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Short Communication

Development and characterization of shelf stable quick cooking carrot

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Abstract

Carrot (*Daucus carota* L.) being a rich source of bioactive and functional components helps significantly as an important health-promoting biomaterial. Presevance of functional components with extended shelf life and ease in use are the common challenges associated with the vegetables of perishable catagories. To meet the objectives of developing shelf stable quick cooking carrot, effect of blanching, freezing and salt treatments were assessed for the dehydrated and rehydrated products characteristics over the control. Pretreated carrot cubes were subjected to hot air drying at 70°C in order to get shelf stable carrot. Depending on the rehydrated product characteristics, treatment conditions were screened out and were characterized on various aspects such as dehydration, rehydration, gravimetric and optical characteristics, proximate composition, β-carotene, total antioxidant capacity, total phenol content. Results were statistically evaluated using two-way ANOVA to elucidate the effects of treatment provided to carrot cubes. Significant effects of treatments were observed for physico-chemical, dehydration, rehydration and optical characteristics.

Introduction

India ranks first in the production of fruits and second in the production of vegetables in the world (Rais and Sheoran, 2015). Carrot being root vegfruit belongs to genus daucus and species carota with family umbelliferae (apiaceae) as it has an umbrella like inflorescence called umbel (Haq *et al*., 2013). Consumption of carrot both fresh as well as processed forms has increased steadily in recent days due to their recognition as an important source of natural antioxidants, dietary fibre and other available phytochemicals of therapeutic importance. It contains high amount of moisture like other fruits and vegetables besides containing sugar, dietary fibers, protein, minerals and water insoluble β-carotene. Its characteristic and bright orange color is related to its β-carotene content, which the body converts to vitamin A (Bao and Chang, 1994). The soluble fibers consist of fermentable hemicellulose and pectin. This constitutes 8 to 50% of the total fiber. Carrot contains phenolic compound mainly chlorogenic acids which contribute to the organoleptic properties of fresh and processed carrots. The fibre and phenolic compounds with antioxidant properties (Naczk and Shahidi, 2003) help in prevention of oxidative damage caused by free radicals, as well as various known health-protective action.

Seasonal nature in production and being highly susceptible to moisture loss restricts the availability of fresh carrot round the year. Thus convertion of perishable vegetables into storable forms during glut season is cost effective alternatives in order to make them available to the consumers throughout the year. However, the process success largely depends on the rehydrated product characteristics (Singh *et al*., 2013). To alleviate the adverse effect of drying, various pretreatments were suggested before drying process to set (Kulkarni and Govindene 1994; Krokida and Maroulis 2001; Shivhare *et al*., 2009). In this respect, steam blanching is one of the used pretreatment, where basic aim in maintaining the quality is by inactivation of responsible enzymes causing deterioration. Rehydration characteristics could also be improved by the application of freezing and thawing application given to the product before dehydration. Also, salt treatment plays a synergistic role in improving the rehydration characteristics. The application of various pretreatments may thus provide the dried products which may be acceptable for food uses having high overall acceptability, ease in use with maintained level of nutritive value for various food products applications (Suman and Kumari 2002).

Considering the basic gap in the process technology, objectives of this investigation was critically planned to assess the effect of pretreatments on changes in physico-chemical characteristics

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to develop and characterize the self stable quick cooking carrot.

Materials and Methods

Sample preparation

Premium quality fresh carrot of Pusa Red variety was procured from the local market of Sangrur city (Punjab, India) for the present research work. The procured carrot was sorted according to the uniformity based on size, maturity, defects, rots, mechanical damage if any. After sorting sorted carrots were washed thoroughly in running tap water thrice to remove dust particles. Carrots were manually scraped to remove the secondary roots. The prepared carrot was subjected to cubing machine to get the carrot cubes. The dimensions of used carrot cubes are represented in Table 1.

The carrot cubes were further subjected to pretreatments then dehydration and rehydration studies. Pretreatment as steam blanching, freezing and thawing with salt treatment (1% NaCl, 1% $CaCl_2$ and combination) were tried for developing quick cooking carrot. Steam blanching was provided to the carrot cubes for 2 minutes in a developed precision steam blancher (Singh and Prasad, 2013a) consisted of two chambers, one as steam generation chamber and other as steam generation cum blanching chamber. Blanched samples were blast air cooled and then dipped in salt solution for half an hour. Non-blanched sample in case of carrot cubes of the same dimensions were used as control. The developed precision dehydration chamber having control unit was used to dehydrate the carrot cubes at an isothermal dehydration temperature of 70°C with an average temperature fluctuation of ±1°C (Prasad and Singh, 2014). The nomenclature of the carrot cube samples are as follows: C_1 = Unblanched, C_2 = Steam Blanched, C_3 = Steam Blanched + 1%NaCl, C_4 = Steam Blanched + 1%$CaCl_2$ and C_5 = Steam Blanched + 1%NaCl + 1%$CaCl_2$.

