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Effect of temperature and concentration of osmotic solution on moisture loss and solid gain during osmotic dehydration of carrot

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Abstract
The effect of temperature and osmotic solution concentration on solid gain and moisture loss drying characteristics of carrot were studied. The moisture loss and solid gain increased with increase in salt and sugar concentration and temperature. The moisture loss by carrot slices increased non-linearly with increase in duration of osmosis, solution concentrations and temperature. Mass transfer was faster in initial period of osmosis than the later period. Maximum moisture loss was obtained at 60 ºC for osmotically dehydrated carrot (60% sugar, 3% salt) and it ranged from 13.32% to 56.93%. Solid gain increased with duration of osmosis and did not approach the equilibrium after 3hrs of osmotic dehydration. Solid gain at 60 ºC solution temperature for osmotically dehydrated carrot (60% sugar, 3% salt) ranged from 2.34% to 5.86%. 60% sugar and 3% salt concentration with 60 ^{0}C solution temperature was found as an optimum process condition for osmosis with 3 h duration.

Keywords: Osmotic dehydration, solid gain, moisture loss, temperature, concentration

Introduction
Fruits and vegetables comprise of wide range of plant organs which are excellent sources of vitamins, minerals, fiber and carbohydrate. By proper selection, one can achieve a balance of nutrients even for those people who avoid animal sources of vitamins, minerals and carbohydrates. India is the second largest producer of vegetables in the world (ranks next to China) and accounts for about 15% of the world's production of vegetables. During 2017-18, area under vegetable cultivation in India was 10.26 million hectares with 184.40 million tonnes of production level (Horticultural Statistics at a Glance 2018) [5]. The process of impregnating the fruit in hypertonic syrup is called osmotic dehydration in which there is loss of water and gain of solute simultaneously. During the osmotic dehydration process partial dehydration and solute uptake occurs simultaneously. More water than solute usually transfers due to differential permeability of cellular membranes (Mauro and Menegalli 2003) [14]. Osmotic dehydration can be used as a pre-treatment for partial dehydration of fruits and vegetables. This technique also allows the incorporation of certain solutes, without modifying the integrity of the product. The removal of water from solid foods is a form of food conservation, inhibiting the growth of microorganisms, besides preventing a large part of biochemical reactions, which occur while the moisture is present (Park *et al*. 2002) [18]. The osmotic dehydration of fruits, meats and vegetables has been the aim of steady research attention during recent years as a useful method to improve the economics of dehydration processes.

Recently, osmotic dehydration process received more attention due to the consumer demand of minimally processed products. Carrot (*Dancus carota* L.) is cultivated in winter season throughout the world and is is rich in β – carotene, a precursor of vitamin A, thiamine. Iron, vitamin C, lycopene, lutein and sugar (Mondhe *et al*. 2017 and Selvakumar *et al*. 2018) [15, 22]. As it is seasonal and perishable in nature, it can be preserved by means of osmotic dehydration to extend its availability in off season (Sagar *et al*. 2010) [21]. The osmotic dehydration is also economical as compared to traditional drying method because high expenditure in case of conventional way of dehydration for fruits and vegetables (de Silva *et al*. 2013) [4].

The use of osmotic dehydration process in the food industry has several advantages *viz*. quality improvement in terms of colour, flavour, texture, energy efficiency, packaging and distribution cost reduction, no chemical pretreatment, provide required product stability and retention of nutrients during storage (Salbani *et al*. 2002) [20].
The rate of water loss and solids gain depends on several factors such as solution concentration, its temperature, contact time, level of agitation, sample size and geometry and solution/food ratio (Lerici *et al*. 1985) [13]. Solute choice and concentration depend on several factors, namely the effect on organoleptic quality properties, solute solubility, cell membrane permeability, its stabilizing effect and cost. The two most common solutes sugars and salts with relevance for sucrose and sodium chloride are used for osmotic treatment. Sugar is added to prevent the bleaching effect of salt (Jackson and Mohammed 1971) [8]. Previous workers have also pointed out the effectiveness in combining both solutes to obtain a maximum water loss with low solids gain by the product without significantly affecting product taste. Little information is available on systemic work of osmotic dehydration of carrots as influenced by process parameters. Therefore, an experiment was conducted to study the effect of temperature and osmotic solution concentration on solid gain and moisture loss during osmotic dehydration of carrot.

