Quality of dried carrot pomace powder as affected by pretreatments and methods of drying

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Abstract: In order to develop dried carrot pomace of high quality, experiments were conducted in completely randomized design (CRD). The carrot pomace was subjected to various blanching pretreatments i.e. water blanching (WB), steam blanching (SB), citric acid blanching (CB) and potassium metabisulphate (KMS) dipping after blanching (WBS). A control sample (untreated, UT) was kept for comparison. The samples were further dried by various drying methods i.e. convective drying (55°C and 65°C), sun drying and solar drying. The 65°C convective dried samples witnessed minimum drying time with higher fiber, total carotenoids, β-carotene content and minimum change in color parameters. Among the blanching pretreatments, the CB pretreatment showed better efficacy in retaining the quality attributes. Overall, the CB pretreatment followed by convective drying at 65°C was found to be the best drying combination for retaining the quality attributes of carrot pomace.

Keywords: Carrot pomace, pretreatments, blanching, drying, physicochemical properties

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1 Introduction

Carrot (*Daucus carota* L.) is a rich source of β-carotene and contains thiamine, riboflavin, vitamin B-complex and minerals (Walde et al., 1992). Carrot is an excellent source of calcium pectate; an pectin fiber that has cholesterol lowering properties, and reduces the risk of high blood pressure, stroke, heart disease and some types of cancer (Bakhru, 1993). Carrot juice has a high content of pro-vitamin A (β-carotene) and is also high in B-complex vitamins and calcium, copper, magnesium, potassium, phosphorus, iron and folic acid.

Carrot pomace is a by-product obtained during carrot juice processing. The carrot juice yield is 60% to 70%, and pomac contains up to 80% of carotene (Bohm et al., 1999). Carrot pomace contains vitamins, minerals and dietary fiber. After juice extraction left over pomace is either dumped or fed to animals and not directly used for human benefit. Pomace is perishable due to high moisture. Drying or dehydration is used to increase shelf-life of perishable food for further use (Roberts et al., 2008). Dried pomace has β-carotene and ascorbic acid in the range of 9.87 to 11.57 mg and 13.53 to 22.95 mg per 100 g, respectively (Upadhyay et al., 2008). Dried carrot pomace can be used to develop exudates and flavors.

Dehydration of carrot pomace in mechanical dryers, solar dryers, or by air drying with direct sun exposure are alternatives for long term cold storage or canning. Pretreatments and methods of dehydration influence dried product quality (Kulkarni et al., 1994; Waghmore et al., 1999; Krokida and Maroulis, 2001). Blanching is one of the pretreatment methods. The main purpose of blanching is to neutralize enzymes such as polyphenoloxidases, peroxidase, catalase, and phenolase, which may reduce deterioration such as undesirable color,

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flavor or texture changes in the product (Arroqui et al., 2003; Mazza, 1983; Prakash et al., 2004; Severini et al., 2005). Blanching can be performed by dipping in hot water (the most common method); hot or boiling solutions containing acids and/or salts, or steam (Kidmose and Martens, 1999) for few minutes. Fresh carrot pomace, if properly dried, packaged and stored, may increase availability for utilization in fiber rich products.

The study was undertaken to select suitable blanching pretreatments and drying methods for production of carrot pomace and determine their effect on dried carrot pomace powder quality.

2 Materials and methods

2.1 Development of carrot pomace powder

2.1.1 Sample preparation

Commercial variety of carrot was procured from local market of Ludhiana, Punjab, India. Carrots were sorted for uniform size, color, physical damage and washed in running tap water to remove impurities followed by juice extraction using a juice mixer cum grinder.

2.1.2 Pretreatments

Pomace was subjected to different blanching pretreatments. The blanching of pomace was standardized by performing the quality test i.e. peroxidase test. Preliminary trials were conducted to standardize the blanching time for different blanching pretreatments. Pomace was given steam blanching (SB), 1% weight by volume (w v^{-1}) citric acid blanching (CB) and 6% KMS dipping after water blanching (WBS). No blanching and chemical dipping treatment was given to control (raw) sample and was expressed as untreated sample (UT).

2.1.3 Drying methods

Three drying methods were used for the development of dried carrot pomace viz. convective drying, solar drying and sun drying.

