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Effect of Drying Temperature and Microwave Power on the Physico-Chemical Characteristics of Osmo-Dehydrated Carrot Slices

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ABSTRACT

Osmotic dehydration of carrot slices in sugar solutions at different solution concentrations, temperatures and process duration of 120min. was analyzed for moisture content (% w.b.), ash content, pH and beta-carotene. The beta-carotene content increased with increase of syrup concentration and temperature, and the ash, pH and moisture content (% w.b.) decreased with increase of syrup concentration and temperature. The osmotically pretreated carrot slices were further dehydrated in a cabinet dryer at 65^{0}C for 4h and microwave oven at an input power of 20W for 22min. The optimum conditions of various process parameters were 30-50^{0}B sugar concentration, 30^{0}C and 40^{0}C osmotic solution temperature and process duration of 120 min.

INTRODUCTION

Carrot (*Daucus carota* L.) is one of the important root vegetable crops and is highly nutritious as it contains appreciable amounts of vitamins B_1, B_2, B_6 and B_{12} aside from being rich in beta-carotene. It also contains many important minerals. Beta-Carotene is a precursor of vitamin A and is reported to prevent cancer. Beta-carotene is one of the common carotenoid hydrocarbons that contain specific end groups or two beta rings and it acts as provitamin A, which is converted by humans to vitamin A. However, in the food industry, carrots must generally be processed prior to their use and drying is one of the most frequently used processes. Its maximum retention is of utmost importance for the preservation of the attractive appearance and dietary value of the product. Carrots have a moisture content of 80–90% (wet basis) at the time of harvest. They are seasonal in nature and highly susceptible to moisture loss leading to wilting and loss of fresh appeal.

Osmotic dehydration is a non-thermal treatment, the aim of which is to modify the composition of food material by partially removing water and impregnating it with solutes, without affecting the material's structural integrity. Osmotic dehydration (OD), a technique used to produce high or intermediate moisture products, involves immersing pieces of food in a hypertonic solution. Such processes allow the adjustment of the physical-chemical properties of food by reducing water content and simultaneously incorporating ingredients or additives with antioxidant or other preservative properties into the food (Torreggiani 2001). Although the osmotic dewatering consists of a mild process to partially dehydrate fruits and vegetables, its application can cause changes in cellular tissues, influencing the rheological behavior of the material.

Osmotic dehydration is a water removal process involving soaking foods, mostly fruits and vegetables, in a hypertonic solution such as concentrated sugar syrup. If the solutes are correctly chosen, and the ratio of water removal to solute impregnation is controlled, the natural flavour of fruit products and colour retention can be enhanced. Osmotic dehydration is now considered a valuable tool in minimal processing of foods. It can be applied either an as autonomous process or as a processing step in alternative processing schemes leading to a variety of end products (Lazarides et al. 1995). During osmotic dehydration, a product is continuously immersed in the osmotic solution, making the process oxygen free. There is, therefore, no need to use sulphur dioxide and/or blanching for protection against oxidative and enzymatic discoloration. Osmotic dehydration is one of the effective ways to reduce overall energy requirements in dehydration. Osmotic dehydration is one of the simple and inexpensive processes, which offers a way to make available the low cost, highly perishable and valuable crop available for the regions away from production zones and also during off season. The objective of the research was to determine the physico-chemical characteristics of osmodehydrated carrot slices using tray and microwave drying.

MATERIALS AND METHODS

Sample preparation

Good quality carrots were procured for this investigation from the local market Allahabad on daily basis prior to each set of experiment. Undamaged carrots without any defect on visual inspection were selected. The carrots were thoroughly washed and cut into 3mm slices. Sucrose was used as an osmotic agent and was purchased from the local market. Initial moisture content of carrot slices was 86.7%.

