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Influence of Edible Coating and Drying Methods on Quality and Thermal Properties of Apple Slices

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Abstract: In this research, the effect of edible coating carboxyl methyl cellulose before osmotic dehydration and various drying methods were investigated to evaluate color changes (ΔE), shear strength on texture (SS) and thermal properties of dried apple (*Golden delicious cultivar*) slices. Thermal properties of different samples were determined by differential scanning calorimetry (DSC). The coated and non-coated samples with or without osmotic pretreatment in sucrose solution (50%) were dried by freeze drier (-45°C, 2.2 Pa), air drier (60°C, 1.5 m/s). The coating had significant effect on ΔE and SS (p□0.05). The coating led to decrease ΔE and increase SS. The effect of osmotic dehydration and drying methods had significant effect on SS, ΔE and thermal properties such as ΔC_p, T_g and T_m.

Key words: Edible Coating ・ Drying methods ・ Thermal properties ・ Quality

INTRODUCTION

One of the preservative methods of food stuff is drying [1]. The quality of dried products is greatly affected by process and/ or storage-induced changes. Some of these involve changes in the physical state of the material and include appearance, color and texture [2]. Osmotic dehydration has an insignificant effect on physical and chemical changes of treated plant tissue in comparison with other processing methods. Osmotic dehydration involved soaking foods such fruit, vegetables in a hypertonic solution i.e. concentrated sugar, salt, alcohols, or soluble starch solutions, which partially dehydrates the food [3]. During the osmotic dehydration, intensive solute uptake could affect the rate of water removal, as well as that in the complementary drying process. Application of hydrophilic coating prior to osmotic dehydration could limit intensive solute uptake without seriously affecting water loss [4]. Edible coatings are used as barriers to protect the plant tissue from adverse microbiological, chemical and physical changes [5]. There are several supplementary drying methods, among them the most commonly applied are hot air (convective), freeze and spray drying [2].

The rate of several collapse phenomena, such as recrystallization of FD sugars or structural collapse has been shown to be governed by the T_g; physical changes are related to viscosity, which in amorphous materials, such as dried fruit, decreases with increasing $T-T_g$. However, the physical state of dehydrated food materials has been suggested as one of the rate-defining factors of diffusion-controlled deteriorative changes, such as non enzymatic browning in low and intermediate moisture foods [6]. Glass transition greatly influences food stability, as the water in the concentrated phase becomes kinetically immobilized and, therefore, does not support or participate in reactions. Formation of a glassy state results in a significant arrest of translational molecular motion and chemical reactions become very slow [7]. Glass transition is a second-order

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time-temperature-moisture-dependent transition, which is generally characterized by a discontinuity in physical, mechanical, thermal and other properties of a material [8].

The technical difficulties of drying such sugar- rich foods are associated with the basic physical characteristics of the mixture of the low molecular weight sugars present, especially sucrose, maltose, glucose and fructose. The fast removal of moisture during drying results in either a completely amorphous product or with some microcrystalline regions dispersed in the amorphous mass [9].

In the literature, glass transitions of pure components [10], fresh and dehydrated food such as fruit [5-12] are more commonly reported than using of coating fruits such as apple before the different combined method of drying.

The objective of this work was to study of the color, texture, T_g and T_m of coated and non-coated apple slices that pretreated with osmotic solution and then dried with different drying methods (freeze drying, air drying).

MATERIALS AND METHODS

Raw Material: The Apples (*Golden Delicious cultivar*) used in this study were purchased at the local market (in Karaj, Iran), stored at 1±1°C and 85% relative humidity for 2 days. Then fresh apples were washed, cored, peeled and cut into flat slices with 5 mm thickness. The initial moisture content of the fresh apples varied from 84% (wet basis).

Coating: Apple rings dipped for 30 seconds, in CMC solution (0.5%). Then they were dipped for 1 minute in 0. 2% $CaCl_2$ solution and finally samples dried at 60°C for 5 minutes.

Osmotic Pretreatment: It was carried out at 30°C using sucrose hypertonic solution (50% w/w) for about 180 minutes. The fruit to osmotic solution ratio kept 1:4. The solution was stirred with manual stirrer and temperature was controlled automatically in water bath.

Drying: Some samples were placed as a thin layer and subjected to tray drier (armfield, UK) at air temperature of 60°C and velocity of 1.5 m/s. Freeze drying (GPERGN, South Korea) was performed with vacuum chamber total pressure and temperature equal to 2.2 KPa and -45°C, respectively. The samples were subsequently kept in desiccators of $KC_2H_3O_2$ solution with RH=23% for measuring phase transition at same water activity.

