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An Investigation of Mass Transfer Phenomena during Osmotic Dehydration of Orange Slices

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ABSTRACT

The osmotic dehydration causes water removing from food and also a soluble solid uptake into the foodstuffs. However, large penetration of solute into the food becomes a major problem in osmotic dehydration.

Pre-coating the food to be dehydrated with an artificial, edible barrier was also explored as a way to efficiently hinder solute penetration. In this study the effect of edible coating (CMC), concentration of sucrose solution (50 and 60%), temperature (35, 45 ºC) of Thomson orange, as a model fruit were studied on the factors affected of mass Transfer phenomena during osmotic dehydration. The results showed that the soluble solid gain(SG) , water loss(WL) and productivity ratio(WL/SG) rise with increase of temperature and solute concentration. Coating has affected significantly on the productivity ratio.

Keywords: Osmotic dehydration; Edible coating; Solid gain; Water loss.

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INTRODUCTION

Fruit drying is a well known process mostly used for preservation of fruits. The traditional way, which is often used in Iran for orange drying, is to spread it into the direct sunlight.

According to FAO report, about 1.9 million tons of oranges are produced yearly in Iran (making it the world eight largest producer) and Iran is one of the main producer of the orange. The post harvest losses are estimated from 25-30 percent of total production. Drying of orange is a practical method for its preservation. In traditional drying methods, serious losses of physicochemical and sensorial values are possible (Rahimzade & Hesari, 2007).

Air drying in a simultaneous heat and mass transfer process, accompanied by phase change and is a high cost process. A pre-treatment, such as osmotic dehydration, can be used in order to reduce the initial water content, reducing total processing and air-drying time (Sereno *et al*., 2001).

Osmotic dehydration is a useful technique that involves product immersion in a hypertonic aqueous solution leading to loss of water through the cell membranes of the product and subsequent flow along the inter-cellular space before diffusing into the solution (Fabiano, 2007). The difference of chemical potential between components in the solution and the material leads to mass transfer. This mass transfer involves water transfer from the material to the solutions, uptake of solutes from solution into dehydrated material and leaching of low molecular mass compounds, minerals, vitamins, colorants from the material to the osmotic medium (Sablani & Rahman, 2003; Mayor *et al*., 2005)

The osmotic process has received considerable attention as a pre-treatment to reduce energy consumption and improve food quality, besides reducing the drying time. The osmotic dehydration as a pre-treatment also inhibits enzymatic growing, retains natural color (without sulphit addition) and retains volatile aromas during the subsequent drying (Fabiano, 2007).

The influence of the main process variables, such as concentration and composition of the osmotic solution(Riva *et al*., 2005; Fabianno *et al*., 2007; Rahimzade & Hesari, 2007; Singh *et al*., 2007; Ozdemir *et al*., 2008), temperature and immersion time (Shukla & Singh , 2007; Jalali *et al*., 2008), agitation (Martines *et al*., 2007), solution /sample ratio (Shulka & Singh, 2007; Rahimzade & Hesari, 2007), nature of food (Sunjaka & Raghavan, 2004) on mass transfer mechanism and product quality have been studied extensively.

The difference in the respective chemical potentials of water and solute in a solid–liquid (solution) system results in fluxes of several components of material and solution. The water outflow and solute inflow mainly occur in the first 2–3 hours of immersion. After that the water content between food and osmotic solution gradually decreases, until eventually the system reaches a state of dynamic equilibrium of molecule transfer (Shi & LeMaguer, 2002)

However, the potential application of osmotic dehydration is limited, due to the undesirable large solute uptake in osmotically dehydrated products. The large solute uptake cause additional resistance to mass transfer of water and leads to lower dehydration rate in the complementary drying. A number of studies have been conducted aiming to control the large solute uptake. Use of coating as a barrier is very promising. Appropriate coating materials could efficiently inhibit the extensive solute uptake without affecting too much on water removal (Khin *et al*., 2007; Ikoko & Kuri, 2007).

The purpose of this study was to investigate the effect of concentration, temperature and coating on mass transfer kinetics (WL, SG, WL/SG) of osmotic treated orange slices.

