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# Osmotic dehydration of pineapple slices pre-treated by electroplasmolysis: Determination of color change kinetics

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**Abstract**

The pineapple (*Ananas comosus* (L.) Merrill) is a commercial tropical fruit belonging to the Bromeliaceae family. It is rich in organic acids (citric acid, malic acid), minerals (Fe, Mg, Ca, P, K, and Zn), and vitamins ($A, B_1, B_2, B_3$, and $B_6$). Osmotic dehydration is a water removal technique by immersing the fruit in a hypertonic solution to obtain minimally processed food with a longer shelf life and high nutritional value. It can also be considered as a pretreatment that reduces the required energy inputs for convective drying and freeze-drying. Electroplasmolysis is an electrical method that is based on the growth of pores in cell membranes. It has an important effect on the dehydration and extraction processes as it increases the cell permeability and mass transfer coefficients of plant tissues. In this study, it was aimed to determine the effect of electroplasmolysis pretreatment on color change kinetics in the osmotic dehydration of pineapple slices. Electroplasmolysis was applied by a drum-type electroplasmolyzator with 80 V/cm voltage gradient for 60 s. The osmotic dehydration process was carried out with sucrose solutions of 40, 50 and 60 $^{\circ}B_x$ at 20 °C. The processing time was 6 h in all osmotic treatments. This time was determined in preliminary experiments. Osmotically dehydrated samples with elelctroplasmolysis pretreatment and the samples without electroplasmolysis application were compared via $L$, $a$, and $b$ values during 8 hours. The results of the study showed that fresh pineapple samples had higher $L$, $a$, and $b$ values than both electroplasmolysis treated and untreated samples. The color values of all the samples, with and without electroplasmolysis pretreatment, decreased parallel to time increase after the osmotic dehydration process. $L$, $a$, and $b$ values of the samples which osmotically dehydrated at 60 $^{\circ}B_x$ solution were higher than the color values of the samples which were dehydrated at 40 and 50 $^{\circ}B_x$ solutions. Lightness and yellowness were found higher in the electroplasmolysis group than the other groups. The zero-order and first-order kinetic models were used to explain the color change kinetics and it was observed that $L$, $a$, and $b$ were fitted to a first-order kinetic model.

**Keywords:** pineapple, electroplasmolysis, osmotic dehydration, color, kinetic

## 1. INTRODUCTION

Pineapples are consumed fondly and they are low in calories and rich in minerals, vitamins, fiber, and bromelain, which aids in reducing inflammations and also contributes to good digestion (Wijeratnam 2016). Pineapples were pretreated with osmo-dehydration with the advantage of providing longer post-harvest life and increasing the quality by removal of excess water (Lombard, Oliveira, Fito, & Andrés 2008). Osmotic dehydration is a preservation method that provides the partial removal of water from foods by immersing the fruit in a hypertonic solution to obtain minimally processed food with a longer shelf life and high nutritional value. It was indicated that the pretreatments to osmotic dehydration such as high hydrostatic pressure, high electric field pulses, gamma irradiation, ultrasound, and vacuum and centrifugal force, can make the process easier by preventing the slower mass transfer rates (Rastogi, Raghavarao, & Niranjan 2014). Electroplasmolysis is an electrical method that promotes cell disintegration (Lebovka, Praporscic, &

Vorobiev 2004). It helps the transfer of water with electroporation and makes the drying process faster (Çakmak, Tekeoğlu, Bozkır, Ergün, & Baysal 2016). Traffano-Schiffo et al. (2017) emphasized that the application of an electric field before the osmotic dehydration produces a process of plasmolysis. Food processes may cause some changes in the color of the food products. The color is one of the most important features of raw and dried plant tissue quality because the external appearance influences the consumer acceptability and decision-making process. Pineapple color is a decisive factor in the judging of product acceptability since a pale yellow is associated with ripening and development of the flavor characteristic of the fruit (Singh, Varshney, & Agarwal 2016). Taking into consideration the combined effect of electrical pretreatment and osmotic dehydration, the objective of the study was to evaluate the effect of electroplasmolysis pretreatment and determination of the color change kinetics after osmotic dehydration of pineapple slices. Three different concentrations were applied during 6 hours. *L*, *a*, and *b* values were measured during 8 hours and compared with the control group without electroplasmolysis application.

