Research Article

Effect of Osmotic Treatments on Weight Reduction, Water Loss, Solid Gain, Moisture, Total Solids, Yield and Drying ratio of Carrot (*Daucus carota* L.) slices

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Abstract

Osmotic dehydration (OD) conditions of carrot slices were optimized using sucrose concentration (40-70°B), immersion time (20-40 h) and process temperature (35-55 °C) for maximum weight reduction (WR), water loss (WL), minimum solute gain (SG) and minimum dehydration ratio (DR) as response variables. Carrot slices pre-treated with 70°Brix syrup for 40 hours resulted in maximum weight reduction (11.24%), water loss (49.29%) and solid gain (38.05%). Pretreatments with low sugar syrup concentration of 40 and 50°Brix at both osmotic duration 20 and 40 hours resulted in an overall weight gain as values for weight reduction (WR) were negative (-9.37 to -29.00%), as well as an increase in solid gain and water loss in osmotically dehydrated carrot slices. Different osmotic treatments significantly affected weight reduction (WR), water loss and solid gain in carrot slices after osmosis. Weight reduction ranged from -29.00 to 11.24 per cent, weight loss from 1.33 to 49.29 per cent and solid gain from 20.70 to 38.05 per cent. Carrot slices subjected to 70°Brix syrup for 40 hours osmosis recorded maximum yield (58.33%) and lowest drying ratio (1.71:1) followed (58.26%) by 60°Brix syrup for 20 hours osmosis and (57.17%) 60°Brix syrup for 40 hours osmosis.

Keywords: Carrot, osmotic dehydration, lye peel, brix, syrup, organoleptic

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Introduction

Carrot (*Daucus carota* L.) belongs to the family Umbelliferae. It is a very popular winter vegetable and one of the important root crops cultivated throughout the world for its fleshly delicious, attractive edible roots [1]. It is the most widely grown root vegetable crop in India wherein it occupies an area of 79, 000ha with a production of 1.254mt and an average yield of 145.83q/ha [2]. In recent years, the consumption of carrot and its products have increased steadily due to their recognition as an important source of natural antioxidants besides, anticancer activity of β-carotene being a precursor of vitamin A. Though there is sufficient production of carrot in India, yet its availability is scanty for greater part of the year. Due to seasonal variations in price of carrots, the preparation of some carrot products is restricted to main season when it is available in plenty. Carrot being a perishable and seasonal crop, it is not possible to readily make it available throughout the year. So, osmotic dehydration of carrot during the main growing season is one of the important alternatives for preservation. It can also be used for making value added products throughout the year specially vitamin A rich functional products for children's [3]. According to the WHO vitamin-A deficiency blinds, or partially blinds, over 3, 00, 000 children a year worldwide. Hence, osmotically dehydrated carrot products can be utilized for mitigation of vitamin A associated deficiency disease. There are several techniques for processing of fruits and vegetables. Among them, dehydration of perishables like fruits and vegetables are best suited under Indian conditions [4-7]. In recent years, osmotic dehydration has been widely used for fruits and vegetables preservation due to its potential to keep sensory and nutritional properties similar to the fresh fruits and enrich products with some compounds, like the functional foods [8-9]. Osmotic dehydration (OD) is a method for the partial dehydration of water-rich foods such as fruit and vegetable, which involves immersing samples for definite duration in a concentrated solutions of sugar or salt, with a water activity (aw) lower than that of the foodstuff [10-13]. The osmotic pressure difference between plant cells and surrounding concentrated solution supported the driving force of diffusion water [14]. Osmotic dehydration of carrot seems to be convenient alternative for long term storage as compared to cold storage or canned products. The pre-treatments and methods of dehydration have been reported to influence the quality of dried products [14-16]. Not much information is available on the preparation of osmotically dehydrated carrot slices grown in India. From the available literature it was observed that most of the osmotic dehydration research have been done on fruits and vegetables focused on mass transfer kinetics studies. Systematic work on carrot with varying osmotic time and concentration is required to be generated. Hence, in recognition of the above needs and in order to explore the possibility of preparation of osmotically dehydrated carrot slices the present investigation was undertaken to study the mass transfer changes, moisture, total solids, yield and drying ratio of osmotically dehydrated carrot slices.