Quantitative Analyses

Color: Color measured using a colorimeter HUNTERLAB-D25-9000 to obtained CIE lab values (L*, a*, b*). The subscript 0 (Eq. 1) denotes the color parameters of fresh apple slices. The higher total ΔE represents greater color change from the fresh apple [13].

$$\Delta E = \sqrt{(L^* - L_2^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \qquad \text{Eq. 1}$$

Shear Strength: Shear strength of texture was measured using a Texture Analyzer (HOUNSFIELD-H5K5) by means of penetration test [14].

$$SS = Fmax/(L\times \qquad \text{Eq. 2}$$

In every case, $F_{max,}$ L, D was referred to force, displacement at F_{max} and diameter of penetration probe, respectively.

Thermodynamic Properties: Phase transitions were determined by differential scanning calorimeter (DSC, Mettler Toledo, Switzerland). The instrument was calibrated by standard procedure. Equilibrated samples (3-5 mg) were placed in aluminum DSC pans (ME.27331, 40 µl) and hermetically sealed; an empty aluminum pan was used as reference. Samples were heated at a rate of 10° C/min and scanned from -40 to 100°C. The glass transition (onset, midpoint, end point) was measured. All measurement was performed in three repeats. The midpoint temperature of glass transition (T_g), onset temperature of ice melting (T_m), ΔC_p across the glass transition were calculated with the help of the software Universal STAR^e SW 9.20.

Statistical Methods: The experiment was conducted according to a completely randomized design. Data were evaluated by analysis of variance (ANOVA) and Duncan test, using SPSS-16 software version 16.0.

RESULTS AND DISCUSSION

Color: Desired color properties of dried apple slices are related to minimum total color differences (ΔE) of dried and fresh apple. The data were significantly different (p□0.05). Porous material such as FD food stuff can absorb more light and hence, give a brighter color (15). These results are similar by results of Chin-Lin [16] and Poonam [17]. The color changes of FD and AD samples were 879.3 and 929.2 respectively. Higher drying temperature led to darker apple slices [18], as shown in Fig. 1.

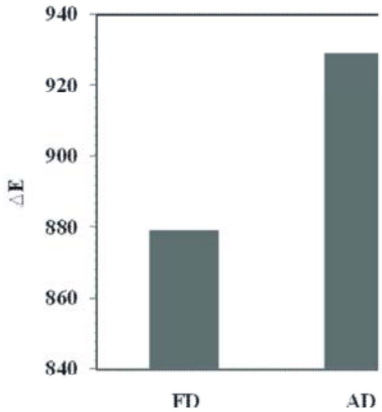

Fig. 1: The effect of drying methods on ΔE. FD: Freeze dried sample, AD: Air dried sample.

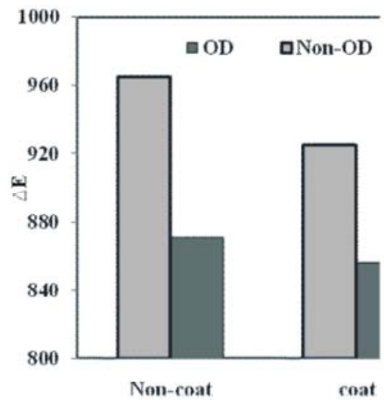

Fig. 2: The effect of coating and osmosic pretreatment on the ΔE, OD: Osmotic dehydration, 0Non-OD: Non-osmotic dehydration.

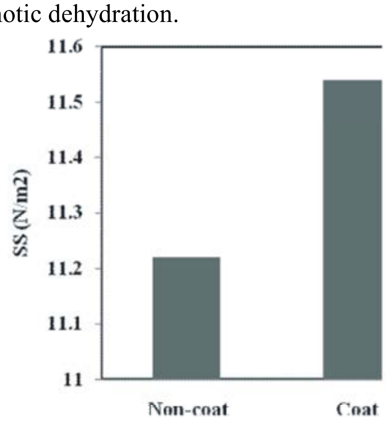

Fig. 3: The effect of coating on the SS. Coat: Coated sample, Non-coat: Non coated sample.

