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Comparative Drying Studies of Carrot Pomace by Microwave Dryer and Mechanical Tray Dryer

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A B S T R A C T

Utilization of pomace in food applications is important from nutritional point of view as they possess good amount of tocopherols, phytosterols, carotenoids and antioxidant activity. Drying is the oldest method of preserving food. The pomace weighing 250g were dried in mechanical tray dryer at air temperature of 50, 65 and 80ºC at fixed air velocity of 2m/s and in microwave dryer at power level of 420, 560 and 700W. Drying took place in falling rate period and constant rate period was absent in both drying experiments. The moisture diffusivity varied in the range of 4.54×10^{-9} m²/s to 1.45×10^{-8} m²/s during drying in mechanical tray dryer and varied in the range of 1.29×10^{-8}m²/s to 4.28×10^{-8} m^2/s in microwave dryer. β-carotene range was found between 1.10 mg/100g and 5.25 mg/100g in mechanical tray dryer and between 1.02 mg/100g and 3.36 mg/100g in microwave dryer. Ascorbic acid range was found between 1.5 mg/100g and 2.1 mg/100g in mechanical tray dryer and between 0.75 mg/100g and 1.425 mg/100g in microwave dryer. Maximum redness was found in sample dried at 420W microwave power level in microwave dryer.

Introduction

Addition of large quantity of carrot to the daily diet has a good effect on nitrogen balance. The drying of carrot is an important aspect for its value addition. Dehydrated carrot in the form of gratings can be used in the preparation of slice, gajarhalwa with skim milk, sugar and other ingredients (Manjunatha *et al.*, 2003). Processed fruit industry has accounted 25 per cent losses and wastages after processing of fruits and vegetables that includes 10 per cent during distribution and 7 per cent during consumption. The major waste produced includes the organic waste such as peel, stem, core, seeds and pomace from juice extraction. By-product obtained from fruit-processing plants offers untapped potential of producing low cost natural bio-components having food applications. Hence, there is need to pay attention to utilize tons of pomace produced each year to address environmental issues and generate new income source. Utilization of pomace in food applications is important from nutritional point of view as they possess good amount of tocopherols, phytosterols, carotenoids and antioxidant activity. Hussein *et al.,* (2015) studied the possibility of utilizing fruit and vegetables by-products to produce high dietary fibre jam. The author reported that these by-products were excellent source of low-priced functional food components and the jam prepared using carrot peel, apple pomace, banana peels and mandarin peels was high in dietary fibre, vitamin C, intensified minerals, total flavonoids and antioxidant activity. This modification of by-products into a high value product makes it feasible for food companies to reduce their cost and generate profits, thereby, improving their competitiveness. The main goal is to highlight the potential of fruit and vegetable processing waste especially with respect to pomace. Basically, pomace is defined as the solid remains of fruit and vegetable after pressing for juice or oil. It is perishable due to high moisture.

Materials and Methods

Fruit

Carrot was procured from local market of Udaipur, Rajasthan (India). Carrot was washed thoroughly three to four times under tap water to remove adhering impurities. It was peeled out and juice was extracted and remained pomace was blanched in hot water at 90±2°C temperature for 3min with the ratio of pomace to water of 1:6 and dipped immediately in normal water for 3 min to prevent excess cooking, then the blanched product was kept in strainer (Chantaro *et al.,* 2008).

Drying Kinetics

Mechanical tray dryer subsisted of drying chamber, blower, heaters and thermostat. Air circulating fan moved air through heaters in the insulating chamber. The drying chamber size was 150 × 100 × 40 cm accommodating 12 stainless steel trays. The carrot pomace samples were spread in stainless steel trays having flat surface and inserted into the mechanical tray dryer. The drying temperatures were taken as 50, 65 and 80°C at consistent drying air velocity of 2 m/s in drying chamber. During drying, the samples were weighed at an interim of 10 minutes until the point that the samples attained constant moisture content (EMC). At the completion of each experiment, the final moisture content of dried sample was considered as EMC.

