International Journal of Agriculture and Food Science Technology.
ISSN 2249-3050 Volume 5, Number 3 (2014), pp. 219-226

http://www.ripublication.com

Convective Drying of Osmo-Dehydrated Sapota Slices

Suchita V. Gupta[1], Bhagyashree N. Patil [2]

[1]*Department of Farm Structures, Dr. PDKV, Akola 444001 Maharashtra, India*
[2]*Department of Agricultural Process Engineering, Dr. PDKV, Akola 444001 Maharashtra, India*

Abstract

In present study, the effects of drying air temperatures (50, 60 & 70 °C) on the drying kinetics of sapota slices were investigated using a hot-air tray dryer. In order to select the appropriate drying model, five mathematical drying models were fitted to the experimental data. Result indicated that the drying took place in the falling rate period. Considering the statistical criteria (R^2, χ^2 & RMSE) the model suggested by Page (1949), model was found to be the best model to describe the drying behavior of sapota. Multiple regression analysis was used to find the correlation of the model coefficients with temperatures. Model coefficient equations predicted the moisture ratio (MR) well at three drying temperature 50, 60 and 70 ^{o}C for the sapota with an R^2 = 99.87 and SE = 0.0001.

Key words Sapota , thin layer drying, mathematical modeling, tray drying.

Introduction

Drying of perishable fruit is an important sector of the fruit processing industry. The major objective in drying of perishable fruit is the reduction of moisture content to a certain level, which allows safe storage and preservation. Drying is regarded as a complicated process and the most difficult operation in food processing. This is due to simultaneous heat and mass transfer and considerable undesired quality changes in the product during the drying process. The methods and the variables of drying, influence both the quality and physicochemical characteristics of the dried products (Krokida & Maroulis, 1997). The drying kinetics is greatly affected by air temperature and material characteristics. Sapota (*Achras sapota* L.) is a tropical fruit belonging to the sapotaceae family, on which few studies have been reported. The most common cultivars grown are Kalipatti, Round, Cricket Ball, Oval and Calcutta Round in

Maharashtra, India. Sapota contains high fiber content and hence its powder can be consumed as a fiber supplement for children as well as for adults. Fresh sapota fruit is perishable due to its high moisture content. Drying is a process to remove the moisture content and preserve the sapota slices for longer period of time. The most common drying method is open air-sun drying, which is used for drying of vegetables and fruits. There are many problems associated with sun drying method, such as lack of sufficient control during drying, being extremely weather dependent, contamination with dust, soil and insects and undesirable changes in the quality of products. These problems could be overcome if conventional dryers are used.

Modeling of drying processes and kinetics is a tool for process control and necessary to choose suitable method of drying for a specific product. The developed models fall into three categories namely the theoretical, semi-theoretical and empirical. Semi-theoretical models offer a compromise between theory and ease of application (Khazaei & Daneshmandi, 2007). Semi-theoretical models are Lewis, Page, Henderson and Pabis, logarithmic, two term and two term exponential, models are used widely for designing as well as selection of optimum drying conditions and for accurate prediction of simultaneous heat and mass transfer phenomena during drying process. It also leads to produce the high quality product and increases the energy efficiency of drying system. Semi-theoretical models such as Page, Henderson and Pabis and logarithmic models are only valid under the drying and product conditions for which these models were developed. Thin-layer drying models have been used to describe the drying process of several agricultural products

The aim of the present work was to investigate the thin-layer convective drying behavior ofsapota slices. However, the drying kinetics is greatly affected by the air temperature, material size, drying time and etc. (Erenturk & Erenturk, 2007).

2 Materials and methods

2.1 Materials

The fresh sapota fruits were procured from the Department of Horticulture, Dr. Panjabrao Deshmukh Krushi Vidyapeeth, Akola, India. They were sorted visually for uniform maturity and size; then were washed with tap water and surface dried with a filter paper. The average initial moisture content was determined by using oven method at 70 °C for 18 h (AOAC, 2000).

2.2 Drying equipment

Drying was performed in a hot air tray dryer. The dryer mainly consists of three basic units, namely, air supply unit, electrical heaters controlling the temperature of drying air and drying chamber.

