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Drying Behavior of Osmo-convective Drying of Carrot Slices and Quality Characteristics of Dehydrated Products

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A B S T R A C T

The present study was carried out to investigate the drying behavior of carrot slices (osmosed as well as control sample) as influenced by temperature under tray dryer. Quality characteristics of osmo-convective dehydrated carrot slices were also carried out with respect to rehydration ratio, color change and sensory characteristics. The findings of drying characteristics of osmo-convective drying showed that the drying time for control and osmosed samples were 12 hrs, 8 hrs respectively at 60°C and 10 hrs, 6 hrs at 70°C for reduction of moisture content upto 3- 5 %. In osmo-convective dried carrot, average RBG value was 71.934 at 70°C and it showed light color compared to fresh dried sample. The rehydration ratio of osmo-convective dried samples ranged from 2.8 to 2.94 while it was found to be 4.14 to 4.66 for hot air dried samples (control). Sensory evaluation reveals that the osmo-convective dried carrot was found best among all four samples with highest overall acceptability.

Introduction

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. Among vegetables, carrots are the richest source of β- carotene, which is the precursor of vitamin A. It also contains other vitamin B_1, B_2, B_{12}, anthocyanin minerals and phytochemical. It is a root vegetable, usually orange in color, though purple, red, white and yellow varieties exist. It has a crisp texture when fresh. It contains high moisture (> 85%) and perishable in nature. For its availability throughout the year, options like storage at low temperature, freeze drying and storage or extraction of juice has been considered by many workers. Due to improper post harvest handling, transport, storage, marketing and processing techniques, there is large amount of losses, leading to poor utilization of carrot. Carrot can be made available throughout the year by adopting improved post harvest practices viz., cutting the whole carrot into slices and processing like canning, dehydration and freezing, jams, juices, concentrates, pastes, soups, marmalades, candy etc and utilizing the byproduct of carrot juice industry for fortification in different products like ice-cream, cakes and other value added product.

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. Such partially dried products need further dehydration upto safe limit for its storage for long period and to make it available throughout the year to the consumer. 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). Recently osmotic dehydration process received more attention due to the consumer demand and improvement in quality (Sablani *et al*., 2002). During osmotic dehydration, 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). The two most common solute types used for osmotic treatments are sugars (mainly for fruits) and salts (for vegetables, fish, and meat), with relevance for sucrose and sodium chloride, which show advantages already described by several authors (Lenart, 1984). In osmotic dehydration, the use of sugar or syrup as osmotic agent prevents loss of flavor commonly found with ordinary air or vacuum drying. The process of osmotic dehydration increases solid density due to solid uptake and helps in getting quality product in freeze drying. Several researcher have worked in the area of drying and dehydration of fruits, vegetables and in forage crops and recommended for the use of improved drying techniques (Singh *et al.,* 2017, Singh *et al.*, 2020a and Singh *et al.*, 2020b). Considering all these points, an experiment was conducted to study the drying behavior of osmotically treated carrot slices and qualitative evaluation of the dehydrated product. The quality of osmo-convective dried carrot samples was evaluated on the basis of color, rehydration ratio and sensory characteristics.

Materials and Methods

Preparation of materials

Fresh and good quality carrot (*Daucus carota,* subsp. *Sativus)* were washed in tap water, peeled manually and then washed again in order to remove the adhered surface particles. Surface water was removed with help of tissue paper. Carrots were cut into slices of thickness 10 mm each. Osmotic solution (60% sugar and 3% salt concentration) was prepared with distilled water by blending the desired solute (w/v basis). Sugar was used as osmotic agent and NaCl was added to osmotic solution to improve the osmotic dehydration process and quality of samples. A stirrer was used to dissolve the solute content.

Dehydration of carrot slices

The samples of carrot slices were osmotically dehydrated in prepared osmotic solution at 60 ºC of solution temperature for 3hrs duration. Osmotically dehydrated carrot samples were taken out of the sugar salt solution and blotted on tissue paper to remove the adhered water. These osmotically dehydrated carrot slices were then dried in tray dryer at drying temperature 60°C and 70 °C. The tray dryer was set at the desired temperature and was allowed to run for about 30 minute to attain steady state condition. The temperature control was within ± 1 °C. These temperatures were chosen because highly moisture fruits and vegetable like onion are reported to be conventionally dried in this temperature range (Siddappa, 1986). Samples were periodically removed and weighed during the drying experiments to achieve the final moisture content. Each experiment was replicated thrice. The dried samples were cooled in a desiccators containing silica gel for 1hr, and then taken out for evaluation of quality characteristics.

