Research Article

Optimization of the Impact of Different Cooking and Storage Conditions on β-carotene Bioavailability and Total carotenoids of Carrots (*Daucus carota*)

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Abstract

β-carotene, a natural antioxidant is found in nature in *trans*-form. However under different treatments some of the molecules may be converted to *cis*-isomer although *trans*-form is more bioavailable. The study aims to optimize the usual cooking/storing processes to retain the more bioavailable *trans* β-carotene of a popular vegetable, carrot. While, during microwave assisted cooking process, the optimum *trans* β-carotene was achieved after 180s in both wet & dry methods of irradiation {783.74 ppm MW(dry) and 1453.98ppm MW(wet)}, highest *trans* β-carotene was found after 20 min (2517.05 ppm) of boiling with water. Among the storing processes, refrigerated storage for 3-day may be prescribed to get optimum bioavailable *trans* β-carotene from mashed carrot, though some isomeric transformation has been noticed from *trans*- to *cis*-form. Total carotenoids yield percentages are also measured and are consistent with the β-carotene contents under different treatments.

Keywords: *trans* β-carotene, carrot, bioavailable, total carotenoids yield, spectral study, optimization

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Introduction

Carotenoids are organic pigments that are found in the chloroplasts and chromoplasts of plants and some other photosynthetic organisms, including some bacteria and fungi. In nature carotenoids exist primarily in the more stable all *trans*- (or all-*E*) form, but small amount of *cis*- (or -*Z*) isomers do occur.

β-carotene, whether provitamin A or not, have been credited with beneficial effects on human health: enhancement of the immune response and reduction of the risk of degenerative diseases such as cancer, cardiovascular diseases, cataract, and macular degeneration [1,2,3,4,5,6,7,8]. The action of carotenoids against diseases has been attributed to an antioxidant property, specifically, their ability to quench singlet oxygen and interact with free radicals [9]. The ability of carotenoids to quench singlet oxygen has been linked to the conjugated double bond system, the maximum efficiency being shown by carotenoids with nine or more conjugated double bonds [10]. In ripe fruits carotenoids are located in the chromoplasts and hydroxycarotenoids are mostly esterified with fatty acids. Differences among cultivars [11,12,13] of the same food, stage of maturity are the factors that decisively affect carotenoid composition due to enhanced carotenogenesis [12,13,14,15,16,17,18].

Elevated temperature and greater exposure to sunlight increase carotenogenesis. Thus, tropical climates favor carotenoid biosynthesis, with fruits produced in such climates containing distinctly higher carotenoid concentrations [20,21].

Though there are so many fruits and vegetables which are excellent source **of β-carotene, Carrot (*Daucus carota*)** being the richest source has been preferred in this study. Carotenoids in nature are protected by the cellular structure, the destruction of which renders carotenoids vulnerable to degradation. Processing and storage of foods should be optimized to prevent or reduce degradation while accentuating bioavailability. Alteration or loss of carotenoids during processing and storage of foods occurs through physical removal (e.g., peeling), geometric isomerization, and enzymatic or non-enzymatic oxidation [22,23]. Freezing (especially quick-freezing) and frozen storage generally preserve carotenoids, but slow thawing can be detrimental, particularly when the product has not been properly blanched. Enzymatic oxidation can also take place in minimally processed [24] and in unblanched frozen foods. In recent years, however, attention has shifted to the effect of processing on the bioavailability of carotenoids.

The aim of the present study was to optimize the cooking process, along with storage time in order to get better nutrition from carrot by retaining the more bioavailable *trans*-form. Several processes have been undertaken for the experiment, viz; microwave irradiation in dry & wet manner, boiling with water, carrot (mashed) kept in ambient conditions (room temperature) as well as in refrigerator and uv (longwave) irradiation for several hours to optimize/maximize *trans* β-carotene availability, total carotenoids yield and to study uv-visible spectral characteristics.

Experimental

Materials and Reagents

Raw, ripened and fresh carrot were purchased from local market.
Acetone AR Grade was bought from Merck while β-carotene standard from SRL, Assay -90%
Instruments used: UV-Vis spectrophotometer UNICAM 300 – Thermospectronics, Monopan Weighing balance of Mettler, uv-illumination chamber, microwave oven, magnetic stirrer, mixer grinder, Hot-air oven and refrigerator were utilized in the study.

Sample Preparation

The fresh, raw and ripened samples were washed with water, grated into finer fractions and homogenised in a mixer grinder.

