.04 ± 1.43	[a]	0.72 ± 1.15	[a]	18.15 ± 0.89	[c]
4HR	76.59 ± 0.89	[a,b]	-0.68 ± 0.94	[a]	19.98 ± 0.64	[b,c]
NaB	79.30 ± 0.39	[b]	-5.73 ± 0.43	[b]	22.30 ± 0.87	[a,b]

a, b, c - groups which differed statistically significant (p< 0.05) from one to another according to different pre-treatment methods
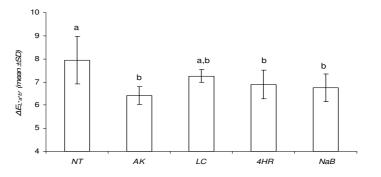
Table 2. RGB colour parameters of dried apple discs

sample	R		G		B	
NT	214.75 ± 2.34	[a]	186.57 ± 1.92	[a]	125.64 ± 2.26	[a]
AK	219.57 ± 1.88	[a]	152.51 ± 1.61	[b]	152.51 ± 1.61	[a,b]
LC	225.53 ± 0.71	[a]	160.96 ± 1.22	[b]	160.96 ± 1.22	[c]
4HR	220.97 ± 0.29	[a]	164.91 ± 2.09	[b]	164.91 ± 2.09	[b,c]
NaB	225.70 ± 2.21	[a]	145.28 ± 1.72	[b]	145.28 ± 1.72	[a,b]

a, b, c - groups which differed statistically significant (p< 0.05) from one to another according to different pre-treatment methods

Figure 3 shows total colour changes of dried apple discs after different pre-treatment methods for $L^*a^*b^*$ colour model. The biggest changes in L*a*b* colour model were measured on apple samples treated with L-cysteine while the smallest changes were observed on samples pre-treated with ascorbic acid. An ANOVA analysis showed the existence of two groups which differed significantly (p < 0.05; *post-hoc* LSD) according to different pre-treatment method. The total colour changes in $L^*a^*b^*$ colour model were $\Delta E_{L*a*b*} = 6.41– 7.94$. Pre-treatment with ascorbic acid reduces total colour change in $L^*a^*b^*$ colour model up to 19.27%, with L–cysteine 8.59%, with 4–hexyl resorcinol 13.10% and with sodium metabisulphite 14.99% in comparison with non-treated apple samples.

a, b - groups which differed statistically significant (p < 0.05) from one to another according to different pre-treatment methods

Fig. 3. Total colour changes (ΔE_{L*a*b*}) of dried apple discs after different pre-treatment methods

Figure 4 shows the total colour changes of dried apple discs after different pre-treatment methods for RGB colour model. In RGB colour model the biggest changes were measured on samples treated with 4–hexyl resorcinol while the smallest changes were observed on apple samples treated with ascorbic acid. An ANOVA analysis showed the existence of three groups which differed significantly from one to another (p < 0.05; *post-hoc* LSD). The one group corresponded with non-treated discs, another with discs pre-treated with ascorbic acid solution and with sodium metabisulphite solution, and third one corresponded with discs pre-treated with L–cysteine solution and with 4–hexyl resorcinol solution. The total colour changes in RGB colour model were $\Delta E_{RGB} = 10.91– 28.36$. The pre-treatment with ascorbic acid reduces total colour changes in RGB colour model up to 61.53%, with L–cysteine 20.06%, with 4–hexyl resorcinol 19.04% and with sodium metabisulphite 56.95% in comparison with non-treated apple discs.

The correlation coefficient between colour changes for used colour models was calculated to be at value of 0.894.
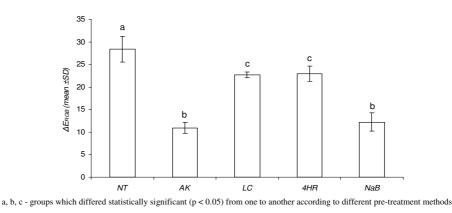
a, b, c - groups which differed statistically significant (p < 0.05) from one to another according to different pre-treatment methods

Fig. 4. Total colour changes (ΔE_{RGB}) of dried apple samples after different pre-treatment methods

Conclusions

Colour changes of dried apples discs were observed applying Minolta chromameter (CR-400) in $L^*a^*b^*$ colour model and image analysis system in RGB colour model. An ANOVA analysis showed statistically significant influence of different pre-treatment methods on the total colour changes for both chosen colour models. According to colour changes the smallest changes were found at samples pre-treated with 0.5% ascorbic acid solution. Pre-treatment with ascorbic acid reduces total colour change in $L^*a^*b^*$ colour model up to 19.27% while that value in RGB colour model was found to be up to 61.53%. 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 the calculated results (high correlation between chosen colour models) image analysis method as well as colorimetric method can be used to observe the colour changes on dried apple samples.

Abbreviations

NT   non-treated apple discs
AK   ascorbic acid solution
LC   L–cysteine solution
4HR   4–hexyl resorcinol solution
NaB   sodium metabisulphite solution

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