Physico-chemical characteristics

The average initial moisture content of the fresh carrot as determined using hot air oven method was found to be 86.4±0.19% (AOAC, 2000). The dehydration characteristics for dehydration ratio, rehydration ratio and coefficient of rehydration were assessed (Ranganna, 1997). The dehydration ratio (DR) was determined by dividing the total solids in the dried product by the total solids in the raw material. Rehydration ratio (RR) was determined by placing a weighed sample of dehydrated carrot in boiling water for 10 min, draining for 2 minute and reweighing the sample. The optical characteristics of the samples were evaluated using the Hunter Colorimeter in terms of L, a, b values where L corresponds to the luminance or brightness and a, b to the chromaticity. ‘a’ value peculiarly represents the red-green component from positive to negative values; ‘b’ peculiarly represents the yellow-blue component (Prasad *et al.*, 2010a).

The dimensional characteristics were assessed using dial type vernier caliper (Mitutoyo Corporation, Japan) having least count 0.02 mm and verification using image analysis technique (Prasad *et al*., 2012) and the dimension of the carrot cube is represented in terms of geometrical mean dimension (Prasad *et al*., 2010b). The procedure for the determination of the gravimetric properties (Bulk density, BD and True density, TD) was adopted as described elsewhere (Singh and Prasad, 2013b).

The chemical analysis of raw and processed samples for the moisture, ash, crude fat, crude protein and crude fibre contents were carried out using standard methods (Ranganna, 1997). Total carbohydrate content of the sample was determined as total carbohydrate by difference, which is by subtracting the measured protein, fat, fibre, ash and moisture from 100. β-carotene was estimated using the method as suggested by Bala *et al*. (2011). Sample was extracted for β-carotene estimation in acetone, transferred to petroleum ether phase and observed colourimetrically at 452 nm using petroleum ether as blank. The total antioxidant capacity (TAC) of was measured using the 1,1-diphenyl-2-picrylhydrazyl (DPPH assay) radical scavenging activity as described by (Singh and Prasad, 2013a). The antioxidant activity of the samples was compared to that of a synthetic antioxidant (Trolox) and expressed as Trolox equivalent antioxidant activity values. Total phenol content (TPC) was determined spectrophotometrically at 750 nm by adding Folin-Ciocalteu reagent to the extract and expressing the results as milligram gallic acid equivalents, (GAE)/100 g of sample weight (Singh and Prasad, 2013a).

Statistical analysis

All the experiments were carried out atleast in triplicate and the results were expressed as mean value ± standard deviation. The data for each variable were subjected to analysis of variance and critical differences (CD) at $p \leq 0.05$. Means were tested for significant differences ($p < 0.05$) by Duncan’s Multiple Range Test (Singh and Prasad, 2013b).

Table 1. Dimensional characteristics (mm) of carrot cubes

Treatments		Fresh		Dehydrated		Rehydrated	
		Unfrozen	Frozen	Unfrozen	Frozen	Unfrozen	Frozen
Control (Unblanched)		8.26±0.70	7.72±0.86	4.82±0.77	4.46±0.97	6.20±0.87	6.72±0.78
Blanched	Control	8.29±0.66	8.65±0.67	4.77±0.82	5.42±1.12	6.20±0.70	6.83±0.80
	NaCl	8.09±0.92	9.49±0.74	5.18±0.90	4.88±0.81	6.24±0.88	6.16±0.69
	$CaCO_3$	8.84±0.53	9.17±0.64	4.85±0.77	4.61±0.87	5.57±0.76	6.32±0.68
	NaCl+ $CaCO_3$	8.74±0.70	9.10±1.93	5.33±1.14	5.01±0.93	5.95±0.76	6.30±0.73

Mean ± standard deviation (n=3)

Table 2. Dehydration, gravimetric and optical characteristics of dehydrated carrot cubes as affected by processing treatments