Material and Methods

Raw material

Carrots were procured from K.R. Market in Bangalore. Fresh carrots with uniform colour, size shape, were selected, weighed, washed, lye peeled (5% NaOH boiling aqueous solution for 2 min). Lye peeled carrots were thoroughly washed with tap water, weighed and cut into 3-4 mm thick slices after removing top and bottom portion. Prepared slices were again weighed to record the yield recovery of fresh slices to be used for osmotic dehydration. After words, slices were subjected to low- temperature-long-time (LTLT) blanching for 30 min at 60°C in 5 per cent aqueous solution of sugar. Blanched carrots were air cooled and used for osmotic dehydration.

Treatment

Prepared carrot slices (1 kg each) were dipped in 40, 50, 60 and 70°Brix sugar syrup containing 0.3 per cent of citric acid and 0.1% each of potassium metabisulphite (KMS) and sodium metabisulphite (NaMS) in 1:2 fruit to syrup ratio and allowed to undergo osmosis for 20 and 40 h at room temperature (20-30^{o}C). Slices were drained and rinsed with cloth to remove adhering syrup. One lot of slices without osmotic dip (untreated) was sulphited in 0.1% KMS for 10 min to serve as control. Treatment details are as follows:

T_1: Osmosis in 40°Brix sugar syrup for 20 h
T_2: Osmosis in 40°Brix sugar syrup for 40 h
T_3: Osmosis in 50°Brix sugar syrup for 20 h
T_4: Osmosis in 50°Brix sugar syrup for 40 h
T_5: Osmosis in 60°Brix sugar syrup for 20 h
T_6: Osmosis in 60°Brix sugar syrup for 40 h
T_7: Osmosis in 70°Brix sugar syrup for 20 h
T_8: Osmosis in 70°Brix sugar syrup for 40 h
T_9: Control (dip in 0.1% KMS for 10 min)

Dehydration

Osmosed slices from different treatments were spread on stainless steel trays and were dehydrated in a cabinet drier at 55 to 60°C on to till the slices reached the desired moisture content and product quality. The dried carrot samples were packed in plastic punnets.

Rate of mass transfer

To predict water loss (WL) and sugar gain (SG) during osmotic concentration, the phenomenon of mass transfer was studied. The weight reduction (WR) and sugar gain (SG) percentages were calculated as per the method of Sharma et al. (2004). The using of various formulas as following

$$\text{Weight Reduction (WR\%)} = \frac{\text{Initial weight – weight at time ‘t’}}{\text{Initial weight}} \times 100$$

$$\text{Water Loss (WL\%)} = \frac{\text{Initial moisture – moisture at time ‘t’}}{\text{Initial moisture}} \times 100$$

$$\text{Solid Gain (SG\%)} = \text{Moisture loss (\%) – weight loss (\%)}$$

$$\text{Slice recovery (\%)} = \frac{\text{Weight of prepared carrot slices}}{\text{Weight of fresh carrot slices}} \times 100$$

$$\text{Dehydrated Yield (\%)} = \frac{\text{Weight of dehydrated carrot slices}}{\text{Weight of fresh carrot slices}} \times 100$$

Moisture content

Moisture content of fresh slices, osmosed slices, as well as osmotically dehydrated samples were determined on percentage basis. Five grams of sample was taken in a pre-weighed China dish and kept in a hot air oven for overnight and then the weight was recorded using electronic balance. Moisture content was determined on fresh weight basis. Total solids were calculated by subtracting moisture content from 100.

$$\text{Moisture content (\%)} = \frac{\text{Moisture loss}}{\text{Sample weight}} \times 100$$

Statistical analysis

The experiment was carried out by using a Completely Randomized Block Design (CRBD) with 9 treatments and 3 replications. The data for variations in different physico-chemical attributes were analyzed by using Analysis of variance (ANOVA) technique.