MATERIALS AND METHODS

Raw material

Oranges (Var. Thomson) of uniform quality were purchased from the local garden in south of Iran and stored at 1±1°C and 80-90 percent relative humidity for 2 days, until they arrived to equal temperature. Then fresh oranges were washed, peeled, cut into flat rings with 5 mm thickness. The initial content of the fresh oranges varied from 85-86 percent (wet basis).

Coating treatment

The slices of oranges were immersed in CMC solution (0.5% w/w) for 30 second and then put in calcium chloride solution (0.2%) for 2 minutes. Then they were dried at 55-60°C for 5-10 minutes, in order to fix the coating on the samples.

Osmotic treatment

Osmotic treatment was carried out at 35°- 45°C using sucrose hypertonic solution (50-60%) about 180 minutes. The ratio of fruit to osmotic solution was 1:4 (w/w)

Drying

After osmotic treatment, Drying of samples were performed in a pilot plant tray-dryer at an air temperature of 60°C and air velocity of 1.5 m/s with direction of air flow through the product for 8 hours. The final moisture content of dried samples was 12±2 percent.

Analytical Methods

Measurement of Water Loss and Solid Gain

Moisture content was determined by the oven drying method (AOAC 1984). Samples were weighed and placed in an oven(Memmert, Schwabach, Germany) set at 105°C. The samples were kept in this oven for 24 h until a constant weight was reached. The samples were cooled down in desiccators and weighed. Moisture content of the samples was then calculated from the sample weights before and after drying. The water loss (WL), solid gain (SG) and productivity ratio of osmotic dehydration process(WL/SG) ,were calculated using the following equations (Kalbasi & fatemian, 2000).

$$SG = [(FS \cdot FM / IM) - IS]\, IM / IS \qquad \text{eq. 1}$$

$$WL = [(IM - IS)\, IM - (IM - FS)\, FM] / IS \qquad \text{eq. 2}$$

FS : solid content of final material after osmosis period (percent)
FM: final mass after osmosis period (g)
IM : initial mass before osmosis period (g)
IS: solid content of initial material before osmosis period (percent)

Statistical Analysis

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

RESULTS AND DISCUSSION

The results of analysis of variance for dried Oranges were shown in Table 1.

Table 1: Analysis of variance for dried Orange

Factors	Df	Solid gain	Water loss	WL/ SG
Concentration (A)	1	**	**	**
Temperature(B)	1	**	**	**
Coating (C)	1	Ns	**	**
A* B		Ns	ns	Ns
A * C	1	Ns	ns	**
B * C	1	Ns	ns	*
A *B * C	1	Ns	ns	Ns
Errors	16			
R^2		.647	.978	.885

**: p<0.01, *: p<0.05, ns: no significant

1-Water loss and WL/SG , concentration of osmotic solution on Solid Gain of Effect 1.

