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Drying of carrots in slices with osmotic dehydration

Araújo, P. M.*, Fonseca, J. R. L., Magalhães, M. M. A. and Medeiros, M. F. D.

Laboratory of Food Technology, Federal University of Rio Grande do Norte, 59072-970, Natal/RN, Brazil.

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Carrot is dried for consumption in the form of slices and cubes. The objective of this work was to find alternative ways for the conservation of carrot slices by osmotic dehydration with additional drying in heat. Pre-osmotic dehydration (temperature, immersion time and type of osmotic solution) based on the results of humidity loss, solid gain, weight reduction and efficiency ratio of pre-dehydrated carrot slices were initially defined as the best conditions for this study. The osmotic solutions used were composed of NaCl (10%) and sucrose (50° Brix) named OD1 and sucrose (50° Brix) called OD2. The experiment of pre-osmotic dehydration of carrot slices in two temperature levels with complementary drying in heat with air circulation at 70°C was used. The best results were obtained with the solution OD1 at 60°C with immersion time of 60 min. The osmotic pre-treatment reduced the initial humidity of carrot slices, reducing the time for the product to reach the same humidity content.

Key words: Carrot, conservation, osmotic solution, pre-osmotic dehydration.

INTRODUCTION

Carrot *Daucus carota, L.*, is rich in β-carotene, a precursor of vitamin A. The daily requirement of vitamin A can be met almost entirely by consuming only 100 g of this vegetable. This vitamin contributes to good vision, skin and mucous membranes. It is also a significant source of calcium, potassium and phosphorus, and contain B vitamins, which help regulate the nervous system and digestive function. Among vegetables, carrot has higher sugar content and therefore is a good source of energy.

Most fruits and vegetables have a definite harvesting time and a limited shelf-life. Most harvested fruits quickly deteriorate due to microbial and biochemical activity. However, different preservation methods are used to extend the shelf-life by a few weeks, one year or more. The methods include canning, bottling, freezing, drying, fermentation, pasteurisation, chemical additives, packaging and irradiation (Burrows, 1996).

The technique of food dehydration is probably the oldest method of food preservation. The main purpose of drying is to allow longer periods of storage, minimize packaging requirement and reduce shipping weight (Amiryousefi and Mohebbi, 2009).

In recent years, some pre-treatments including osmotic dehydration, blanching, and microwave have been used for improving the quality of fruit products and reducing energy consumption (Levent and Ferit, 2011).

Dehydration techniques are based on the fact that the main causes of deterioration of fresh and processed foods is the amount of free water contained in the aliment. The water activity in vegetables and fruits can be reduced through dehydration techniques, consequently

*Corresponding author. E-mail: paulymedeiros@msn.com.

there are reducing weight, greater stability and lower cost storage products (Lopes, 2007). Water activity (a_w) is the most important factor that affects the stability of dehydrated and dry products during storage. It is determinant for microbial growth and can be associated with most degradation reactions of a chemical, enzymatic and physical nature (Levent and Ferit, 2011).

The drying of food using heated air is based on the product temperature increasing to evaporate water and if not properly controlled can cause undesirable changes in the appearance, color and texture, as well as in the nutrient content of the final product (Rastogi et al., 2004). As it is a process of simultaneous transfer of heat and mass, the drying usually requires heat to evaporate moisture from the product and to remove water vapor formed in the product surface to be dried. The process involves three modes of heat transfer: Convection, conduction and radiation. During the drying process, moisture migrates from the interior to the surface of the product, where it evaporates into the environment (Meloni, 2005).

Ponting et al. (1966) are among the first to suggest dehydration process based on the osmotic exchange. Osmotic dehydration (OD) is also known as a technique of removing water by impregnation or saturation. As a technique of removing water, applying the principle of osmosis, the OD generates foods with intermediate water activity (a_w).

OD is used as pre-treatment, it is also used as a stage previous to the freezing process, microwave, lyophilization, vacuum drying or drying by hot air in order to improve product quality, lower energy costs, or even make new products (Gomes et al., 2007).