Material and Methods

Sample preparation

Fresh carrots procured from local market of Meerut, UP, were washed, graded and peeled followed by washing and slicing (10 mm thickness). Weighing of prepared samples of carrots were done and used for osmotic dehydration in binary mixture of sugar and salt solutions using solution to sample ratio 1:5. Fifty gram sample was taken with the help of electronic balance for osmosis and initial moisture content was determined for the same sample. Salt concentrations were chosen as 1, 2 and 3% by weight. Sugar concentration was kept at 40, 50 and 60%. Higher sugar concentration as recommended by (Islam and Flink 1982) [6] was not considered because preliminary trials in the present study indicated that this did not result in substantial advantage over 60% sugar concentration in respect of the extent of moisture loss related to the resultant sugar gain. Three levels of osmotic solution temperature (40, 50 and 60^{0}C) were considered with three replication of experiment.

Osmotic Dehydration

For each replication of an experiment, 50 gm prepared sample immersed in 250 ml osmotic solution was taken in 400 ml beaker. Nine beakers were taken for taking sample for dehydration at 40 ^{0}C each having different sugar and salt solution for different time intervals (0, 15, 30, 45, 60, 90, 120,150 and 180 min). Likewise, other samples were taken at 50 ^{0}C and 60 ^{0}C. The temperature was maintained with the help of water bath. The sample solution was agitated to reduce the mass transfer resistance at the surface of the carrots and for good mixing and close temperature control in the osmotic medium**.** After each time interval of osmosis, samples were removed from the osmotic solution. During experimentation, it was assumed that the amount of solids (sugar, acids, minerals and vitamins) coming out of products enter into the medium as negligible. Although, these solids may be recognized as affecting the organoleptic and nutritional characteristics of the product. Osmotic dehydration was carried out from 0 to 180 min with varying time interval to investigate kinetics at each experimental condition. Five gram sample was taken from each sample for determination of moisture loss and solid gain. The moisture loss and solid gain were computed on the basis of mass balance.

Determination of Process Parameters

Moisture content

Moisture content was determined by hot air oven method recommended by Ranganna (2001) [19] for fruits and vegetables which had successfully been used for potato, carrot, etc. (Lenart and Flink 1984) [12]. Samples of 5 gm each were dried at 110 ^{0}C in oven for 16 to 18 hours. Weighing of sample was performed in petri plates by electronic balance of 0.0001g accuracy and 150 gm capacity. Hot air oven was thermostatically controlled with an accuracy of ±1.0 ^{0}C. Moisture content (MC) was calculated using following equation:

MC % (w.b.) = weight of moisture / weight of the sample

$$\text{MC \% (w.b.)} = \frac{(W+W_1) - W_2}{W} \text{x}100$$

Where,
W = Net weight of sample taken, g
W_1= Weight of the dish, g
W_2= Weight of dish and oven dried sample, g

Moisture loss

Based on review of earlier works (Lenart and Flink 1984) [12], the moisture loss (percentage) was characterized using the following equation.

$$\text{Moisture loss (\%)} = \frac{\text{(Weight of initial moisture – weight of final moisture)}}{\text{Initial weight of sample}} \text{x}100$$

Solid gain

The solid gain percentage was measured by the following equation as suggested by Lenart and Flink (1984) [12].

$$\text{Solid gain (\%)} = \frac{\text{(weight of final solid – weight of initial solid)}}{\text{Initial weight of sample}} \text{x}100$$

Statistical Analysis

The experimental drying data were graphically analyzed in terms of moisture loss, and solid gain with drying time. The experimental data was analyzed with the help of spread sheet (EXCEL) software packages on personal computer.

Results and Discussion

Effect of temperature and osmotic solution concentration on moisture loss during osmotic dehydration

Immersion in 40% sugar + 1%, 2%, 3% salt, 50% sugar + 1%, 2%, 3% salt and 60% sugar + 1%, 2%, 3% salt solution held at 40 ^{0}C