A lab microwave dryer was also utilized as a part of this drying experiment which has maximum frequency range of 2450 MHz. It has working chamber of dimension 700×700×550 mm and having three vent of size 100 mm diameter at the top side. A roundabout turntable made up of Teflon material having diameter 600 mm and height of the rim about 120 mm is used inside the chamber for increasing the consistency in drying. An air blower or exhaust fan is allocated for provision for inlet and outlet air from the working chamber. Air blows at velocity of 0.75 to 1.0 m/s. Fresh carrot pomace samples of known initial moisture content were evenly spread on the turntable inside the microwave cavity. Carrot pomace sample was weighted in every 5 min till completion of experiment (up to EMC). Microwave power levels value given as 420, 560 and 700 W respectively and the average values were used for calculation.

Moisture Content

Moisture content of the sample during experiments at various times was determined on basis of dry matter of the sample. Moisture content (db) during drying was calculated (Brooker *et al.,* 1974) as:

$$Moisture\ Content = \frac{W_\theta - DM}{DM} \times 100$$

Where,

W_θ= Weight of sample at time θ, g
DM = Dry matter of the sample, g

Drying rate

The moisture content data recorded during experiments were analysed to determine the moisture lost from the samples in particular time interval. The drying rate of sample was calculated by following mass balance equation (Brooker *et al.*, 1974).

$$R = \frac{WML}{Time\ Interval\ (min.) \times DM}$$

Where,

R = Drying rate at time, g water/ g-min
WML = Initial weight of sample – Weight of sample after time

Moisture Ratio

The moisture ratio was calculated by using the following equation:

$$Moisture\ Ratio = \frac{M - M_e}{M_o - M_e}$$

Where,

M = Moisture content at any specified time t (per cent db)
M_e = Equilibrium moisture content (per cent db)
M_o= Initial moisture content (per cent db)
M_e in comparison to M_o and M is very small, hence M_e can be neglected and moisture ratio can be presented in simplified form (Doymaz, 2004b; Goyal *et al.*, 2007).

$$MR = \frac{M}{M_o}$$

Moisture Diffusivity

Fick's second law has been adopted for evaluation of moisture transport mechanism of the falling rate regions and is mathematically expressed by classical mass balance equation (Crank, 1975) as,

$$\frac{\partial M}{\partial \theta} = \frac{\partial}{\partial R}\left(D_d \frac{\partial M}{\partial R}\right)$$

Where,

M = moisture content, kg water per kg dry solids
θ = time, s
R = diffusion path or length, m
D_d = moisture dependent diffusivity, m^2/ s

The solution of Fick's second law in slab geometry, with the assumption that moisture migration was caused by diffusion, negligible shrinkage, constant diffusion coefficients and temperature was as follows (Crank, 1975):

$$MR = \frac{M - M_e}{M_o - M_e} = \frac{8}{\pi^2} \sum_{n=1}^{\infty} \frac{1}{(2n+1)^2} exp\left[\frac{-(2n+1)^2 \pi^2 D_{eff} t}{L^2}\right]$$

For long drying periods, above Eqn. can be further simplified to only the first term of the series as,

$$ln\left(\frac{M - M_e}{M_o - M_e}\right) = ln\frac{8}{\pi^2} - \frac{\pi^2 D_{eff} t}{L^2}$$

Where,

MR = Moisture ratio, dimensionless
M = Moisture content at any time, g H_2O/g dry matter
M_o= Initial moisture content, g H_2O /g dry matter
M_e = Equilibrium moisture content, g H_2O /g dry matter
D_{eff} = Effective diffusivity in m^2/s
L = thickness of carrot pomace layer (0.002 m)
n = Positive integer
t = Time (s)

A general form of above Eqn. could be written in semi-logarithmic form, as follows:

$$\ln (M_R) = A - Bt$$

Where, A is constant and B is slope.

From moisture ratio Equation, a plot of ln (MR) versus the drying time gives a straight line with a slope B as,

$$\text{Slope} = \frac{\pi^2 D_{eff}\, t}{L^2}$$

The effective diffusivity was determined by substituting value of slope B and thickness L.