The homogenised mass was divided into different parts as per the requirement of the study, viz.,

1. Fresh sample
2. Room temperature treatment
3. Freezing temperature treatment
4. Boiling temperature treatment
5. Microwave irradiation treatment (wet & dry) and
6. UV irradiation treatment.

Extraction Method and different treatments

Acetone AR Grade was used as the extracting solvent for β-carotene. The homogenised mass was used as the sample for the entire study. After each treatment and/or interval samplings were done and a weighed sample was extracted with the solvent for several times using magnetic stirrer for proper solute-solvent interaction to determine the

carotenoid content, yield of the carotenoid and the spectral study. The extracted carotenoid was taken in a known volume of volumetric flak to determine the β-carotene content (in ppm) using a standard β-carotene calibration curve at 450 nm and also scanned to note the spectral data within the wavelength range from 325-600 nm, using spectrophotometer (Unicam 300, Thermospectronics). The solution then dried in hot-air oven at 45-50^{o}C to determine the yield percentage. For each such sample, moisture was determined simultaneously to have the actual weight of the sample taken for experiment.

Fresh sample

A known weight of the mashed carrot was taken as sample to determine the β-carotene content, total carotenoids yield, spectral study as well as the moisture content.

Ambient (Room) temperature treatment

The mashed sample was kept at the ambient temperature prevailing, i.e. at around 30-32^{o}C and samplings were done periodically after 1st, 2nd and 3rd day for the studies.

Freezing temperature treatment

The mashed sample was kept in the freezing temperature in a refrigerator, i.e. at around 4-6^{o}C and samplings were done periodically after 1st, 2nd and 3rd day for the studies.

Boiling temperature treatment

The mashed sample was boiled with potable water in open flame and samplings were done periodically after 10, 20 and 30 minutes for the studies.

Microwave irradiation treatment (wet & dry)

The mashed sample was irradiated with microwave ray directly (without added water and with added water) and samplings were done periodically after 30 sec, 1, 2, 3, 4 and 6 minutes for the studies. The radiation frequency (ν_{rad}) being 2450 MHz/sec.

UV irradiation treatment

The mashed sample was irradiated in uv ray (long wave) directly and samplings were done periodically after 2 hours, 4 hours and 6 hours for the studies.

Establishment of Calibration Curve

A calibration curve was made with standard β-carotene (SRL, assay 90%), Acetone AR Grade was used as the solvent. The concentrations of 2, 5 and 10 ppm β-carotene standards used were and measured at a wavelength of 450 nm (λ_{max}) using spectrophotometer (UNICAM 300 – Thermospectronics).

A = 0.0788 x Conc. (Factor = 12.6860); Selected fit: linear to zero; Coefficient: 0.999401; Sum of Residuals: 0.0002

β-carotene content

The extracted β-carotene was made up into a known volume with acetone and concentrations were measured against the standard calibration curve at a wavelength of 450 nm (λ_{max}).

Spectral Study:
Each β-carotene extract was scanned in the range of 325 – 600 nm in the spectrophotometer to obtain the absorbance peaks.

Percentage of Yield
Each extract was dried in hot-air oven at 45-50ºC and a constant weight was taken in the weighing balance.
Each sample weight was corrected w.r.t moisture content by expressing the data on dry weight basis.

Results and Discussion

Table 1 β-carotene content, wavelength of absorption of β-carotene & β-carotene Yield (%) of mashed carrot subjected to different treatments