The moisture loss by carrot during osmosis as calculated by mass balance is given in the Table 1**.** It was observed that the moisture loss from the sample when immersed in 40% sugar + 1%, 2%, 3% salt, 50% sugar + 1%, 2%, 3% salt and 60% sugar + 1%, 2%, 3% salt solution held at 40^o C temperature for 0, 15, 30, 45, 60, 90, 120,150, 180 minutes respectively was found to be in range of 4.56 - 23.93 for 40% sugar and 1% salt, 5.10- 24.90 for 40% sugar and 2% salt, 5.96- 26.35 for 40% sugar and 3% salt, 6.25-32.69 for 50% sugar and 1% salt, 7.03-34.81 for 50% sugar and 2% salt, 7.66- 36.23 for 50% sugar and 3% salt, 8.11-43.31 for 60% sugar and 1% salt, 9.1- 45.12 for 60% sugar and 2% salt and 9.98- 46.23 percent for 60% sugar and 3% salt. The moisture loss by carrot slices increased non-linearly with duration of osmosis at all solution concentrations and the mass transfer was faster in initial period of osmosis than the later period. This is due to rise on fruit membrane permeability caused by higher temperatures which promotes swelling and plasticization of cell membrane, favouring mass transfer (Lazarides *et al*. 1995) [10]. Higher temperatures promote faster water loss through swelling and plasticizing of cell membranes as well as the better water transfer characteristics on the product surface due to lower viscosity of the osmotic medium (Lazarides *et al*. 1995) [10]. Thus, high temperature would release trapped air from the tissue resulting in more effective removal of water by osmotic pressure. It was observed form these data that the moisture loss increased nonlinearly with time (Table 1) and sugar salt solution concentration. A high initial rate of water removal followed by a slower removal in the later stages was observed. Several researchers observed similar trends for osmotic dehydration of foods (Kaymak-Ertekin and Sultanoglu, 2000 and Park *et al*. 2002) [9, 18].

Table 1: Moisture loss during osmotic dehydration and different solution concentration of carrot slices at 40 ˚C temperature

Time (min)	40% sugar + 1% salt	40% sugar + 2% salt	40% sugar + 3% salt	50% sugar + 1% salt	50% sugar + 2% salt	50% sugar + 3% salt	60% sugar + 1% salt	60% sugar + 2% salt	60% sugar + 3% salt
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	4.56	5.10	5.96	6.25	7.03	7.66	8.11	9.10	9.98
30	9.23	10.20	10.54	11.6	12.32	13.64	14.55	15.86	17.32
45	12.89	13.45	14.69	16.16	17.26	18.62	20.84	22.32	24.27
60	15.97	16.56	17.86	20.43	21.49	23.41	26.33	27.79	29.35
90	18.89	19.36	20.83	23.68	25.57	27.54	31.06	32.82	34.54
120	20.66	21.43	23.25	26.96	29.15	30.74	36.05	37.41	38.74
150	22.33	23.52	24.89	29.97	32.21	33.64	40.08	41.69	42.98
180	23.93	24.90	26.35	32.69	34.81	36.23	43.31	45.12	46.23

Immersion in 40%sugar + 1%, 2%, 3% salt, 50% sugar + 1%, 2%, 3% salt and 60% sugar + 1%, 2%, 3% salt solution held at 50 ^{0}C

The water loss by carrot slices during osmosis was measured by mass balance and is given in the Table 2. It was observed that the moisture loss from the sample when immersed in 40% sugar + 1%, 2%, 3% salt, 50% sugar + 1%, 2%, 3% salt and 60% sugar + 1%, 2%, 3% salt solution held at 50 ºC temperature for 0, 15, 30, 45, 60, 90, 120,150, 180 minutes respectively was found to be 5.56- 26.62 for 40% sugar and 1% salt, 6.05- 29.63 for 40% sugar and 2% salt, 7.1- 32.82 for 40% sugar and 3% salt, 8.12- 37.52 for 50% sugar and 1% salt, 9.00- 39.98 for 50% sugar and 2% salt, 9.66- 42.03 for 50% sugar and 3% salt, 10.01- 45.94 for 60% sugar 1% salt, 10.03-47.33 for 60% sugar and 2% salt and 11.09-49.23percent for 60% sugar and 3% salt. The moisture loss by carrot slices increased non-linearly with duration of osmosis at all solution concentrations and the mass transfer was faster in initial period of osmosis than the later period. A high initial rate of water removal followed by a slower removal in later stages was observed.

