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Physico-chemical changes in osmotically dehydrated carrot slices during storage

R Selvakumar and RB Tiwari

Abstract
Process for preparation of carrot slices using osmotic dehydration was standardized. Fresh carrots were washed, lye peeled (5% NaOH for2 min) and slices of 3-4 mm thickness were prepared. The carrot slices was soaked in 40, 50, 60, 70° Brix sugar syrup containing 0.1% citric acid + 0.1% KMS + 0.1% NaMs and control (0.1% KMS for 10 min) respectively. After 20 h and 40 h soaking, drained using cloth and then cabinet drying at 55-60°C for up to 14-15% moisture content was done. The dried products were packed in plastic punnets and stored at ambient condition for 6 months. The physical, chemical and organoleptic changes were monitored for 6 months. The osmo-dried carrot slices prepared 60°Brix sugar syrup containing 0.1% citric acid+ 0.1% KMS+ 0.1% NaMS were found better with respect to colour, appearance, flavour, texture, taste and overall acceptability with non-stickiness of the product. Storage study showed that there was marginal decrease in moisture content and organoleptic quality and increase in total sugars and reducing sugars content of osmodried carrot slices.

Keywords: carrot, lye peel, osmo-dried, organoleptic

Introduction
Carrot (*Daucus carota* L.) is the most important biennial winter root vegetable crop. It has rich sources of genetic resources for β-carotene, lycopene, lutein and anthocyanin in orange, red, yellow and black colour of carrot respectively (Selvakumar *et al*., 2016) [1]. 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 (Hashimoto and Nagayama, 2004) [2]. The important varieties of carrot grown in different parts of India are Pusa Kesar, Pusa Asita, Pusa Kulfi, Pusa Yamdagni, Pusa Meghali, Pusa Nayanjyothi, Pusa Rudira, Zeno, Early Nantes, Nantes, Nantes Half Long, Imperator and Chantenay. It is a versatile root crop which are used in a number of vegetable preparations and sweet dishes. Carrots are cooked alone or with other vegetables in the preparation of soups, stews and pies, fresh grated roots are used in salad, tender roots are pickled (Torreggiani and Bertolo, 2004) [3]. Processed products of carrot supplement to human diet such as murrabba, chips, canned slices, juice, concentrate, pickle, preserve, cake, halwa, strips, cubes, squares, flakes intermediate moisture foods, dehydrated, frozen canned product and various types of ready to serve beverages such as carrot juice, flavoured and blended beverage (Kalra *et al*., 1987) [4]. 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 (Sra *et al.*, 2011) [5]. So, osmotic dehydration of carrot slices during the main growing season is one of the important alternatives for preservation. Osmotic dehydration involves three simultaneous counter-current fluxes of mass transfer (Tiwari, 2005) [6]. Two major simultaneous counter-current types of mass transfer consist of water diffusion from product to solution followed by uptake of solutes from solution into product (Uribe *et al*., 2010) [7]. It is a useful technique for the production of 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 fruits or vegetable could be made available to the consumer throughout the year. The principle of osmosis as a means of water removal has been known for a long time. However, application of osmotic treatments to food can be considered among the new or improved techniques, as its main characteristics are

that the materials are exposed to minimal thermal stress and that the processing in most cases is applied in combination with other preservation methods. The inclusion of osmotic process in conventional dehydration has two major objectives first one is quality improvement (Sagar and Sureshkumar, 2010) [8] and second most important one is energy savings (Lewicki and Lenart, 1995) [9]. Osmosed products fall under the group of intermediate moisture foods. Therefore, addition of preservatives, air drying, vacuum drying, freeze drying, dehydro-freezing and dehydro-canning have been used to stabilize them (Buggenhout, 2008) [10]. Hence, osmotically dehydrated carrot products can be utilized as intermediate moisture food and concentrated foods in near future. Present investigation was conducted to study the physico-chemical changes of osmotically dehydrated carrot slices during storage.

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.

Osmotic 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°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.

