Characterization and Dehydration Kinetics of Carrot Pomace

Ashutosh Upadhyay[1], H.K Sharma, [2] and B.C. Sarkar[2]
[1]Department of Food Tech, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna MP- 485331
[2]Department of Food Engineering and Technology, S L Institute of Engineering and Technology Longowal, District - Sangrur, Panjab, India.
harish.sharma@lycos.com

ABSTRACT

Carrot (*Daucus carota L.*) is cultivated throughout the world. It has been used in soups, stews, curries, pies and salads traditionally. Among the carrot products, juice seems to gain popularity but pomace remains (PR) obtained as a by-product after carrot juice extraction does not find its proper utilization. However it may be used as source of pectin, fiber and carotene - a precursor of vitamin B. In the present study raw carrot (var. *Pusa Kesar*) and fresh/dried PR were characterized for selected physico-chemical parameters. Further PR was dried in open Sun and in tray drier at 60, 65 70, 75 and 80º C. Mathematical modeling for the drying was also established. Mechanical drying was found superior to the sun drying. Increasing temperature from 60 to 75º C., β-carotene retention (db) was increased from 9.86 to 11.57 mg/100g and ascorbic acid retention decreased from 22.95 to 13.53 mg/100g. Optimal drying was observed at 65º C on the basis of β-carotene and ascorbic acid retention. On the basis of R^2 value Page model rendered better prediction of drying data than the Lewis model.

Keywords: Carrot, pomace, physico-chemical characterization, drying, β-carotene, Lewis and Page model, India

1. INTRODUCTION

Among vegetables, carrot (*Daucus carota L.*) is an important vegetable and belongs to the family *Umbelliferae*. It is cultivated throughout the world for its fleshy edible roots and is used for human consumption as well as for animal feed. Carrots are cooked alone or with other vegetables in the preparation of soups, stews, curries and pies. Abu-Khalaf (2004) distinguished carrot characteristics by Near Infra Red Reflectance and multivariate data analysis. Fresh sliced and grated roots are used in salads; tender roots are pickled (Bhupinder *et al*., 2003). For slicing, energy and peak force were found to be influenced mainly by core diameter and central part of the carrot (Sharma *et al*., 2005).

The commercial exploitation of carrot has not been so far taken place in most of the developing countries despite having the potential for processing and value addition. So far most of the work with carrot is in juice form only. Yield and quality of carrot juice extracted by pressing is varied with the pretreatment conditions such as pH, temperature and time (Sharma *et al*., 2006). The effect of pretreatment conditions on the physico-chemical parameters of carrot juice and the effects of different blanching solutions and blanching times (1-5 min) on the quality of carrot juice have been studied (Bin-Lim and Kyung-Jwa, 1996, Sharma *et al*., 2007).

In his efforts to study the effect of pectolytic and cellulolytic enzymes on the carrot juice recovery, Chaddha *et al*., (2003) concluded that effect of incubation temperature and enzyme concentration were more pronounced than those of incubation time and enzyme ratio. Sharma *et al*., (2005) optimized enzymatic process parameters for increased juice yield from carrot using response surface methodology.

Among the carrot products; juice has gained the popularity in west. Carrot juice and blend thereof are among the one of the most popular non-alcoholic beverages in Germany where carrot juice production increased by 69 % between 1995 to 1999 and was amounting more than 42 million liter in 2001. Carrot juice is also reported to have its use with the other juices in blended form (Stoll *et al*., 2001). As stated in Wealth of India, (1976), carrot juice is blended with juice of a citrus fruit (*Kinnow*) of the *Himachal Pradesh* of India, to reduce bitterness in citrus juice. Bohm *et al*., (1999) reported juice yield in carrots as only 60-70%, and even up to 80% of carotene may be lost with left over carrot pomace. So far the left over pomace, received after juice extraction from carrots, does not find its proper utilization. However these pomace remains may be used as a source of pectin and carotene - precursor of vitamin B (Schieber *et al*., 2001). The chances for the development of recipes containing PR could be quite high as in some of the European countries there are already breads and cakes in the market with added grated carrots. Drying of left over pomace seems to be one of the best processing tools for the utilization of this by product. Machewad *et al*., (2003) have already indicated the suitability of whole carrot shreds for drying and feasibility of dried carrot shreds for further processing applications. Therefore, the present study aims to characterize the carrot pomace under different conditions and to study the drying kinetics for the future use of by product under study.