ΔE were significantly lowest pronounced in Coated-OD slices (p□0.05). The preservative effect of osmotic process and decrease uptake of solute with coating, that causes decrease collapse of external cells and browning reaction [6]. In the coated and the

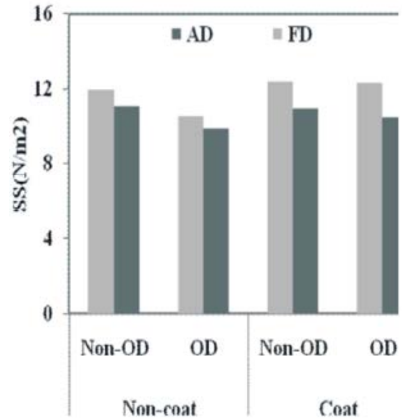

Fig. 4: The effect of coating, osmotic dehydration and drying methods on the SS. AD: Air dried sample, FD: Freeze dried sample, OD: Osmotic dehydrated sample, Coat: Coated sample.

non-coated samples without regard to the supplementary drying methods, osmotic treatment causes decreasing ΔE, on account of decreasing time of ultimate drying. Also coating has caused to decrease ΔE of samples because coating helped to prevent over softening of cell wall structure, leading to low soluble uptake. So cells inside the coated samples were more pronounced under high process temperature in comparison with the non-coated samples [4].

Texture: The data were significantly different (p□0.05). The SS of the coated and the non coated treated samples were 11.5 and 11.2 Nm^{-2}, respectively. In the non-coated and OD apples, collapse of external cells due to large solute uptake lead to decrease diffusivity of water at drying process. Coating helped to prevent over softening of the cell wall structure. So, cells inside the coated samples were more pronounced under high process temperature in comparison with the Non-coated samples [4].

The data were significantly different (p□0.05). Uptake of sucrose molecules and accumulation of solutes in OD samples lead to decrease elasticity and increase brittleness in texture [19]. As shown in Fig. 4, the FD samples had higher SS than AD samples due to lower texture deformation. In coated and Non-coated samples, SS of the Non-OD samples are more than the OD samples, because of solid gain and more cell collapse [4].

Calorimetric Analysis: Two glass transition temperatures were observed in thermograms of the osmotic and non-osmotic pretreated and dried apples such as dried

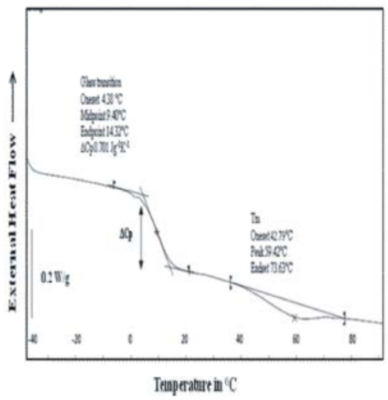

Fig. 5: DSC profile for AD apple slice conditioned at aw of 0.23 and 24°C.

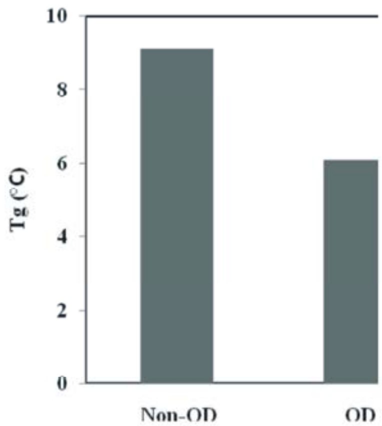

Fig. 6: The effect of osmotic pretreatment on T_g of the samples. OD: Osmotic dehydrated sample, Non-OD: Non osmotic dehydrated sample.

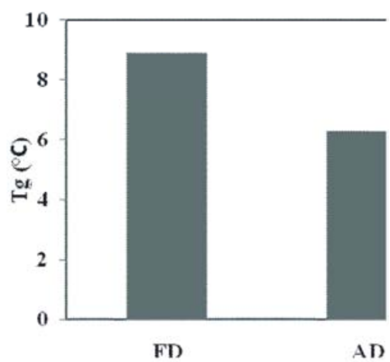

Fig. 7: The effect of drying methods on Tg of the samples.

apple [2], persimmon [5] and raspberry [20]. Fig. 5 has typically shown one of the thermograms of the dried samples.

The data were significantly different at p□0.05. The T_g of OD and Non-OD samples were 6.1°C and 9.1°C, respectively. Many amorphous low molecular weight sugars are extremely hygroscopic and their processing and storage is difficult because of their low T_g. Therefore various high molecular weight compounds have been used to improve their process ability and storage stability (23). The coating had no significant effect on T_g of the samples. During the osmotic treatment, there is always a leaching of solutes from the solid sample and its impregnation with solutes from the solution (17). As shown in Fig. 6, increase of amount of sucrose decreases of Tg for OD apple samples. Similar results were reported by sa [11] and Telis & sobral [2]. Tg of fruit materials with high sugar content were related to Tg values of constituent sugars. More than 85% of the solids in apple tissue soluble solids, while the remaining insoluble cell wall material does not show apparent Tg as measured by DSC [22]. Considering the distribution of fructose, sucrose and glucose in apples and the anhydrate Tg values of these sugars, the midpoint glass transition temperature of dried apple with osmotic dehydration is different with the non-osmotic dehydrated sample.