Determination of moisture content

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

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

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

Determination of quality characteristics

For the determination of rehydration ratio, the final dehydrated carrot slice samples were rehydrated in a beaker, containing one part sample to ten parts of water. The following equation was used as recommended by Ranganna (2001).

$$\text{Rehydration ratio} = \frac{\textit{weight of rehydrated material}}{\textit{weight of dehydrated material}}$$

The color of samples was measured by using color software (IMAGE J). RGB color space is an additive color system based on tri-chromatic theory. In case of color image, in the RGB color space, every individual color component, namely Red, Green and Blue has its histogram. Then, the percentage compositions of every individual color component are to be evaluated. Using this percentage composition the level for a component can be set as a standard in classifying the dried carrrot based on a particular color orientation. Then the Image J software was used for measuring the values of red, green and blue.

The organoleptic quality of osmo-convective dehydrated carrot was determined with the help of ten member consumer panel using a 9-Point hedonic scale following standard procedure given by Bureau of Indian standards (IS: 6273, 1971). The aspects considered for dehydrated carrot slices were color, taste, aroma, flavor, texture, appearance, overall acceptability. The score sheets were provided to the panelists with the product and were requested to mark the product according to their liking. In between testing different samples, the panel members were given fresh water to rinse the mouth. The average scores of all the 10 panelists were computed for different characteristics.

Results and Discussion

Drying behavior of osmo-convective tray drying of carrot slices

Figures 1 and 2 show the variation in moisture content of fresh and osmo-tray dried carrot slices at different drying temperatures. The drying times of control and osmosed carrot slices by hot air tray drying at 60^{o}C and

70^{o}C were 12 and 10 hrs (for control sample) and 8 and 6 hrs (for osmosed sample). However, the drying of un-osmosed carrot slices had been started at relatively high moisture content (approximately 86% w.b.) whereas the drying of osmotically dried samples began at low moisture content of about 71% (w.b.). The control and osmosed samples were dried upto final moisture content of 3-5 % and 3-4 % respectively. There was decrease in total convective drying rate for osmosed samples as compared to control samples which might be due to the resistance offered to water removal by the solute gained during osmotic pretreatment. Kaleemullah *et al.*, (2002) reported that, even a simple immersion of raw material into an osmotic solution, caused a substantial decrease of water removal rates in convective dehydration. The decrease in moisture removal rates during complementary convective dehydration might be due to the fact that the solute uptake blocks the surface layers (pores) of the product, posing an additional resistance to mass exchange, which was in close agreement with results of Telis *et al.*, (2003). Lenart and Flink (1984) also reported that the resistances imparted by infused sugar and salt to moisture out flow during convective dehydration were different because the sugar (having high molecular weight) accumulates in a thin subsurface layer resulting in surface tissue compaction (an extra mass transfer barrier), while salt (having low molecular weight) penetrates the osmosed tissue to a much greater depth. It can be concluded that the osmotic pretreatments lowered the rates of complementary convective drying process and increased the total dehydration time as compared to direct convective drying to a final moisture contents of 4-5 % (w.b.) This contradicted the results of Torringa *et al*., (2001) according to which osmotic dehydration spectacularly shortened the total convective drying time.

Qualitative evaluation of dehydrated carrot slices

Rehydration ratio

The Rehydration ratio (RR) is represented in Fig. 3. The value of RR of hot air dried samples (control) ranged from 4.14 to 4.66 at a drying temperature varied from 60°C and 70°C. The RR of osmo-convective dried samples ranged from 2.8 to 2.94 depending on the experimental condition and was much lower than that of convective dried carrot samples (control). The lowering of RR due to osmosis has also been reported by Mazza (1983). The low RR of osmo-convective dried product could be due to higher amount of solute gain in the osmosed slices which in turn would not permit absorption of water on account of the preoccupation of pore spaces. It is clear from figure 3 that the RR is significantly affected by osmotic pretreatment. This behavior of low RR of osmotically dehydrated carrot cubes may be explained on the basis that the osmotically pretreated sample contains 8-12 % solute which was infused during osmotic dehydration and leached into water during rehydration process without contributing to the rehydrating process. So it was only the dried matter of carrot pieces (and not the infused solute), which is responsible for absorption of water during rehydration.

