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Research Article

# A COMPARATIVE STUDY ON PHYSICOCHEMICAL CHANGES DURING STORAGE OF HOT AIR AND RADIO FREQUENCY DRIED CARROT SLICES

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**Abstract:** Drying of steam balanced 4mm thickness carrot slice was carried out in three drying methods such as tray drying at 70ºC, Radio frequency (RF) drying with initial moisture content of 90%wb at 210mm electrode distance and combination drying which includes drying of carrot slices of moisture content up to 40%wb in tray dryer at 70ºC followed by RF drying until complete drying. The dried carrot slices were stored in Zip lock pouches at ambient condition for 90 days and its physic-chemical changes were compared. During the 90th day of storage, the rehydration ratios were 9.3, 9.4 and 9.4 for tray dried, RF dried and combination dried carrot slices respectively. The L value of dried carrot slices changed to 32.57, 38.45 and 37.21, the 'a' value of dried carrot slices changed to 19.07, 17.65 and 19.54 and the 'b' value of dried carrot slices changed to 21.41, 24.16 and 23.52 for tray dried, RF dried and combination dried carrot slices respectively during 90th day of storage. After drying the β carotene content were found to be 21.23, 68.21 and 38.78 mg/100g of dry sample. During the 90th day of storage, the β carotene content were found to be decreased to 18.75, 50.6 and 28.26 mg/100g of dry sample for tray dried, RF dried and combination dried carrot slices respectively. During the 90th day of storage, the total sugar content were 60.56, 80.24 and 64.59 mg/100g of dry sample for tray dried, RF dried and combination dried carrot slices respectively.

**Keywords:** *Carrot Slices, Radio Frequency (RF) drying, Tray drying, Physicochemical Changes*

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## Introduction

The production of horticulture crops in India was about 295.2 million tonnes from an area of 24.9 million hectares during 2016-17. The production of vegetables is about 175 million tonnes during to 2016-17. Out of these amounts, only 2.2 % are being processed. The losses in postharvest sector are estimated to be from 10 to 25 percent in durables such as fruits and vegetable. Carrot (*Daucus carota*) is one of the major root vegetable in India with annual production of 1379 MT in 87,000 Ha [1]. In case of carrot, size, appearance and wholesomeness plays a major role in consumer preference, broken and un sized roots are not fetching appropriate price in the market. Hence there is a need for value addition and preservation of such produce which in turn minimize the total post harvest losses. Converting carrot into dehydrated carrot slices will increase its value and it will add additional income to farmers. Drying processes offer an alternative way of using fresh carrots for consumption. Dried carrot in the form of slice or powder helps to develop instant food products such as soups, noodles, snacks, rice mixes and so on. Recently, there is a great demand for dried carrot slices in the international markets. Also, the process allows a substantial reduction in terms of mass, volume, packaging requirement, storage and transportation costs with more convenience.

## Materials and Methods

### Raw Material Preparation

Freshly harvested carrots (Nantes variety) procured from farmers were used for the study. Carrot was graded based on size and cleaned well before slicing in commercial vegetable slicer. The carrot slices were steam blanched autoclave and cooled immediately by spreading it in SS trays before drying.

### Drying of carrot slices

The carrot slices were placed in perforated trays which are commercially used for drying food materials. The drying of carrot slice was carried out in three drying methods such as tray drying at 70ºC, Radio frequency (RF) drying with initial moisture content of 90%wb at 210mm electrode distance and combination drying which includes drying of carrot slices of moisture content up to 40%wb in tray dryer at 70ºC followed by RF drying until complete drying. Dried carrot slices were packaged using low density polyethylene (LDPE) Zip lock pouches (100 microns). The packaged pouches were stored at room condition (temperature 28±2ºC and relative humidity 60±5 percent) for three months. During three months of storage, studies on changes in rehydration ratio, colour, and β carotene content were carried out at fifteen days intervals and recorded.