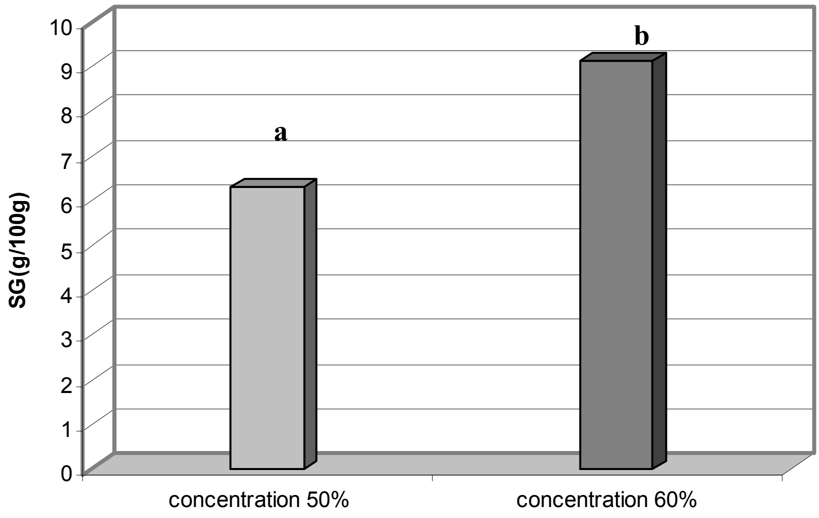

Fig. 1: Effect of concentration on SG

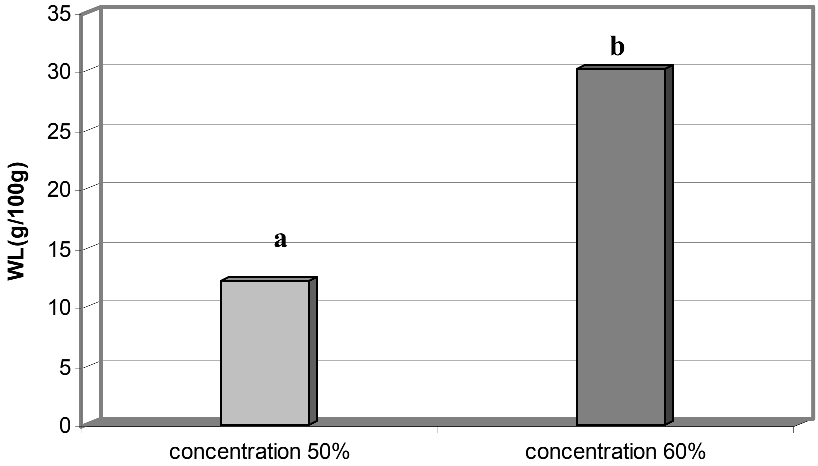

Fig.2: Effect of concentration on W

The data from figurs 1 and 2 show that by increasing the concentration of sucrose solution, Increase solid uptakes and water losses. These phenomena are due to high difference in the chemical potential of water and solute between the sample and osmotic solution.

Increase in solution concentration resulted in an increase in the osmotic pressure gradients and, hence, higher water loss (and salt uptake) values throughout the osmosis period were obtained. These results indicate that by choosing a higher concentration medium, some benefits in terms of faster water loss could be achieved. However, a much greater gain of solids is observed

The influence of the concentration of the osmotic solution is seen mainly for water loss: the higher the concentration, the higher the water loss. By increasing the concentration of sucrose solution from 50 to 60% , the SG increased about 45% and the maximum WL occurred when osmotic treatment was carried out in the high concentrated solution. These results are in accordance with those obtained by the other researchers (Sereno *et al.*, 2001; Chafer *et al.*, 2002;

Alline *et al.*, 2003; Fabianno *et al.*, 2007; Rahimzade & Hesari, 2007; Lombard *et al.*, 2007; Jalali *et al.*, 2008).

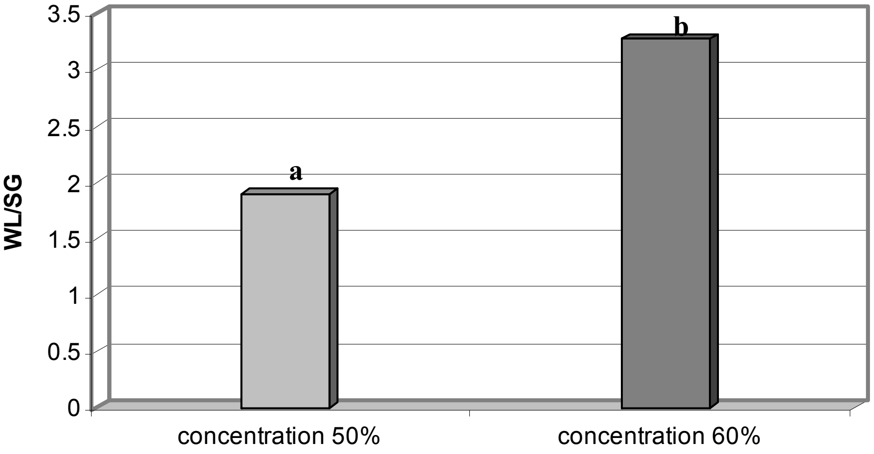

Fig.3: Effect of concentration on WL/SG

As shown in figure 3 Increase in solution concentration resulted an increase in ratio of water loss to solid uptake.. These results indicate that by choosing higher concentration medium, some benefits in terms of faster water loss could be achieved .(Giraldo *et al.*, 2003)