Determination of β - carotene

β-carotene in fresh and rehydrated carrot samples will be determined using AACC method 14-50, which works on the principle of solvent-extraction of the pigments and measuring colour absorbance using UV-Visible spectrophotometer at 435.8 nm. The β-carotene content then calculated (mg/g) using Eq. given below (Johnson *et al.*, 1980):

$$\beta - Carotene\left(\frac{\mu g}{g}\ or\ ppm\right) = \frac{sample\ abs. \times 0.4}{1.6632 \times sample\ mass\ (db)} \times 100$$

Where 1.6632 is conversion factor 1 µg pigment absorbance in 1 g of sample of 1.0 cm cuvette, 0.4 is the volume (L) of the solvent used for extraction of the pigments**.**

Determination of Ascorbic Acid Content

Ascorbic acid content of carrot pomace powder was estimated by titration method (Ranganna, 2000) using dye solution of 2, 6-dichlorophenol indophenol.

Dye factor was determined by the following equation:

$$Dye\ Factor = \frac{0.5}{Titrate\ Vol.}$$

Ascorbic acid was estimated as mg of ascorbic acid per ml and was determined by the following equation:

$$Ascorbic\ acid\left(\frac{mg}{mL}\right) = \frac{titrate\ Vol.(mL\ of\ dye\ used) \times dye\ factor \times Vol.made\ up \times 100}{aliquot\ of\ sample\ taken\ for\ estimation \times Vol.of\ sample}$$

Colour

Colour of carrot pomace powder was measured using a Hunter Lab Colorimeter (Model CFLX/DIFF, CFLX-45).

Results and Discussion

Preparation of sample

Extraction of juice from carrot was done with the help of juicer and pomace was separated out. Pomace was washed thoroughly under tap water. The 250g of pomace were blanched in boiling water with ratio of 1:5 for 3min and dipped immediately in normal water for 3 min to prevent excess cooking and then the blanched product was kept in strainer.

Initial moisture content

The initial moisture content of carrot pomace was determined by oven drying method. The initial moisture content was found as 705.67, 716.38 and 749.52 per cent (db).

Drying Characteristics of Carrot Pomace Mechanical Tray Drying

Fresh Carrot pomace samples were blanched and dried under mechanical tray dryer at 50, 65 and 80°C. The air-flow rate of the drying air was kept at 2 m/s throughout the drying period. The results of each drying experiment are presented in the following section.

Effect of temperature on moisture content

The change in moisture content of carrot pomace with elapsed drying time, at each of drying temperature 50, 65 and 80°C at air velocity of 2 m/s are presented in Fig 1. In case of carrot pomace sample, drying time at 50, 65 and 80°C was 420, 230 and 160 min respectively.

Effect of temperature on drying rate of carrot pomace

The drying rate of carrot pomace under different convective tray drying temperature were calculated and plotted with moisture content presented in Fig 2.The drying rate for carrot pomace sample was observed at initial stage of drying 4.248, 6.259 and 9.140 g-water/ g-DM-min at 50, 65 and 80°Cof drying air temperature respectively.

A second order polynomial relationship was found to have fitted adequately to desirable variations in the drying rates with moisture content at all three experimental temperatures and is represented by given Eqn.:

$$Y= ax^2 + bx + c \qquad \text{. .. (3.1)}$$

Effect of temperature on moisture diffusivity

Effective diffusivities are typically determined by plotting experimental drying data in terms of ln (MR) versus time (Lomauro *et al.*, 1985; Tutuncu and Labuza, 1996).The variation in MR with drying time of carrot pomace has been presented in Fig.3 for mechanical tray drying.

Microwave Drying

Fresh Carrot pomace samples were blanched and dried under microwave dryer at 420, 560 and 700W.

Effect of power level on moisture content

Carrot pomace required 60 to 180 min to dry under microwave drying to bring down initial moisture content ranging from 705.67 to 749.52 per cent (db) to final moisture content in the range of 8.45 to 9.78per cent (db) at different studied power levels.

Effect of power level on drying rate curves

The drying rate of carrot pomace under different microwave power levels were calculated and plotted with moisture content presented in Fig 5. The drying rate for carrot pomace sample was observed at initial stage of drying 14.532, 20.161 and 35.521 g-water/ g-DM-min at 420, 560 and 700Wof drying power respectively.

Effect of power level on moisture diffusivity

The moisture loss data from microwave drying were analyzed and moisture ratios at various time intervals were determined.