Parameters	Processing Condition (P)	Treatment (T) C_1	C_2	C_3	C_4	C_5	CD at 5% (P)	(T)	(P×T)
DR	Unfrozen	13.62±0.16^{G}	14.30±0.15^{F}	15.56±0.17^{E}	16.76±0.18^{D}	15.65±0.17^{E}	0.016	0.025	0.035
	Frozen	14.31±0.15^{F}	13.44±0.14^{G}	18.44±0.20^{B}	18.80±0.19^{A}	17.20±0.17^{C}			
RR	Unfrozen	3.93±0.12^{C}	3.88±0.12^{C}	3.6±0.11^{D}	2.99±0.08^{E}	2.99±0.09^{E}	0.013	0.021	0.029
	Frozen	4.71±0.14^{A}	4.02±0.12^{BC}	4.22±0.13^{B}	3.68±0.11^{D}	4.06±0.12^{BC}			
COR	Unfrozen	0.29±0.02^{C}	0.27±0.01^{D}	0.23±0.02^{E}	0.18±0.01^{G}	0.19±0.02^{FG}	0.003	0.005	0.007
	Frozen	0.33±0.01^{A}	0.30±0.01^{B}	0.23±0.01^{E}	0.20±0.02^{F}	0.24±0.01^{E}			
BD	Unfrozen	380.5±5.29^{B}	401.3±5.58^{A}	365.2±5.08^{C}	365.6±5.08^{C}	353.6±4.92^{D}	0.240	0.379	0.536
	Frozen	371.0±5.16^{C}	383.5±5.33^{B}	334.3±4.65^{F}	331.8±4.61^{F}	342.9±4.77^{E}			
TD	Unfrozen	1302.9±13.96^{E}	1881.8±20.17^{A}	1488.9±15.96^{B}	1436.9±15.4^{C}	1368.6±14.67^{D}	1.813	2.867	4.055
	Frozen	1206.2±12.93^{GH}	1241.2±13.30^{F}	1131.2±12.12^{I}	1185.2±12.7^{H}	1214.5±13.01^{G}			
Porosity	Unfrozen	70.79±0.71^{EF}	78.67±0.52^{A}	75.47±0.59^{B}	74.55±0.62^{BC}	74.16±0.63^{C}	0.057	0.089	0.127
	Frozen	69.23±0.75^{G}	69.11±0.75^{G}	70.45±0.72^{F}	72.02±0.68^{D}	71.76±0.68^{DE}			
L	Unfrozen	35.38±2.18^{C}	58.34±1.54^{A}	59.33±2.31^{A}	46.14±5.57^{B}	60.39±4.04^{A}	2.329	3.6833	5.209
	Frozen	40.39±2.11^{C}	43.76±1.05^{BC}	47.45±2.54^{B}	48.83±1.53^{B}	56.24±3.21^{A}			
a	Unfrozen	13.68±1.53^{F}	23.38±2.08^{DE}	19.29±2.33^{E}	24.07±3.06^{D}	14.30±2.12^{F}	1.958	3.096	4.378
	Frozen	31.91±2.89^{C}	33.85±2.52^{BC}	33.77±4.36^{BC}	37.61±2.98^{B}	42.58±1.53^{A}			
b	Unfrozen	25.60±3.11^{BCD}	28.73±3.61^{BC}	20.49±1.73^{DE}	23.78±4.32^{CDE}	16.57±3.06^{E}	2.567	3.246	5.741
	Frozen	27.39±3.37^{BC}	30.98±3.46^{B}	29.01±2.52^{BC}	30.04±2.25^{B}	39.04±3.19^{A}			

DR (Dehydration Ratio); RR (Rehydration Ratio); COR (Coefficient of Rehydration); BD (Bulk Density); TD (True Density)
Mean values in the same row which is not followed by the same letter are significantly different ($p<0.05$).
Mean ± standard deviation (n=3)

Results and Discussion

Dimensional characteristics

Fresh carrot cubes having geometric mean dimension of 8.26±0.70 mm and unit mass, 0.36±0.01g with the moisture content as 86.4±0.19% (wwb), bulk density (669.58±10.49 Kg/m^3) and true density (1036.38±13.27 Kg/m^3) on subjecting to see the effect of pretreatments of blanching, freezing, salt treatment and dehydration on the dimensional, gravimetric and optical characteristics of carrot cubes are shown in Table 1 and Table 2. The dimensional decrease was found to be highest to an extent of 37.0% and associated with unfrozen and calcium salt treated samples. This may be due to the formation of calcium pectate bond and not allowed the dehydrated cubes to swell on cooking as per other pretreated samples.

