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Effect of Relative Humidity on Shrinkage and Color Changes in Dehydrated Strawberry

Lina Marcela Agudelo Laverde, Nuria Acevedo, Carolina Schebor and María del Pilar Buera

Abstract

Dehydrated fruits are prone to suffer discoloration during storage. Many natural pigments are unstable in dried media, and also brown pigments can be formed. The objective of this work was to evaluate shrinkage and color changes in freeze-dried strawberry slices as a function of relative humidity (RH) employing a computer vision system. Fruit discs were stored at 45ºC and color and area changes were recorded with time. Strawberries presented heterogeneous color distribution. Besides analysing the global color variables (L*, a* and b*), the disk areas were divided into four different zones according to their a* values and segmented image analysis was performed. The heat treatment caused browning and anthocyanin destruction. The color changes in strawberry were better represented by the a* variable, which decreased during storage. Also, at the highest RH analysed, the strawberry slices became homogeneous. The main radial area reduction (shrinkage) was observed after 14 days of humidification at 20ºC and it increased as RH increased. Computer vision analysis is a useful tool to assess optical properties and allows the analysis of heterogeneous materials. The segmented image analysis was appropriate to evaluate some relevant characteristics of the visual appearance changes occurring in dehydrated strawberries, related to the humidification level and storage time. Water mobility seems to be involved in drastic shrinkage and color changes.

Introduction

Dehydrated fruits are prone to suffer discoloration during storage. Many natural pigments are unstable in dried media, and also brown pigments can be formed. The rate of physical and chemical changes in dried vegetables and food models is slow in the glassy state. At temperatures above the glass transition, in addition to the decreasing viscosity and increasing rate, other changes such as crystallisation and structural collapse affect the discoloration rate (Karmas, Buera and Karel 1992). Diffusion-controlled chemical reactions are particularly dependent on translational diffusivity of the reactants (or on the viscosity of the matrix material), and are thus susceptible to the physical state of the system (Slade *et al.* 1995). It has been shown that matrix collapse caused by storage above the glass transition temperature(T_g) or by mechanical compression and porosity (Burin *et al.* 2004, White and Bell 1999) affected browning rates, indicating that besides water content, the system structure plays a relevant role.

Color and size changes affect the fruit appearance and organoleptic quality, and may be an indication of the decreased nutritional and functional properties of foods. Food discoloration can occur homogeneously, but most of the times heterogeneous distribution of color is observed. The objective of this work was to assess the effect of relative humidity (RH) on color alterations and shrinkage in freeze-dried strawberry slices.

Materials and Methods

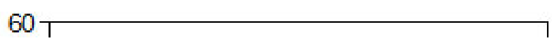
Strawberries were cut into slices (2.0 cm diameter, 0.5 cm thick), frozen with liquid nitrogen and freeze-dried. The freeze drier was operated at -84ºC, at a chamber pressure of 0.04 mbar, and the process lasted 48 h. The discs were located in rubber o-rings on a glass plate, and equilibrated in a range of 11–84% RH for 14 days at 20ºC (Greenspan 1977). After equilibration the glass plates were hermetically sealed (to avoid water loss), and then placed in a forced air oven operated at 45 ± 1ºC. Each glass plate containing six fruit slices was removed every certain time to acquire images and placed back in the oven.

Color changes were determined using a computer vision system (CVS). Images were taken in a standardised black box using a D65 illuminant and a digital camera (Power Shot A70, Canon Inc., Tokyo, Japan). Color images were converted to the CIELAB coordinates L*, a*, b*. Collapse of the systems was determined by measuring the average diameter of the fruit discs from the pictures taken with the CVS (as previously described). Radial area reduction was expressed as the diameter percentage with respect to a control disc without shrinkage. Six replicates of each sample were measured and the average and standard deviation determined.

Glass transition temperature (Tg) was determined by differential scanning calorimetry (DSC; onset values) using a calorimeter model 822 (Mettler Toledo, Schwerzenbach, Switzerland). The instrument was calibrated with indium (156.6ºC), lead (327.5ºC) and zinc (419.6ºC). All measurements were performed at a heating rate of 10 Co/min. Approximately 10 mg of each sample were placed in 40 ml aluminum pans which in turn were hermetically sealed. An empty pan served as reference. Thermograms were evaluated using Stare software v. 6.1 (Mettler Thermal Analysis).

Results and Discussion

Figure 1 shows the global color changes observed for freeze-dried strawberries humidified at several RHs when stored at 45° C as a function of time. At 11% RH, the samples presented a lighter color, manifested by the higher L* and lower b* values, while at 43% RH L* and b* values were relatively constant during storage time. Slight changes were observed in the L* and b* values at 52% RH. In the rest of the samples, due to browning reactions, L* and b* values decreased causing a change from the original light color to different brown degrees. However, the a* component decreased drastically at all RH values, and the rate of these changes was more important with the increase in RH.