According to Torreggiani (1993), osmotic dehydration is a special method of drying which is based on the principle that when cellular material are immersed in a hypertonic aqueous solution, a driving force for water removal sets up because of the higher osmotic pressure of the hypertonic solution. There are two major count-current flows during osmotic dehydration, that is, water flows out of the food into the solution and likewise solute is transferred from the solution into the food. The osmotic dehydration of fruits and vegetables there is a reduction of water content and consequently the water activity too, but these values are not sufficient to generate stable intermediate moisture products. Therefore, exists the necessity of an additional drying process, the most common is dried with hot air or vacuum. The pre-drying by osmosis, followed by a hot air drying has been widely used in producing dried fruits and partially dried for minimizing the adverse effects that usually appear when the product is subjected to drying with hot air (Neto et al., 2005). This combination of drying methods has been identified as a safe and economical alternative for the conservation of dehydrated products with a better quality when compared to conventional dehydrated products (Brandão et al., 2003). A complex issue in the osmotic dehydration is the choice of the type and concentration of osmotic substance, which is directly related to the sensory properties of the final product and the cost of the processing.

The influences of concentration and composition of osmotic solution, temperature, immersion time, pretreatments, agitation, nature of food and its geometry, and solution to sample ratio on the process have been studied extensively (Singh and Gupta, 2007). The osmotic agent type affects the kinetics of water removal and the incorporation of solids. As one increases, the molecular weight of the solutes observed a solids reduction incorporated and increased water loss. Osmotic agents commonly used are sucrose and sodium chloride, but any water-miscible solution may be used (dextrose 1996).

Considering the importance of researching alternative technologies that enable low cost production of dehydrated carrots, this work studied the drying of carrot with pre-osmotic dehydration.

MATERIALS AND METHODS

The Brasilia variety of carrot used in this study was purchased from a local market. The carrots were selected in order to standardize the maturation stage, picking up, and without any perforations in the skin or other physical damage. They were then washed in water, peeled manually and cut into slices, approximately 3.8 mm thick.

The osmotic solution was prepared using distilled water, commercial sucrose and sodium chloride, purchased from the local market, in pre-defined proportions. The pH of the solution was adjusted in the range of 4 to 5 by adding citric acid. The addition of sodium metabisulfite and calcium chloride at concentrations of 200 ppm was also required. The carrots were blanched in boiling water for approximately 3 min.

The carrot slices were placed in a solution with osmotic concentration, temperature and immersion time defined. The solution was kept under stirring and the temperature controlled by a heating plate. The osmotic proportion between the solution and carrot was 5:1.

Processing conditions

Preliminary tests were performed in six trials with three replicates for each parameter, using two types of osmotic solution. During the preliminary tests, the immersion time of the carrot slices was 3 h at a controlled temperature of 60°C. The following conditions were based on the preliminary tests chosen:

•Composition of the osmotic solution:

a. Sucrose 50° Brix solution + 10% NaCl.
b. Sucrose 50° Brix solution.

•Osmotic solution temperature: 50 and 60°C.
• Immersion Time: 1, 2, 3 and 4 h.

Each processing condition of osmotic dehydration were calculated as water loss (PU), soluble solid gain (SG), weight loss (RP), according to the study of Levi et al. (1983), and dehydration efficiency index (Pr).

$$PU = \frac{Mo.Xo - Mf.Xf}{Mo}$$

Table 1. Results of water loss (PU), solid gain (GS), weight loss (RP), dehydration efficiency (Pr) and water activity (a_w) in OD1 and OD2 solution to carrot slices with 60ºC, in preliminary tests.

Condition	t (min)	PU (%)	GS (%)	RP (%)	P_r	a_w
OD1	180	60.98	29.18	35.03	2.09	0.840
OD2	180	50.99	30.57	18.76	1.67	0.935

$$GS = \frac{Mf.Yf - Mo.Yo}{Mo}$$

$$RP = \frac{Mo - Mf}{Mo}.100$$

$$Pr = \frac{PU}{GS}.100$$

Where, Mo is the initial weight; Xo is the initial water content; Mf is the final weight; Xf is the final water content; Yf is the final soluble solids and Yo is the initial soluble solids.