Treatment	Duration	β-carotene (ppm) Dried				Wavelength of absorbtion (nm) of β-carotene	Total carotenoids (ppm) Dried			
		VALUE	MEAN	SD	SE		VALUE	MEAN	SD	SE
Fresh	--	252.899	252.47	0.374	0.216	429,454,478	61.52	61.70	0.25	0.15
		252.217					61.59			
		252.290					61.99			
Microwave radiation (Dry Heat)	30s	332.31	332.27	0.18	0.10	428,450,476	22.38	22.43	0.31	0.18
		332.08					22.15			
		332.43					22.77			
	60s	360.31	360.11	0.32	0.19	426,450,476	22.78	22.74	0.23	0.13
		359.74					22.49			
		360.29					22.94			
	120s	658.29	658.11	0.15	0.09	430,452,478	18.14	18.40	0.33	0.19
		658.01					18.29			
		658.04					18.77			
	180s	783.55	783.74	0.17	0.10	425,450,476	9.15	9.31	0.15	0.09
		783.78					9.45			
		783.89					9.34			
	240s	487.01	486.96	0.07	0.04	425,449,478	8.14	8.44	0.32	0.19
		486.88					8.78			
		487.00					8.40			
	360s	453.68	453.46	0.24	0.14	426,450,475	7.22	7.45	0.29	0.17
		453.50					7.35			
		453.21					7.77			
Microwave radiation wet (with added water)	30s	766.62	766.62	0.27	0.16	428,452,477	12.99	12.81	0.21	0.12
		766.35					12.87			
		766.89					12.58			
	60s	1166.04	1166.06	0.18	0.10	429,452,478	12.56	12.71	0.16	0.09
		1165.89					12.88			
		1166.25					12.69			
	120s	1191.50	1191.41	0.17	0.10	427,452,477	16.53	16.34	0.37	0.22
		1191.51					16.58			
		1191.21					15.91			
	180s	1454.01	1453.98	0.09	0.05	428,452,478	17.88	17.72	0.38	0.22
		1454.05					17.29			
		1453.87					17.99			
	240s	1345.11	1345.07	0.21	0.12	428,452,477	19.22	18.92	0.34	0.20
		1345.25					18.55			
		1344.84					18.99			
	360s	1337.90	1338.04	0.12	0.07	428,452,478	21.68	21.79	0.11	0.06
		1338.09					21.79			
		1338.12					21.90			
		2374.88					144.78			

Boiling with water (on open flame)	10m	2375.12	2375.09	0.20	0.12	429,451,475	144.34	144.54	0.22	0.13
		2375.28					144.50			
	20m	2517.14	2517.05	0.08	0.05	428,451,476	136.30	136.39	0.29	0.17
		2517.00					136.16			
		2517.00					136.71			
	30m	1830.11	1830.38	0.29	0.17	345,370,430,451,475	126.27	126.27	0.17	0.10
		1830.35					126.10			
		1830.69					126.44			
Room Temperature	01 D	481.56	481.63	0.22	0.13	426,450,473	40.12	39.97	0.13	0.08
		481.45					39.87			
		481.88					39.91			
	02D	685.52	685.55	0.15	0.09	427,451,473	32.11	32.00	0.19	0.11
		685.41					31.78			
		685.71					32.10			
	03D	1133.00	1133.10	0.11	0.06	425,450,473	26.71	26.67	0.20	0.11
		1133.21					26.84			
		1133.08					26.45			
Freezing temp	01 D	161.94	162.16	0.29	0.17	427,449,479	35.88	35.65	0.22	0.13
		162.05					35.44			
		162.49					35.64			
	02D	869.00	869.31	0.42	0.24	425,452,478	34.14	34.33	0.21	0.12
		869.14					34.56			
		869.79					34.29			
	03D	1313.62	1313.50	0.35	0.20	426,454,478	30.47	30.75	0.27	0.16
		1313.77					31.01			
		1313.10					30.76			
UV radiation (long wave)	02Hr	389.44	389.61	0.24	0.14	335,425,445,473	24.74	24.67	0.08	0.04
		389.89					24.59			
		389.50					24.69			
	04Hr	363.42	363.50	0.34	0.20	335,426,445,474	26.11	25.90	0.23	0.13
		363.21					25.66			
		363.88					25.94			
	06Hr	150.00	150.05	0.24	0.14	335,428,449,478	10.38	10.58	0.22	0.13
		150.31					10.82			
		149.84					10.54			

abbrv: --s: second; m: minute; Hr: hour; D: day; ppm: parts per million

Table 2 Correlation between the β-carotene content (ppm), total carotenoid yield % and duration of each treatment of carrot w.r.t different cooking and storage conditions

Treatment	β-carotene & total carotenoids yield (%) Correlation Coefficient (R_1)	β-carotene & duration (sec) in each treatment Correlation Coefficient (R_2)	Status of *trans*-isomer (bioavailable) after treatment	Formation of *cis*-isomer after treatment
Microwave irradiation (dry)	**-0.46**	**0.05**	**unchanged**	**No**
Microwave irradiation (wet)	**0.72**	**0.49**	**unchanged**	**No**
Boiling with water on open flame	**0.78**	**-0.56**	**unchanged**	**No**
Ambient temp. Storage (30-32ºC)	**-0.94**	**0.96**	**unchanged**	**No**

Freezing temp. Storage (4-6°C)	**-0.87**	**0.98**	**Transformed partially**	**Yes**
Uv irradiation (longwave)	**0.98**	**-0.83**	**Transformed partially**	**Yes**

positive	Positive & significant	Negative	Partial transformed to cis- β-carotene	Formation of cis-β-carotene