Osmotic solutions

Osmosis solutions of different concentrations (30-50^{0}B) were prepared by dissolving the desired solutes on a w/w basis with distilled water. A magnetic stirrer was used to dissolve the contents. Sucrose was weighed on an electronic balance. Fresh osmotic solution was prepared for every run.

Experimental Procedure

The experiments were conducted in the laboratories of the Department of Food Process Engineering, SHIATS, Allahabad (India). Fresh, well-graded carrots were procured from the local market of Allahabad, and the experiments were conducted on the same day. After washing, peeling was accomplished manually by stainless steel hand peeler. The green parts of carrots were removed to retain the final quality of the product. A vegetable dicer was used to prepare carrot slices of 3mm. The carrot slices were washed with fresh water to remove the carrot fines adhered to the surface of the carrot slices. The leftover material of carrot slices was separated manually. No blanching was conducted prior to osmosis as it has been reported to be detrimental to osmotic dehydration processes as a result of the loss of semi-permeability of the cell membranes (Ponting 1973) and reduction of beta-carotene (Sharma *et al*. 2000; Reyes *et al*. 2002). Sugar solution was chosen for osmosis, as it is an excellent osmotic agent, retarding oxidative and non-enzymatic browning (Arya *et al*. 1979). For each experiment, known weights of carrot slices (51 g) were put in stainless steel containers containing calculated volumes of osmotic solutions of different concentrations (30-50^{0}B) preset at the specified temperature (30-40^{0}C) in a hot water bath under shaking conditions. The sample to solution ratio in osmotic dehydration process was kept as 1:10. The carrot slices were removed from the osmotic solutions after 120min. and rinsed with water to remove the surplus solvent adhering to the surfaces. These osmotically dehydrated slices were then spread on the absorbent paper to remove the free water present on the surface. The slices were dehydrated to final moisture of 8-13% (wet basis) using a hot air drier preset at an air temperature of 65^{0}C and 9-14% (w.b.) using microwave oven preset at an input power of 20W. The moisture content of fresh carrots was 86.7% (wet basis). The dried samples were cooled in a desiccator containing silica gel for 1 h, packed in low-density polyethylene bags and kept at ambient temperature (28–35C) for quality analysis. The analysis was completed within 2 days. The stored samples were analyzed at intervals of 15 days for moisture (AOAC, 1990), ash (AOAC, 1984), pH and ß-carotnene (Rangana1986).

Statistical analysis

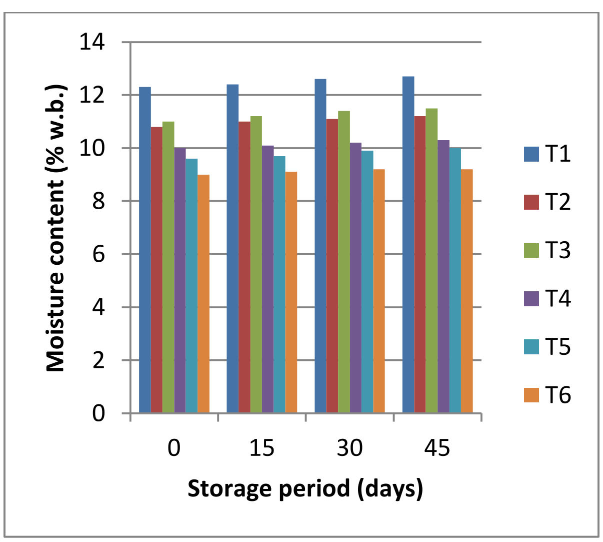
The experiments were conducted by adopting completely randomized design of the data recoded. During the course of investigation, product of different formulations were analysed statistically by the 'Analysis of Variance' (ANOVA). The significant effect of treatment is judged with the help of 'F' (Variance Ratio). F values were compared with the table value of F at 5% level of significance. If calculated value exceeds the table value, the affect is considered to be significant. The significance is tested at 5% level.