### Rehydration Ratio

A sample of 5 g of the dried carrot slices was placed in a 250 ml beaker containing 150 ml of boiling distilled water. The contents were boiled for 5 min to allow the slices to rehydrate. After rehydration, the free surface water on the carrot slices was removed before assessing the rehydrated mass [2]. Triplicate measurements were done and the average values are reported here. The rehydration ratio (RR) was calculated as follow

$$\text{Rehydration ratio} = \frac{\text{Drained weight of rehydrated sample,g}}{\text{Weight of sample taken,g}} \quad (1)$$

### Colour Value

Colour flex meter (Make: Hunter Lab) was used for the measurement of colour. The instrument was calibrated each time by reading defined colours like white and black. The parameters such as 'L', 'a' and 'b' generally give the total colour of dried carrot slices.

### β carotene content

Acetone-petroleum ether extract method was used to estimate it during the storage period. Quantity of beta carotene (mg) present in 100 g of the sample was calculated using the formula as given below:

$$\text{Beta carotene (mg/100 g)} = \frac{\text{Absorbance at 453 nm}}{0.2592} \times \frac{\text{Total volume}}{\text{Weight of the sample}} \times 100 \quad (2)$$

### Total sugar content

Total sugar content was estimated by Phenol Sulphuric Acid Method described by [3].The amount of total sugars present in the sample expressed in mg/100 g of the fresh weight was estimated using the standard graph and calculated using following formula:

$$Total\ sugar\left(\frac{\text{mg}}{100\text{g}}\text{ of sample}\right) = \frac{\text{Concentration from standard graph of glucose}}{\text{Aliquot taken for estimation}} \times 100 \times \frac{100}{\text{Weight of the sample}} \times \frac{1}{1000} \quad (3)$$

## Results and Discussion

### Effects of drying methods on rehydration ratio of dried carrot slices

The effect of drying methods (M) and storage days (S) on rehydration ratio of dried carrot slices are shown in the [Fig-1] and the ANOVA for the same were presented in the [Table-1]. During the entire storage period of 90days, the rehydration ratio was found to vary between 9.3 and 9.7 among the different drying methods. During the initial storage day, the rehydration ratios were 9.5, 9.7 and 9.7 for tray dried, RF dried and combination dried carrot slices respectively. During the 90$^{th}$ day of storage, the rehydration ratios were 9.3, 9.4 and 9.4 for tray dried, RF dried and combination dried carrot slices respectively. The effect of drying methods and effect of storage days were significant at 5% level. Whereas, the interaction effect between the drying methods and storage days were non-significant. The coefficient of variance value of the rehydration ratio during storage days was estimated to be 2.06%. The reason for high in rehydration ratio in RF dried carrot slices among the different drying treatments is less changes in cell structure during RF drying. The changes in rehydration depended also on the temperature of drying process.[4]Similar result was reported by [2] that there is a difference between rehydration characteristics of dried products with different pre-treatments even when the products were dried by the same drying method.

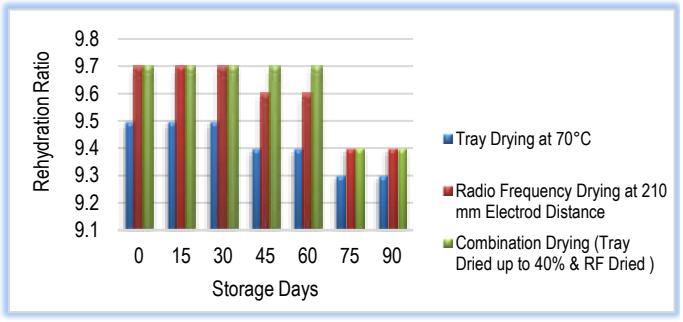


Fig-1 Effect of different drying methods on rehydration ratio during storage

Table-1 *ANOVA for rehydration ratio during storage studies*

| Source | df | SS | MS | F | PROB |
|---|---|---|---|---|---|
| TOT | 62 | 2.89 | 0.05 | 1.25 | |
| Rep | 2 | 0.05 | 0.02 | 0.60 | |
| Trt | 20 | 1.35 | 0.07 | 1.81 | 0.055 NS |
| Err | 40 | 1.49 | 0.04 | 1.00 | |
| M | 2 | 0.49 | 0.25 | 6.56 | 0.003** |
| S | 6 | 0.79 | 0.13 | 3.52 | 0.007** |
| MS | 12 | 0.07 | 0.01 | 0.16 | 0.999 NS |
| Err | 40 | 1.49 | 0.04 | 1.00 | |
| CV = 2.06% | | | | | |
| | | SED | CD(0.05) | CD(0.01) | |
| M | | 0.06 | 0.12 | 0.16 | |
| S | | 0.09 | 0.18 | 0.25 | |
| MS | | 0.16 | 0.32 | 0.43 | |