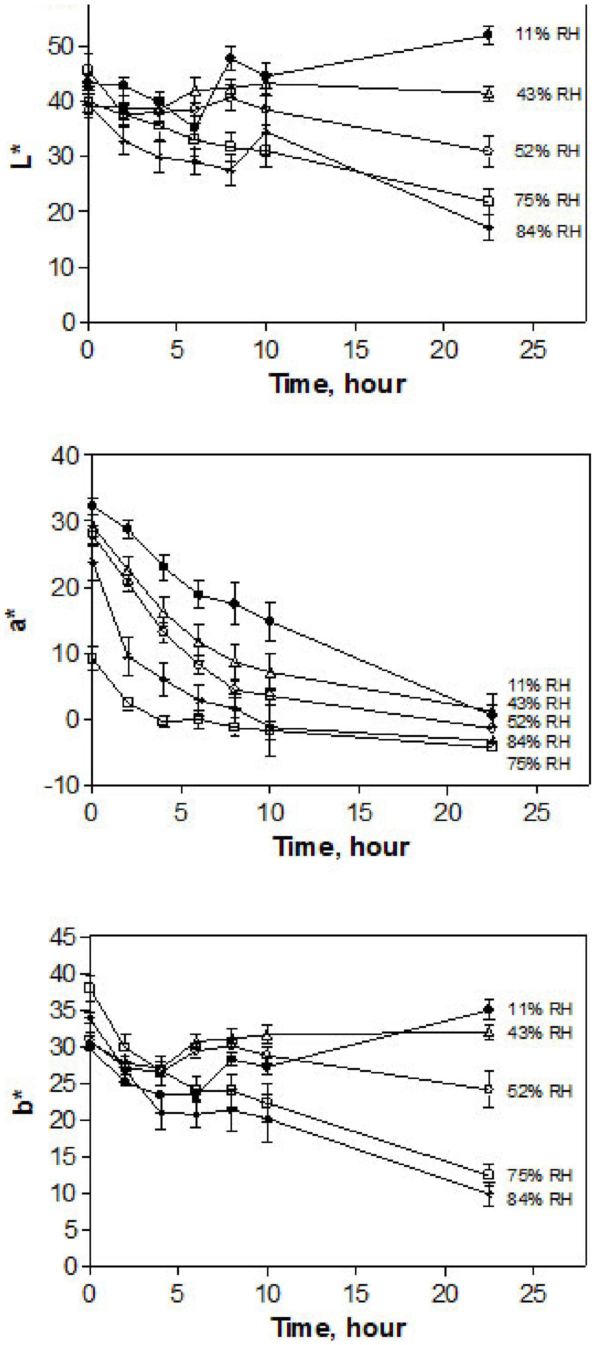
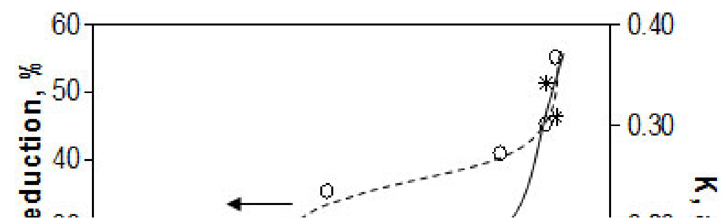


Figure 1: L*, a* and b* changes as a function of time at 45°C for strawberry discs at several relative humidities

The rate of redness loss was approximated by the slope of the initial linear part of the curves shown in Figure 1 (as pseudo zero order reaction rate), and shrinkage was determined as the % of radial area reduction relative to the control sample. Both parameters were plotted in Figure 2 as a function of (T-T_g), the difference between storage temperature and T_g, for the samples stored at 45°C for 22.5 h.

As observed in Figure 2, the radial area reduction and redness loss increased at increasing (T-T_g) due to RH increase. The observed shrinkage was caused by storage at conditions well above the T_g (T-T_g > 30ºC). The rate of initial redness loss showed a drastic increase at (T-T_g) values higher than 70°C, when the sample shrinkage approximated 50% (corresponding to 84% RH). It is important to note that at these conditions populations of water molecules with high mobility are present, as determined by pulsed 1H-NMR, and frozen water is detected by DSC (Agudelo *et al.* 2010).



