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THIN LAYER DRYING KINETICS OF POTATO MASH

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ABSTRACT

This study was conducted to investigate the effect of temperature on hot-air drying kinetics of potato (Solanum tuberosum) mash and to evaluate the best model predicting the drying kinetics along with the colour changes during mechanical tray drying. Commonly cultivated variety namely Kufri Pukhraj was selected for the study. Potato mash were soaked in 0.2 % Kms solution to reduce the reducing sugar % followed by hot-air drying in single layer mash with thickness vary from 5-7 mm at different temperatures (50–70°C) in a forced convection dryer. In order to estimate and select the appropriate drying model, five different models which are semi theoretical and/or empirical were applied to the experimental data and compared. The goodness of fit was determined using the coefficient of determination (R^2), reduced chi square (χ^2), root mean square error (RMSE) and mean bias error (MBE). Among the models proposed, the semi-empirical logarithmic model was found to best explain thin layer drying behavior of the potato mash as compared to the other models over the experimental temperature range. By increasing the drying air temperature, the effective moisture diffusivity values increased from from 1.43684×10^{-10} m^2/sec to 2.40882×10^{-10} m^2/sec as temperature increase from 50°C to 70°C. The relationship between the drying rate constant and drying air temperature was also established. Samples dried at lower temperature had better lightness (higher L values) compared to those dried at higher temperature.

KEYWORDS: Kufri Pukhraj, Tray Drying, Moisture Diffusivity, Drying Model, Drying Rate

INTRODUCTION

The potato is a starchy, tuberous crop from the perennial Solanum tuberosum of the Solanaceae family (Spooner 2005). It is a wholesome food. It produces 47.6 kg of food/ha/day whereas wheat, rice and maize produce 18.1, 12.4 and 9.1 kg food/ha/day respectively (Kumar and Pandey 2008). It also has superior dietary fibre with tiny amount of fat (0.1%) with majority being the unsaturated fatty acid (linoleic acid), which is nutritionally superior. It is rich in potassium and good source of phosphorus.

Fruits and vegetables are perishable in nature and get spoiled due to improper handling, growth of spoilage microorganisms, action of naturally occurring enzymes, chemical reactions and structural changes during storage. For the prevention of crop from deterioration and for increasing its shelf life, various preservation methods are employed. A major goal of food processing is to convert perishable commodities into stable products that can be stored for extended periods thereby reducing losses and making them available at the time of shortage and off-season use and for places which are far away from production site. Processing can change foods into new or more usable forms and make them more convenient to prepare. Several processing technologies have been employed on industrial scale to preserve food products. These include canning, refrigeration, controlled atmosphere storage, dehydration, chemical treatment and use of subatomic particles. Drying is the most common way to preserve agricultural produce especially the surplus ones. It is well known that the product quality is greatly affected by drying methods and drying process. Dried foods can be stored for long periods without deterioration. The principle reasons for this are that the micro-organisms which cause food spoilage and decay are unable to grow and multiply in the absence of sufficient water and many enzymes which promote undesired changes in the chemical composition of the food cannot function without water.

Processing is a fast growing sector in potato world economy. Organized and unorganized Indian processing industries presently consume only 4% of the total produce in the country as compared to about 30-67% in developed European countries (Rana and Pandey 2007). The growth of potato processing industry is hampered mainly due to lack of round-the-year supply of fresh potatoes meeting the required quality. India stands second in vegetables and fruit production, hardly two percent of the produce is processed and 30% to 40% is being wasted due to lack of processing and preservation infrastructure. Physical methods like drying or dehydration is one of the most commonly used method of preservation at household levels.

The present study was therefore undertaken to investigate the thin layer drying characteristics of potato mash in a convective dryer. Also the experimental data were fit to the proposed mathematical models in order to estimate the constant parameters for calculating the effective diffusivity for drying of potato mash.

MATERIAL AND METHOD

The experiment to accomplish the desired objectives was performed in the laboratories of the Department of Processing and Food Engineering and Punjab Horticultural Postharvest Technology Center, Punjab Agricultural University, Ludhiana. Potatoes of selected variety namely Kufri pukhraj were procured from the farmer. The fresh potatoes were sorted based on size visually, washed, peeled and boiled to prepare mash. The mash was then dried under different drying methods; to evaluate the effect on the drying behavior. Vital physiochemical characteristics viz. TSS, Reducing sugar, Starch and Moisture content of fresh and processed potato mash were also estimated.