Results and Discussion

Mass transfer

Among different osmotic treatments, significantly highest weight reduction of 11.24 per cent was recorded in treatment T_8 (70°Brix syrup for 40 hours) which was non-significant (11.22 per cent) followed by T_7 (70°Brix syrup for 20 hours) (**Figure 1a**), whereas weight reduction was only 4.05 per cent in treatment with 60°Brix syrup for 40 hours (T_6). In contrast, pre-treatments with low sugar syrup concentration of 40 and 50°Brix at both osmotic duration 20 and 40 hours resulted in an overall weight gain as values for weight reduction were negative. Weight reduction (WR) values were -29.00 per cent in slices treated with 50°Brix syrup for 40 hours (T_4) followed by (-26.12%) 40°Brix syrup for 20 hours (T_2), (-17.70%) 40°Brix syrup for 20 hours (T_1) and (-9.37%) 50°Brix sugar syrup for 20 hours (T_3). Pre-tretments with low sugar syrup concentration of 40 and 50°Brix at both osmotic duration 20 and 40 hours resulted in an overall weight gain in carrot slices as values for weight reduction were negative. Carrot slices treated with 50°Brix with 40 hours (T_4) recorded weight reduction value in -29.00 per cent, water loss 1.67 per cent and solid gain 30.67 per cent. Significantly highest (**Table 1**) solid gain (SG) 38.05 per cent was recorded in slices treated with 70°Brix sugar syrup for 40 hours (T_8), followed by T_6 (35.26%), T_7 (33.44%), T_5 (32.92%), T_4 (30.67%), T_3 (28.11%), T_2 (27.45%) while it was lowest 20.70% in the treatment T_1 (40°Brix for 20 hours) (Figure 1b). Different osmotic treatments significantly affected (Table 1) water loss (WL) in carrot slices after osmosis. Further, osmotic pretreatments with 60 and 70°Brix resulted in higher water loss and maximum values of 49.29 per cent was recorded in treatment T_8 (70°Brix syrup for 40 hours) significantly followed by T_7 (44.66%), T_6 (39.31%), and T_5 (32.84%), T_3 (18.74%), while water loss values were lower in T_1 (3.00%), T_4 (1.67%) and T_2 (1.33%). In general, it was also observed that an increase in the duration of osmosis or syrup concentration resulted in the increase in water loss as shown in Figure 1c. Significant differences were also found (Table 1) in the moisture content of osmosed slices as influenced by different osmotic treatments. Similar observation has been made in apple fruit [17-18]. On the other hand carrot slices treated with 70°Brix for 40 hours (T_8) recorded maximum weight reduction (11.24%), water loss (49.29%) and solid gain (38.05%). Among different fruits, variability is mainly related to the tissue compactness, initial insoluble and soluble solids content, inter cellular spaces and enzymatic activity of the fruit [19-20]. There was 27.5 to 37.0 per cent loss in initial weight of mango slices due to osmosis in 70°Brix sugar syrup for 24 hours at 30°C [21-23]. Variation in mass reduction, solid gain and water loss were observed in different varieties of apricot [25].

Moisture and Total Solids

Among treatments, lowest moisture content 44.49 per cent was observed in slices treated with 70°Brix sugar syrup for 40 hours (T_8) closely followed by T_7, T_6 and T_5, while highest value (71.84%) was observed in the treatment T_1 (40°Brix sugar syrup for 20 hours). Variation in moisture content in osmosed carrot slices was mainly due to loss of water as well as uptake of solids, which is supported by the findings during the investigation [25-27]. Various osmotic treatments significantly affected (Table 1) total solids content in osmosed slices. Among treatments, lowest total solids content (28.16%) was observed in the treatment T_1 (40°Brix sugar syrup for 20 hours) and highest value (55.51%) was found with 70°Brix sugar syrup for 40 hours (T_8) closely followed by T_7, T_6 and T_5. This is also in conform that osmotic dehydration removes 30-50% of the water from fresh ripe fruits like mangoes, pineapple, sapota, papaya, guava and jackfruit [28-33].