Physico-chemical characteristics

The quality of dehydrated carrot cubes was found to be treatment and process dependent as per found significant variations in the quality parameters. The characteristics of dehydration and rehydration ratio of the carrot cubes (Table 2) found to have in the range of 13.44 to 18.80 and 2.99 to 4.71, respectively. The bulk and true density of the dehydrated carrot cubes was also found to be directly affected and dependent on pretreatment (Table 3) and varied from 331.8 to 401.3 Kg/m^3 and 1131.2 to 1881.8 Kg/m^3, respectively. The least density and colur parameters were found to be on the extreme end and associated with the 1% common salt treated samples. The pretreatment of size reduction, blanching, freezing

Table 3. Gravimetric and optical characteristics of rehydrated carrot cubes as affected by processing treatments

Parameters	Processing Condition (P)	Treatment (T)					CD at 5%		
		C_1	C_2	C_3	C_4	C_5	(P)	(T)	(P×T)
BD	Unfrozen	298.2±10.29^{CDE}	328.3±11.33^{A}	303.2±10.46^{BCD}	306.1±10.56^{BCD}	309.1±10.67^{BC}	0.456	0.722	1.021
	Frozen	287.7±9.93^{DE}	313.5±10.82^{AB}	290.7±10.03^{CDE}	282.8±9.76^{EF}	267.8±9.24^{F}			
TD	Unfrozen	1250.5±27.30^{A}	1240.4±27.08^{A}	1047.7±22.88^{B}	1087.9±23.75^{B}	1062.8±23.2^{B}	1.599	2.528	3.576
	Frozen	1087.9±23.75^{B}	1088.3±23.76^{B}	1003.9±21.91^{C}	997.0±21.77^{C}	965.5±21.07^{C}			
Porosity	Unfrozen	76.13±1.34^{A}	73.51±1.48^{AB}	71.04±1.68^{B}	71.84±1.58^{B}	70.90±1.63^{B}	0.071	0.113	0.160
	Frozen	73.53±1.48^{AB}	71.18±1.61^{B}	71.02±1.56^{B}	71.61±1.59^{B}	72.24±1.51^{B}			
L	Unfrozen	44.82±1.15^{AB}	44.54±2.65^{AB}	42.23±1.56^{BC}	44.35±1.55^{ABC}	43.55±1.15^{ABC}	1.237	2.469	3.556
	Frozen	42.78±1.53^{ABC}	43.09±2.89^{ABC}	40.76±3.61^{C}	46.87±3.06^{A}	45.39±2.08^{AB}			
a	Unfrozen	39.61±2.72^{AB}	39.36±2.85^{AB}	40.21±2.16^{AB}	39.65±3.06^{AB}	41.60±2.52^{A}	1.139	2.518	3.319
	Frozen	40.54±2.50^{AB}	38.69±2.08^{AB}	35.30±3.21^{B}	37.68±1.53^{AB}	37.49±1.15^{AB}			
b	Unfrozen	34.56±2.89^{A}	33.43±2.44^{A}	30.35±2.08^{B}	34.54±3.61^{A}	32.56±3.14^{A}	0.912	1.789	2.224
	Frozen	32.38±3.36^{A}	33.03±2.12^{A}	29.70±3.41^{B}	34.65±3.46^{A}	32.47±3.37^{A}			

BD (Bulk Density); TD (True Density)
Mean values in the same row which is not followed by the same letter are significantly different ($p<0.05$).
Mean ± standard deviation (n=3)

Table 4. Chemical composition of fresh and dehydrated carrot cubes as affected by processing treatments