A) Variation in β-carotene content (ppm) under different cooking and storage conditions

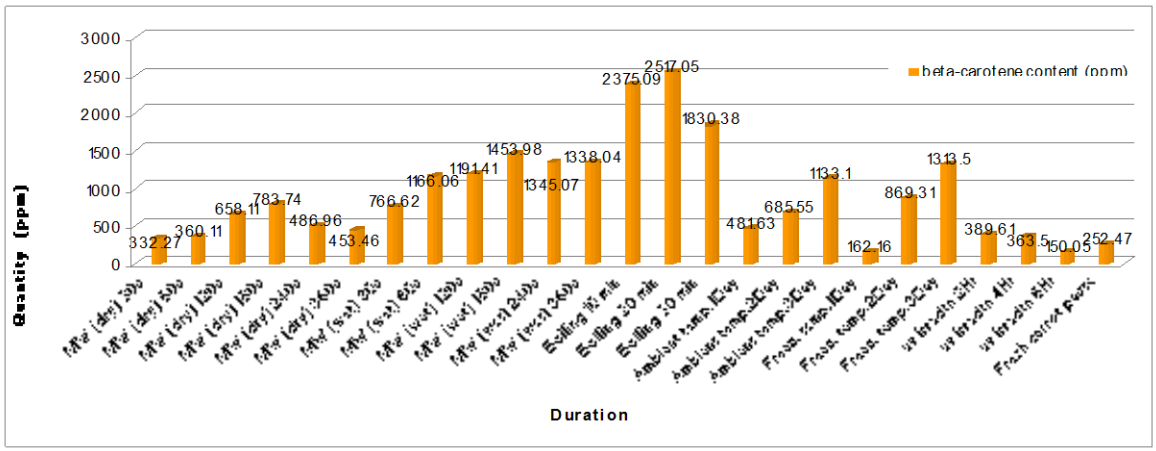

Figure 1 Changes in β-carotene content (ppm) during several treatments/storage

B) Variation in Total carotenoids yield (%) with duration of treatments and storage

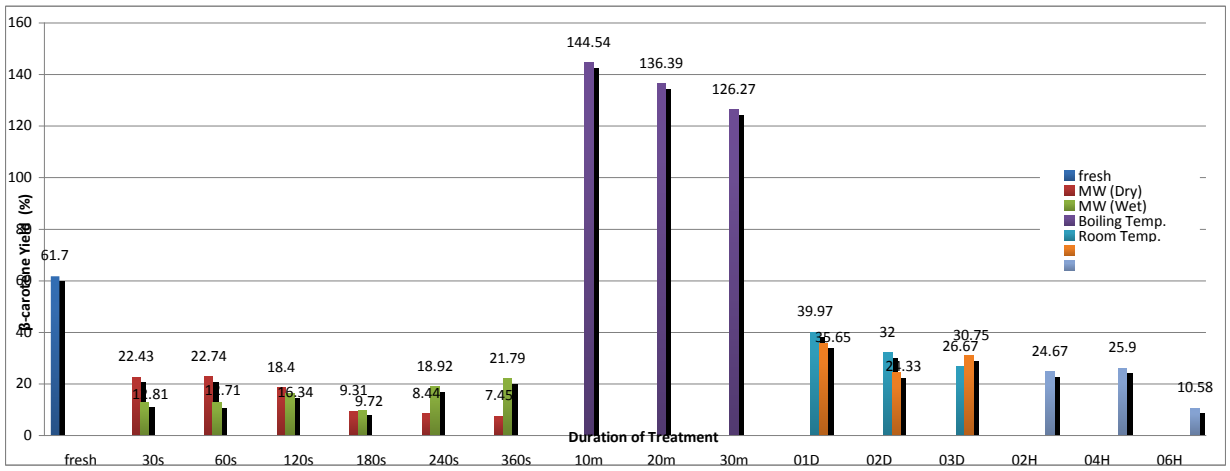

Figure 2 Total Carotenoids Yield (dry basis) of mashed carrot under different treatments/storage