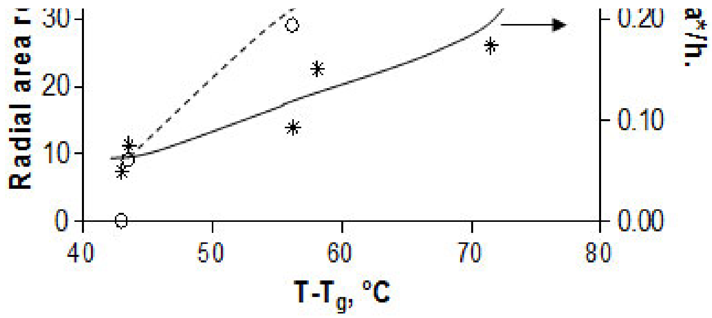


Figure 2: Shrinkage of strawberry slices (o) and rate of redness changes (*) after 22.5 h of storage at 45°C, as a function of (T-T_g)

As strawberry slices presented heterogeneous color distribution, besides analysing the global color changes, the image analysis of the slices was done by dividing the area into four different zones. The color changes were better represented by the a* variable, showing a decrease along storage time because the heat treatment caused anthocyanin pigment destruction. Before storage at 45ºC the a* values could be distributed in different sections, having different red degree as expected for strawberry slices (Figure 3). The pixels proportion of red areas in the pictures was greater at low RHs and short storage times. As increasing RH and storage time the areas with high a* values decreased and the homogeneity of color distribution increased.

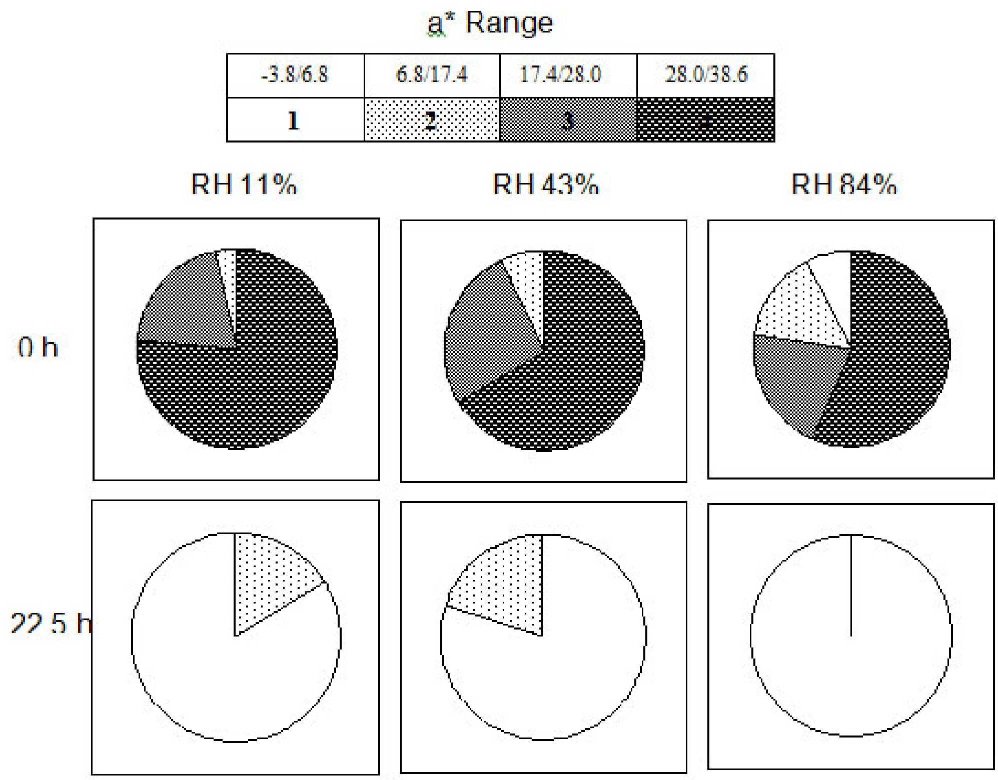


Figure 3: Proportion (%) of pixels corresponding to different sections of a* values for 0 and 22.5 h of storage at 45ºC at 11, 43 and 84% RH

45°C at 11, 43 and 84% RH

Conclusions

The final color of freeze-dried strawberries during storage was the result of loss of redness and browning development. Redness loss and browning could be related to the decrease of CIELAB coordinates a* and L*, respectively. During storage at 45°C for 22.5h, a* constantly decreased as increasing RH but L* decrease was not significant below 43% RH.

Sample shrinkage and redness loss were significantly affected by RH. Both shrinkage and color changes seem to be affected by RH and (T-Tg) values at which water mobility is characterised by T2 relaxation times in the order of ms, and water is able to crystallise.

The segmented image analysis revealed that humidification level and storage time, besides influencing the kinetics of changes, were determinant factors to define the degree of color heterogeneity in dehydrated strawberries.

Acknowledgements

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Drs Lina Marcela Agudelo Laverde (e-mail:marcegulav@di.fcen.uba.ar), Nuria Acevedo (e-mail:acevedonuria@yahoo.com.ar), Carolina Schebor (e-mail: cschebor@di.fcen.uba.ar) and María del Pilar Buera (e-mail: pilar@di.fcen.uba.ar are Professors in the Industry Department School of Exact and Natural Sciences, University of Buenos Aires (Departamento de Industria, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires), Buenos Aires, Argentina. Authors Schebor and Buera are Members of CONICET, the National Research Council of Argentina, and Professor Buera is a Fellow of the International Academy of Food Science and Technology.

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