RESULTS AND DISCUSSIONS

The prepared osmotic dehydrated carrot slices were evaluated for various physico-chemical, characteristics. The changes in various physico-chemical parameters of the dehydrated carrot slices stored in ambient temperature are presented in Figs. 4.1 – 4.8.

Moisture content (%w.b.)

The moisture content varied from sample to sample. Fig. 4.1 shows the effect of storage period on percent moisture content of osmo-tray dehydrated samples (T_1, T_2, T_3, T_4, T_5 and T_6) at 15 days interval during storage. T_1, T_3 and T_5 were treated with 30, 40 and 50^0B respectively and syrup temperature was 30^0C and T_2, T_4 and T_6 were treated with 30, 40 and 50^0B respectively and syrup temperature was 40^0C. Fig. 4.2 shows the effect of storage period on percent moisture content of osmo-microwave dehydrated samples (T_7, T_8, T_9, T_{10}, T_{11} and T_{12}) at 15 days interval during storage. T_7, T_9 and T_{11} were treated with 30, 40 and 50^0B respectively and syrup temperature was 30^0C and T_8, T_{10} and T_{12} were treated with 30, 40 and 50^0B respectively and syrup temperature was 40^0C. The moisture content of osmo-tray dehydrated samples was in the range of 8.9% to12.2% on the 0^{th} day and the moisture content of osmo-microwave dehydrated samples was in the range of 9.9% to13.6% on the 0^{th} day. **Rahman et al. (2010)** reported the moisture content of 7.05% in solar dried carrot and **Kumar et al. (2008)** reported the moisture content of 9.0% in osmo-vac dehydrated mango slices. On evaluation of result, it was found that there was a decrease in moisture content in the samples with increasing the concentration of sugar solution from 30-50^0B and syrup temperature 30-40^0C, which was obvious and is presented in Fig. 4.1 and 4.2. Increased solution concentration resulted in increase in the osmotic pressure gradients and higher moisture loss**.** It might be noted that the moisture content of products on storage is an important determinant of their keeping quality. There was some amount of moisture ingress in samples during storage and it was increased as the duration of storage increased and the increase in moisture content was observed due to temperature fluctuations or storage conditions that may have caused migration of water into the pouch, as the samples were stored at ambient temperature. This hypothesis was verified by **Manzano et al. (1997)** that storage temperature affects the moisture content of fruits during storage. Similar results were also reported by **Kumar et al. (2008), Rahman et al. (2010) and Mizanur et al. (2012).** ANOVA at 5% significance show significant results.