2.1.3.1 Convective drying

The convective drying at constant temperature of 55°C and 65°C was done in a tray drier of dimensions 1.37 × 0.94 × 0.43 cm^3. The carrot pomace to be dried was spread on the pre fabricated trays (27.94 × 21.59 cm^2) with drying bed thickness of 4 mm.

2.1.3.2 Sun drying

For sun drying, the carrot pomace samples were spread uniformly on the aluminum trays (21 cm × 30 cm) covered with black polyethylene sheet and exposed to open sun. The initial weight of each sample was 200 g, irrespective of the drying methods. Weight of each samples were recorded at regular intervals using electronic weighing balance.

The samples kept under sun drying and in solar dryer were dried up to their equilibrium moisture content whereas, the samples kept in tray dryer were dried up to the desired moisture content of 8.0% d.b. (dry basis). The temperature and relative humidity of ambient air and drying air during sun drying and solar drying were recorded throughout the drying process with the help of digital hygrometer.

2.1.3.3 Solar drying

For solar drying, the Punjab Agricultural University domestic solar dryer of natural circulation type with provision of three trays (55.5 cm × 15.3 cm × 3 cm) was used. The material used for construction was 4 mm thick window glass, mild steel sheet and angle iron. The whole internal body of dryer was painted black except the window glass, to absorb more heat by the dryer and increase the rate of drying. A provision to cover the trays with shading plates was designed. Overall size of dryer was 64.4 cm × 27.2 cm × 54.4 cm and it was inclined at 45° with the horizontal. The dryer was designed with air inlet from the holes in bottom of the dryer, passing through the trays before leaving from the holes at the top of dryer.

2.2 Quality attributes

The dried carrot pomace samples were grinded to powder in a Juicer Mixer-cum-Grinder and were packed in laminated aluminum foil packs for further quality analysis. The developed powder samples were then evaluated for their physico-chemical quality attributes. Quality parameters named non enzymatic browning, crude fiber, total carotenoids and β-carotene were estimated according to methods suggested by Ranganna (2003). The color, texture and water activity were determined by the procedure as given below.

2.2.1 Water activity (a_w)

The water activity of fresh and dried samples was measured directly by using water activity meter.

2.2.2 Color measurement

The color property of the fresh carrot pomace and dried carrot pomace powder samples was measured by using Color Reader CR-10 (Konica Minolta Sensing Inc., New Jersey). For determination of color, the sample was completely filled in petri dish under no light condition during measuring process. The 'L', 'a' and 'b' values were recorded at D 65/10° and were compared to the standard values of fresh carrot pomace. The color change was measured by the equation given by (Gnanasekharan et al.,1992).

$$\text{Color change} = \sqrt{[(L-L_0)^2 + (a-a_0)^2 + (b-b_0)^2]}$$

where, L_0, a_0 and b_0 represent the respective readings of fresh sample.

The chroma and Hue angle were estimated as

$$\text{Chroma} = \sqrt{(a^2 + b^2)}$$

$$\text{Hue angle} = \text{Tan}^{-1}(b/a)$$

2.2.3 Textural parameter

The texture analyzer –TA-XT2 (Stable Micro Systems, UK) was used with a back extrusion A/BE assembly (cylindrical acrylic cup 60 × 75 mm^2 and a 45 mm diameter disk) to measure powder compaction of carrot pomace. For the experiment, back extrusion rig probe was used with 2 mm s^{-1} test speed, 5 seconds test time and 10 mm distance. The readings were noted in terms of gram force (g) required for compaction of powder (Eduardo and Lannes, 2007).

2.3 Statistical analysis

Each experiment was replicated three times. All the results were statistically analyzed to estimate the significant difference between treatments and drying methods on the basis of physico-chemical quality attributes. The analysis was done using univariate analysis of variance (UNI-ANOVA) in general linear model using SPSS 11.0 (Statistical Package for Social Sciences). Means were computed and the least significant difference (LSD) was calculated at 5% level of significance (P=0.05).