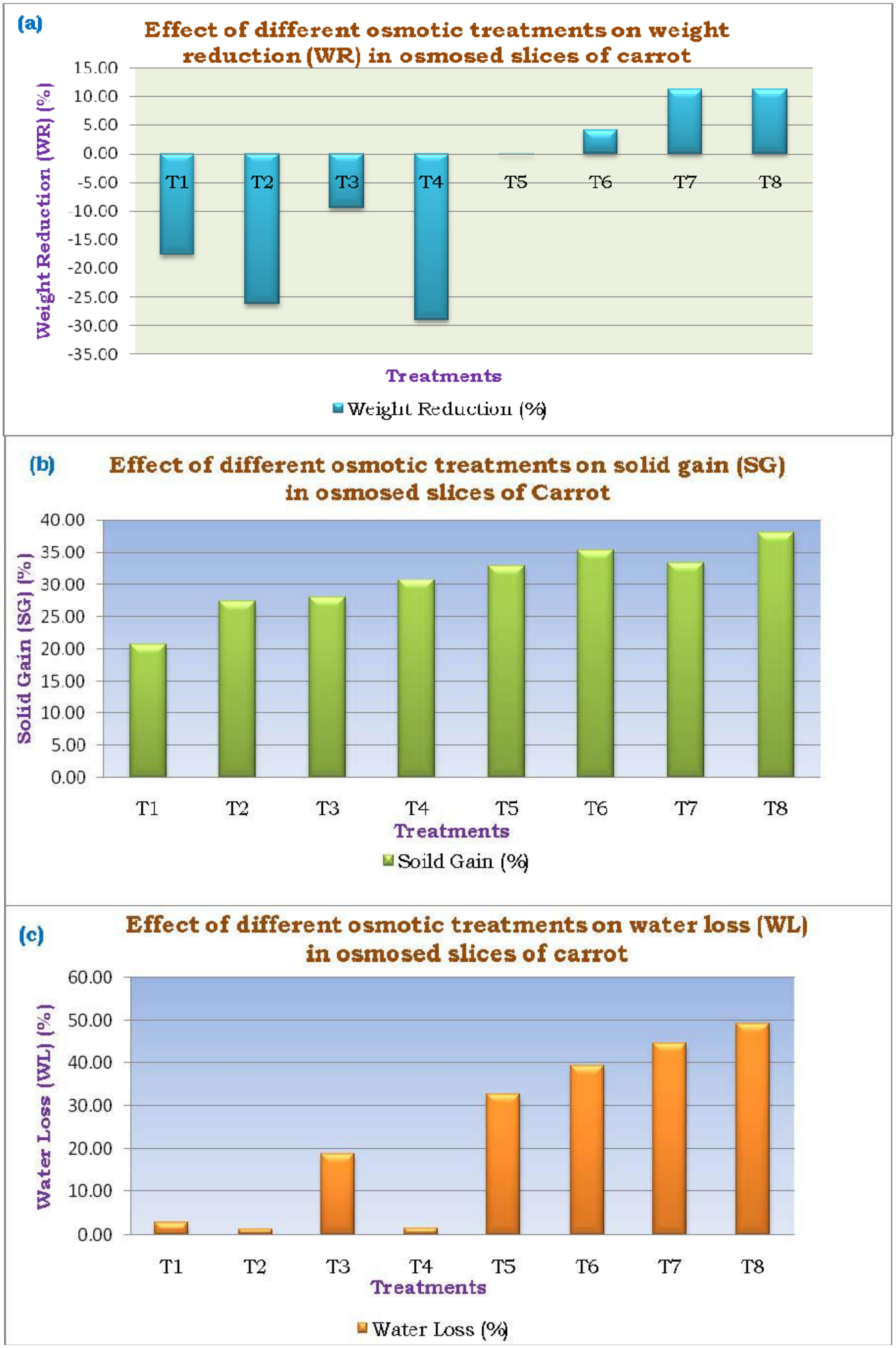

Figure 1 (a) Effect of different osmotic treatments on weight reduction (WR), (b) Effect of different osmotic treatments on solid gain (SG) in osmosed slices of carrot, (c) Effect of different osmotic treatments on water loss (WL) in osmosed slices of carrot

Table 1 Effect of osmotic treatments on weight reduction (WR), solid gain (SG), water loss (WL), moisture and total solids in osmosed slices of carrot

Treatment	Weight Reduction (WR) (%)	Solid Gain (SG) (%)	Water Loss (WL) (%)	Moisture (%)	Total Solids (%)
T_1 40°B 20h	-17.70^e	20.70^f	3.0^f	71.84^a	28.16^f
T_2 40°B 40h	-26.12^f	27.45^e	1.33^g	69.41^b	30.59^e
T_3 50°B 20h	-9.37^d	28.11^e	18.74^e	63.08^c	36.92^d
T_4 50°B 40h	-29.00^g	30.67^d	1.67^g	61.62^c	38.38^d
T_5 60°B 20h	-0.08^c	32.92^c	32.84^d	54.47^d	45.53^c
T_6 60°B 40h	4.05^b	35.26^b	39.31^c	48.45^e	51.55^b
T_7 70°B 20h	11.22^a	33.44^{bc}	44.66^b	48.17^e	51.83^b
T_8 70°B 40h	11.24^a	38.05^a	49.29^a	44.49^f	55.51^a
CD at 5%	1.13	1.88	1.22	1.82	2.32
S.EM±	0.16	0.266	0.17	0.26	0.33