2. MATERIALS AND METHODS

Carrots (var. *Pusa Kesar*), were procured from the local market. All the chemicals used were of AR grade.

Preparation and Drying of Samples

Locally available red carrots were washed under running stream of water to remove all dirt, dust and foreign materials attached to carrot surface. De-heading and trimming of the carrots were carried out manually using a vegetable knife. The juice was extracted from the carrots with the help of domestic juicer-mixer-grinder (Make: *Usha Lexus India, JMG model*). The post juice extraction remains / shreds of carrots were collected and their drying of carrot pomace was carried out in a tray drier (Make: *Bent, Delhi, India*). These remains were designated as pomace remains (PR) in the study. For the drying experiments, only temperature was kept variable. Drying bed thickness in the tray drier was kept 0.5 cm and the temperature was varied from 60º to 80º C at an interval of 5º C, as given in Table 1. The sample was also dried under the sun for comparison.

During tray drying, moisture content was recorded at a 10 minutes interval for first hour and later at 30 minutes interval until the sample attained equilibrium with the drying environment and no reduction in the mass of the sample was recorded. After removal from the tray the dried samples were cooled in desiccators each time, prior weighing.

Physico-chemical Characterization of Carrot and LOP

Moisture Content, ascorbic acid, β -carotene, crude fiber and ash content were recorded in carrot and fresh/dried PR were estimated as per the standard methods (Ranganna 1991) where for the evaluation of β-carotene alumina was used as adsorbent in column chromatography.

Mathematical Modeling

The following mathematical models (Vishwanathan *et al.*, 2003, Waewsak *et al.*, 2006) for characterizing drying rates were explored in the study:

Lewis Model MR = Exp (-kt) …..(1)

Page Model MR = Exp (-kt n) …..(2)

Where,

MR = Moisture Ratio = (M-Me / Mo-Me), M = Moisture content at time t (% db), Mo = Initial moisture content (% db), Me = Final moisture content where no further moisture removal was recorded at a particular drying temperature (% db), Exp = Exponential value, t = Drying time (h), k and n = drying constants.

The recorded drying data were used for calculating drying constants of above drying models. Related calculation and regression analysis to determine the model constant and their fitness were carried out by using MS excel was used for model constant determination by regression and for the value of coefficient of determination (R^2). Individual model performance was compared on the basis of actual versus predicted plots and respective model standard error value in residuals.

3. RESULTS AND DISCUSSION

The effect of experimental temperature conditions and corresponding drying time on physico-chemical parameters of PR is reported in Table 1. The composition of carrot was found in agreement with the earlier findings (Reed, 1976, Wealth of India, 1976).

Table 1. Physico-chemical parameters of carrot, carrot residue / PR

S. No.	**PRODUCTS**	**Moisture Content (% wb)**	**Crude Fiber (%)**	**Ash (%)**	**Ascorbic Acid-db (mg/100g)**	**β-Carotene db (mg/100 g)**
1.	Raw Carrot	90.8	1.87	0.83	32.60	55.25
2.	Pomace	85.62	15.89	2.80	23.44	14.39
3.	Dried PR (at 60º C for 7.5 h)	9.31	18.35	6.20	22.95	9.86
4.	Dried PR (at 65º C for 6.0 h)	8.85	18.37	6.21	20.62	10.77
5.	Dried PR (at 70º C for 5.5 h)	8.19	18.38	6.22	17.12	10.88
6.	Dried PR (at 75º C for 5.0 h)	7.68	18.38	6.22	13.53	11.57
7.	Dried PR (at 80º C for 5.0 h)	7.51	-	-	-	9.39
8.	Sun Dried PR	11.37	-	-	11.90	1.19

It was observed that moisture content and ascorbic acid content of PR was decreased with the increase in drying temperature. The moisture content of the dried samples of pomace at the selected temperatures from 60 to 75º C varied between 9.31 to 7.68 % (wb). Drying time decreased from 7.5 h to 5.0 h for the temperature rise as higher temperature favored the faster removal of moisture. The moisture of the sun dried sample, 11.37% was higher than the mechanical drying, even after drying for 3 consecutive days. Drying curves recorded at different temperatures for different interval of time are shown as Fig. 1. The trend of the drying curve was similar to other agricultural product (Waewsak *et al*., 2006), as the moisture ratio decreased exponentially.