The ln (MR) was plotted with drying time in order to find out moisture diffusivity for carrot pomace. The variation in ln (MR) with drying time of carrot pomace has been presented in Fig. 6 for microwave drying.

Comparison of quality of tray and microwave dried carrot pomace

On the basis of β– Carotene

Change in β-carotene content as effect of different drying conditions ranged from 1.10 to 5.25 mg/100g with increase of drying temperature from 50º C to 80º C in mechanical tray dryer and ranged from 1.02 to 3.36 mg/100g with increase of microwave power level from 420W to 700W in microwave dryer (Table 5). A retention trend of β-carotene in pomace during drying was similar to the earlier findings with drying of carrots (Banga and Bawa, 2002).

Table.1 Drying rate equation with respect to moisture content (g w/g dm-min)

Temperature (˚C)	Equation	R^2
50	$y = -0.0524x^2 + 0.8726x + 0.1922$	0.9832
65	$y = -0.1175x^2 + 1.4816x + 0.5212$	0.9336
80	$y = -0.1941x^2 + 2.6182x + 0.325$	0.971

Table.2 Moisture diffusivity values for dried carrot pomace

Drying temperature (°C)	Regression equation	Moisture diffusivity	R^2
50	$y = -0.0112x + 0.5021$	4.54×10^{-9}	0.9399
65	$y = -0.0204x + 0.5808$	8.27×10^{-9}	0.9083
80	$y = -0.0358x + 0.596$	1.45×10^{-8}	0.9142

Table.3 Drying rate equation with respect to moisture content

Microwave powerlevel (W)	Equation	R^2
420	$0.0093x^2 + 1.7076x + 0.5233$	0.9896
560	$-0.2945x^2 + 4.927x + 0.4705$	0.9912
700	$-0.7515x^2 + 10.277x – 0.7361$	0.9906

Table.4 Moisture diffusivity values for dried carrot pomace

Microwave power level (W)	Regression equation	Moisture diffusivity (m^2/s)	R^2
420	**$y = -0.0318x + 0.5371$**	**1.29×10^{-8}**	**0.9421**
560	**$y = -0.0659x + 0.5233$**	**2.67×10^{-8}**	**0.9301**
700	**$y = -0.1057x + 0.2766$**	**4.28×10^{-8}**	**0.9899**

Table.5 β-carotenevalues for dried carrot pomace

Mechanical tray dryer		**Microwave Dryer**	
Temperature (°C)	β-carotene mg/100g	Microwave power level (W)	β-carotene mg/100g
50	5.25	420	3.36
65	3.25	560	3.16
80	1.10	700	1.02

Table.6 Ascorbic Acid values for dried carrot pomace

Mechanical tray dryer		**Microwave Dryer**	
Temperature (°C)	Ascorbic acid (mg/100g)	Microwave Power level (W)	Ascorbic acid (mg/100g)
50	2.1	420	1.425
65	1.875	560	1.2
80	1.5	700	0.75

Table.7 Colour (L, a and b) values for dried carrot pomace

Mechanical tray dryer				**Microwave Dryer**			
Temperature (°C)	L	a	b	Microwave power level (W)	L	a	b
50	70.1	21.3	30.2	420	75.2	25.4	42.1
65	65.4	20	19.2	560	68.5	22.1	29.3
80	59.1	18.3	17.3	700	60.1	19.2	18.1

Fig.1 Variation in moisture content of carrot pomace with time at 50, 65 and 80˚C drying temperature