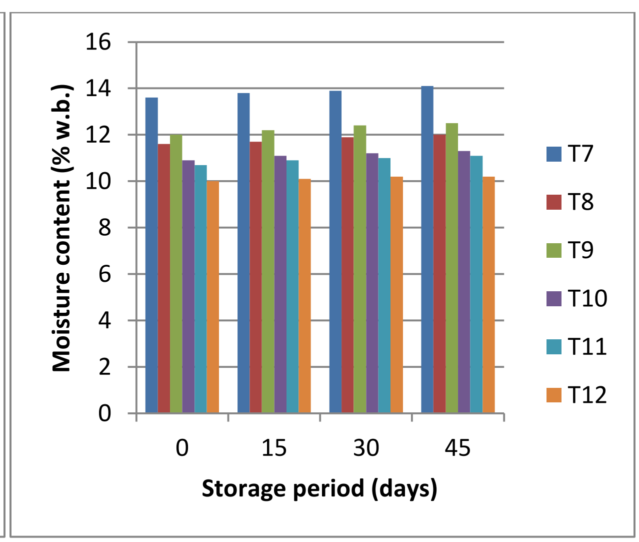


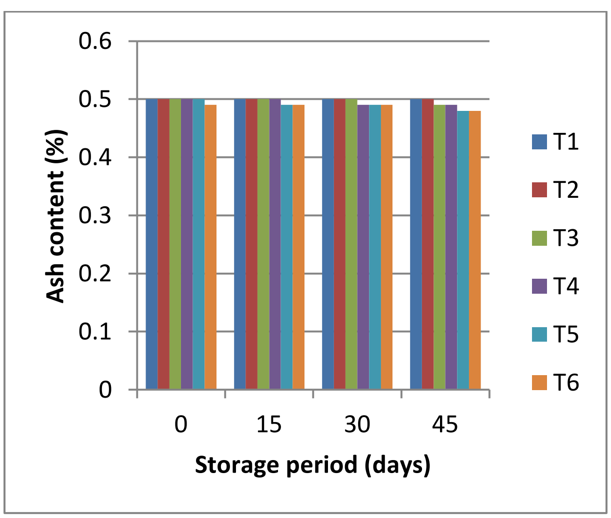
Fig. 4.1. Effect of storage period on m.c. (%w.b.) of osmo- tray dehydrated carrot slices

Fig. 2. Effect of storage period on m.c. (%w.b.) of osmo- microwave dehydrated carrot slices.

Ash content (%)

The ash content varied from sample to sample. Fig. 4.3 shows the effect of storage period on ash content of osmo-tray dehydrated samples (T_1, T_2, T_3, T_4, T_5 and T_6) at 15 days interval during storage. T_1, T_3 and T_5 were treated with 30, 40 and 50^{0}B respectively and syrup temperature was 30^{0}C and T_2, T_4 and T_6 were treated with 30, 40 and 50^{0}B respectively and syrup temperature was 40^{0}C. Fig. 4.4 shows the effect of storage period on ash content of osmo-microwave dehydrated samples (T_7, T_8, T_9, T_{10}, T_{11} and T_{12}) at 15 days interval during storage. T_7, T_9 and T_{11} were treated with 30, 40 and 50^{0}B respectively and syrup temperature was 30^{0}C and T_8, T_{10} and T_{12} were treated with 30, 40 and 50^{0}B respectively and syrup temperature was 40^{0}C. The ash content of osmo-tray and osmo-microwave dehydrated samples was in the range of 0.49% to 0.50% on the 0th day**. Abd El-Hamid et al. (1986)** reported the ash content of 0.51% in Zebda variety (mango) and this was in agreement with the results obtained by **Abd El-Baki *et al*., (1981). Shahnawz et al. (2010)** reported the ash content of 0.16% in mango sample.

On evaluation of result, it was found that there was a decrease in ash content in the samples with increasing the concentration of sugar solution from 30-50^{0}B and syrup temperature 30-40^{0}C, which was obvious and is presented in Fig. 4.3 and 4.4. The decrease in ash content may be due to leaching of some minerals from carrot slices during osmotic step. Similar results were also reported by **Abd El-Hamid *et al*., (1986).** On critical evaluation of the result during storage, it was clear that the ash content of carrot slices packed in LDPE decreased slightly with increase in the storage period. According to **Jain et al. (1992),** ash is the inorganic residue remaining after the water and organic matter and could not be decreased during storage. Similar results were also reported by **Nielsen, (1998).** ANOVA at 5% significance show significant results.