Physico-chemical analysis

Fresh and dried carrot slices were analysed for different attributes. Moisture content was determined by drying the samples to a constant weight in a hot air oven at 70 ± 1 °C. The total soluble solids (TSS) were recorded using Erma hand refractometer. The titratable acidity, reducing sugars, total sugars, non-enzymatic browning and carotenoids content were determined according to Ranganna (1991) [11].

Sensory evaluation

Osmotically dehydrated carrot slices were evaluated by a panel of 15 judges using hedonic scale having score for colour (30), texture (30) and flavour (40). Total sensory range was very good (80-100), good (60-79), average (30-59) and poor (0-29).

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.

Result and Discussion

Physico-chemical composition of carrot

The data on physico-chemical parameters of carrot used for the study are presented in the Table 1. Carrot having average weight of roots 275g, average length of 17.75 cm whereas breadth was 30.38 mm in diameter. Values for processing parameters such as slices recovery, lye peeling loss and unaccounted loss in carrot was 70.1, 23.0, 6.9 per cent respectively. The average moisture content in the carrot was 89.35 per cent, total solids 10.65 per cent, TSS 8.73°Brix, carotenoids 9.83 mg/100g, titrable acidity 0.16 per cent; reducing sugars were 1.79 per cent, non-reducing sugars 4.20 per cent and total sugars of 5.99 per cent. These findings are in conformity with the observation made by Simon and Lindsay (1983) [12].

Table 1: Physico-chemical parameters of fresh carrot used for osmotic dehydration

	Physical Parameters	**Values***
1.	Weight of carrot (g)	275.0
2.	Length (cm)	17.75
3.	Breadth (mm in diameter)	30.38
4.	Slices Recovery (%)	70.1
5.	Lye Peeling Loss (%)	23.0
6.	Unaccounted Loss (%)	6.9
	Chemical Parameters	
7.	Moisture (%)	89.35
8.	Total Solids (TS) (%)	10.65
9.	Total Soluble Solids (TSS)(°Brix)	8.73
10.	Carotenoids (mg/100g)	9.83
11.	Total Titrable Acidity (%)	0.16
12.	Reducing Sugars (%)	1.79
13.	Non-reducing Sugars (%)	4.20
14.	Total Sugars (%)	5.99

*Means of three observations

Moisture content and total solids

Data presented in Table 2 indicates that the average moisture content of osmo-treated carrot was 13.06 per cent at initial stage which increased to 14.00 per cent per cent after two months of storage, 14.43 per cent after four months of storage and 15.22 per cent after six months storage. Moisture content in osmotically dehydrated carrot slices slightly increases after six months of storage at room temperature. The gain in moisture by samples during storage may be due to absorption of moisture from the atmosphere (Abdelhaq and Lubuza, 1987) [13]. These finding are in conformity with the observations of other workers (Kumar *et al.*, 2009) [14].

Table 2: Effect of different osmotic treatments on the moisture, total solids and total titrable acidity in osmotically dehydrated slices of carrot at different stages of storage