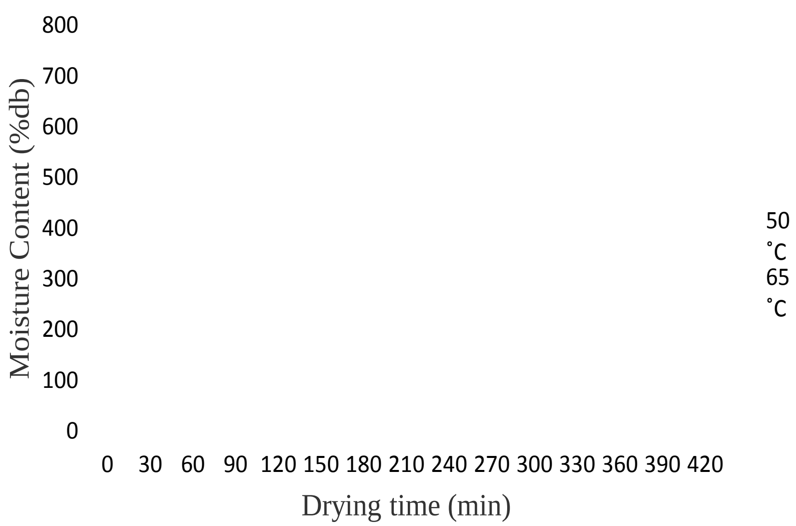

Fig.2 Variation in drying rate of carrot pomace with moisture content at 50, 65 and 80°C drying temperature

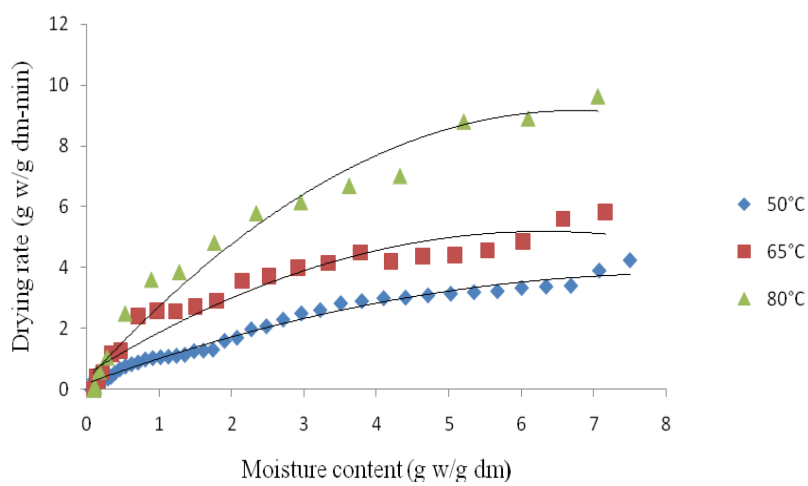

Fig.3 Variation in MR of carrot pomace with drying time at 50, 65 and 80°C drying temperature

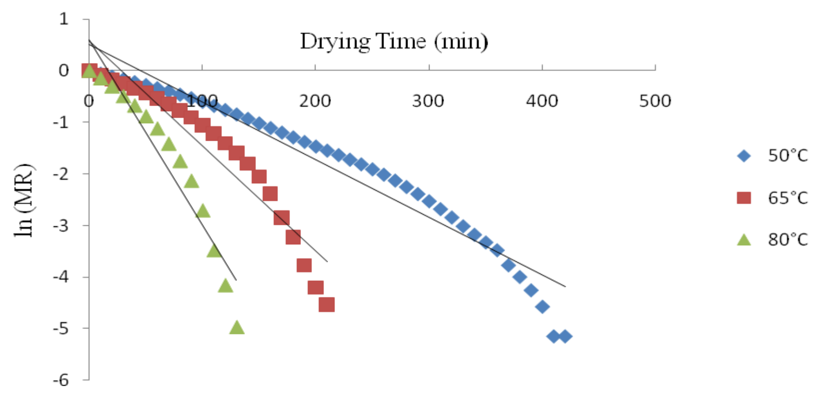

Fig.4 Variation in moisture content of carrot pomace with time at 420, 560 and 700W power level

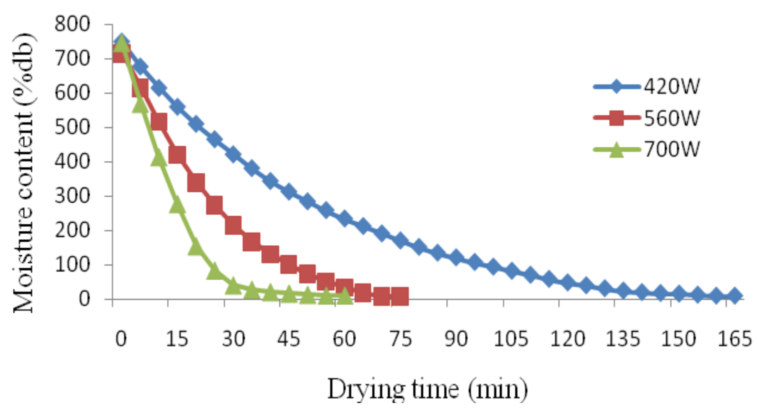

Fig.5 Variation in drying rate of carrot pomace with moisture content at 420, 560 and 700W power level