Table 2: Moisture loss during osmotic dehydration and different solution concentration of carrot slices at 50 ˚C temperature

Time (min)	40% sugar + 1% salt	40% sugar + 2% salt	40% sugar + 3% salt	50% sugar + 1% salt	50% sugar + 2% salt	50% sugar + 3% salt	60% sugar + 1% salt	60% sugar + 2% salt	60% sugar + 3% salt
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	5.56	6.05	7.10	8.12	9.00	9.66	10.01	10.03	11.09
30	9.23	10.23	11.3	12.89	14.24	15.58	16.52	17.52	18.32
45	13.29	14.39	15.56	17.93	18.98	20.32	22.93	24.33	25.67
60	16.47	17.98	19.56	22.35	23.81	25.51	29.3	30.53	32.53
90	19.09	21.09	23.42	27.04	28.78	30.29	34.60	36.30	38.29
120	21.56	24.00	26.90	31.00	33.24	35.14	39.2	40.86	43.04
150	24.23	27.04	29.94	34.49	37.24	39.24	43.00	44.68	46.57
180	26.62	29.63	32.82	37.52	39.98	42.03	45.94	47.33	49.23

Immersion in 40%sugar + 1%, 2%, 3% salt, 50% sugar + 1%, 2%, 3% salt and 60% sugar + 1%, 2%, 3% salt solution held at 60ºC

From the obtained data as shown in Table 3, it was observed that the moisture loss from the sample when immersed in 40% sugar + 1%, 2%, 3% salt, 50% sugar + 1%, 2%, 3% salt and 60% sugar + 1%, 2%, 3% salt solution held at 60 ºC temperature for 0, 15, 30, 45, 60, 90, 120, 150, 180 minutes respectively was found to be 7.86-34.62 for 40% sugar and 1% salt, 8.56- 39.01 for 40% sugar and 2% salt, 9.01- 41.82 for 40% sugar and 3% salt, 10.22- 45.55 for 50% sugar and 1% salt, 11.00- 48.14 for 50% sugar and 2% salt, 11.66- 50.03 for 50% sugar and 3% salt, 12.36- 52.92 for 60% sugar and 1% salt, 12.93- 54.89 for 60% sugar and 2% salt and 13.32-56.93 percent for 60% sugar and 3% salt.

Overall from the above discussions, it was observed from the Tables 1 to 3, that the loisture loss increased with temperature and concentration of osmotic solution.

Table 3: Moisture loss during osmotic dehydration and different solution concentration of carrot slices at 60 ˚C temperature

Time (min)	40% sugar + 1% salt	40% sugar + 2% salt	40% sugar + 3% salt	50% sugar + 1% salt	50% sugar + 2% salt	50% sugar + 3% salt	60% sugar + 1% salt	60% sugar + 2% salt	60% sugar + 3% salt
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	7.86	8.56	9.01	10.22	11.00	11.66	12.36	12.93	13.32
30	12.23	13.45	15.08	17.05	18.04	19.58	20.23	21.12	22.72
45	17.29	19.00	20.56	23.65	25.38	27.32	28.54	29.01	30.67
60	21.17	24.10	25.56	29.22	31.81	33.51	35.80	37.10	38.53
90	25.00	28.50	30.42	34.36	36.68	38.39	41.85	43.69	45.29
120	28.56	32.95	35.02	38.44	40.64	42.64	46.27	48.06	50.04
150	31.83	36.21	38.94	42.40	44.64	46.84	49.82	51.98	53.57
180	34.62	39.01	41.82	45.55	48.14	50.03	52.92	54.89	56.93

Immersion in 40%sugar + 1%, 2%, 3% salt, 50% sugar + 1%, 2%, 3% salt and 60% sugar + 1%, 2%, 3% salt solution held at 40 ^{0}C

Effect of temperature and osmotic solution concentration on solid gain during osmotic dehydration

The solid gain by carrot slices during osmosis was calculated by mass balance and is given in Table 4. The solid gain during osmotic dehydration when immersed for 0, 15, 30, 45, 60, 90, 120,150, 180 minutes respectively was found to 0.55-3.01 for 40% sugar and 1% salt, 0.80-3.28 for 40% sugar and 2% salt, 0.95-3.51 for 40% sugar and 3% salt, 1.08-3.98 for 50% sugar and 1% salt, 1.23-4.23 for 50% sugar and 2% salt, 1.44-4.54 for 50% sugar and 3% salt, 1.60-4.86 for 60% sugar and 1% salt, 1.80-5.21 for 60% sugar and 2% salt and 2.00-5.46 percent for 60% sugar and 3% salt.. The solid gain by carrot slices during osmosis increased with increase in osmotic solution concentration.