### Effects of different drying methods on L value of dried carrot slices

The effect of drying methods (M) and storage days (S) on L value of dried carrot slices are shown in the Fig. 2 and the ANOVA for the same were presented in the Table 2. During the entire storage period of 90days, the L value was found to vary between 32.57 and 51.53 among the different drying methods. During the initial storage day, the L value was 37.41, 51.53 and 37.45 for tray dried, RF dried and combination dried carrot slices respectively. During the 90th day of storage, the L value of dried carrot slices changed to 32.57, 38.45 and 37.21 for tray dried, RF dried and combination dried carrot slices respectively. Effect of drying methods, effect of storage days and its interaction were found to be significant at 5% level. The coefficient of variance for the L value during storage days was estimated to be 2.35%.Similarly, the result obtained by [5]shows that the changes in L∗ (lightness) were also dependent on drying air temperature as well as drying time.

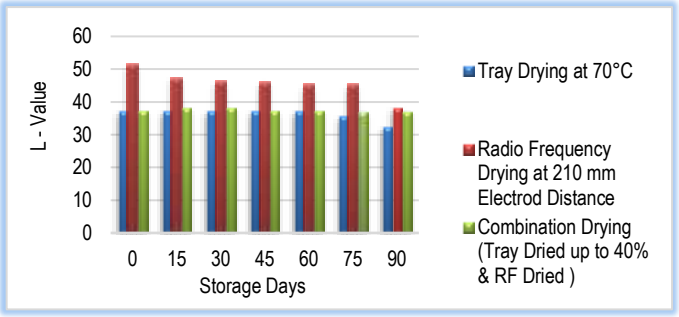


Fig-2 Effect of different drying methods on L- value during storage

Table-2 *ANOVA for L value during storage studies*

| Source | df | SS | MS | F | PROB |
|---|---|---|---|---|---|
| TOT | 62 | 1429.72 | 23.06 | 27.16 | |
| Rep | 2 | 3.39 | 1.70 | 2.00 | |
| Trt | 20 | 1392.36 | 69.62 | 81.98 | 0.000** |
| Err | 40 | 33.97 | 0.85 | 1.00 | |
| M | 2 | 1058.17 | 529.08 | 623.05 | 0.000** |
| S | 6 | 196.27 | 32.71 | 38.52 | 0.000** |
| MS | 12 | 137.92 | 11.49 | 13.53 | 0.000** |
| Err | 40 | 33.97 | 0.85 | 1.00 | |
| CV = 2.35% | | | | | |
| | | SED | CD(0.05) | CD(0.01) | |
| M | | 0.28 | 0.57 | 0.77 | |
| S | | 0.43 | 0.88 | 1.17 | |
| MS | | 0.75 | 1.52 | 2.03 | |