The osmotic solution temperature was controlled at 60°C in preliminary tests. Table 1 presents the results of loss of moisture (PU), solid gain (SG), weight reduction (RP), efficiency (Pr) and water activity (a_w) for osmotic agents: OD1 (solution 10% NaCl and 50° Brix sucrose) and OD2 (50° Brix sucrose solution).

The results presented in Table 1 show that moisture loss was higher and solid gain lower when the combination of sucrose (50° Brix) and 10% NaCl with a dehydration efficiency index of 2.09 was used. Similar results were observed in the study of Borin et al. (2008) for squash, and Singh and Mehta (2008) for carrot cubes. The cited authors found that the best solutions were composed of sucrose-NaCl.

Dehydration OD2 with the solution obtained results consistent with the literature for cubes of carrot treated with sucrose solution (Singh et al., 2007b).

Oven drying

After osmotic dehydration, carrot slices were distributed within a single layer of perforated trays and taken to an oven with air circulation of 70°C for 3 h for the completion of drying.

Physical-chemical

Samples were taken at each stage of processing (fresh carrots, bleached, after the osmotic dehydration - OD1 and OD2 - and after final drying), to perform the following analysis according to the method of the Institute of Adolfo Lutz (1985).:

a) pH - measured directly in pot Digimed - DMPH - 2
b) Total titratable acidity, expressed in mg citric acid/100mg per sample.
c) Soluble solids (° Brix) - RL2 refractometer directly measured in the NR 2720-25°C
d) Moisture - determined in an oven with air circulation, until constant weight at 70°C.
e) Weight Loss - obtained directly using balance semi-analytical model BEL MARK 35545.
f) Water activity (aw) - measured directly on the analyzer activity, model AQUALAB series 3TE.

RESULTS AND DISCUSSION

Tests with the osmotic agents

To define the type of osmotic agent, tests were performed with two different solutions. Six trials were performed for solutions OD1 and OD2, with immersion time of 180 min.

Definition of solution temperature on osmotic dehydration of carrot slices for osmotic agents OD1 and OD2

Table 2 shows the results for the dehydration of carrot slices in four differents immersion times, provided OD1 (10% NaCl and 50° Brix sucrose) at 50 and 60°C. It was observed that the best efficiency ratio (Pr) was obtained at a temperature of 50°C and immersion time of 60 min. The greatest loss of moisture (PU) was the measured slices dried for 60 min at 50°C. When dried at a temperature of 60°C, slices began to lose moisture during further drying, where the PU rates increased with the immersion time of slices, reaching a maximum of 67.94% at 180 min (Table 2). For the immersion time of 240 min, there was a decrease due to increased Pr, GS by carrot slices.

Table 3 shows the results for the dehydration of carrot slices in four differents immersion times, provided OD2 (50° Brix sucrose) at 50 and 60°C. It also appears that with sucrose solution; only the best efficiency ratio was obtained at a temperature of 50°C and immersion time of 60 min. Singh et al. (2007) observed similar behavior in dehydrated carrot cube, where the dehydration in shorter time and lower temperature showed better efficiency with better value for PU/GS. With increasing time of immersion, PU tends to increase, but due to the increased rate gain solid efficiency tends to decrease (Table 3). Manivannan and Rajasimman (2009) also observed this behavior for pre-dehydrated beets with sucrose solution at a temperature of 45°C.

From the results in Tables 2 and 3, it can be seen that the immersion time of 60 min was the most efficient in osmotic dehydration. Dehydration with the osmotic agent OD1 (10% NaCl and 50° Brix sucrose) gave better results in the same condition as compared to the osmotic agent OD2 (50° Brix sucrose).