C) Variation in Wavelength of Absorbtion with duration of treatments and storage

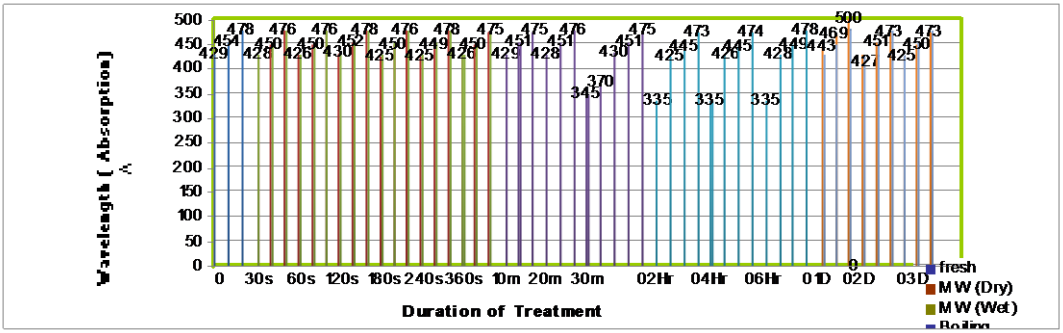

Figure 3 Absorption wavelengths (spectral study) of extracted β-carotene from differently treated/stored mashed carrot

D) uv-vis spectrum of β-carotene of carrot extracts under different treatments/storage

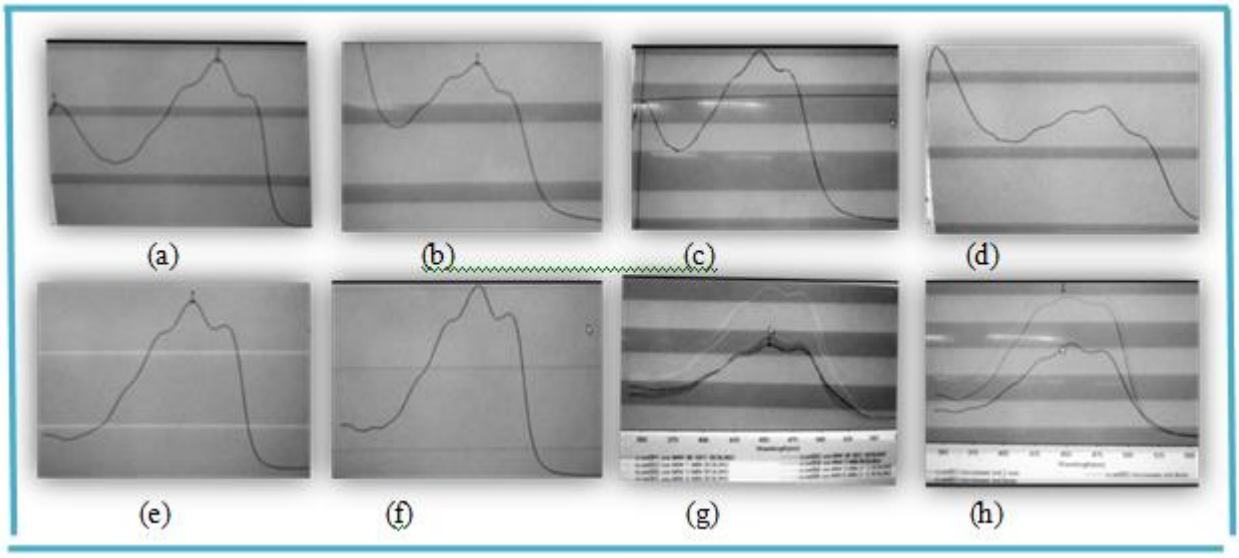

Figure 4 Absorbtion spectrum of β-carotene *(a-freezing 3day; b-ambient 3day; c-uv 2hr; d-uv6hr; e-boiling 10min; f-boiling 20min; g-MWwet; h-MWdry)*

E) Correlation study of β-carotene content & treatment duration(s)

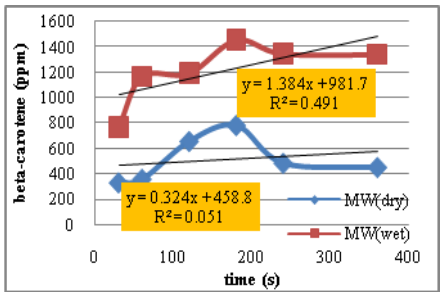

Figure 5a Correlation between MW (wet & dry) treatment & β-carotene content

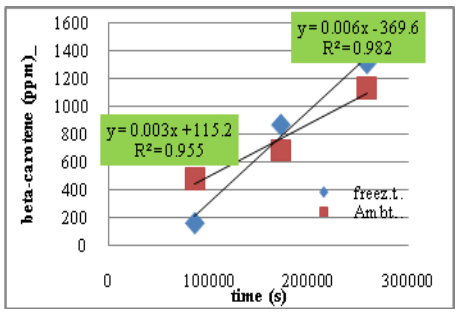

Figure 5d Correlation between refrigeration and ambient temperature storage & β-carotene content