*Values with common superscript do not differ significantly

Yield and Drying ratio

Various osmotic pre-treatments significantly affected the yield of osmotically dehydrated carrot slices. Significantly highest yield of 58.33 per cent was recorded in pre-treatment with 70°Brix sugar syrup for 40 hours (T_8) which was non-significantly followed by T_5 (58.26%) and T_6 (57.17%) while lowest yield 7.37 per cent was observed in untreated control samples (T_9). Final dried yield of osmotically dehydrated carrot slices ranged from 40.96 to 58.33 per cent. Carrot yield was increasing with the concentration of sugar syrup from 40 to 70°Brix and duration of osmosis from 20 to 40 hours while in general the drying ratio decreased by increasing the syrup brix. It has been reported that due to increase in the solid gain and the volume reduction of the osmo-dehydrated products there is threefold increase in drier load and process yield [34]. Data given in **Table 2** indicates that different pre-treatments significantly affected the drying ratio of dehydrated carrot slices. Maximum drying ratio 13.88 was observed in case of control (T_9). The drying ratio was minimum 1.71: 1 in sample prepared after osmotic pre-treatment with 70°Brix sugar syrup for 40hr hours (T_8) followed by T_5 and T_6. In general the drying ratio decreased by increasing the syrup brix (Table 2). Further, it has been reported that there was increase in recovery of dried product by osmotic treatments in other fruits like ber, sapota, banana and guava [35].

Table 2 Effect of different osmotic treatments on the yield and drying ratio in osmotically dehydrated slices of carrot

Treatment	Yield (%)	Drying ratio (%)
T_1 40°B 20h	40.96^d	2.44: 1^b
T_2 40°B 40h	49.28^{bc}	2.05: 1^b
T_3 50°B 20h	48.10^c	2.08: 1^b
T_4 50°B 40h	53.92^{ab}	1.85: 1^b
T_5 60°B 20h	58.26^a	1.73: 1^b
T_6 60°B 40h	57.17^{ab}	1.75: 1^b
T_7 70°B 20h	55.42^{ab}	1.81: 1^b
T_8 70°B 40h	58.33^a	1.71: 1^b
T_9 Control	7.37^e	13.88: 1^a
CD at 5%	4.80	1.17
S.EM±	0.64	0.17

*Values with common superscript do not differ significantly

Conclusion

Carrot slices pre-treated with 70°Brix syrup for 40 hours resulted in maximum weight reduction (11.24%), water loss (49.29%) and solid gain (38.05%). Pretreatments with low sugar syrup concentration of 40 and 50°Brix at both osmotic duration 20 and 40 hours resulted in an overall weight gain as values for weight reduction (WR) were negative (-9.37 to -29.00%), as well as an increase in solid gain and water loss in osmotically dehydrated carrot slices. Different osmotic treatments significantly affected weight reduction (WR), water loss (WL) and solid gain (SG) in carrot slices after osmosis. WR ranged from -29.00 to 11.24 per cent, WL from 1.33 to 49.29 per cent and SG from 20.70 to 38.05 per cent. Carrot slices subjected to 70°Brix syrup for 40 hours osmosis recorded maximum yield

(58.33%) and lowest drying ratio (1.71:1) followed (58.26%) by 60°Brix syrup for 20 hours osmosis and (57.17%) 60°Brix syrup for 40 hours osmosis. Therefore, osmotic dehydration of carrot slices has several advantages in comparison to other presently used processes for safe, stable, nutritious, tasty, economical and concentrated food obtained by placing the solid food, whole or in pieces in sugar or salt aqueous solution of high osmotic pressure. Apart from this, problems of marketing, handling and transportation becomes much simpler and carrots could be made available to the consumer throughout the year.

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