Treatments		Moisture (%)				Total Solids (%)				Total Titrable Acidity (%)			
		Initial	2 MAS	4 MAS	6 MAS	Initial	2 MAS	4 MAS	6 MAS	Initial	2 MAS	4 MAS	6 MAS
T_1	40°B 20h	13.10^{ab}	13.71^{ab}	14.04^{ab}	14.70^{ab}	86.90^{bc}	86.29^{bc}	85.96^{b}	85.30^{bc}	0.40^{b}	0.36^{bc}	0.35^{d}	0.33^{c}
T_2	40°B 40h	13.29^{ab}	13.94^{ab}	14.06^{ab}	14.63^{ab}	86.71^{bc}	86.06^{bc}	85.94^{b}	85.37^{bc}	0.52^{b}	0.47^{b}	0.43^{bc}	0.40^{b}
T_3	50°B 20h	12.93^{ab}	14.15^{ab}	14.49^{ab}	15.81^{ab}	87.07^{bc}	85.85^{bc}	85.51^{bc}	84.19^{bc}	0.52^{b}	0.47^{b}	0.43^{b}	0.41^{b}
T_4	50°B 40h	13.37^{ab}	14.44^{a}	14.89^{a}	15.56^{ab}	86.63^{bc}	85.56^{c}	85.11^{c}	84.44^{bc}	0.40^{b}	0.36^{bc}	0.33^{d}	0.31^{c}
T_5	60°B 20h	12.50^{ab}	14.07^{ab}	14.56^{ab}	14.99^{ab}	87.50^{bc}	85.93^{bc}	85.44^{bc}	85.01^{bc}	0.39^{b}	0.36^{bc}	0.33^{d}	0.29^{c}
T_6	60°B 40h	13.93^{a}	15.21^{a}	15.87^{a}	16.40^{a}	86.07^{bc}	84.79^{c}	84.13^{c}	83.60^{c}	0.31^{b}	0.31^{c}	0.28^{d}	0.28^{c}
T_7	70°B 20h	11.87^{b}	12.41^{b}	12.99b	14.12^{b}	88.13^{b}	87.59^{b}	87.01^{b}	85.88^{b}	0.33^{b}	0.31^{c}	0.31^{d}	0.30^{c}
T_8	70°B 40h	13.44^{ab}	14.08^{ab}	14.56^{ab}	15.58^{ab}	86.56^{bc}	85.92^{bc}	85.44^{bc}	84.42^{bc}	0.32^{b}	0.31^{c}	0.30^{d}	0.29^{c}
T_9	Control (0.1% KMS)	5.28^{c}	6.93^{c}	7.85^{c}	11.24^{c}	94.72^{a}	93.07^{a}	92.15^{a}	88.76^{a}	1.27^{a}	1.26^{a}	1.24^{a}	1.14^{a}
CD at 5%		2.03	1.86	1.80	2.21	2.03	1.86	1.80	2.21	0.22	0.12	0.06	0.05
S Em±		0.27	0.25	0.24	0.30	0.27	0.25	0.24	0.30	0.03	0.02	0.01	0.01

*Values with common superscript do not differ significantly

***** MAS-Months after storage

Total titrable acidity

Among the osmotically dehydrated samples, slices treated with 50°Brix sugar syrup for 20 hours (T_3) recorded highest titrable acidity 0.52, 0.47 and 0.43 and 0.41 per cent during initial, two, four and six months after storage respectively which was closely followed by T_2. While acidity contents in control samples were 1.27, 1.26, 1.24 and 1.14 per cent respectively. Further, increase in concentration of syrup or duration of osmosis decreased the acidity of dehydrated slices. The main reason of variation in acidity in osmotically dehydrated sample was the varying solid uptake, resultant variation in yield and drying ratio of the products. Samples with higher drying ratio had more acidity than samples with lower drying ratio obtained in case of highest syrup concentration and longest duration of osmosis. As the sugar syrup was also containing the additional 0.3% acidity, this added acidity played significant role in content in the final products. The loss of acid in the samples during storage might be due to utilization of acids for conversion of non-reducing sugars to reducing sugars and in non–enzymatic browning reactions as reported by Sharma *et al.* (2004) [15]. These results are also in conformity with findings of other workers as in case of mango (Varany Anond *et al*, 2000) [16], banana (Thippanna, 2005; Sumitha, 2010) [17-18], papaya (Jain *et al.*, 2011) [19], guava (Anitha, 2007) [20], pineapple (Pokharkar and Prasad, 1998 and Tiwari and Jalali, 2004b) [21-22], apricot (Manafi *et al.*, 2010) [23] and litchi (Kumar *et al.*, 2009) [24].

Total carotenoids

Among the osmotic pretreatments, total cartenoids content of untreated sample was more due to high yield and high drying ratio. In contrast to osmotically treated carrot was less due to low drying ratio. Carotenoids content in osmotically dehydrated sample generally decreased during the subsequent storage period in comparison to initial content. Maximum total carotenoids were found in samples treated with low concentration of sugar syrup (T_1) which was closely followed by T_2, T_3 and T_4. The loss of carotenoids content in processed samples was mainly due to leaching in syrup, oxidation as well as thermal degradation. Variation in carotenoids content in osmotically dehydrated samples of mango have been reported by Sagar and Khurdiya (1999) [25]. These results are also inconformity with the findings of Sra *et al*., (2011) [5].