Color

The color was measured in terms of red, green and blue values after proper mixing the dehydrated carrot slices at 70 ^{0}C. Lower the histogram (RBG) value the more darker is the color. It was observed that, the fresh carrot (control) slices dried at 70^{o}C showed the red, green, and blue values 141.512, 85.181, 59.462 respectively (Fig 4). The red, green, blue values for osmo-convective dried carrot at 70^{o} C were found to be 203.357, 99.801, 71.934 respectively which was consistent with the results of previous studies. The comparison of average values of red, green and blue values for osmo-convective dried carrot showed a decrease in color as compared to that of control sample. Histogram represents the good uniform of color due to the effect of osmotic dehydration. The osmo-convective dried slices showed less color development due to osmosis treatment. Thus, the color value can be minimized by involving the osmosis treatment. This was reported by Rapusas and Driscoll (1995).

Fig.1 Variation of MC of fresh dried carrot slices at different drying temperatures

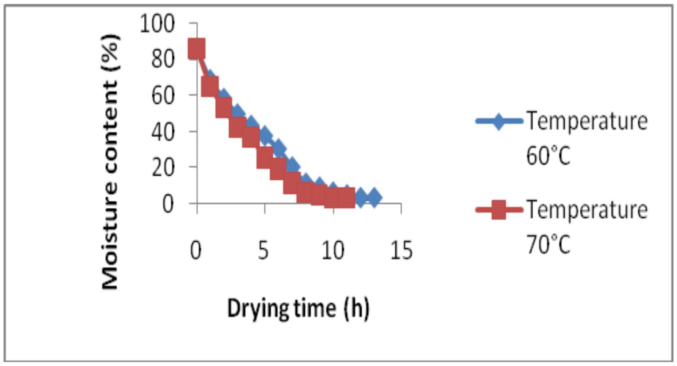


Fig.2 Variation of MC osmo-tray dried carrot slices at different drying temperatures

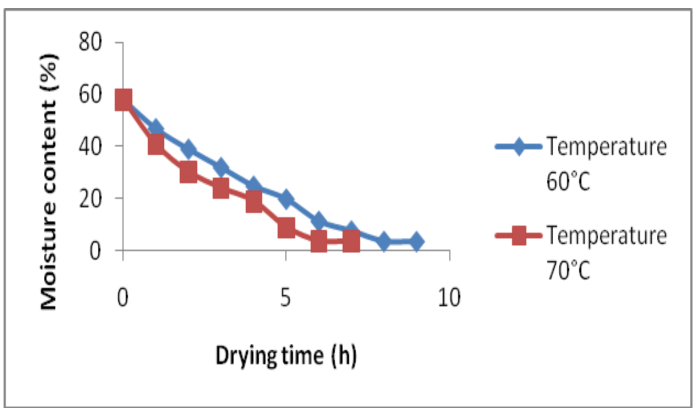


Fig.3 RR of tray dried and osmo-tray dried carrot slices at different temperatures