## 2. MATERIALS AND METHODS

Fresh pineapples were purchased from a local market in İzmir. The initial soluble solids content of the fruit (°Brix) was determined by a refractometer. Pineapple samples were divided into two groups the electroplasmolysis application group (EP) and the group without electroplasmolysis application (N-EP). Electroplasmolysis was applied by a drum-type electroplasmolyzator with 80 V/cm voltage gradient for 60 s. Pineapple cylinders 4 cm in diameter and 2 cm thick were cut and the pieces were immersed in sucrose solutions of 40, 50, and 60 °Brix, with added citric acid (1%) and ascorbic acid (0.2%) at 20 °C for 240 min. Commercial food grade sucrose was used as the osmotic agent and a ratio of pineapple pieces to syrup (w/w) of 1:10. The color values of the pineapple samples were obtained using a chromameter (CR-10, Konica Minolta, Japan). The degradation of color values in the pineapples was calculated by using the standard equation for zero and first-order reactions and degradation rate constants were determined by fitting Eqs. (1) and (2) to experimental data.

$$C = C_0 + k_0 t \quad (1)$$

$$C = C_0 e^{-k1t} \quad (2)$$

where $C$ is the color value at any given time, $C_0$ is the initial value of the untreated samples and $k_0, k_1$ are rate constants.

## 3. RESULTS AND DISCUSSION

The *L*, *a*, and *b* values for fresh pineapples were 57.04, -5.02, and 19.21, respectively. For the kinetic modeling of color degradation of red pineapples, zero-order and first-order kinetic models were used. Calculated kinetic parameters of color values in pineapples during various conditions are given in Table 1.

**Table 1.** Kinetic parameters of color values of osmotically dehydrated pineapple samples with and without EP.

| Parameter | Sample | Zero-order model | | First-order model | |
|---|---|---|---|---|---|
| | | $k_0$ | $R^2$ | $k_1(h)$ | $R^2$ |
| L | EP-40 | 0.0178 | 0.9351 | 0.0056 | 0.9402 |
| | N-EP-40 | 0.4937 | 0.8808 | 0.1987 | 0.8872 |
| | EP-50 | 0.0165 | 0.8729 | 0.0042 | 0.8827 |
| | N-EP-50 | 0.3856 | 0.8099 | 0.0672 | 0.8173 |
| | EP-60 | 0.0074 | 0.9183 | 0.0016 | 0.9308 |
| | N-EP-60 | 0.1347 | 0.9521 | 0.0377 | 0.9694 |
| **Parameter** | **Sample** | **Zero-order model** | | **First-order model** | |
| | | $k_0$ | $R^2$ | $k_1(h)$ | $R^2$ |
| a | EP-40 | 0.0647 | 0.8386 | 0.0112 | 0.8413 |
| | N-EP-40 | 1.0514 | 0.8094 | 0.0239 | 0.8123 |
| | EP-50 | 0.0567 | 0.9859 | 0.0088 | 0.9863 |
| | N-EP-50 | 0.5472 | 0.8019 | 0.0153 | 0.8137 |
| | EP-60 | 0.0302 | 0.9536 | 0.0047 | 0.9566 |
| | N-EP-60 | 0.1710 | 0.9566 | 0.0114 | 0.9703 |
| **Parameter** | **Sample** | **Zero-order model** | | **First-order model** | |
| | | $k_0$ | $R^2$ | $k_1(h)$ | $R^2$ |
| b | EP-40 | 0.8183 | 0.9753 | 0.7595 | 0.9882 |
| | N-EP-40 | 1.9342 | 0.9492 | 1.0337 | 0.9603 |
| | EP-50 | 0.7260 | 0.9558 | 0.0665 | 0.9719 |
| | N-EP-50 | 0.9013 | 0.9524 | 0.9322 | 0.9599 |
| | EP-60 | 0.0646 | 0.9781 | 0.0605 | 0.9908 |
| | N-EP-60 | 0.1630 | 0.9530 | 0.4262 | 0.9553 |
| **Parameter** | **Sample** | **Zero-order model** | | **First-order model** | |
| | | $k_0$ | $R^2$ | $k_1(h)$ | $R^2$ |
| L | EP-40 | -0.0074 | 0.9351 | -0.4880 | 0.9402 |
| | N-EP-40 | -0.4937 | 0.8808 | -0.0078 | 0.8872 |
| | EP-50 | -0.8382 | 0.8729 | -0.0118 | 0.8827 |
| | N-EP-50 | -0,0165 | 0,7899 | -0.0317 | 0.8073 |
| | EP-60 | -0.0178 | 0.9183 | -12.377 | 0.9308 |
| | N-EP-60 | -0.1347 | 0.9521 | -0.0167 | 0.9694 |
| **Parameter** | **Sample** | **Zero-order model** | | **First -order model** | |
| | | $k_0$ | $R^2$ | $k_1(h)$ | $R^2$ |
| a | EP-40 | -0.0302 | 0.8386 | 0.0047 | 0.8413 |
| | N-EP-40 | -0.0710 | 0.8094 | 0.0114 | 0.8123 |
| | EP-50 | -0.0567 | 0.9859 | 0.0088 | 0.9863 |
| | N-EP-50 | -10.472 | 0.7719 | 0.0053 | 0.8137 |
| | EP-60 | -0.0647 | 0.9536 | 0.0102 | 0.9566 |
| | N-EP-60 | -10.514 | 0.9566 | 0.0239 | 0.9703 |
| **Parameter** | **Sample** | **Zero-order model** | | **First-order model** | |
| | | $k_0$ | $R^2$ | $k_1(h)$ | $R^2$ |
| b | EP-40 | -0.0646 | 0.9753 | -17.595 | 0.9882 |
| | N-EP-40 | -0.9342 | 0.9492 | -0.0337 | 0.9603 |
| | EP-50 | -18.183 | 0.9558 | -0.0665 | 0.9719 |
| | N-EP-50 | -0.9013 | 0.9524 | -0.0322 | 0.9599 |
| | EP-60 | -17.260 | 0.9781 | -0.0605 | 0.9908 |
| | N-EP-60 | -0.7630 | 0.9530 | -0.0262 | 0.9553 |