It is important to use solutions combined to improve efficiency of the osmotic dehydration.

Table 2. Performance of water loss (PU), solid gain (GS), weight loss (RP), dehydration efficiency (Pr) and water activity (a_w) in OD1 solution to carrot slices with 50 to 60ºC.

Condition	T (ºC)	t (min)	PU (%)	GS (%)	RP (%)	P_r
OD1 (10% NaCl + 50°Brix Sucrose)	50	60	65.60	15.74	50.10	4.16
	60		62.65	18.32	45.51	3.42
	50	120	59.43	23.37	48.20	3.26
	60		64.29	18.53	48.25	3.47
	50	180	60.19	25.28	47.25	3.09
	60		67.94	23.80	44.31	2.85
	50	240	61.09	29.99	46.34	2.85
	60		63.91	29.00	45.62	2.20

Table 3. Performance of water loss (PU), solid gain (GS), weight loss (RP), dehydration efficiency (Pr) and water activity (a_w) in OD2 solution to carrot slices with 50 to 60ºC.

Condition	T (ºC)	t (min)	PU (%)	GS (%)	RP (%)	P_r
OD2 (50° Brix Sucrose)	50	60	59.53	14.94	43.54	3.98
	60		46.29	20.83	32.23	2.22
	50	120	64.12	16.82	46.16	3.81
	60		53.76	21.42	36.00	2.51
	50	180	65.08	19.25	45.24	3.38
	60		56.37	25.16	33.36	2.24
	50	240	62.95	22.13	39.23	2.84
	60		54.15	28.49	27.58	1.90

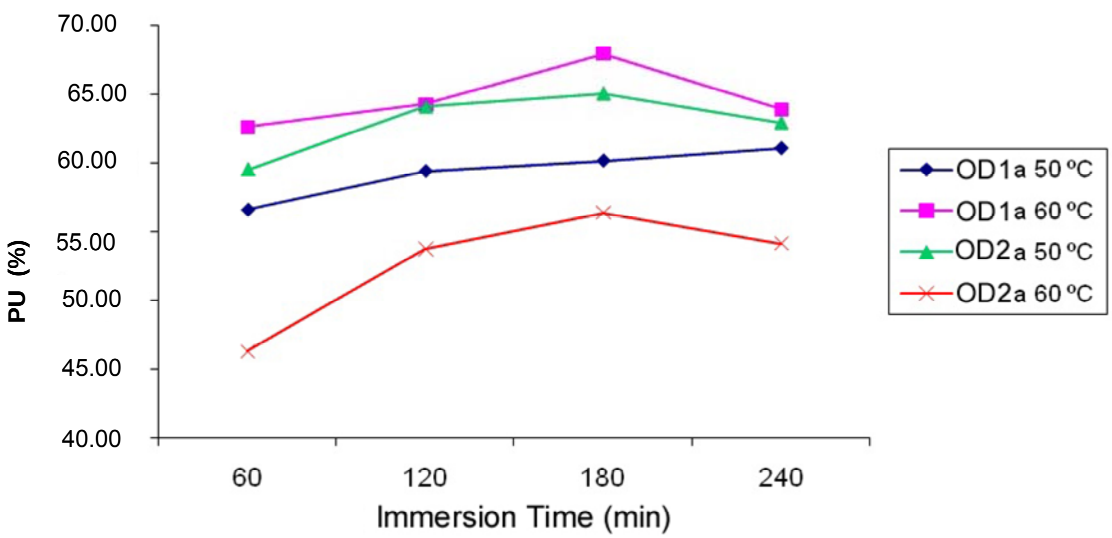

Figure 1. Effect of immersion time (60, 120, 180, 240 min) on water loss (PU) during osmotic dehydration of carrots slices at OD1 and OD2 solution.