3 Results and discussion

3.1 Drying time of carrot pomace

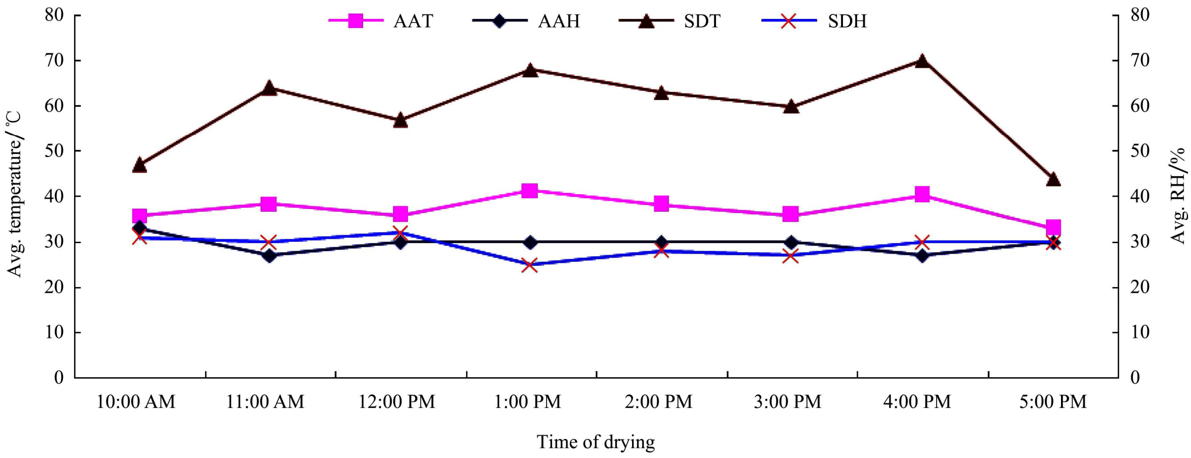
The drying time required by different drying methods as convective drying (at 55°C and 65°C temperature), sun drying and solar drying along with their final moisture content is presented in Table 1. The final moisture content to which the carrot pomace dried under sun drying and solar drying varied from 9.15% d. b. to 11.35% d. b. irrespective of blanching pretreatments. The samples dried under convective drying (6 to 9 hrs) witnessed comparatively lesser drying time than sun drying (17 to 19 hrs) and solar drying (12 to 14 hrs). This can be related to the fact that drying at higher temperatures provides larger driving forces for heat transfer, which increases the drying rate. Furthermore, the moisture diffusivity is also higher at a higher drying temperature (Leeratanarak et al., 2006). The statistical results also corroborate to the results showing significant ($P \leq 0.05$) affect of drying methods and blanching pretreatments on drying time and final moisture content. Similar results were reported for air drying of blueberries (Veerachandra et al., 2013).

Table 1 Effect of blanching pretreatments and drying methods on drying time and moisture content of carrot pomace

Drying method	Blanching pretreatment	Drying time /hrs	Final moisture content/%
Convection (55°C)	UT	7.0^{ab}	8.0^{a}
	SB	7.5^{b}	8.0^{a}
	CB	9.0^{c}	8.0^{a}
	WBS	9.0^{c}	8.0^{a}
Convection (65°C)	UT	6.0^{a}	8.0^{a}
	SB	7.0^{ab}	8.0^{a}
	CB	7.0^{ab}	8.0^{a}
	WBS	7.5^{b}	8.0^{a}
Sun	UT	17.0^{f}	10.65^{cd}
	SB	18.0^{f}	10.44^{cd}
	CB	19.0^{g}	11.01^{d}
	WBS	19.0^{g}	11.35^{d}
Solar	UT	12.0^{dg}	9.87^{bc}
	SB	13.0^{de}	9.15^{c}
	CB	14.0^{e}	10.88^{cd}
	WBS	14.0^{e}	10.67^{cd}

Note: UT = untreated control, SB = steam blanched sample, CB = citric acid blanched, WBS = water blanching followed by sulphiting, Conv = convectively dried; Analysis by Tukey's method for drying time and final moisture content at different drying method and blanching pretreatments. Values within columns with different superscripts implies that they are significant ($p \leq 0.05$).

During sun drying, the average air temperature (AAT) and average relative humidity (AAH) ranged between 33°C to 41.3°C and 27% to 33% respectively whereas, within solar dryer, the relative humidity (SDH) and temperature (SDT) varied between 25% to 32% and 44°C to 70°C respectively throughout drying process (Figure 1).