Table 4: Solid gain during osmotic dehydration of carrot slices at 40˚C temperature

Time (min)	40% sugar + 1% salt	40% sugar + 2% salt	40% sugar + 3% salt	50% sugar + 1% salt	50% sugar + 2% salt	50% sugar + 3% salt	60% sugar + 1% salt	60% sugar + 2% salt	60% sugar + 3% salt
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.55	0.80	0.95	1.08	1.23	1.44	1.60	1.80	2.00
30	1.02	1.20	1.45	1.59	1.79	1.98	2.23	2.5	2.81
45	1.42	1.65	1.89	2.08	2.26	2.48	2.80	3.10	3.38
60	1.80	2.02	2.24	2.5	2.75	2.99	3.31	3.60	3.89
90	2.16	2.38	2.62	2.96	3.18	3.43	3.78	4.10	4.36
120	2.47	2.73	2.97	3.32	3.57	3.86	4.15	4.52	4.78
150	2.78	3.00	3.28	3.68	3.92	4.21	4.53	4.85	5.12
180	3.01	3.28	3.51	3.98	4.23	4.54	4.86	5.21	5.46

Immersion in 40%sugar + 1%, 2%, 3% salt, 50% sugar + 1%, 2%, 3% salt and 60% sugar + 1%, 2%, 3% salt solution held at 50^{o}C

The results are tabulated in Table 5. The solid gain during osmotic dehydration when immersed for 0, 15, 30, 45, 60, 90, 120,150, 180 minutes respectively was found was found to be 0.55-3.5 for 40% sugar and 1% salt, 0.65-3.97 for 40% sugar and 2% salt, 0.83-4.32 for 40% sugar and 3% salt, 1.00-4.82 for 50% sugar and 1% salt, 1.19-5.13 for 50% sugar and 2% salt, 1.34-5.47 for 50% sugar and 3% salt, 1.52-5.92 for 60% sugar and 1% salt, 1.70-6.24 for 60% sugar and 2% salt and 1.94-6.51 percent for 60% sugar and 3% salt. The solid gain by carrot slices during osmosis increased with increase in osmotic solution concentration. The solid gain for 60% sugar and 3% salt at this temperature was found to be maximum.

Table 5: Solid gain during osmotic dehydration and different solution concentration of carrot slices at 50 ˚C temperature

Time (min)	40% sugar + 1% salt	40% sugar + 2% salt	40% sugar + 3% salt	50% sugar + 1% salt	50% sugar + 2% salt	50% sugar + 3% salt	60% sugar + 1% salt	60% sugar + 2% salt	60% sugar + 3% salt
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.51	0.65	0.83	1	1.19	1.34	1.52	1.7	1.94
30	0.98	1.19	1.38	1.58	1.89	2.12	2.3	2.58	2.81
45	1.41	1.71	1.96	2.21	2.51	2.75	3	3.31	3.58
60	1.87	2.19	2.49	2.85	3.21	3.48	3.75	3.98	4.31
90	2.31	2.71	2.98	3.45	3.71	4	4.32	4.59	4.93
120	2.67	3.21	3.48	3.88	4.23	4.53	4.89	5.24	5.51
150	3.1	3.58	3.89	4.33	4.69	5	5.48	5.78	6.08
180	3.5	3.97	4.32	4.82	5.13	5.47	5.92	6.24	6.51

Immersion in 40%sugar + 1%, 2%, 3% salt, 50% sugar + 1%, 2%, 3% salt and 60% sugar + 1%, 2%, 3% salt solution held at 60 ^{0}C

The total solid gain by carrot slices during osmosis was calculated by mass balance and is given in Table 6. The solid gain during osmotic dehydration when immersed for 0, 15, 30, 45, 60, 90, 120,150, 180 minutes respectively was found to be 0.29-2.51 for 40% sugar and 1% salt, 0.45-2.72 for 40% sugar and 2% salt, 0.80-3.45 for 40% sugar and 3% salt, 1.00-3.63 for 50% sugar and 1% salt, 1.09-4.01 for 50% sugar and 2% salt, 1.23-4.60 for 50% sugar and 3% salt, and 1.46-5.23 for 60% sugar and 1% salt, 2.00-5.52 for 60% sugar and 2% salt and 2.34-5.86 percent for 60% sugar and 3% salt. It was revealed that the solid gain increased with duration of osmosis and did not approach the equilibrium after 3 hour of osmotic dehydration it also increased with the concentration of the solution except few points. This was because of the increased concentration difference between carrot slices and solution. The solid gain also increased with increase in solution temperature. It may be due to collapse of the cell membrane at higher temperatures. Similar results have also been reported for peas and blueberries respectively.