Reducing sugars, non-reducing and total sugars

Sugars content in osmotically dehydrated slices of treatments showed significant variations with respect to reducing sugars, while variation in non-reducing and total sugar contents were statistically non-significant. On the other hand, different osmotic pre-treatments significantly affected the reducing, non-reducing and total sugar contents in dehydrated slices. Among the treatments maximum reducing sugar (58.45%) were recorded in slices treated with 50°Brix syrup for 40 hours (T_4) which closely followed by T_5 and T_3 while maximum non-reducing sugar (17.36%) and total sugar (70.20%) was recorded in slices treated with 40°Brix syrup for 40 hours (T_2) followed by T_3, T_4 and T_5. Whereas the lowest sugar contents were observed in control (T_9).

An increase in the sugar syrup concentration from 40 to 50°Brix as well as duration of osmosis from 20 to 40 hours resulted in increase in reducing, non-reducing and total sugar contents in osmotically dehydrated slices of carrot whereas it was noticed that an increase in the sugar syrup concentration from 60 to 70°Brix as well as duration of osmosis from 20 to 40 hours resulted in decrease in reducing, non-reducing and total sugar contents in osmotically dehydrated slices of carrot. This characteristics phenomenon of uptake of solutes and a resultant increase in sugar content in fruit slices during osmotic dehydration process as been reported (Souza *et al*. 1996) [26]. Giraldo *et al*. (2003) [27] stated that variables affecting osmotic dehydration kinetics also affect sugar content in the final products. The results of present study are in conformity with the observations made by several earlier workers (Sharma *et al.* 2004) [15].

Non-enzymatic browning (NEB)

In case of non-enzymatic browning (NEB OD at 440 nm) in osmo-dried samples the values were very low and ranged from 0.100 to 0.151. However the variation was significant due to the treatments. Average NEB value was 0.137 in carrot slices at initial stage and increased to 0.162 after 2 months storage, 0.195 after 4 months of storage and 0.248 after 6 months storage. As the preservatives were added to the osmotic medium and control was treated with potassium meta-bisulphite it helped to maintain the NEB in slices at very low level. However, there was slight increase in the non-enzymatic browning during storage which was may be due to loss of sulphur dioxide. These finding are in conformity with the observations of other workers (Sharma *et al*., 2004) [15]. Further, several factors such as temperature, moisture, carbonyl compounds, organic acids, oxygen and sugars have also been reported to be responsible for causing NEB in stored food as reported by Sumitha (2010) [18].

Sensory qualities of osmotically dehydrated carrot slices affected by different osmotic pre-treatments

Colour

All osmotically dehydrated carrot slices of colour were slightly varying from initial level. However, carrot slices treated with 50°Brix with 40 hours (T_4) was high acceptable range of colour after six months of storage period at room temperature followed by T_4. Although all osmotically treated samples maintain its colour was acceptable range after subsequent months of storage period. These results are in conformity with the findings of Torreggiani (2004) [3] who reported that sugar uptake owing to the protective action of the sugars in syrup helps in the stability of product colour during osmotic process and subsequent storage.

Texture

Osmotically treated of various carrot samples noticed at initial level was good to very good range. Not much variation in the texture of osmo-treated carrot slices at subsequent storage level and there it was noticed that slight reduction in texture value among dehydrated slices. Even though comparison of other sample slices treated with T_4 (50°Brix syrup for 40 hours) and T_5 (60°Brix syrup for 20 hours) noticed maintaining of its texture at room temperature of different storage period. Improvement in texture of osmotically dehydrated slices may be due to positive role of sugars available in the carrot slices. These results are in conformity with the findings of Tiwari and Jalali (2002) [22]. Variation in texture score of osmotically dehydrated banana slices has been reported by Thippanna (2005) [17].