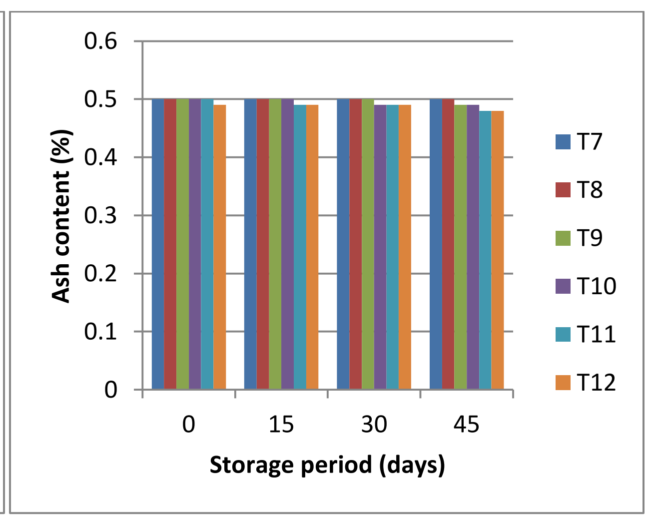
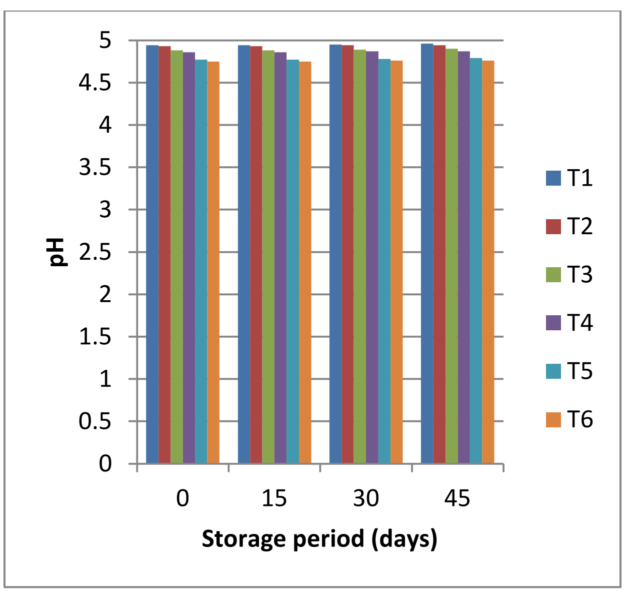


Fig. 4.3. Effect of storage period on ash content Fig. 4.4. Effect of storage period on ash content (%) of osmo-tray dehydrated carrot slices (%) of osmo-microwave dehydrated carrot slices.

pH

The pH varied from sample to sample. Fig. 4.5 shows the effect of storage period on pH of osmo-tray dehydrated (T_1, T_2, T_3, T_4, T_5 and T_6) at 15 days interval during storage. T_1, T_3 and T_5 were treated with 30, 40 and 50^0B respectively and syrup temperature was 30^0C and T_2, T_4 and T_6 were treated with 30, 40 and 50^0B respectively and syrup temperature was 40^0C. Fig. 4.6 shows the effect of storage period on pH of osmo-microwave dehydrated samples (T_7, T_8, T_9, T_{10}, T_{11} and T_{12}) at 15 days interval during storage. T_7, T_9 and T_{11} were treated with 30, 40 and 50^0B respectively and syrup temperature was 30^0C and T_8, T_{10} and T_{12} were treated with 30, 40 and 50^0B respectively and syrup temperature was 40^0C. The pH of osmo-tray dehydrated samples was in the range of 4.94 to 4.75 on the 0^{th} day and the pH of osmo-microwave dehydrated samples was in the range of 4.96 to 4.78 on the 0^{th} day. On evaluation of result, it was found that there was a decrease in pH of the samples with increasing the concentration of sugar solution from 30-50^0B and syrup temperature 30-40^0C, which was obvious and is presented in Fig. 4.5 and 4.6. The decrease in pH was attributed to the loss of moisture during osmotic step. According to the **Hussain et al. (2004)** the pH values of osmodehydrated banana slices at different syrup concentrations were in the range of 5.06-4.86. **Abd El-Hamid et al. (1986)** reported pH of 3.6 in the Zebda mango fruit.