2- Effects of temperature of osmotic solution on SG , WL and WL/SG

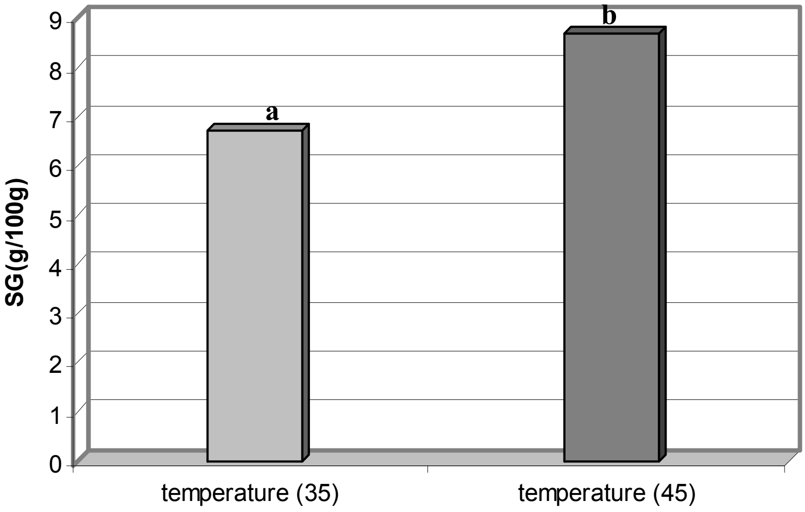

Fig. 4: Effect of temperature on SG

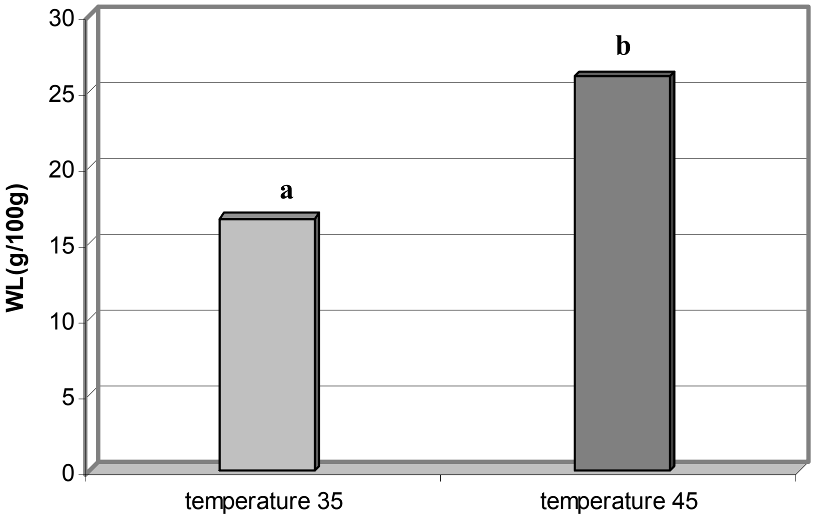

Fig.5: Effect of temperature on WL

As shown in figs.4 and 5 increasing temperature increased water loss and solids gain. Higher temperatures cause swelling and plasticizing of cell membrane and in that way membrane becomes more permeable to water coming out of the product and solute uptake in product. (Saputra, 2001; Martinez *et al.*, 2007; Saputra, 2001).