Flavour

Among the osmotically dehydrated slices, the flavour was highly maintain using of carrot slices treated with 50°Brix sugar syrup in 40 hours (T_4) followed by 60°Brix sugar syrup in 20 hours (T_5) subsequent storage period. Although, all osmotically treated samples of overall acceptability was acceptable range subsequent storage period. Improvement in flavour of osmotically treated slices from the above treatments was mainly due to better sugar acid ratio. The sugar syrup is reported to have a protective effect not only on retention of fresh flavour during drying but also during storage (Kumar *et al*., 2009) [24]. It has been reported that variables affecting osmotic dehydration kinetics, as well as final ratio of water loss and sugar gain has great influence on product characteristics (Giraldo *et al*., 2003) [27] and improved product from fruit can be obtained through osmotic dehydration (Ahsan *et al*., 2008) [28].

Overall acceptability

At initial stage in all the osmotically dehydrated carrot samples, sensory score for colour, texture and flavour was in the range of good to very good. After subsequent storage period there was slightly lower score for colour, texture and flavour. However samples obtained with 50°Brix sugar syrup in 40 hours (T_4) and 60°Brix sugar syrup in 20 hours (T_5) was found to maintain superior organoleptic qualities even after six months of storage at room temperature. Besides this, all osmotically treated samples were found to be acceptable after six months of storage. These results are in conformity with the findings on organoleptic properties of osmotically dehydrated mango slices (Varany Anond *et al*., 2000) [16]. They have studied the effects of temperature, sucrose solution and processing time in osmotic dehydration of mango and stated that the best treatment for mango was 60°Brix sucrose treatment under 50 °C for 4 hour. Similarly, Madamba and Lopez (2002) [29] reported that the treatment time of 6 hours, temperature 35 °C and sugar concentration of 65 per cent was best for the osmotic dehydration of mango slices.

Table 3: Effect of different osmotic treatments on the reducing sugars, non-reducing sugars and total sugars in osmotically dehydrated slices of carrot at different stages of storage

Treatment		Sugars											
		Reducing Sugars (%)				Non-reducing Sugars (%)				Total Sugars (%)			
		Initial	2 MAS	4 MAS	6 MAS	Initial	2 MAS	4 MAS	6 MAS	Initial	2 MAS	4 MAS	6 MAS
T_1	40°B 20h	52.31^{c}	53.16^{b}	53.94^{c}	56.61^{b}	15.00^{a}	14.02^{a}	12.94^{a}	9.95^{b}	67.31^{b}	67.18^{ab}	66.88^{b}	66.55^{b}
T_2	40°B 40h	53.35^{bc}	54.65^{b}	55.45^{b}	56.11^{b}	17.36^{a}	15.30^{a}	14.19^{a}	13.30^{a}	70.70^{a}	69.95^{a}	69.63^{a}	69.41^{a}
T_3	50°B 20h	54.15^{b}	55.14^{b}	56.47^{b}	57.99^{b}	15.09^{a}	13.14^{a}	11.58^{a}	9.85^{b}	69.25^{ab}	68.28^{ab}	68.05^{ab}	67.84^{ab}
T_4	50°B 40h	58.45^{a}	59.52^{a}	60.36^{a}	62.07^{a}	10.22^{b}	8.77^{c}	7.70^{d}	5.88^{d}	68.67^{ab}	68.29^{a}	68.06^{a}	67.94^{ab}
T_5	60°B 20h	57.42^{a}	58.69^{a}	59.38^{a}	61.44^{a}	10.62^{b}	9.29^{b}	8.40^{c}	6.23^{d}	68.04^{b}	67.98^{ab}	67.79^{ab}	67.67^{ab}
T_6	60°B 40h	52.98^{bc}	54.65^{b}	55.88^{b}	57.06^{b}	14.89^{a}	12.62^{a}	11.27^{b}	9.90^{b}	67.87^{b}	67.27^{b}	67.14^{b}	66.96^{b}
T_7	70°B 20h	52.46^{c}	53.96^{b}	54.79^{b}	57.31^{b}	14.84^{a}	13.17^{a}	11.94^{a}	9.16^{c}	67.29^{b}	67.13^{b}	66.73^{b}	66.46^{b}
T_8	70°B 40h	53.1^{bc}	55.12^{b}	55.80^{b}	57.19^{b}	17.29^{a}	14.80^{a}	13.76^{a}	12.19^{ab}	70.41^{a}	69.93^{a}	69.56^{a}	69.38^{a}
T_9	Control	5.06^{cd}	5.09^{c}	5.09^{d}	5.05^{c}	3.47^{c}	3.36^{d}	3.48^{e}	3.37^{d}	8.53^{c}	8.45^{c}	8.57^{c}	8.42^{c}
CD at 5%		1.62	1.72	1.92	1.76	2.74	2.68	2.79	2.93	2.12	2.21	1.89	1.91
S Em±		0.22	0.23	0.26	0.24	0.37	0.36	0.37	0.39	0.28	0.30	0.25	0.26