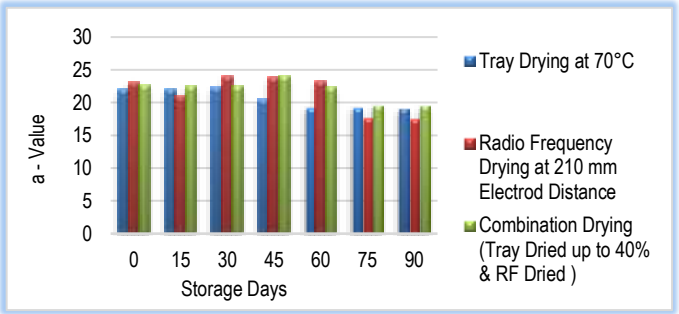


Fig-3 Effect of different drying methods on a- value during storage

Table-3 *ANOVA for 'a' value during storage studies*

| Source | df | SS | MS | F | PROB |
|---|---|---|---|---|---|
| TOT | 62 | 252.59 | 4.07 | 20.02 | |
| Rep | 2 | 0.13 | 0.06 | 0.31 | |
| Trt | 20 | 244.32 | 12.22 | 60.03 | 0.000** |
| Err | 40 | 8.14 | 0.20 | 1.00 | |
| M | 2 | 16.54 | 8.27 | 40.64 | 0.000** |
| S | 6 | 173.74 | 28.96 | 142.29 | 0.000** |
| MS | 12 | 54.04 | 4.50 | 22.13 | 0.000** |
| Err | 40 | 8.14 | 0.20 | 1.00 | |
| CV = 1.96% | | | | | |
| | | SED | CD(0.05) | CD(0.01) | |
| M | | 0.14 | 0.28 | 0.38 | |
| S | | 0.21 | 0.43 | 0.58 | |
| MS | | 0.37 | 0.74 | 1.00 | |

**Effects of different drying methods on 'a' value of dried carrot slices**

The effect of drying methods (M) and storage days (S) on 'a' value of dried carrot slices are shown in the [Fig-3] and the ANOVA for the same were presented in the Table 3. During the entire storage period of 90days, the 'a' value was found to vary between 17.65 and 23.97 among the different drying methods. During initial day of storage, the 'a' value was 23.03, 23.16 and 22.65 for tray dried, RF dried and combination dried carrot slices respectively. During the 90th day of storage, the 'a' value of dried carrot slices changed to 19.07, 17.65 and 19.54 for tray dried, RF dried and combination dried carrot slices respectively. The changes in the 'a' value throughout the entire storage period irrespective of drying methods were found to follow a decreasing trend. Effect of drying methods, effect of storage days and its interaction were found to be significant at 5% level. The coefficient of variance for the 'a' value during storage days was estimated to be 1.96%.

**Effects of different drying methods on 'b' value of dried carrot slices**

The effect of drying methods (M) and storage days (S) on 'b' value of dried carrot slices are shown in the Fig. 4 and the ANOVA for the same were presented in the Table 4. During the entire storage period of 90days, the 'b' value was found to vary between 34.73 and 20.41 among the different drying methods. During the 1st day of storage, the 'b' values were 28.11, 34.73 and 23.42 for tray dried, RF dried and combination dried carrot slices respectively. During the 90th day of storage, the 'b' value of dried carrot slices changed to 21.41, 24.16 and 23.52 for tray dried, RF dried and combination dried carrot slices respectively. The changes in the 'b' value throughout the entire storage period irrespective of drying methods were found to follow a decreasing trend. Effect of drying methods, effect of storage days and its interaction were found to be significant at 5% level. The coefficient of variance for the 'b' value during storage days was estimated to be 2.43%.