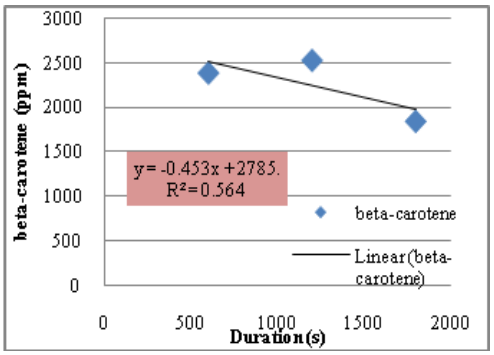

Figure 5c Correlation between boiling treatments & β-carotene content

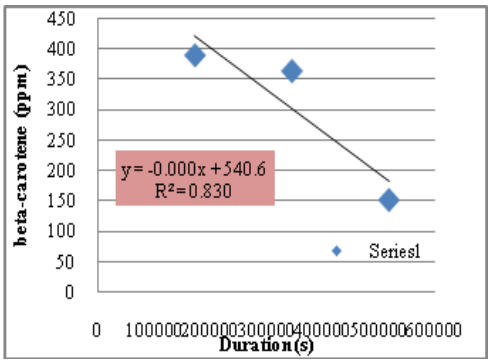

Figure 5d Correlation between uv(longwave) irradiation treatment & β-carotene content

Figure 5 Correlation study of β-carotene and different treatments/storage

Result & Discussion

The experiment was carried out on homogenised mass of mashed carrot sample. The geometrical isomer present in raw & fresh sample was ***trans*-β-carotene**.

The MW Irradiation Treatment

MW irradiation experiment was carried out in two ways, e.g. wet & dry. From the graph **(Figure 1 & 5a)**, it is evident that, in the wet method (water), there was sharp increase in the *trans* β-carotene content of the sample and maximum was reached after 180s MW irradiation (1453.98ppm), thus suggesting the denaturation of proteins and breaking down of the cell wall facilitating the release of carotenoids from the food matrix during irradiation. The same sample revealed an increase in the *trans* β-carotene content upto 783.74ppm, when irradiated through 180s during MW (dry) process. Thus, a two-fold increase in the β-carotene content resulted in case of MW (wet) irradiation in comparison to the MW (dry) method, is probably due to the fact that direct MW may have degraded the carotenoid more, leading to the formation of oxidised products. On further irradiation upto 360s, the β-carotene content decreased in both the cases (to 453.46ppm in MW (dry) irrd. & to 1338.04ppm in MW (wet) irrd.), due to the degradation of β-carotene via oxidation process producing lower molecular masses (**Figure 1**). All the experimental data are in **Table 1.** No distinguishable change in isomeric forms was noticed during MW irradiation (retention of bioavailable *trans*-isomer) **(Figure 4g & 4h).**

The Boiling Treatment

The boiling of sample on open flame with water revealed remarkable increase in the *trans* β-carotene content, which is almost 10-fold higher (2375.09ppm) than the initial value obtained from fresh carrot (252.47ppm), when duration of boiling was for 10 minutes. The increment of the β-carotene content (from 2375.094ppm to 2517.05ppm) continued on further boiling for 10 mins i.e. 20 minutes in total. But, on further boiling, there has been a sharp decrease (by about 27%) in the β-carotene content (from 2517.05 to 1830.38ppm), depicting the same fact that initially the food mesh is opened up on heating, resulting in more availability of β-carotene in the medium [26, 27] **(Table 1, Figure 1& 5c**). But, on prolong heating the β-carotene gets degraded as oxidative damage supercedes the availability of β-carotene in the medium. The carotenoid retention decreases with longer processing time, higher processing temperature. Rapid processing at higher temperature is a good alternative. No appreciable change occurred during boiling w.r.t. geometrical isomerism (retention of bioavailable *trans*-isomer). **(Figure 4e & 4f).**