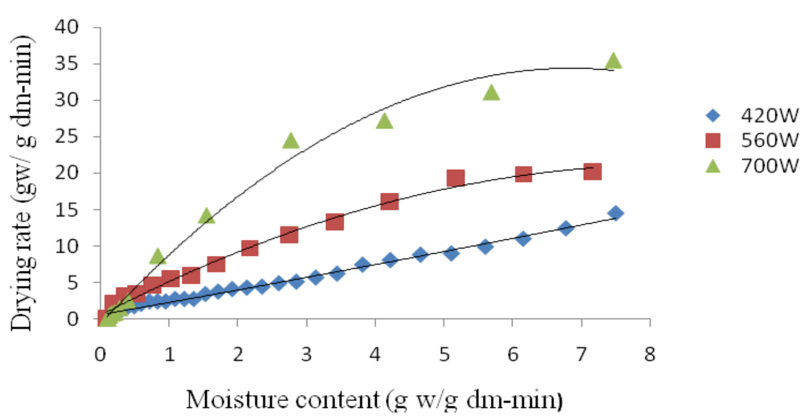

Fig.6 Variation in MR with drying time for carrot pomace at 420, 560 and 700W power level

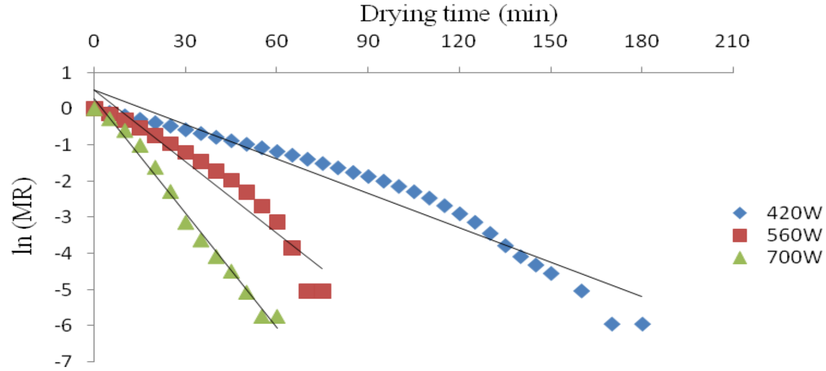

Plate.1 Carrot pomace powder dried at 45, 60 and 75 °C drying air temperatures in mechanical tray dryer and at 420, 560 and 700W power levels in microwave dryer

On the basis of ascorbic acid

In dried pomace heat labile nature of ascorbic acid reduced its availability from 2.1 to 1.5 mg/100g as drying temperature in mechanical tray dryer increased from 50°C to 80°C and in microwave dryer reduced its availability from 1.425 to 0.75 mg/100g as power level increased from 420 to 700W.

Colour

Colour values measured using a hunter lab colourimeter, were relative to the absolute values of perfect reflecting diffuser as measured under the same geometric conditions. Observations were taken at room temperature 30.5°C and 25 per cent relative humidity and values are given in Table 7.

In conclusion the minimum drying time taken at 80°C in mechanical tray dryer and at 700W microwave power level in microwave dryer. Drying takes completely in falling rate period. Moisture diffusivity increases with increase in temperature in mechanical tray dryer and power level in microwave dryer. It was found maximum at 80°C temperature and 700W microwave power level.β-carotene and ascorbic acid content decreases with increase in temperature in mechanical tray dryer and power level in microwave dryer. It was found maximum at 50°C temperature and 420W microwave power level. Redness of the sample decreases with increase in temperature and power level and found maximum at 420W power level in microwave power dryer.

Practical applications

The main aim of drying is to reduce water content without substantial loss of flavour, taste, colour and aroma. Therefore the present research work was undertaken to comparative studies of carrot pomace drying in mechanical tray and microwave dryer.

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