Note: AAT = Ambient air temperature, AAH = Ambient air relative humidity, SDT = Solar drying temperature, SDH = Solar drying relative humidity

Figure 1 Variation in average temperature and average humidity measured during the time of drying.

3.2 Non enzymatic browning

The results for different experimental combinations of blanching pretreatments and drying methods on non enzymatic browning (NEB) are presented in Table 2. Both the maximum (2.748, UT) and minimum (0.400, WBS) NEB values were observed for 65°C convectively dried samples. Among drying methods, the sun dried samples witnessed minimum NEB values irrespective of blanching pretreatments. Among pre-treatments, WBS indicated the lowest non enzymatic browning (NEB) irrespective of the drying methods. Similar results were also observed by Sra et al. (2011) for dried carrot slices. The NEB values were minimum for KMS pretreated carrot pomace, which might be due to higher SO_2 concentration. Similarly in earlier studies, use of sulphites reduced the NEB in dried tomatoes (Latapi and Barrett, 2006). The NEB of developed carrot pomace powder was significantly (P≤0.05) affected by the drying methods and blanching pre-treatments. Moreover, the change due to blanching pre-treatments was more pronounced (Table 2).

3.3 Total carotenoids

It is evident from the Table 2 that the highest value (10.842 mg 100 g^{-1}) of total carotenoids was recorded for solar dried-CB sample whereas, the lowest (5.838 mg 100 g^{-1}) was observed for convectively dried (55°C)-SB sample. The total carotenoid content decreased irrespective of the drying methods and blanching pretreatments used. Similar results of decrease in total carotenoids were reported by Chen et al. (2007) for mango. The statistical analysis corroborate to the fact that the interaction of drying methods and blanching pretreatments had significantly higher (P≤0.05) effect on total carotenoids in comparison to drying methods and blanching pretreatments individually.

3.4 β-carotene

The β-carotene was affected by blanching pretreatment, drying method and their interaction. The maximum β-carotene (633.57 μg 100 g^{-1}) value was for solar dried-CB samples; the minimum value (186.01 μg 100 g^{-1}) was for sun dried-CB samples (Table 2). The lower β-carotene content occurred in samples receiving lower drying temperatures. This may be due to longer drying time required to achieve desired final moisture content (Prakash et al., 2004). Solar dried samples had the best β-carotene values among drying methods. The β-carotene retention for convective drying was lower than for solar dried samples. Reduction in β-carotene at high temperature drying could be due to increased oxidation rate of its highly unsaturated chemical structure (Jayaraman and Gupta, 1995). Also, lipoxygenase, which is an aerobic catalyst of oxidation reactions, is activated above 60°C (Cui et al., 2004) and its activity increases with high temperature.

The reduction in β-carotene content of carrots during pretreatment is consistent with that reported by Zhao and Chang (1995) who found that sulfite and starch treatment reduced amounts of β-carotene with time. Among pretreatments, control and CB samples had better results than SB and WBS treated samples. Veda et al. (2008) indicated acidulants, such as citric acid, prevented loss of β-carotene during thermal processing.

Table 2 Effect of blanching pretreatments and drying methods on physico-chemical quality attributes of carrot pomace