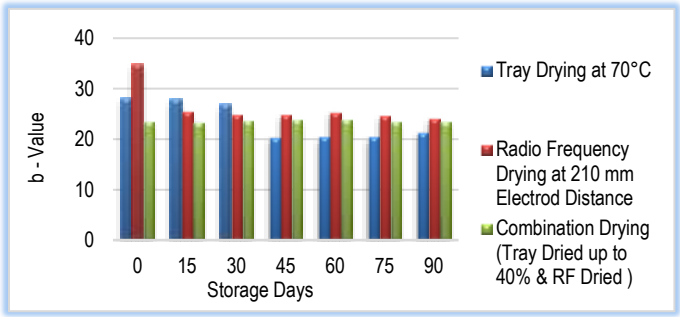


Fig-4 Effect of different drying methods on b - value during storage

Table-4 *ANOVA for 'b' value during storage studies*

| Source | df | SS | MS | F | PROB |
|---|---|---|---|---|---|
| TOT | 62 | 614.84 | 9.92 | 29.69 | |
| Rep | 2 | 0.18 | 0.09 | 0.27 | |
| Trt | 20 | 601.29 | 30.06 | 90.01 | 0.000** |
| Err | 40 | 13.36 | 0.33 | 1.00 | |
| M | 2 | 102.70 | 51.35 | 153.73 | 0.000** |
| S | 6 | 251.19 | 41.87 | 125.33 | 0.000** |
| MS | 12 | 247.40 | 20.62 | 61.72 | 0.000** |
| Err | 40 | 13.36 | 0.33 | 1.00 | |
| CV = 2.43% | | | | | |
| | | SED | CD(0.05) | CD(0.01) | |
| M | | 0.17 | 0.36 | 0.48 | |
| S | | 0.08 | 0.43 | 0.34 | |
| MS | | 0.16 | 0.35 | 0.41 | |

**Effects of different drying methods on β carotene content of dried carrot slices**

The effect of drying methods (M) and storage days (S) on β carotene content of dried carrot slices are shown in the Fig. 5 and the ANOVA for the same were presented in the Table 5. During initial day of storage, the β carotene content were 21.23, 68.21 and 38.78 mg/100g of dry sample for tray dried, RF dried and combination dried carrot slices respectively. The initial β carotene content for RF dried carrot slices was high when compared to other drying method this is due to less total drying time. During the 90th day of storage, the β carotene content were 18.75, 50.6 and 28.26 mg/100g of dry sample for tray dried, RF dried and combination dried carrot slices respectively. Even though the final β carotene content on 90th day of RF dried carrot slice is high, irrespective of drying method the depletion of β carotene content was found in all samples. The highest value of β carotene content of 38.78 mg/100g of dry sample found during 1th day of storage in the RF dried carrot slices, whereas, the lowest value β carotene content of 18.75 mg/100g of dry sample was found during 90th day of storage in tray dried sample. The effect of drying methods, effect of storage days and its interaction were found to be significant at 5% level. The coefficient of variance value of the β carotene content during storage days was estimated to be 2.48%. The β carotene content was found to decrease with increase in drying temperature, this phenomena is may be due to thermal degradation. Similarly, the result obtained by[6] also conform the thermal degradation of β carotene content with drying temperature.

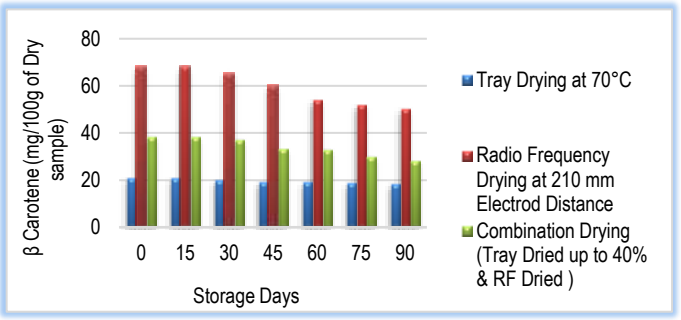


Fig-5 Effect of different drying methods on β Carotene during storage

Table-5 *ANOVA for β carotene content during storage studies*

| Source | df | SS | MS | F | PROB |
|---|---|---|---|---|---|
| TOT | 62 | 18582.50 | 299.72 | 366.05 | |
| Rep | 2 | 0.76 | 0.38 | 0.46 | |
| Trt | 20 | 18548.99 | 927.45 | 1132.70 | 0.000** |
| Err | 40 | 32.75 | 0.82 | 1.00 | |
| M | 2 | 17181.15 | 8590.57 | 10491.72 | 0.000** |
| S | 6 | 953.87 | 158.98 | 194.16 | 0.000** |
| MS | 12 | 413.98 | 34.50 | 42.13 | 0.000** |
| Err | 40 | 32.75 | 0.82 | 1.00 | |
| CV = 2.48% | | | | | |
| | | SED | CD(0.05) | CD(0.01) | |
| M | | 0.28 | 0.56 | 0.76 | |
| S | | 0.43 | 0.86 | 1.15 | |
| MS | | 0.74 | 1.49 | 2.00 | |