In several studied, it has been concluded that cell membrane destruction at higher temperature lead to higher solid uptake by plant based materials during osmosis treatment (Tortoe *et al*. 2007 and Correa *et al*. 2010) [23, 3]. Previous research findings revealed higher amout of water loss and solid gain in more concentrated solution due to the greater osmotic pressure gradients (Ispir and Togrul 2009) [7]. In addition, increasing temperature caused a reduction on solution viscosity, lowering external resistance to mass transfer and resulted into easier water and solutes transport. Similar results were obtained by Mundada *et al*. 2011 [16] in osmotically dehydrated pomegranate arils. The experimental values for water loss and solid gain under different treatment conditions showed that water removal was always higher than the solid gain and it was in agreement with the results of other workers (Lenart 1996) [11].

Standardization of optimum process condition of osmotic dehydration of carrots

Results of our study indicates that the moisture loss was more in solution of 60% sugar and 3% salt with allowable solid gain at 60 ^{0}C. However, greater solid gain can result in sucrose layers on carrot slices which further affect the product acceptability. This might be due the fact that salt molecule could diffuse more in the fruit tissue than sucrose molecule due to lower molecular weight, which was in close agreement with the results of Ade-Omowaye (2002) [1] and Chang *et al*. (2003) [2]. The decrease in salt gain was the result of the possible formation of a concentration gradient around the fruit tissue by sucrose, which hindered the entrance of salt in to the product. The results were consistent with the findings of Ade-Omowaye *et al*. (2002) [1] and Ozen *et al*. (2002) [17] for osmotic dehydration of red paprika and green pepper in sugar-salt mixture solution. Therefore, for acceptable quality, the solid gain in carrot slices should be less. The moisture loss at 5.86% solid gain was higher at 60% sugar and 3% salt concentration than salt concentrations at all temperature levels. Therefore, 60% sugar and 3% salt concentration with 60 ^{0}C solution temperature may be chosen as an optimum process condition for osmosis with 3 h duration. The higher temperatures at 60% sugar and 3% salt concentrations even require very less time for same moisture loss and solid gain but are not used because of energy requirement for heating osmotic solution as well as the disadvantage of quality deterioration of produce due to high temperature (Lenart and Flink 1984) [12].

Table 6: Solid gain during osmotic dehydration and different solution concentration of carrot slices at 60 ˚C temperature

Time (min)	40% sugar + 1% salt	40% sugar + 2% salt	40% sugar + 3% salt	50% sugar + 1% salt	50% sugar + 2% salt	50% sugar + 3% salt	60% sugar + 1% salt	60% sugar + 2% salt	60% sugar + 3% salt
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.29	0.45	0.80	1.00	1.09	1.23	1.46	2.00	2.34
30	0.59	0.90	1.20	1.40	1.59	1.79	2.05	2.30	2.68
45	1.01	1.30	1.45	1.78	1.89	2.32	2.64	2.87	3.01
60	1.35	1.55	1.78	2.12	2.41	2.82	2.91	3.50	3.88
90	1.65	1.85	2.21	2.46	2.68	3.25	3.63	3.87	4.03
120	2.01	2.18	2.78	2.95	3.21	3.85	3.93	4.72	4.98
150	2.23	2.47	3.02	3.30	3.61	4.21	4.71	5.02	5.42
180	2.51	2.72	3.45	3.63	4.01	4.60	5.23	5.52	5.86

Conclusions

Study revealed the following conclusions:

- The effect of temperature and osmotic solution concentration on moisture loss during osmotic dehydration revealed that the moisture loss by carrot slices increased non-linearly with increase in duration of osmosis, solution concentrations and temperature and mass transfer was faster in initial period of osmosis than the later period.
- Maximum moisture loss was obtained at 60 ^{0}C for osmotic dehydrated carrot of 60% sugar and 3% salt concentration and it ranged from 13.32% to 56.93%.
- Solid gain increased with duration of osmosis and did not approach the equilibrium after 3 hour of osmotic dehydration. Solid gain at 60 ^{0}C solution temperature for osmotic dehydrated carrot of 60% sugar and 3% salt concentration ranged from 2.34% to 5.86%.
- 60% sugar and 3% salt concentration with 60 ^{0}C solution temperature may be chosen as an optimum process condition for osmosis with 3 h duration.

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