*Values with common superscript do not differ significantly
*MAS-Months after storage

Table 4: Effect of different osmotic treatments on the carotenoids content in osmotically dehydrated slices of carrot at different stages of storage

Treatments		Carotenoids (mg/100g)				Non-enzymatic browning (NEB)			
		Initial	**2 MAS**	**4 MAS**	**6 MAS**	**Initial**	**2 MAS**	**4 MAS**	**6 MAS**
T_1	40°B 20h	39.09^{b}	35.61^{b}	33.73^{b}	32.15^{b}	0.134^{b}	0.176^{b}	0.201^{bcd}	0.274^{ab}
T_2	40°B 40h	36.57^{b}	34.00^{b}	32.53^{b}	31.80^{b}	0.150^{b}	0.172^{b}	0.219^{bc}	0.265^{abc}
T_3	50°B 20h	35.78^{b}	33.03^{b}	31.25^{b}	30.09^{b}	0.151^{b}	0.185^{b}	0.245^{b}	0.306^{ab}
T_4	50°B 40h	32.25^{b}	31.52^{b}	30.58^{b}	29.83^{b}	0.144^{b}	0.154^{b}	0.180^{bcd}	0.265^{abc}
T_5	60°B 20h	32.20^{b}	31.09^{b}	30.29^{b}	29.54^{b}	0.141^{b}	0.160^{b}	0.178^{cd}	0.242^{bc}
T_6	60°B 40h	32.58^{b}	30.66^{b}	29.53^{b}	28.52^{b}	0.100^{b}	0.121^{c}	0.146^{d}	0.168^{c}
T_7	70°B 20h	32.04^{b}	30.94^{b}	29.99^{b}	28.84^{b}	0.169^{ab}	0.176^{b}	0.211^{bcd}	0.244^{bc}
T_8	70°B 40h	33.09^{b}	32.36^{b}	31.70^{b}	30.78^{b}	0.107^{b}	0.153^{b}	0.183^{bcd}	0.219^{bc}
T_9	Control	164.57^{a}	148.12^{a}	127.43^{a}	115.20^{a}	0.240^{a}	0.279^{a}	0.333^{a}	0.357^{a}
CD at 5%		8.65	6.26	6.88	6.43	0.073	0.061	0.065	0.097
S Em±		1.16	0.84	0.92	0.86	0.009	0.008	0.009	0.013

*Values with common superscript do not differ significantly
* MAS-Months after storage

Table 5: Effect of different osmotic treatments on the sensory quality osmotically dehydrated slices of carrot at different stages of storage