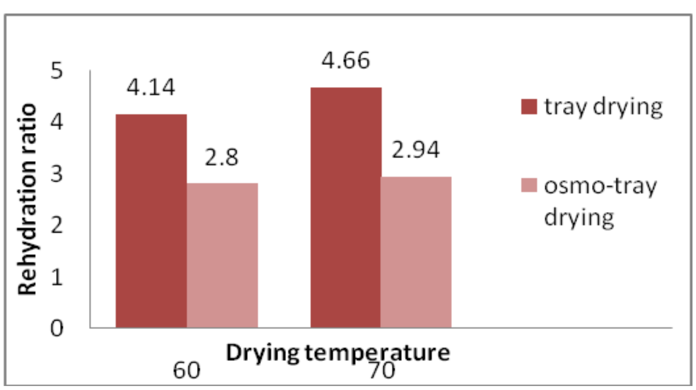


Fig.4 Histogram of tray dried (control) samples at 70 °C

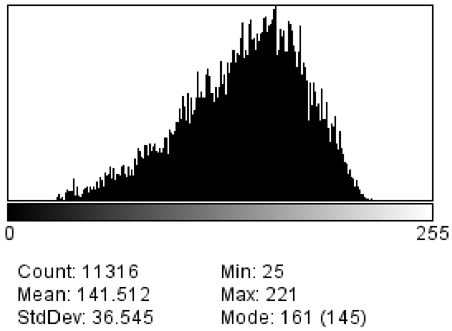


Fig.5 Histogram of osmo-convective tray dried sample at 70°C

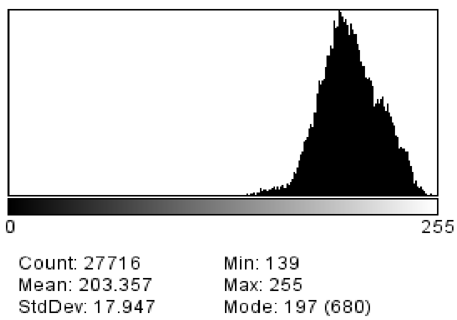
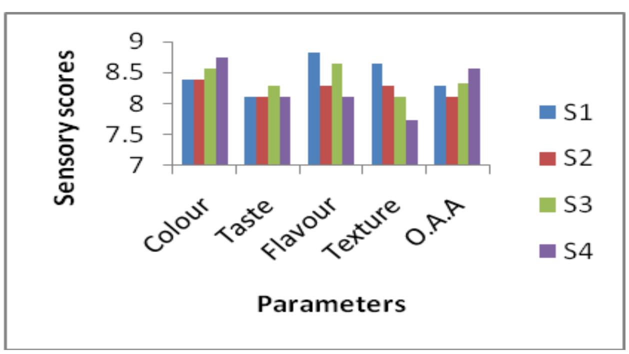


Fig.6 Sensory evaluation of different samples



Sensory characteristics

The various sensory quality attributes viz. color, taste, flavor, texture and overall acceptability of control and osmo-convective carrot, each dried at two different temperatures i.e. 60 and 70°C were evaluated. The results of sensory data on various quality attributes are presented in Fig. 6. It is clear from the figure that the osmo-convective dried carrot slices dried at 70°C obtained the maximum score of 8.71. Whereas, the minimum score of 8.36 (like very much) was awarded to fresh dried carrot slices dried at 60°C (S1 sample) and 70°C (S2 sample). It was observed that the osmo-convective dried carrot slices dried at 70°C (S3 sample) obtained the maximum taste score of 8.28.

Whereas, the minimum score of 8.10 (like very much) was awarded to fresh dried carrot slices dried at 60°C (S1 sample) and 70°C (S2 sample) and osmo-convective dried carrot slices dried at 70°C (S4 sample). Results of sensory scores of flavor revealed that the fresh dried carrot slices dried at 60°C obtained the maximum score of 8.82, whereas, the minimum score of 3.64 (dislike slightly) was awarded to osmo-convective dried carrot slices dried at 60°C. Results of the study revealed that the fresh dried carrot slices dried at 60°C & 70°C were awarded texture score of 8.64 (like extremely) and 8.28 (like very much). However, osmo-convective dried carrot slices dried at 60°C were rated as 8.10 (like very much) and osmo-convective dried carrot slices dried at 70°C were rated as 7.74 (like moderately). The sensory data for changes in overall acceptability score of fresh dried carrot slices and osmo-convective dried carrot slices dried at 60°C, 70°C revealed that the fresh dried carrot slices dried at 60°C & 70°C were awarded texture score of 8.28 (like very much) and 8.10 (like very much), respectively. However, osmo-dried carrot slices dried at 60°C were rated as 8.32 (like very much) and those dried at 70°C were rated as 8.56 (like extremely). It is, therefore, concluded that the osmo-convective dried carrot slices dried at 70°C obtained the maximum score of 8.56, whereas, the minimum score of 8.10 (like very much) was awarded to fresh dried carrot slices dried at 70°C. These results are in conformity with the findings on organoleptic properties of osmotically dehydrated mango slices (Varany Anond *et al*., 2000 and Kumar *et al*., 2009).

Following conclusions were drawn:

The drying time for control and osmosed samples were 12 hrs, 8 hrs respectively at 60^oC and 10 hrs, 6 hrs at 70^oC for reduction of moisture content upto 3- 5 %.

The average RBG values of control sample were 100.245 and 95.377 at 60°C and 70°C respectively. This shows that color increases with increase in temperature. In osmo-convective dried carrot, average RBG values were 73.102 and 71.934 at 60°C and 70°C, respectively. Osmotically dried samples showed light color compared to fresh dried sample but color increased with the increase in temperature.

The values of rehydration ratio of tray dried sample (control) ranged from 4.14 to 4.66 which were higher than that of osmo-tray dried carrot sample ranged from 2.8 to 2.94.

The osmo-convective dried slices showed less color development due to osmosis treatment. Thus, the color value can be minimized by involving the osmosis treatment.

Sensory evaluation reveals that the osmo-convective dried carrot was found best among all the samples with highest overall acceptability.

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