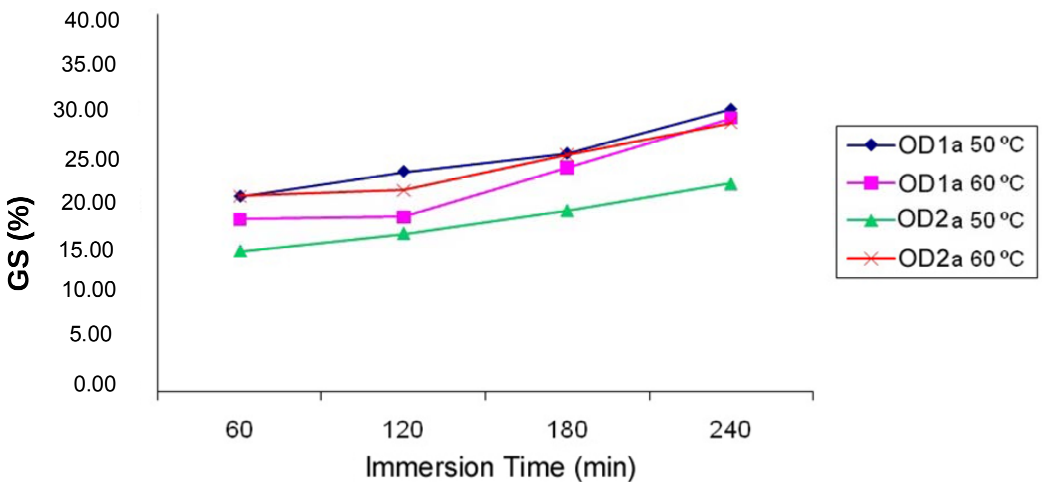

Figure 2. Effect of immersion time (60, 120, 180, 240 min) on solid gain (GS) during osmotic dehydration of carrots slices at OD1 and OD2 solution.

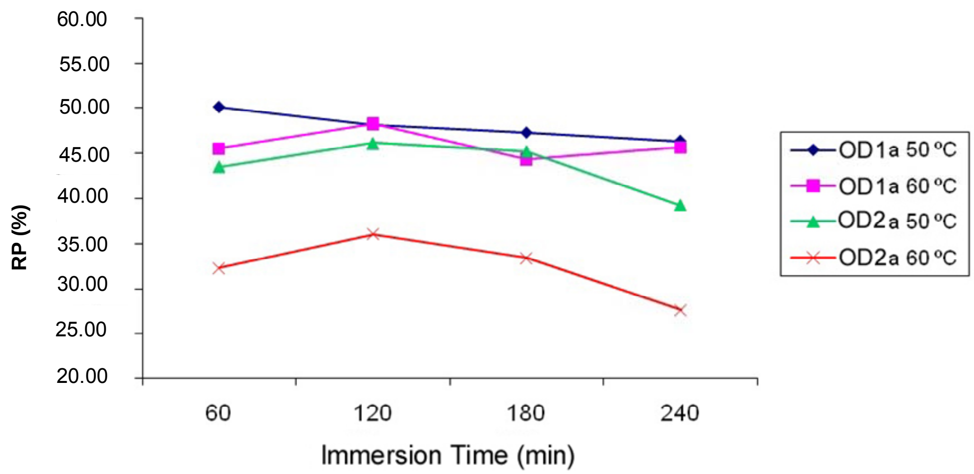

Figure 3. Effect of immersion time (60, 120, 180, 240 min) on weight reduction (RP) during osmotic dehydration of carrots slices at OD1 and OD2 solution.

Several authors use a combination of solutions to achieve better value for PU/GS (Borin et al., 2008; Ayşe and İnci, 2008; Singh and Mehta, 2008).

Comparison between osmotic agents

Figures 1, 2, 3 and 4 show the variation of moisture loss (PU), solid gain (GS), weight reduction (RP) and efficiency (Pr) in dehydrated carrot slices in different immersion times with osmotic agents OD1 and OD2 at 50 and 60°C, using the data from Tables 2 and 3.