The Refrigerated & Ambient Temperature Storage

The storage of mashed carrot under ambient room temperature (30-32ºC) and refrigerator (4-6ºC) and the periodical estimation of β-carotene content were done **(Table 1, Figure 1 &5b**). Although, in the case of 1-day refrigerated storage, there has been a sharp decrease in β-carotene content by as much as 36% (from the initial 252.47ppm in fresh carrot to 162.16ppm) it is increased thereafter. On the other hand, for ambient temperature stored sample, β-carotene (after 1-day storage) increased by almost two-fold (from 252.47ppm to 481.63ppm). This is perhaps due to the fact in refrigerated storage condition the enzymatic action leading to carotenogenesis might not had set in during this time (1 day). But, after the 2nd day of storage, the β-carotene content increased in both the cases, more so in the refrigerated sample, the probable cause might be: non-enzymatic (oxidative) loss of carotenoid is more than counterbalanced by the opening up of the food matrices liberating more β-carotene. Carotenogenesis due to enzymatic action was more effective and efficient at a temperature below 10ºC. On further storage, β-carotene increased in both the cases (refrigerated- 869.31 to 1313.50ppm & ambient- 685.55 to 1133.10ppm). The liberation of more β-carotene due to carotenogenesis is surely much greater or supercedes the degradation of β-carotene due to enzymatic action and/or oxidative breakdown. The enzymes responsible for carotenoid biosynthesis may remain active at a lower temperature, resulting in carotenogenesis raising the carotenoid content, which might not be possible to that extent in case of higher temperature stored mashed carrot. Here, although partial geometrical isomeric transformation of β-carotene (*trans*- to *cis*-isomer) was noticed in case of refrigerated sample after 3-day storage, transformation was not noticeable in the ambient temperature stored product **(Figure 4a & 4b).**

The UV-Irradiation Treatment

By uv-longwave irradiation of the mashed carrot sample for 2 hrs, β-carotene increased by almost 55% (from 252.47 to 389.61ppm). This might be due to the fact that β-carotene biosynthesis has not been affected by much during this initial 2 hrs of irradiation. However, the β-carotene content started decreasing when the irradiation was continued for another 2 hrs (from 389.61 to 363.50 ppm); the decrement continued (to 150.05ppm from 363.50 ppm) upon further exposure to uv-longwave light for 2 more hrs (i.e.6hrs altogether) **(Table 1, Figure 1& 5d)**; i.e. an almost 59% loss of carotenoid has been observed. [27]. As the sample was irradiated from 2-6 hrs with longwave uv light, a hypsochromic shift and a hypochromic effect was observed due to the development of a peak at a wavelength of 335nm **suggesting the formation of *cis*-isomers as irradiation** was continued. The *cis*-isomer ratio increased significantly when two data, after 2 hrs and 6 hrs uv-longwave irradiation duration are compared (almost a two-fold increase has been observed) (**Figure 4c & 4d**). The ratio of two peaks at 335nm and at 450nm (*trans*-isomer) may give a good idea of the *cis*-isomers formed during irradiation of mashed carrot sample. This indicates that uv-longwave light might be a specific regulator of carotenoid synthesis and accumulation under different conditions of post-harvest storage.

In general, the different effects of this kind of treatment reported in the scientific literature should be further investigated, since the hormetic response of the fruit is dependent on several factors, such as the cultivar, maturity stage, physiological stage, and harvest season [25]. In addition, the characteristics of the equipment, the mode of delivery, the total dose of uv-longwave light, and the conditions of storage (time and temperature) during post-harvest also play important roles [28].

The Total Carotenoid Yield

The total carotenoid yields were more or less in agreement with the experimentally found β-carotene content during all the different types of treatments and/or storage conditions undertaken (**Figure 2**). Considering the total carotenoids yield data, it may be reiterated that boiling carrot for 10 min resulted in the carotenoids yield at 144.54%, which is significantly higher than that obtained from the fresh & raw carrot (61.70%); i.e. an increase of almost 2.5 times has been recorded. The yield of β-carotene due to boiling of carrot for the three consecutive durations, viz. For 10, 20 & 30 minutes are substantially higher than that obtained during each treatment and/or storage conditions undertaken. The MW wet heating resulted in the continual increase in β-carotene yield data from 12.81 to 21.79%, but in the case of MW dry heat, the increment of the yield discontinued only after 60s of irradiation (at 22.74%). Thereafter, on further exposure to MW irradiation the yield deteriorated from 22.74 to 7.45% (after 360s exposure). In the cases of ambient temperature & refrigerated storage, the total carotenoids yield declined gradually as we move from 1st day to

3rd day. The increment of total carotenoids yield due to uv (longwave) irradiation continued upto 4 hours, but on prolong exposure upto 6 hours, the yield degraded abruptly from 25.90 to 10.58%. High light intensity could also provoke a photo bleaching phenomenon and lead to the destruction of β-carotene [29,30].