Component	Fresh	Unfrozen	Frozen		CD at 5%
		C_1	C_1	C_3	
Moisture, %	86.40±0.19^{A}	7.31±0.45^{B}	7.11±0.36^{C}	6.92±0.22^{D}	0.404
Crude Protein, %	1.64±0.12^{D}	7.92±0.51^{C}	7.98±0.26^{B}	8.21±0.34^{A}	0.033
Crude Fiber, %	2.26±0.18^{A}	10.41±0.16^{C}	10.77±0.15^{B}	11.11±0.17^{A}	0.043
Crude Fat, %	0.23±0.09^{C}	0.95±0.03^{B}	0.95±0.02^{B}	1.10±0.06^{A}	0.004
Carbohydrate, %	8.02±0.58^{D}	66.74±1.26^{A}	66.31±1.37^{B}	65.37±1.82^{C}	0.296
Ash, %	1.45±0.07^{D}	6.69±0.27^{C}	6.89±0.19^{B}	7.29±0.18^{A}	0.028
β-Carotene, mg/g	8.84±0.49^{D}	33.17±0.93^{C}	35.86±0.71^{B}	39.26±0.48^{A}	0.141
*TAC, mg/g	49.11±1.97^{D}	210.99±2.98^{C}	216.18±3.19^{B}	218.48±2.36^{A}	0.846
#TPC, mg/100g	20.08±0.59^{D}	86.22±0.84^{C}	89.03±0.39^{B}	92.50±0.67^{A}	0.353

*Total antioxidant capacity (Trolox equivalent mg/g), #Total phenol content (gallic acid equivalent mg/100g)
Mean values in the same row which is not followed by the same letter are significantly different ($p<0.05$).
Mean ± standard deviation (n=3)

and thawing employs more salt to move freely inside the inter particle pore space of the carrot cubes and remain in situ on dehydration and allow the water to penetrate easily, swell the tissue to its maximum possible size during cooking of dehydrated carrot cubes.

The colour and appearance of carrot cubes at various level of processing with the effect of pretreatments as obtained is presented in Figure 1. The pictorial representation reflects the clear cut difference in the optical characteristics and supports the product characteristics are pretreatment and processing dependent. Comparing both the dehydrated and cooked carrot cubes of subjected treatments revealed the samples having the pretreatment of blanching, freezing, thawing and soaking in 1% common

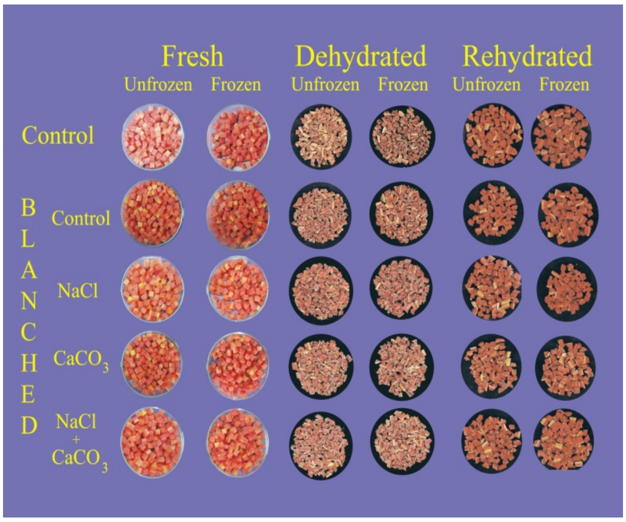

Figure 1. Effect of pretreatments and processing levels on the characteristics of carrot cubes

salt solution produced more appealing colour characteristics with the rehydration characteristics. Thus the process was chemically verified and the data of chemical analysis is represented (Table 4). The analyzed chemical attributes were moisture, crude fat, carbohydrate, crude protein, crude fiber, ash, β-Carotene, total antioxidant capacity and total phenol content. The maximum value of β-Carotene content (39.26±0.48%) was observed for steam blanched frozen dehydrated carrot cubes treated with 1%NaCl solution produced a product having the moisture content of 6.92±0.22%. The treatment of dehydrated carrot exhibited slight variation in the amount of crude fiber, protein, fat and carbohydrate content even on analyzing the stored samples for six months refrigerated condition. Appreciable amount of total antioxidant capacity with phenol content further makes this important biomaterial as therapeutic utility to make the food functional on use of dehydrated shelf stable carrot cubes.

Conclusion

Pretreatments subjected to carrot cubes have found significant effect on physico-chemical properties of both dehydrated and rehydrated carrot cubes. Rehydrated carrot cubes having provided pretreatment as blanching, freezing, thawing and treating with 1%NaCl solution showed superior quality characteristics then other subjected pretreatments. Presence of higher total phenol content reflects more antioxidant activity and presence of β-carotene may further account for the biological and medicinal properties. The process may enhance the usage of carrot and reduce the post harvest loss with the continuous supply of carrot in form of carrot cubes even during the off-season too for the application in the various food products.

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