Figure 1 shows that the greatest loss of moisture (PU) occurs in slices of carrots treated with the osmotic agent OD1 at 60°C. There is an increase in PU with increasing immersion time, which is consistent with the literature studied (Borin et al., 2008; Rastogi et al., 1997; Amami et al., 2007). The highest rates of PU are located in time of 180 min. Result in Figure 2 was observed in all treatments that was a solid gain increase with the immersion time increment. Carrots immersed in OD1 solution showed the highest solids gain (GS) at 50°C and immersion time of 240 min. In the first hour of drying the dehydrated slices in a solution at 50°C OD1 and OD2 dehydrated with a solution at 60°C showed similar GS; with increasing immersion time these values differ. Sodium chloride for presenting a low molecular weight increases outflow of water from the slices to the solution, and the input solid solution for the carrot slices. This is explained by the fact that low molecular weight substances such as salt can easily penetrate into the food, favoring the solid gain (Borin et al., 2008; Singh et al., 2007a). Figure 3 shows that the solution OD2 in tem-

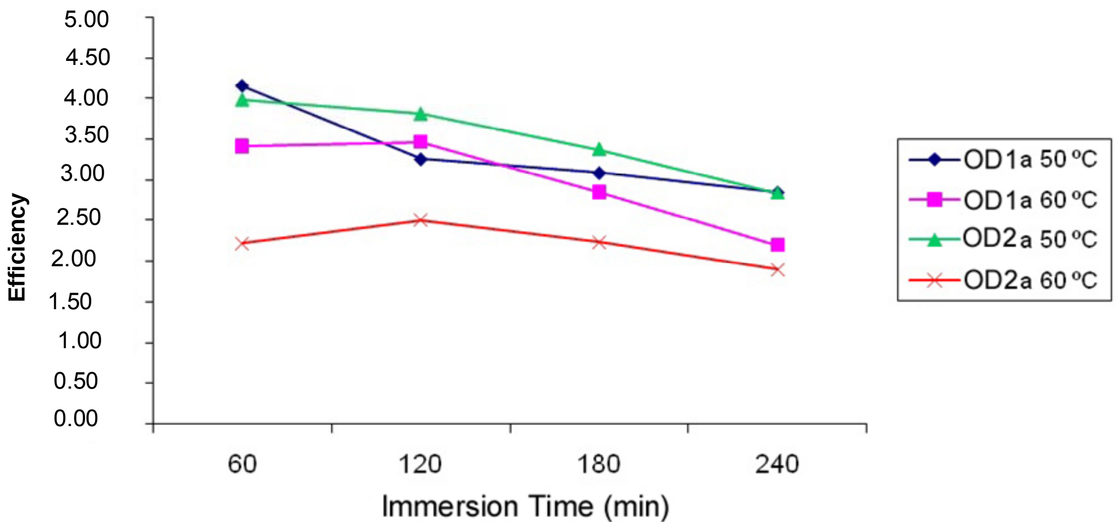

Figure 4. Effect of immersion time (60, 120, 180, 240 min) on rate of efficiency during osmotic dehydration of carrots slices at OD1 and OD2 solution.

perature of 60°C resulted in less weight reduction (RP), while the solution OD1 promoted the highest levels of RP at both temperatures. This is due to be favored by impregnating solution consisting of low molecular weight substances, and the removal of water facilitated by compounds of high molecular weight. Low molecular weight substances can easily penetrate into the food, they are small, and thus favor the solid gain. In contrast, solutions containing high molecular weight, provide favorable conditions for weight reduction. OD1 solution is formed by two compounds, sucrose, high molecular weight and low molecular weight NaCl, favoring the solid gain (GS) and weight reduction (RP). Figures 3 and 4 shows that OD1 immersion in the solution at 50°C provided the best results in 60 min immersion, being the more efficient dehydration.

Conclusion

The pre-dehydration of carrot slices in 10% solution of NaCl and sucrose, for the immersion time of 60 min and 50°C showed the best results. The decrease of the initial water promoted by osmotic dehydration favored the production of carrot slices with intermediate levels of water, requiring additional drying.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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