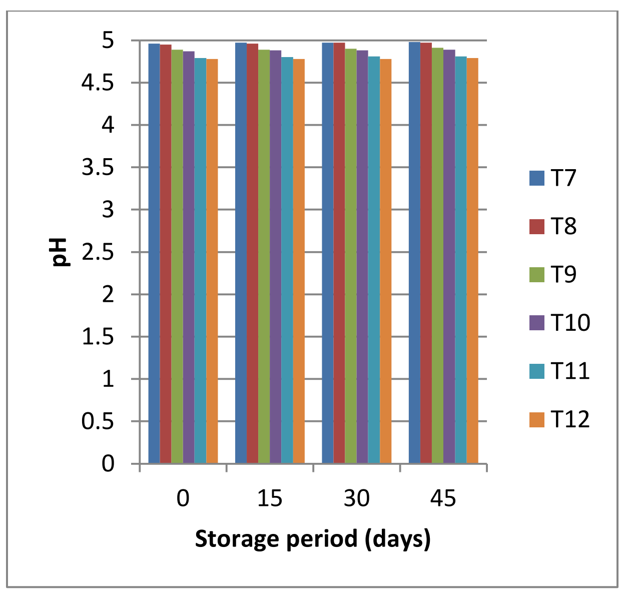


Fig. 4.5. Effect of storage period on pH of dehydrated carrot slices

Fig. 4.6. Effect of storage period on pH of osmo-osmo-tray microwave - dehydrated carrot slices.

From the Figs. it was obvious that the pH followed a slight increasing trend as the storage period was increased. It was observed that as the moisture content was increased during storage, the pH also showed a slight increasing trend. Similar results were also reported by **Abd El-Hamid et al. (1986)** in dehydrated mango where pH ranged from 3.5 to 4.2 during storage. Similar results were also reported by **A.C.C. Rodrigues et al. (2006) and Shahnwaz et al. (2012).** According to the **Kudachikar et al. (2001)** the pH values decreased from 4.2 to 3.0 in Neelum mango during storage. ANOVA at 5% significance show significant results.

Beta-carotene content (mg/100g)

The beta-carotene content varied from sample to sample. Fig. 4.7 shows the effect of storage period on beta-carotene content of osmo-tray dehydrated samples (T_1, T_2, T_3, T_4, T_5 and T_6) at 15 days interval during storage. T_1, T_3 and T_5 were treated with 30, 40 and 50^0B respectively and syrup temperature was 30^0C and T_2, T_4 and T_6 were treated with 30, 40 and 50^0B respectively and syrup temperature was 40^0C. Fig. 4.8 shows the effect of storage period on beta-carotene content of osmo-microwave dehydrated samples (T_7, T_8, T_9, T_{10}, T_{11} and T_{12}) at 15 days interval during storage. T_7, T_9 and T_{11} were treated with 30, 40 and 50^0B respectively and syrup temperature was 30^0C and T_8, T_{10} and T_{12} were treated with 30, 40 and 50^0B respectively and syrup temperature was 40^0C. The beta-carotene content of osmo-tray dehydrated samples was in the range of 10.98mg/100g to 14.28mg/100g on the 0^{th} day and the beta-carotene content of osmo-microwave dehydrated samples was in the range of 9.85mg/100g to 13.98mg/100g on the 0^{th} day. According to the **Abd El-Baki *et al*. (1981)** the total carotenoid content determined in Zebda variety (mango) was 8mg/100g**. Abd El-Hamid *et al*. (1986)** reported that the osmo-air dehydrated mango bar contained higher total carotenoid (5mg/100g) than air dehydrated one (3mg/100g). On evaluation of result, it was found that there was an increase in beta-carotene content in the samples with increasing the concentration of sugar solution from 30-50^0B and syrup temperature 30-40^0C, which was obvious and is presented in Fig. 4.7 and 4.8.