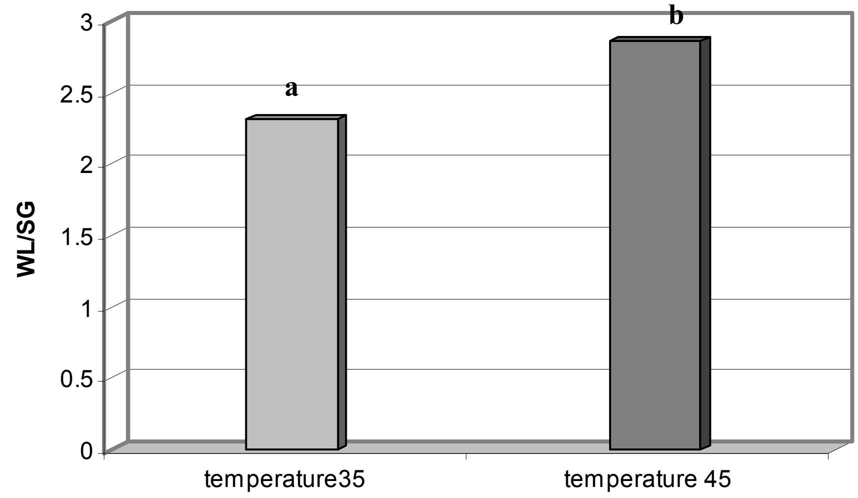

Fig.6: Effect of temperature on WL/SG

The effect of temperature on the SG is given in figure 4. The SG is increasing with temperature. As it was explained for WL (figure 5), temperature has an effect on the cell membrane permeability that could allow solutes to enter by loosing its selectivity. Decrease of solution viscosity at higher temperature may influence SG due to fact that lower viscosity decreases the resistance to diffusion of solutes into the plant tissue. then the rate of WL/SG increased. Similar results were reported for sugar beet (Jokic *et al.*, 2006).

3- Effect of edible coating on WL

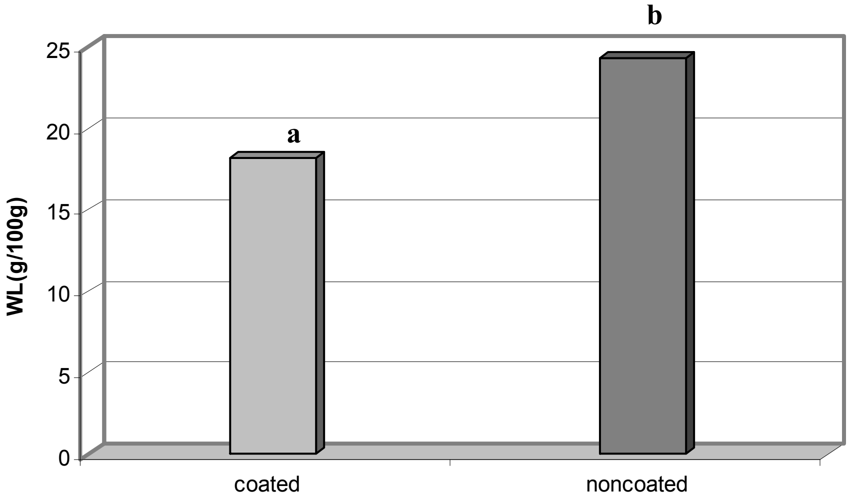

Fig.7: Effect of coating on WL

The water loss of coated and non-coated samples during the osmotic dehydration process is shown in figure 7. Edible coating acts like a barrier which controls water loss . Similar results were reported by camirand *et al*. 1969.

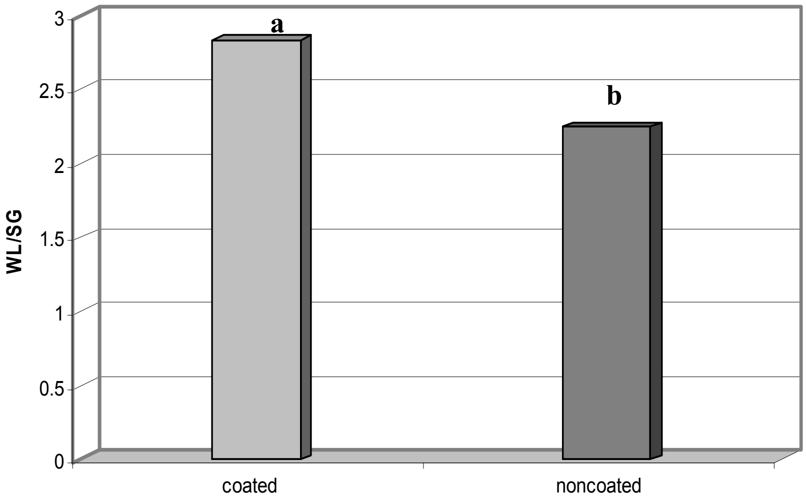

Fig.8: Effect of coating on WL/SG

A few studies have attempted to reduce large solute uptake by using edible coating materials prior to osmotic dehydration (Khin *et al*., 2007). However, the uptake was slow as compared to non-coated orange samples due to the following factors:

The presence of coating around the sample impeded the uptake of sucrose into the sample or it could be that the diffusion of the coating material into the osmotic medium opposed the movement of the sucrose molecules into the sample. This is consistent to the previous research results on sodium alginate coated and low methoxyl pectinate-coated potato and apple cubes (Khin *et al.*, 2007).

The oven-drying step in the coating process caused shrinkage of the cells evidenced by a dramatic reduction in the sample volume especially after 10 min drying in the oven. In addition, the shrinkage of cells could cause a reduction of the intercellular spaces leading to a decrease in the uptake of sucrose into the sample.

When coated and non-coated oranges were compared, coated food had a greatest WL/SG ratio. The greatest percent water losses, the best appearance.

Edible coating acts like a barrier which decreases solute uptake, without having negative effect on the rate of water removal then the ratio of WL/SG for the coated oranges were higher than those for uncoated samples (Figure 8).

4- The Combined effects of Coating and Concentration on WL/SG

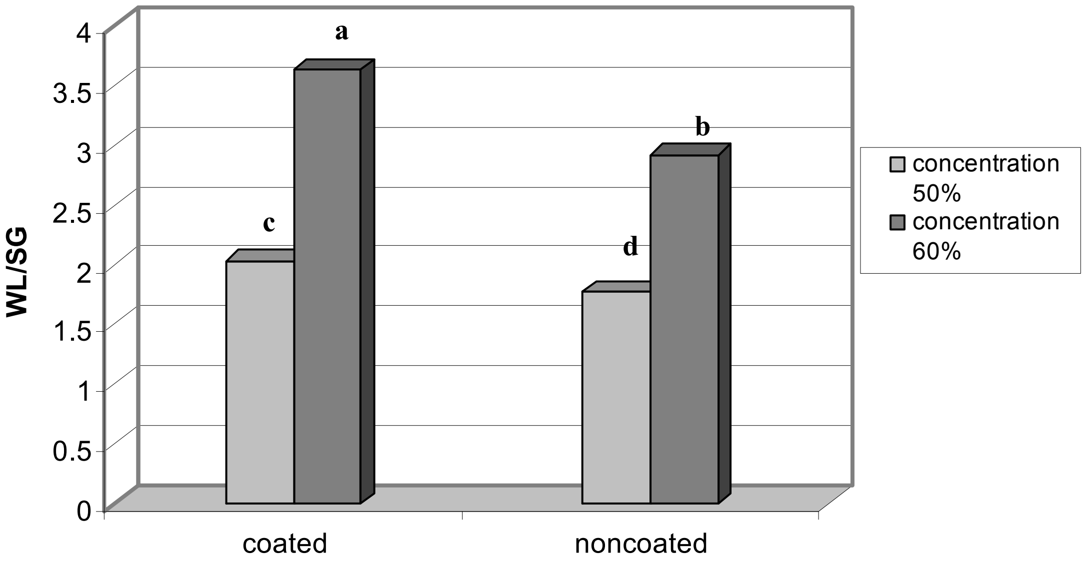

Fig.9: Effects of edible coating and concentration of osmotic solution on WL/SG

As shown in figure 9, The highest efficiency and rate of osmotic dehydration is related to coated samples exposed to sucrose solution 60%w/w at 45ºC.

CONCLUSION

Results after 3 hours of osmotic dehydration of coated orange at 35 and 45ºC in the hypertonic sucrose solutions (50 and 60%w/w), showed that SG, WL and WL/SG are increased with temperature and concentration, but edible coating controls WL and SG. Finally, in this study, the best sample is the edible coated of orange rings, that were processed in 60%(w/w)of sucrose solution at 45ºC.

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