The obtained results showed that both zero- and first-order reaction kinetic models can be used adequately and equally for all values (*L*, *a*, and *b*) with $R^2$ values from 0.8019 to 0.9908.

After EP treatment of fresh pineapple slices, *L* and *b* values were increased, whereas *a* value decreased. The color values of the EP treated samples were protected better than the samples in the N-EP group. For example, at the end of 6 h *L* value was found as 68.91 in the EP-50 group, whereas this value was 60.65 in the N-EP-50 group. In the same group 50 °Brix) after 6h, *b* value was found as 23.81 with EP treatment, whereas 25.13 was found without EP. Redness was decreased to -6.63 from -5.99 when EP was applied. This shows the improvement of color values and decreasing of browning. This can be explained with the electroporation effect that the lightness increased after poration of cells. Color values were decreased during 8 hours. The rates of color changes followed first-order kinetics. The samples which were osmotically treated at high levels had higher color values than the samples treated with lower concentrations of osmotic solutions. Similar results were found in carrot samples after PEF application which provided increases in lightness (Amami, Khezami, Jemai, & Vorobiev 2014). They also explained this situation with the transfer of color pigments after PEF due to electroporation. Amami et al. (2014) reported increases in redness and yellowness after the osmotic dehydration of carrots. In another study, in the samples treated with osmotic dehydration, a 9% increase in *L* values was observed in papaya samples (Moreno, Bugueño, Velasco, Petzold, & Tabilo-Munizago 2006). Pereira, Ferrari, Mastrantonio, Rodrigues, and Hubinger (2006) described the increase in color values to better values of melon pieces due to higher water loss. The color change after osmodehydration was attributed to the sugar gain. They also mentioned that the variables such as sugar type, concentration and the temperature of the solution affected the kinetics of the osmotic process.

## 4. CONCLUSIONS

The color is an important quality criterion of fruits for the consumers, but it can degrade easily. Pineapples can be dried osmotically for better quality in terms of the color properties. Electroplasmolysis with the effect of cell poration facilitates the transfer of water against sugar and protects the lightness and yellowness values better compared with the control group. The color change kinetics of pineapple color parameters such as Hunter lightness (*L*), redness (*a*), and yellowness (*b*) system adequately explained the real behavior of pineapples undergoing osmotic dehydration at different concentrations. Zero-order and first-order kinetic models were used to explain the color change kinetics. The reaction rate constants for color parameters of pineapple samples were highly dependent on the concentration and dehydration time. In further studies, the combination of other technologies before osmotic dehydration can be researched.

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