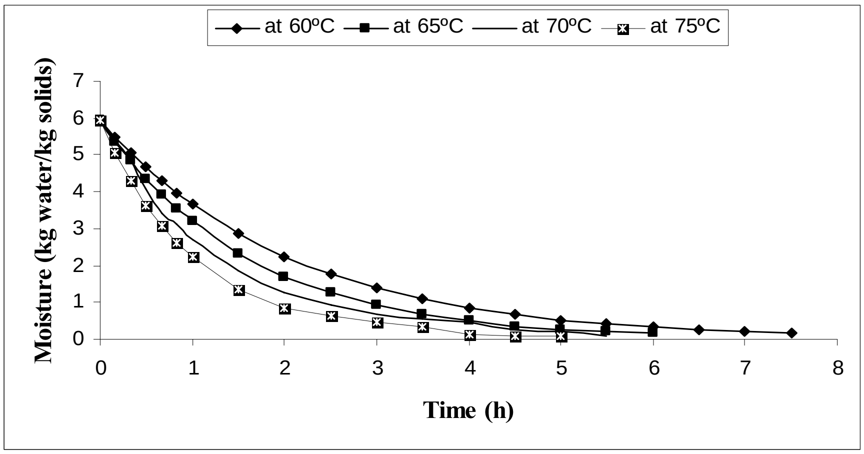

Figure 1. Drying curves at different drying conditions

The β-carotene, 55.25 mg/100g (db) in fresh carrot was reduced to 14.39 mg/100g in fresh PR. This reduction could be accounted for β-carotene gone with the juice. Change in β-carotene content (db) in PR, as a effect of different drying conditions (other than under sun) ranged from 10.77 to 9.39 mg/100g, with increase of drying temperature from 65º C to 80º C. The present trend may be attributed to auto-oxidation of β-carotene consequent to higher exposure time at lower temperatures in the selected range. Low retention of β-carotene in the sun drying samples may also be cited for the same reason. Earlier findings (Machewad et al., 2003, Sagar et al., 2004) with carrot also supported the carotene behavior under drying in the present study. In this sequence the temperature of 80ºC was also tried but a substantial decrease in β-carotene was noted. It reflected that thermal destruction of β-carotene became significant above 75º C. Therefore temperature above 75º C was not considered in the study. A retention trend of β-carotene in PR during drying was similar to the earlier findings with drying of carrots (Banga and Baba, 2002) where open atmosphere sun drying had maximum (71%) loss of β-carotene followed by drying in a solar drier (52%) and hot-air cabinet drier (42%). Thus losses in mechanical drying were least.

Conversion of raw carrot into PR reduced availability of ascorbic acid (db) from 32.60 mg/100g to 23.44 mg/100g respectively. In dried PR heat labile nature of ascorbic acid reduced its availability from 22.95 to 13.53 as dehydration temperature was increased. Fiber and ash content remained almost unaffected with varied drying temperature. Sun drying was not preferred as a choice for drying as it produced a low value dried PR and took a longer drying time. Among the different drying temperatures as given in Table 1, temperature 65 ºC was observed to be an optimum temperature for CPP preparation due to optimum retention of ascorbic acid and carotene compared to other temperatures. However maximum retention of ascorbic acid, being highly heat labile was found maximum at lowest drying temperature (60 ºC) of selected range but β-carotene retention was least (9.86 mg/100g) at this temperature.

Drying data at different temperatures were solved to work out respective Lewis and Page model parameters. Values worked out for model constant at each experimental temperature and respective coefficients of determination (R^2) are shown in Table 2. For the Lewis model 'k' was obtained varying as 0.640 to 1.128 as the temperature varied from 60º C to 75º C. Similarly for Page model 'k' and 'n' values respectively ranged as 0.523 to 1.022 and 1.079 to 1.034 as temperature varied from 60º C to 75º C. The established models had R^2 value greater than 0.93. Higher R^2 value for Page model as compared to Lewis model (Table 2) at all the selected temperatures indicated Page model as a better predictor. Supremacy of Page model over Lewis model and respective rise or fall of drying parameters (k and n) followed the same trend as observed by Vishwanathan *et al*., (2003) during drying of onions.