Drying Method	Blanching Pretreatment	Non enzymatic browning	Total carotenoids /mg/100 g^{-1}	β-carotene /μg 100 g^{-1}	Water activity	Texture/g	Fiber content /%
Conv.(55°C)	UT	0.751 ^{bcd}	9.091 ^{d}	272.73 ^{a}	0.360 ^{ab}	58.816 ^{a}	17.0 ^{f}
	SB	0.706 ^{b}	5.838 ^{f}	219.58 ^{c}	0.391 ^{bc}	53.739 ^{b}	8.0 ^{a}
	CB	0.863 ^{d}	9.174 ^{d}	415.38 ^{d}	0.403 ^{bc}	31.189 ^{c}	13.0 ^{c}
	WBS	0.478 ^{a}	7.298 ^{b}	351.05 ^{e}	0.379 ^{abc}	30.385 ^{d}	15.0 ^{d}
Conv.(65°C)	UT	2.748 ^{f}	6.797 ^{g}	493.71 ^{f}	0.351 ^{ab}	26.877 ^{e}	13.0 ^{c}
	SB	0.836 ^{cd}	9.883^{e}	272.73 ^{a}	0.360 ^{ab}	43.374 ^{f}	7.0 ^{g}
	CB	0.795 ^{bcd}	8.799 ^{c}	387.41 ^{g}	0.444 ^{c}	56.838 ^{g}	19.0 ^{h}
	WBS	0.400 ^{a}	6.464 ^{a}	311.89 ^{h}	0.420 ^{bc}	24.676 ^{h}	16.0 ^{e}
Sun	UT	0.708 ^{bc}	8.715 ^{c}	560.84 ^{b}	0.402 ^{bc}	41.750 ^{i}	15.0 ^{d}
	SB	0.473 ^{a}	7.298^{b}	278.32 ^{i}	0.306 ^{a}	49.247 ^{j}	8.0 ^{a}
	CB	0.470 ^{a}	6.505 ^{a}	186.01 ^{j}	0.420 ^{bc}	28.058 ^{k}	12.0 ^{b}
	WBS	0.463 ^{a}	9.966 ^{e}	269.93 ^{k}	0.454 ^{cd}	47.224 ^{l}	14.0 ^{i}
Solar	UT	2.328 ^{g}	8.215 ^{h}	390.21 ^{l}	0.558 ^{e}	24.246 ^{m}	12.0^{b}
	SB	1.018 ^{e}	8.840 ^{c}	474.13 ^{m}	0.534 ^{d}	44.288 ^{n}	8.0 ^{a}
	CB	1.128 ^{e}	10.842 ^{i}	633.57 ^{n}	0.540 ^{e}	52.454 ^{o}	16.0 ^{e}
	WBS	0.816 ^{bcd}	8.840 ^{c}	560.84 ^{b}	0.549 ^{e}	30.239 ^{p}	16.0 ^{e}

Note: UT = untreated control, SB = steam blanched sample, CB = citric acid blanched, WBS = water blanching followed by sulphiting, Conv = convectively dried; Analysis by Tukey's method for the above mentioned quality attributes at different drying method and blanching pretreatments. Values within columns with different superscripts implies that they are significant ($p \leq 0.05$).

3.5 Water activity

Blanching pretreatment, drying method and their interaction affected water activity (Table 2). The highest water activity (0.558) was for solar dried-UT material and the lowest (0.306) was for sun dried-SB material. On average, minimum water activity was for convectively dried samples, irrespective of pretreatment. Among pretreatment, lowest values were for UT and SB pretreated samples.

3.6 Texture

Drying method, pretreatment, and their interaction affected texture (Table 2). The highest texture value (58.816 g) was for UT-55°C convectively dried samples and the lowest value (24.676 g) was for WBS pretreated-65°C convectively dried samples (Table 2). Among drying methods, the convectively dried (55°C) samples had the highest average texture values. Among pretreatments, the CB pretreated samples had the highest texture.

3.7 Fiber content

Drying method, blanching pretreatment, and their interaction affected texture (Table 2). The minimum fiber content (7%) was for SB pretreatment and the highest fiber content value (19%) was for CB pretreatment and 65°C-convectively dried samples. The CB and WBS pretreated samples had higher average fiber content compared to other pretreatments. Among drying methods used, convectively dried samples had overall higher average fiber content.

3.8 Color attributes

The initial color 'L', 'a' and 'b' values of non-blanched carrots (the reference raw sample) were 78.34, 12.5 and 21.02 respectively. Carrot pomace became darker, corresponding to a decrease in the 'L' values, and loss in redness ('a' value decreased) and yellowness ('b' value decreased) irrespective of blanching pretreatments and drying method used.

3.8.1 'L' value

Pretreatment and drying method affected 'L' values. The highest 'L' value (75.2) was for WBS pretreated convectively (55°C) dried samples; the lowest value (58.2) was for UT-convectively dried (65°C) samples (Table 3). Convective drying at 55°C produced the highest average 'L' values compared to other drying methods. The statistical analysis revealed that the impact of pretreatments was significantly higher on 'L' value as compared to drying methods.