**Effects of different drying methods on total sugar content of dried carrot slices**

The effect of drying methods (M) and storage days (S) on total sugar content of dried carrot slices are shown in the Fig. 6 and the ANOVA for the same were presented in the Table 6. During the 1st day of storage, the total sugar content were 64.89, 82.36 and 68.23 mg/100g of dry sample for tray dried, RF dried and combination dried carrot slices respectively. During the 90th day of storage, the total sugar content were 60.56, 80.24 and 64.59 mg/100g of dry sample for tray dried, RF dried and combination dried carrot slices respectively. The effect of drying methods and effect of storage days were significant at 5% level. Whereas, the interaction effect between the drying methods and storage days were non-significant. The coefficient of variance value of the total sugar content during storage days was estimated to be 2.06%.

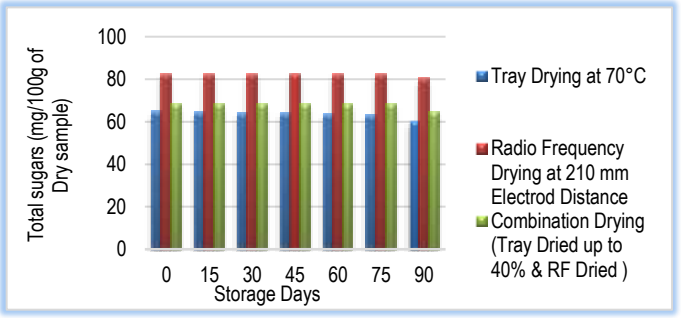


Fig-6 Effect of different drying methods on total sugars during storage

Table-6 *ANOVA for total sugar content during storage studies*

| Source | df | SS | MS | F | PROB |
|---|---|---|---|---|---|
| TOT | 62 | 4149.80 | 66.93 | 24.70 | |
| Rep | 2 | 13.48 | 6.74 | 2.49 | |
| Trt | 20 | 4027.91 | 201.40 | 74.31 | 0.000** |
| Err | 40 | 108.41 | 2.71 | 1.00 | |
| M | 2 | 3947.73 | 1973.86 | 728.31 | 0.000** |
| S | 6 | 73.38 | 12.23 | 4.51 | 0.001** |
| MS | 12 | 6.80 | 0.57 | 0.21 | 0.997NS |
| Err | 40 | 108.41 | 2.71 | 1.00 | |
| CV = 2.19% | | | | | |
| | | SED | CD(0.05) | CD(0.01) | |
| M | | 0.51 | 1.03 | 1.37 | |
| S | | 0.78 | 1.57 | 2.10 | |
| MS | | 1.34 | 2.72 | 3.64 | |

## Conclusion

Dehydrated carrot are of great nutritional importance since they make a significant contribution in supplying wealth of essential vitamins, minerals, fibers and carbohydrates that improve the quality of the diet. The carrot slices dried in radio frequency (RF) dryer shows better retention of nutritional quality when stored in ambient condition. The changes in physicochemical quality of carrot slices dried in combination drying method were also found to be less, whereas results of tray dried carrot slices shows more nutritional change.

**Application of research**: Study highlights the physicochemical changes take place during storage of dried carrot slices under ambient condition. The results help in selecting a suitable drying method for carrot slices to be adapted in large scale.

**Research Category**: Post harvest technology

**Abbreviations**:
%: percent
mg: milligram
ANOVA: Analysis of Variance
MS: Mean sum of Squares
CV: coefficient of variance
SS: Sum of Squares
**: Significant at 1 percent level
*: Significant at 5 percent level
NS: Non significant
F value: Fischer value, Statistical significance value

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***Research Guide: Dr T. Pandiarajan**
University: Tamil Nadu Agricultural University, Coimbatore, 641003, Tamil Nadu
Research project name or number: MTech

**Author Contributions**: All authors equally contributed

**Author statement**: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

**Study area**: Tamil Nadu Agricultural University, Coimbatore, 641003, Tamil Nadu

**Cultivar / Variety name**: Carrot (*Daucus carota*) Nantes

**Conflict of Interest**: None declared

**Ethical approval**: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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