2.3 Experimental procedure

The dryer operated unloaded for about 30 min to achieve a steady state condition. The osmotically dehydrated sapota fruit slice (about 100 g) samples were loaded on the drying trays, weighed and kept in to the dryer. The drying were conducted at various temperatures for 50-70°C at an interval of 10 °C and air velocity was kept at 1 m/s (Antonio *et. al*, 2007, Miranda *et al.*, 2009). Drying data was recorded at 5 minute interval for first half an hour, at 10 minute intervals for until completion of experiment (up to Emc). Each experiment was replicated three times. Then the sapota slices (about 100 g) were put on the tray in single layer. The weight loss was measured by weighing balance. The weight loss of the samples was recorded at every 10 minutes interval. Drying time was defined as the time required to reduce the moisture content of the sapota.

2.4 Mathematical modeling of the drying curves

In this study some of mathematical models, were used to describe the drying kinetic of sapota slices.The obtained drying curves were fitted with twelve different moisture ratio models (Table 1). However, the dimensionless moisture ratio (MR) was simplified to M/M_0 instead of $(M-M_e)\ (M_0-M_e)^{-1}$ for long drying time, because the values of the M_e are relatively small as compared to M or M_0. Hence, the error involved in the simplification is negligible (Doymaz, 2004, Togrul & Pehlivan, 2004).

Table 1 Thin-layer mathematical drying models

Model	Mathematical equation	Reference
Lewis	MR = Exp(-k*t)	Lui, 1977
Henderson and Pabis	$MR = a \exp(-kt)$	Rahman et al., (1998)
Page	$MR = \exp(-kt^n)$	Page (1949)
Modified Page	$MR = Exp - (K*t)^n$	Overhult *et al.*, (1973)
Logarithmic	$MR = a \exp(-kt) + c$	Togrul & Pehlivan (2004)

The non-linear least square regression analysis based on *STATISTCA 8* was used to estimate the parameters of the models (by fitting the model equations to experimental data). The coefficient of determination (R^2), chi square (χ^2) and the root mean square error (RMSE) were used as criteria for verifying the goodness of fit (Togrul, 2005; Sacilik & Elicin, 2006). The best model for describing the thin-layer drying characteristics of sapota slice was chosen as the one with the highest value of R^2 and the least values of χ^2 and RMSE (Togrul, 2005). Then the relationships between coefficients of the best model and the drying variables were determined using multiple regression analysis. All possible combinations of the different drying variables were tested and included in the regression analysis (Togrul, 2005).

3 Results and Discussions

3.1 Drying curves

The initial moisture content of osmo-dehydrated was found to be 73.466% (db). The moisture content versus drying time and the variation of drying rate with moistures content at various air temperatures are shown in Fig. 1 and 2, respectively. It is observed that moisture content of samples decreases exponentially with the drying time. Similar result were reported for These findings are in conformity of the results reported for air drying of osmotically dehydrated banana, pineapple and papaya slices by Pokharkar (1998a and 1998b), Jain (2007) respectively. As shown in Fig. 1, increasing the air temperature reduced the time required to reach a certain level of moisture content. The drying time to reduce the moistures content of sapota slice from 9.11 to 10.65 (g water g dry solid^{-1}) were 600,540 and450 minutes at temperature of 50, 60 and 70 °C, respectively. The analysis of variance indicated that the air temperature had a significant effect on the drying time (P value=0.0001). Similar results were reported for apple drying by several authors (Tugrul, 2005; Sacilik & Elicin, 2006).