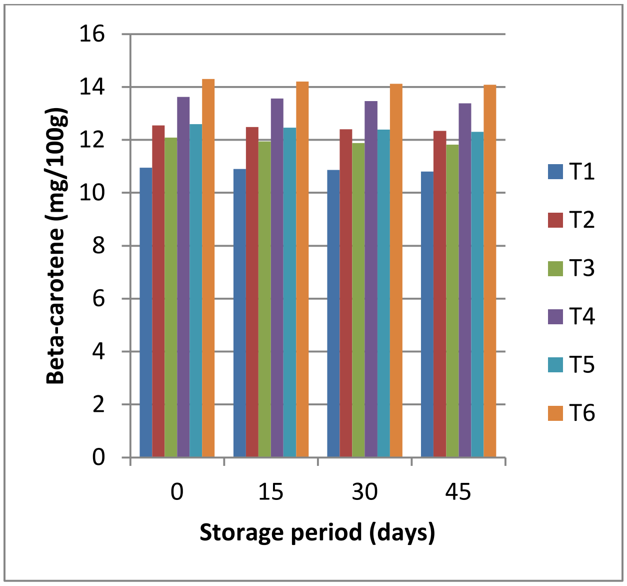


Fig. 4.7.Effect of storage period on beta-carotene (mg/100g) of osmo-tray dehydrated carrot slices.

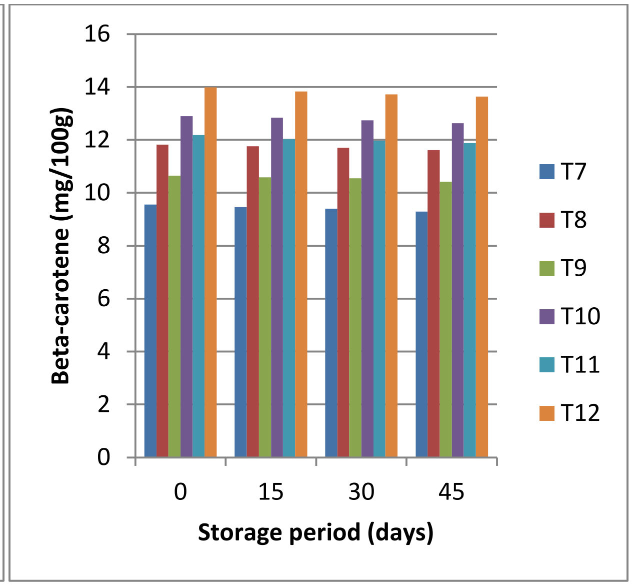


Fig.4.8. Effect of storage period on beta-carotene (mg/100g) of osmo- microwave dehydrated carrot slices.

On critical evaluation of the result during storage, it was clear that the beta-carotene content of carrot slices packed in LDPE showed a decreased trend with increase in the storage period. The decline in beta-carotene content was attributed to the temperature and light effect on pigments. Similar results were also reported by **Rahman et al. (2010)** in case of solar dried carrot. **Howard (1998)** working with jalapeño peppers, evaluated the beta-carotene retention after 12 days of storage at 4.4^{0}C followed by 3 days at 13^{0}C under modified atmosphere using polyethylene films. **Cui et al. (2004)** reported beta-carotene reduction of about 70% during drying of carrots at 60-65^{0}C in a cabinet laboratory dryer. **Kumar et al. (2008)** reported that the main cause of carotenoid degradation is oxidation and further stimulation by presence of light, enzymes and co-oxidation of carotene. ANOVA at 5% significance show significant results.

CONCLUSION

Osmotic pretreatement was used to improve physico-chemical properties of carrot slices. Drying of the carrot using tray drying and microwave drying yeilded samples with low water activity. The tray dried carrot slices contained the highest β-carotene content as compared to the microwave dried samples and moisture content as well as pH were found less in tray dried samples compared to microwave dried samples. There was no change in ash content of tray and microwave dried samples. Results obtained evident that the effect of application of the osmotic dehydration pretreatment was significant on the initial moisture content of the carrot slices, thus allowing a drying time reduction, which may lead to decrease in energy consumption. The carrot dehydration was more appreciable at 50^0B solution concentration and 40°C osmosis temperature followed by 65°C hot air drying temperature on the basis of quality attributes, and also beta-carotene content was found highest under these conditions, compared to microwave drying.

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