3.8.2 'a' value

According to experimental data, the highest 'a' value (10.4) was recorded for CB-convective (65°C) dried sample. On the other hand, the minimum 'a' value (4.5) was recorded for WBS pretreated 55°C convectively dried sample (Table 3). Among the pretreatments, CB pretreated samples indicated overall better color retention supported by highest average 'a' value. This can be attributed to use of citric acid which acts as a chelator and prevents browning reaction (Martinez and Whitaker, 1995). Similar results were recorded by Hiranvarachat et al. (2011) for hot air drying of carrots. The improved red color in CB samples might also be due to increased color pigments in all the pretreated carrot pomace due to improvement in the availability of carotenoid pigments caused by the breaking down of the crystalline carotenoid complexes and breaking down of pectin in carrot cell wall (Micheli, 2001; Sharma et al., 2009). The results are also supported by the statistical analysis showing higher significant effect of pretreatments on the 'a' value as compared to drying methods.

Table 3 Effect of blanching pretreatments and drying methods on color attributes of carrot pomace

Drying Method	Blanching Pretreatment	'L' value	'a' value	'b' value	'ΔE' value	Chroma	Hue angle
Conv. (55°C)	UT	65.0 d	8.6 ef	20.6 g	13.90 b	22.32 fg	1.17 c
	SB	70.7 g	5.6 ab	18.8 cdef	10.53 c	19.62 bcde	1.28 de
	CB	63.0 c	9.9 gh	20.5 g	15.56 d	22.76 g	1.12 b
	WBS	75.2 f	4.5 a	17.5 bc	9.28 e	18.07 ab	1.32 e
Conv. (65°C)	UT	58.2 h	7.7 de	17.9 bcd	20.55 f	19.48 bcd	1.16 c
	SB	66.5 i	6.0 bc	18.4 cde	13.31 g	19.35 bcd	1.25 d
	CB	63.0 c	10.4 h	19.0 def	15.35 h	21.66 fg	1.07 a
	WBS	75.2 f	5.6 ab	18.6 cde	7.25 i	19.42 bcd	1.28 d
Sun	UT	64.7 d	6.0 bc	17.7 bcd	15.47 j	18.69 abc	1.24 d
	SB	68.2 e	5.5 ab	17.9 bcd	12.71 k	18.72 abc	1.27 d
	CB	62.1 bc	7.1 cd	15.9 a	17.86 l	17.41 a	1.15 bc
	WBS	68.1 e	7.0 cd	16.6 ab	12.43 m	18.01 ab	1.17 c
Solar	UT	62.7 c	8.1 de	18.0 cde	16.52 n	19.74 cde	1.14 bc
	SB	61.1 ab	9.7 fgh	20.1 fg	17.49 a	22.32 fg	1.12 b
	CB	60.7 a	10.1 h	18.3 cde	18.01 o	20.90 def	1.07 a
	WBS	61.3 ab	8.8 efg	19.3 efg	17.52 a	21.21 efg	1.14 bc

Note: UT = untreated control, SB = steam blanched sample, CB = citric acid blanched, WBS = water blanching followed by sulphiting, Conv = convectively dried; Analysis by Tukey's method for the above mentioned color attributes at different drying method and blanching pretreatments. Values within columns with different superscripts implies that they are significant ($p \leq 0.05$).

3.8.3 'b' value

The maximum 'b' value (20.6) was recorded for UT sample convectively dried at 55°C, whereas, the minimum 'b' value (15.9) was observed for CB pretreated sun dried samples (Table 3). The 'b' value was higher for drying methods compared to blanching pretreatment.

3.8.4 Color change, chroma and hue angle

Color change was affected by pretreatment and drying method individually and in combination (Table 3). Drying method did not affect chroma and hue angle. The chroma and hue angles were affected by the interaction of pretreatment and drying method. The highest color change (ΔE) (20.553) was for UT samples convectively dried at 65°C; the minimum color change (7.255) was for WBS pretreated samples convectively dried at 65°C irrespective of pretreatment and drying method. This indicates that pretreatment had more affect than drying method on color change of carrot pomace. For chroma (intensity of light), the highest value was for 55°C convectively dried CB samples; the minimum value was for sun dried CB samples. The hue angle was highest for 55°C convectively dried WBS samples and lowest for 65°C convectively and solar dried CB samples.

4 Conclusions

Samples dried convectively at 65°C were preferable. Among pretreatments, CB samples had better quality. Overall, the CB samples convectively dried at 65°C was adjudged as best drying combination for retaining quality attributes of carrot pomace recording minimum drying time, higher fiber, total carotenoids, β-carotene contents and minimum change in color parameters.

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