The UV-Visible Spectral Study

No significant change has been observed w.r.t. the λ_{max} values of β-carotene when treated under different conditions, with the appearance of three characteristic peaks at around 427-428nm, 449-450nm and 477-478nm for all the samples under study (**Figure 3**). Only in respect of the samples stored in refrigerator **(Figure 4a)** & uv-longwave irradiated (**Figure 4c & 4d**), significant peaks at 335nm have been observed, suggesting the hypsochromic or blue shift of the spectrum due to the formation of *cis*-isomer. The area of the *cis*-peak increased progressively as uv-irradiation was done from 2-6 hours. No such *cis*-isomer appeared in case of the samples stored under ambient condition (**Figure 4b**), boiling treatment **(Figure 4e & 4f) & MW irradiation (Figure 4g & 4h).**

Bioavailability of β-carotene

Now, the relative bioavailability of the two geometric isomers has been a focus of long-standing and recent investigations. β-carotene in human plasma and tissues is dominantly in the *trans*-form; *cis*-isomers represent »5% or less of total β-carotene in plasma [28]. However, tissues contain substantially higher proportions of *cis β*-carotene (9-*cis*, 13-*cis*, and 15-*cis* isomers) than does plasma; »20% to 40% of total β-carotene in tissues is in the *cis*-form. Thus, human tissues & plasma may contain 60-80% & 90-95% *trans* β-carotene respectively. Therefore, the cooking/storage conditions that are favourable for retention and increment of *trans* β-carotene, should be optimized for getting more beneficial effect from β-carotene of carrot. Our study suggested that, the usual household open flame boiling for 20 mins may be the recommended cooking process to get optimum bioavailable *trans* β-carotene from mashed carrot. Among the storing processes, refrigerated storage for 3-day may be prescribed, though an insignificant isomeric transformation has been noticed from *trans*- to *cis*-form. Moreover, post-harvest exposure to uv radiation must be avoided for carrot as the *trans* β-carotene declined consistently after only a few hours of radiation leading to the transformational change (*trans* β-carotene to *cis* β-carotene), rendering it less bioavailable.

The correlation study

The correlation study of β-carotene content & treatment duration revealed positive & significant correlation in case of ambient & freezing temperature storage (R_2=0.96 & 0.98 resp.) and similarly, correlation study of β-carotene content & total carotenoids yield (%) indicated positive & significant correlation in case of MW(wet), boiling & uv irradiation treatments (R_1=0.72, 0.78 & 0.98 resp.).

Conclusions

The present study provides results of optimum time required for different cooking processes and storage in different conditions, in order to get better nutrition from mashed carrot. Thus several cooking procedures have been undertaken with the mashed carrot, viz; microwave irradiated cooked mashed carrot in dry & wet processes, open flame boiled mashed carrot with water, carrot mashed stored in ambient & and refrigerated conditions and uv-longwave irradiated mashed carrot. Our study suggested that, the usual household open flame boiling for 20 mins may be the recommended cooking process to get optimum bioavailable *trans* β-carotene from mashed carrot. Among the storing processes, refrigerated storage for 3-day may be prescribed, though an insignificant isomeric transformation has been noticed from *trans*- to *cis*-form. Moreover, post-harvest exposure to uv radiation must be avoided for carrot as the *trans* β-carotene declined consistently after only a few hours of radiation leading to the transformational change (*trans* β-carotene to *cis* β-carotene), rendering it less bioavailable. The 180 sec MW irradiation in wet conditions showed optimum β-carotene content. The 2 hour exposure under uv (longwave) light provides an optimum β-carotene value, which may be treated as safe from the microbiological point of view due to the germicidal effect of the radiation, apart from maintaining its inherent nutritional value by increasing the β-carotene content. This study provides a hint for better storing condition and optimum cooking processes of mashed carrots, so that the nutritional loss with respect to β-carotene content may be minimised.

Acknowledgments
Research conducted with contribution from: Dept. of Home Science, University of Calcutta, West Bengal, India, for funding and infrastructural support and WBPHL, Dept. of Health & F.W. Govt. of West Bengal, India for infrastructural and technical support.

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Publication History
Received 12th Jan 2015
Revised 19th Jan 2015
Accepted 27th Jan 2015
Online 28th Feb 2015