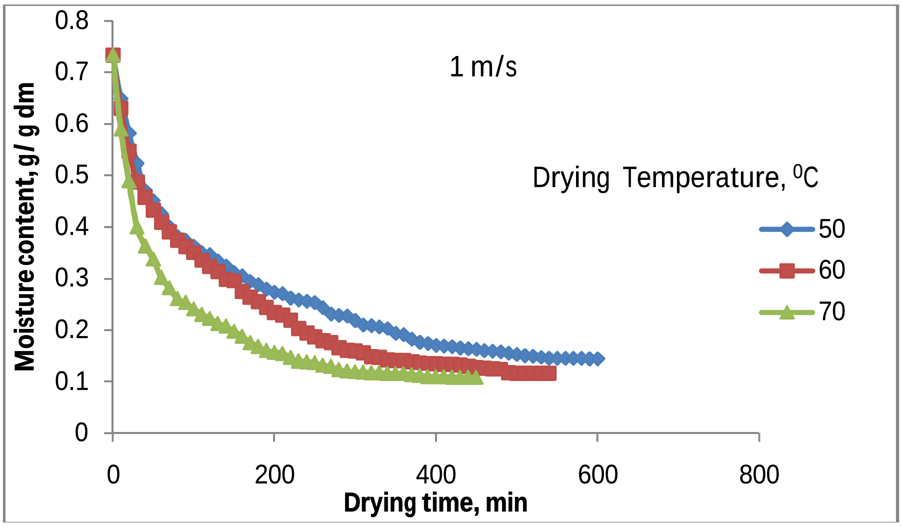

Fig.1 Drying time VS moisture content of osmodehydrated sapota

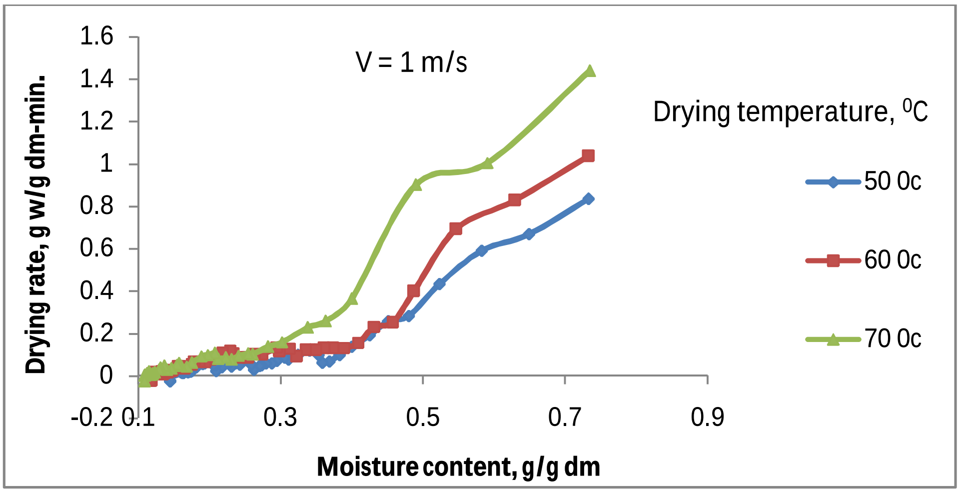

Fig.2 Variation of drying rate with moisture content at different temperature

Fig. 2 illustrates that drying rate decreases continuously with decreasing moisture content. In this curve, a constant drying rate period was not observed and drying process occurred in the falling rate period only and the diffusion mechanism controlled moisture movement in the sapota slices. These results were in agreement with other authors on drying of apple (Togrul, 2005; Sacilik & Elicin, 2006; Schultz et al., 2007). As expected, the drying rate increased with increasing in drying air temperature and consequently decreased the required drying time. It is a fact that the higher temperature difference between the drying air and sapota slices increases the heat transfer coefficient, which influences the heat and mass transfer rate. Several authors reported similar results for drying of fruits and vegetables such as figs (Babalis & Belessiotis, 2004) and apple (Togrul, 2005; Sacilik & Elicin, 2006).

Table 2 Results of statistical analysis of five thin layer drying models.

Name of Model	Air velocity (m/s)	Air temp.	Drying constant				Statistical parameters		
			k	n	a	B	R^2	χ^2	E_{RMS}
Lewis	1	50	0.0095	-	-	-	0.9482	0.0043	0.0658
		60	0.0095	-	-	-	0.9796	0.0021	0.0454
		70	0.0162	-	-	-	0.9682	0.0027	0.0514
Hunderson and pebis	1	50	0.0072	-	0.7985	-	0.9742	0.0021	0.0454
		60	0.0081	-	0.8596	-	0.9912	0.0009	0.0298
		70	0.8493	-	0.0135	-	0.9797	0.0017	0.0415
Page	1	50	0.0586	0.6299		-	0.9983	0.0001	0.0012
		60	0.0309	0.7626	-	-	0.9987	0.0061	0.0239
		70	0.0697	0.6656	-	-	0.9979	0.0002	0.0131
Modified page	1	50	0.0269	0.2727	-	-	0.9539	0.0041	0.0634
		60	0.0608	0.1565	-	-	0.9790	0.0021	0.0453
		70	0.2206	0.0731	-	-	0.9683	0.0027	0.0515
Logarithmic	1	50	0.0106	-	0.8115	0.0691	0.9897	0.0008	0.0288
		60	0.0082	-	0.8588	0.0034	0.9913	0.0009	0.0297
		70	0.1671	-	0.8571	0.0426	0.9878	0.0011	0.0320
	2	50	0.0081	-	0.7782	0.0596	0.9836	0.0014	0.0370
		70	0.0165	-	0.8807	0.0074	0.9853	0.0014	0.0372
	3	50	0.0109	-	00811	0.0751	0.9898	0.0008	0.0288
		60	0.0102	-	0.8284	0.0097	0.9868	0.0013	0.3491
		70	0.0193	-	0.8936	0.0193	0.9866	0.0013	0.3551