Table 2. Drying model constants at different drying conditions

Temperature (º C)	**Lewis Model**		**Page Model**		
	k (1/h)	**R^2**	**k (1/h)**	**n**	**R^2**
60	0.640	0.93	0.523	1.079	0.99
65	0.747	0.97	0.660	1.061	0.99
70	0.757	0.99	0.739	1.044	0.99
75	1.128	0.94	1.022	1.034	0.98

Equation 3 and 4 respectively present the Lewis and Page model ready for the prediction of moisture ratio and drying time at 65º C, the temperature considered optimum in the study. The drying models obtained at 65º C temperature were graphically verified by typical drying curves of moisture content versus time (Fig 2 and 3) and moisture ratio versus time (Fig 4 and 5). The figures were drawn to show predicted value comparison with the actual values. Page model (Fig. 3 and 5) indicated closure values of predicted and actual variables with respect to time. Standard errors in residuals of predicted values at 65º C are presented in Table 3. Lesser standard error value for Page model also indicated the supremacy over Lewis model in the drying of carrot pomace.

$$MR = \mathrm{Exp}\,(-0.747\, t) \quad \ldots\ldots (3) \quad (\mathbf{R^2 = 0.97})$$
$$MR = \mathrm{Exp}\,[-0.660\, (t)^{1.061}] \quad \ldots\ldots (4) \quad (\mathbf{R^2 = 0.99})$$

Table 3. Standard error values for the models

Predictors	**Standard error**	
	Lewis Model	**Page Model**
Moisture Ratio	0.005	0.002
Moisture (db) at time t	3.053	1.328

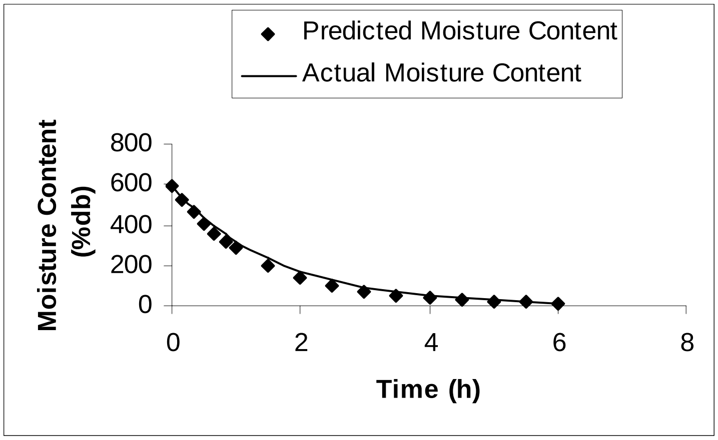

Figure 2. Typical drying curves between the moisture content and time at 65º C (For Lewis Model)

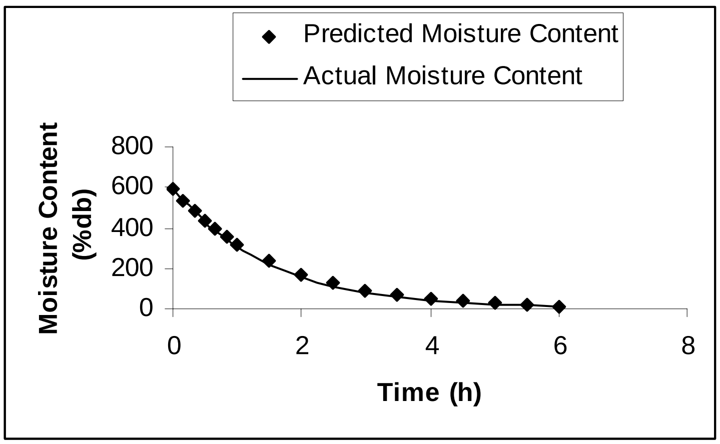

Figure 3. Typical drying curves between the moisture content and time at 65º C (For Page Model)