Treatment		Sensory Score															
		Colour (30)				Texture (30)				Flavour (40)				Overall acceptability (100)			
		Initial	2 MAS	4 MAS	6 MAS	Initial	2 MAS	4 MAS	6 MAS	Initial	2 MAS	4 MAS	6 MAS	Initial	2 MAS	4 MAS	6 MAS
T_1	40°B 20h	24.37^{b}	23.51^{b}	22.51^{a}	21.93^{abc}	23.19^{b}	22.95^{b}	21.75^{a}	21.32^{ab}	28.12^{b}	26.42^{b}	26.15^{b}	25.12^{b}	75.68^{b}	70.41^{bc}	72.88^{c}	68.37^{bc}
T_2	40°B 40h	25.21^{ab}	24.77^{ab}	24.95^{a}	22.59^{ab}	24.07^{ab}	23.90^{ab}	22.33^{a}	21.07^{ab}	28.07^{b}	27.41^{ab}	26.91^{ab}	26.73^{ab}	77.34^{b}	74.19^{ab}	76.07^{abc}	70.40^{ab}
T_3	50°B 20h	24.08^{b}	23.38^{b}	22.17^{ab}	19.50^{bc}	23.73^{b}	23.46^{ab}	23.03^{a}	22.13^{ab}	27.41^{b}	27.28^{b}	26.63^{ab}	25.20^{b}	75.22^{b}	71.82^{bc}	74.11^{bc}	66.84^{bc}
T_4	50°B 40h	26.83^{a}	25.83^{a}	24.86^{a}	23.59^{a}	25.63^{a}	24.24^{a}	23.58^{a}	22.63^{a}	31.48^{a}	29.72^{a}	28.43^{a}	28.22^{a}	83.93^{a}	76.86^{a}	79.80^{a}	74.43^{a}
T_5	60°B 20h	25.81^{ab}	25.53^{a}	23.81^{a}	23.56^{a}	24.54^{ab}	23.51^{ab}	22.81^{a}	21.95^{ab}	29.97^{ab}	28.23^{ab}	27.73^{ab}	27.64^{a}	80.32^{ab}	74.35^{ab}	77.26^{ab}	73.15^{a}
T_6	60°B 40h	24.45^{b}	23.16^{b}	20.73^{b}	18.54^{d}	23.46^{b}	23.13^{ab}	22.93^{a}	20.46^{b}	27.74^{b}	27.48^{ab}	27.06^{ab}	24.73^{b}	75.66^{b}	70.72^{bc}	73.76^{bc}	63.73^{c}
T_7	70°B 20h	24.58^{b}	23.70^{b}	20.76^{b}	19.76b^{c}	22.92^{b}	22.68^{b}	22.43^{a}	22.35^{ab}	28.39^{b}	27.72^{ab}	27.41^{ab}	25.05^{b}	75.88^{b}	70.60^{bc}	74.10^{bc}	67.17^{bc}
T_8	70°B 40h	24.06^{b}	23.34^{b}	19.50^{b}	18.67^{cd}	23.83^{ab}	22.55^{b}	22.27^{a}	20.55^{ab}	28.23^{b}	27.08^{b}	26.60^{ab}	24.93^{b}	76.13^{b}	68.37^{c}	72.97^{c}	64.14^{c}
T_9	Control	12.22^{c}	12.08^{c}	9.90^{c}	8.62^{e}	10.14^{c}	9.14^{c}	8.97^{b}	8.56^{c}	9.67^{c}	9.34^{c}	9.28^{c}	9.26^{c}	32.03^{c}	28.15^{d}	30.55^{d}	26.44^{d}
CD at 5%		2.18	2.11	3.22	3.36	1.86	1.12	2.00	2.10	2.95	2.42	2.03	2.17	5.22	4.04	4.21	4.70
S Em±		0.29	0.28	0.43	0.45	0.25	0.15	0.27	0.28	0.40	0.33	0.27	0.29	0.70	0.54	0.56	0.63

*Values with common superscript do not differ significantly

***** MAS-Months after storage

Conclusion

Based on the physico-chemical composition and sensory quality it is concluded that osmotic pre-treatment of carrot slices with 60ºBrix sugar syrup for 40 h was best. Carrot slices could be successfully osmo-dried by using lye peeling (5% NaOH boiling aqueous solution for 2 min) followed by soaking in 60°Brix sugar syrup (1:2 w/v) + 0.1% KMS +0.1%NaMS+0.1% citric acid with better colour, texture, taste and overall acceptability and could be stored for 6 months at ambient condition without any adverse effect on quality. Moreover, osmosed carrot products fall under the group of intermediate moisture foods. Therefore, addition of preservatives, air drying, vacuum drying, freeze drying, dehydro-freezing and dehydro-canning have been used to stabilize them. Osmotic dehydration of carrots are convenient to be alternative for long term storage as compared to cold storage or canned products. The pre-treatments and methods of dehydration can be influence the quality of dried products

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