From Fig. 3, the moisture ratio reduced exponentially as the drying time increased (Doymaz, 2007). Continuous decrease in moisture ratio indicates that diffusion has governed the internal mass transfer. A higher drying air temperature decreased the moisture ratio faster due to increase in air heat supply rate to the sapota and the acceleration of moisture migration.

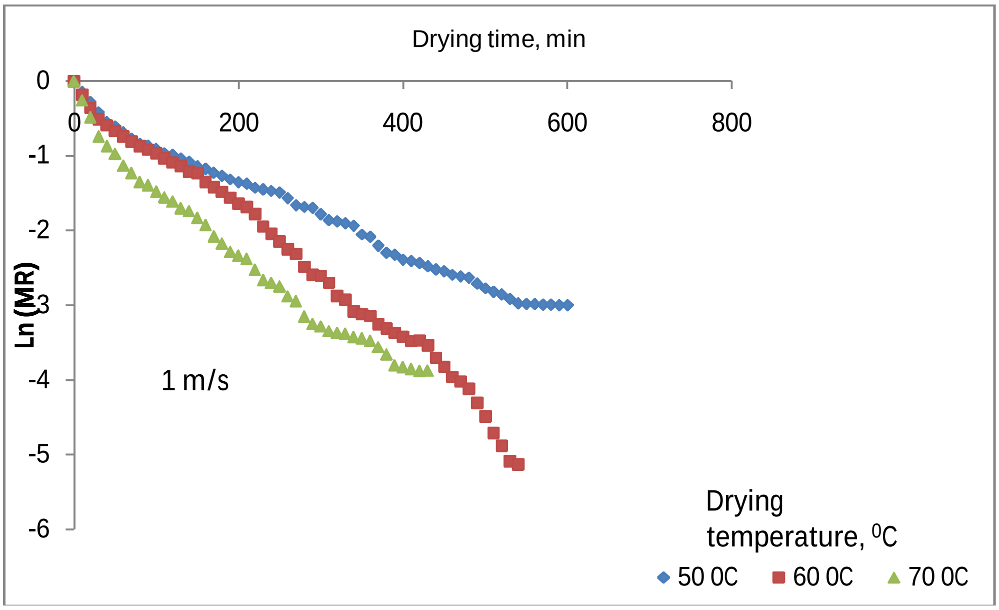

Fig.3 Moisture ratio vs drying time of sapota slices at different temperature

3.2 Modeling of drying curves

The moisture content data obtained at different air temperatures were converted to dimensionless moisture ratio (MR) and then fitted to five drying models (Table 1). Five thin layer drying models were evaluated according to the statistical criteria, R^2, χ^2, and RMSE (Table 2). By comparing the average values of these criteria, it is obvious that the Page model had the highest R^2 and the lowest χ^2 and RMSE values. Generally R^2, χ^2, and RMSE values of the selected model in all experiments were varied between 0.9482 to 0.9987, 0.004 to 0.0001, and 0.35 to 0.001, respectively. Accordingly, the Page et al., (2002) model was selected as the suitable model to represent the thin layer drying behavior of sapota. The coefficients of the models are shown in Table 2. To take into account the effect of drying air temperature on the coefficients of selected model, the values of coefficients were regressed against drying-air conditions using multiple regressions. The multiple combinations of different parameters, which gave the highest R^2 value, were finally included in the selected model.

Conclusion

The drying behavior of the osmotically dehydrated sapota slices were investigated in a thin layer hot-air dryer at air temperatures of 50, 60 and 70 °C. The drying of sapota slices occurred in the falling rate period and the diffusion mechanism controlled moisture movement. Drying air temperature affected the drying rate and time. The drying rate increased with increasing the drying-air temperature.Page, (1949) model was adequate for describing the thin-layer drying behavior of sapota. The drying parameters a, k, n and b in Page, model can be expressed as a liner function of the temperature with an R^2 of 0.9987 and SE of 0.001.