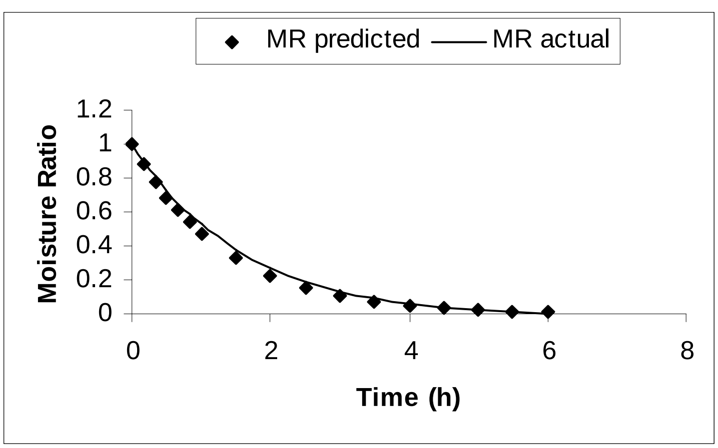

Figure 4. Typical drying curves between the moisture ratio and time at 65º C (For Lewis Model)

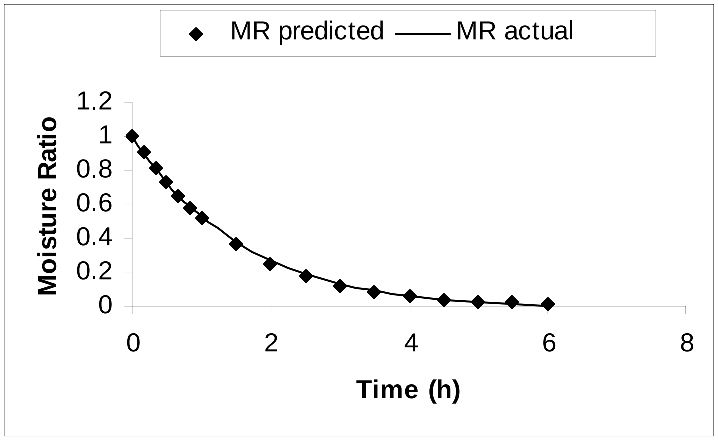

Figure 5. Typical drying curves between the moisture ratio and time at 65º C (For Page Model)

Drying parameters calculated at the drying conditions studied, presented as Table 2, were also regressed (equation 5 to 7) with temperature as dependent linear variable. Drying constant(s) for both the selected models showed temperature dependence with R^2 values between 0.80 and 0.93.

For Lewis Model: $k = 0.029\,T - 9.219$ …… (5) (**$R^2 = 0.80$**)

For Page Model: $k = 0.031\,T - 9.996$ …… (6) (**$R^2 = 0.80$**)

$n = -0.0017\,T + 1.632$ ...…. (7) (**$R^2 = 0.89$**)

The above equations showed that the in case of Page model equations 6 and 7 can be better used for simulating the drying constants data at different drying temperatures than for Lewis model. Temperature dependence of rate constants, k, of both the models was established using Arrhenius equation. Thus obtained relations are represented by Equation 8 and 9 for the Lewis and Page model respectively.

For Lewis model $k=8.92\times10^{4}\,\mathrm{Exp}\,(-3.95\times10^{3})/T$ …..(8) (**$R^2 = 0.83$**)

For Page model $k=1.32\times10^{6}\,\mathrm{Exp}\,(-4.91\times10^{3})/T$ ..…(9) (**$R^2 = 0.96$**)

Coefficient of determination, R^2, in equation 8 and 9 were found higher than equation 5 and 6, for respective models. The page model showed only 4% variability ($R^2 = 0.96$) in the data as compared to the 17% data variability ($R^2 = 0.83$) in Lewis model, when temperature dependence was regressed. Better predictability of k in case of Page model also supported the model for drying predictions.

4. CONCLUSION

The study concluded that the drying temperature of 65 ºC from selected range was optimum in terms of optimal retention of both ascorbic acid and β-carotene for the removal of moisture from carrot pomace. Page model ($R^2 = 0.99$) proved to render better adequacy than the Lewis model ($R^2 = 0.97$). Graphical comparison of predicted and actual moisture content/MR values also supported Page model. Arrehenius equation suitably explained variation in drying constant 'k' with temperature.

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6. NOMENCLATURE

PR	Pomace remains	*db*	Dry basis
wb	Wet basis	*MR*	Moisture Ratio
Exp	Exponential value	*t*	Drying time (h)
k / n	Drying model constants.	*T*	Drying Temperature (º C)