The data were significantly different (p□0.05). The T_g of the FD and AD samples were 8.9°C and 6.3°C, respectively. Second-order transitions of food materials are important to processes which cause a rapid decrease of the amount of water and thus not allowing crystallization during the process for example dehydration and to stability of these products. The different heating rates give different T_g values for all amorphous system including foods [21]. In general, T_g values of the AD samples, especially those corresponding to OD ones, were lower than that observed for the FD material at the same moisture content [2]. T_g of the AD samples was lower than the FD samples that can related to drying rate and structural differences between them [2].

Glass transition was identified in the derivative heat flow signal, as an endotherm and ΔCp associated were obtained from the increase in the reversible Cp. ΔCp is due to structural changes where the most important variation on fusion zone is representative of structure changes and water-sucrose interactions. So that represents a good stability parameter [23]. Coating had insignificant effect on ΔC_p. ΔC_p of the OD samples were lower than the non-OD samples, as T_g of the OD samples were lower too. Also, the FD samples had higher ΔC_p than the AD samples. The data were significantly different (p□0.05).

T_m defines a structural collapse (a material flows and cannot support its own weight) temperature for various materials during their freeze-drying and above T_m

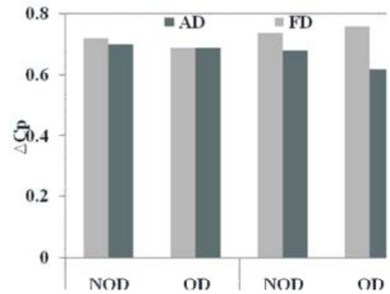

Fig. 8: The effect of coating, osmotic pretreatment and drying methods on ΔCp of the samples. AD: Air dried sample, FD: Freeze dried sample, OD: Osmotic dehydrated sample, Coat: coated sample, Non-coat: Non-coated sample.

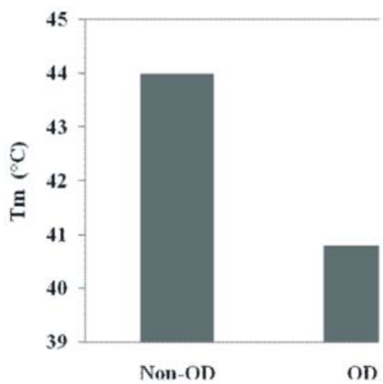

Fig. 9: The effect of osmotic pretreatment (OD) on T_m of the samples. OD: osmotic dehydrated sample, Non-OD: Non osmotic dehydrated sample.

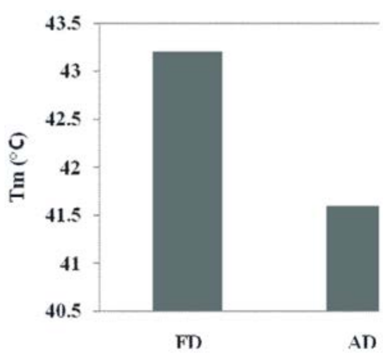

Fig. 10: The effect of drying methods on T_m of the samples. FD: Freeze dried sample, AD: Air dried sample.

increasing water content lead to rapid decrease of viscosity, because of dilution of the food solids (increasing plasticization by unfrozen water) and concomitant decrease of the viscosity controlling T_g. Below Tm the viscosity of frozen materials decrease until a glass is formed at T_g (23). The data were significantly different (p□0.05). T_m of the OD and non-OD samples were 40.8°C and 44°C, respectively. T_m of the OD samples were lower than the non-OD samples, due to increase of solute content (5,17).

The data were significantly different (p□0.05). T_g of the FD and AD samples were 43.2°C and 41.6°C, respectively. T_m of the FD samples was higher than the AD samples. Freeze drying is fast method of drying and decreases crystallization [24] causing to increase T_m (Fig. 10).

CONCLUSIONS

The investigations showed freeze drying due to fast previous freezing and high drying rate led to product amorphous samples that resulting ΔC_p and T_g of samples increased. Decrease of crystallization in these samples causes increase of SS and decrease of ΔE. Lower T_g for the OD samples can relate to gained solutes that lead to increase of crystallization and decrease of SS.

Abbreviations:

OD	Osmotic dehydration
Non-OD	Non-osmotic dehydrated
FD	Freeze dried
AD	Air dried
CMC	Carboxyl methyl cellulose
RH	Relative humidity (%)
ΔE	Color changes
SS	Shear strength ($N\ m^{-2}$)
T_g	Glass transition temperature (°C)
T_m	Melting temperature (°C)
ΔC_p	Changes of Specific Heat Capacity ($J\ g^{-1}K^{-1}$)

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