References

[1] Antonio,V., Uribe, E., Lemus, R. and Miranda., M. 2007. Hot air drying characteristics of aloe vera (*Aloe barbadensis* miller) and influence of temperature on kinetic parameters. *Journal of LWT-Food Science and Technology,* Article in Press, Corrected Proof.

[2] AOAC, 2000. Official methods of Analysis, 17^{th} ed. Association of Official Analytical Chemist, Washington DC, USA.

[3] Babalis, J. S., Belessiotis, G. V., 2004. Influence of drying condition on the drying constants and moisture diffusivity during the thin layer drying of figs. Journal of Food Engineering 65, 449–458.

[4] Bhagyashree N. Patil, Vanita Barval & sneha Deshmukh (2013) Thin layer dying of long paper. Journal of Spices and Aromatic Plants. 22 (1); 31-37

[5] Doymaz, I., 2004. Effect of dipping treatment on air drying of plums. Journal of Food Engineering 64, 465–470

[6] Doymaz, I., 2007. Thin layer drying of spinach leaves in a convective dryer. Journal of Food Engineering 32, 112– 125.

[7] Erenturk, S., Erenturk, K., 2007. Comparison of genetic algorithm and neural network approaches for the drying process of carrot. Journal of Food Engineering 78, 905–912.

[8] Jain S.K., Verma R.C., Murdia L.K., Jain H.K., and Sharma G.P. 2011 Optimization of process parameters for osmotic dehydration of papaya cubes. J. Food Sci Tech. 48(2): 211–217.

[9] Khazaei, J., Daneshmandi, S., 2007. Modeling of thin-layer drying kinetics of sesame seed: mathematical and neural networks modeling. International Agrophysics 21, 335–348.

[10] Krokida, M.K., Karathanos, V.T. and Maroulis, Z.B. 2000b. Effect of osmotic dehydration on visco-elastic properties of apple and banana. *Drying Technology,* 18(4&5):951-966.

[11] Lui Q, Bakker-Arkema FW. Stochastic modelling of grain drying. Part 2: Model development. J Agricult Eng Res 1997;66:275–80.

[12] Miranda, M., Maureira, H., Rodriguez, K. and Vega, A. 2009a. Influence of temperature on the drying kinetics, physicochemical properties and antioxidant capacity of aloe vera (*Aloe Barbadensis* Miller) gel. *Journal of Food Engineering,* 91:297-304.

[13] Overhult, D. D., White, G. M., Hamilton, M. E. and Ross, I. J. 1973. Drying soybeans with heated air. *Transactions of the ASAE*, 16:195–200.

[14] Page, G. E., 1949. Factors influencing the maximum rates of air drying shelled corn in thin layers. *M.Sc. Thesis*, Purdue University, West Lafayette, Indiana.

[15] Pokharkar, S.M. and Prasad, S. 1998a. Water desorption isotherm of osmotically concentrated pineapple. J. Food Sci. and Tech. 35(6): 518-520.

[16] Pokharkar, S.M. and Prasad, S. 1998b. Mass transfer during Osmotic dehydration of Banana slices. J. Food Sci. and Tech. 35(4): 336-338.

[17] Rahman, M. S., Perera, C. O., Thebaud, C., 1998. Desorption isotherm and heat pump drying kinetics of peas. Food Research International 30, 485–491.

[18] Sacilik, K., Elicin, A. K., 2006. The thin layer drying characteristics of organic apple slices. Journal of Food Engineering 73, 281–289.
[19] Schultz, E. L., Mazzuco, M. M., Machado, R. A. F., Bolzan, A., Quadri M. B., Quadri, M. G. N., 2007. Effect of pre–treatment on drying, density and shrinkage of apple slices. Journal of Food Engineering 78, 1103–1110.
[20] Togrul, I. T., Pehlivan, S., 2004. Modeling of thin layer drying kinetics of some fruit under open-air sun drying process. Journal of Food Engineering 65, 413– 425.
[21] Togrul, H., 2005. Simple modeling of infrared drying of fresh apple slices. Journal of Food Engineering 71, 311–323.