Processing of Potato

Selected grown varieties of fresh potatoes were procured from farmer and local market. Potatoes were sorted on the basis of size and maturity. These potatoes were peeled manually with a hand peeler. Sliced potatoes were tested for physiochemical characteristics viz. TSS, reducing sugar, starch and moisture content. Potato mash was prepared as per process flow diagram (Figure 1). Firstly a mash of potatoes was prepared by boiling potatoes in a microwave. On cooling these boiled potatoes were mashed which was followed by soaking in 0.2% KMS solution and after 1 hour water was drained. The potato mash was spread over drying trays and loaded into the tray drier for drying.

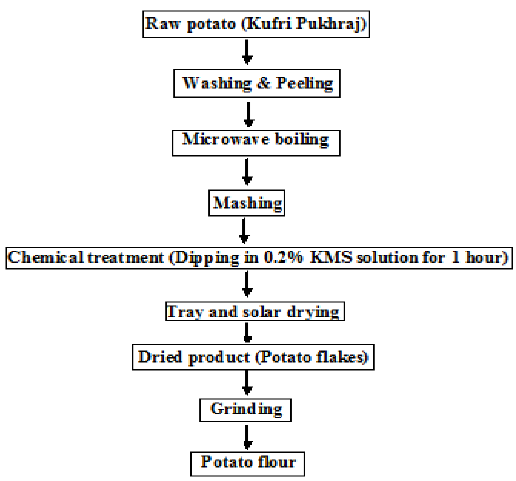


Figure 1: Flow Diagram of the Process Used to Dry Potatoes

Drying of Potato Mash

The convective drying experiment were carried out in, Department of Processing and Food Engineering and Punjab Horticultural Post-harvest Technology Center Laboratory Punjab Agricultural University, Ludhiana. The experimental set up for mechanical tray drying of potato samples consists of a Kilburn make laboratory tray dryer with a maximum attainable temperature of 200ºC as shown in Figure. The dimension of tray drier is 1370 x 940 x 430 mm in which the blower is powered by 0.25 HP, three phase 440 V electric motor with a direct online starter. The prepared sample was spread on the pre fabricated trays (32.5 X 16.25 inches).

The convective dehydration was carried out at different levels of mash thickness (5, 6 and 7 mm) and temperatures (50, 60 and 70^{o}C). The samples were loaded in the tray by using the formula:

Density = mass*volume (1)

Mass = density*area of tray*thickness (2)

Density of boiled potato = 1.03g/cm^3

Area of tray = 1355 cm^2

Thickness of mash = 5-7mm

The samples were convectively dehydrated in hot air tray drier till weight loss becomes constant. The loss in weight was measured at regular interval of 30 min.

Table 1: Design of Drying Experiment for Drying of Potato Mash

Sr. No.	Mechanical Tray Drying	
	Temperature (^{o}C)	Thickness (Mm)
1	50	5,6 and 7
2	60	5, 6 and 7
3	70	5, 6 and 7

Figure 2: Mechanical Tray Drier

Drying Analysis and Evaluation of Thin Layer Drying Models

The semi-theoretical and empirical models used to describe the drying kinetics of sample. Drying curves were fitted to the experimental data using these moisture ratio equations. MR is the moisture ratio defined as M/ M_0: M is the moisture content at time t and M_0 is the initial moisture content, dry basis. . However, moisture ratio (MR) was simplified to M/M_0 instead of (M-Me/ M_0-Me) as used by many authors (Diamante and Munro 1993, Yaldiz et al. 2001, Pokharkar and Parsad 2002).

Table 2: Popular Mathematical Models Used in the Drying of Agricultural Produce

Model Name	Model	Reference
Newton	MR = exp(-kt)	Page (1949)
Henderson and Pabis	MR = a exp(-kt)	Henderson and Pabis (1961)
Two-term	MR = a exp(-kt) + (1 – a) exp (-kat)	Yaldiz and Ertekin (2001); Lee and Hsieh (2008)
Logarithmic	MR = a exp(-kt) + c	Sacilik et al. (2006); Doymaz and Akgun (2009)
Wang and Singh	MR = 1 + at + bt^2	Vega-Gálvez et al. (2008)

Where,

$$\text{M.R} = \text{Moisture ratio} = \frac{X_t - X_e}{X_i - X_e} \tag{3}$$

X_t, X_e and X_i are moisture contents (db) at any time‘t’, at equilibrium and at time t=0, respectively.

a, c, n and k are constants in drying models.

Adequacy of Fit of Various Empirical Models

Modeling the drying behavior of different agricultural products often requires the statistical methods of regression and correlation analysis. Linear and nonlinear regression models are important tools to find the relationship between different variables, especially for which no established empirical relationship exists. Regression analysis was conducted to fit the mathematical models by the statistical package for social sciences (SPSS version 11.5). The determination coefficient (R^2) and plots of residuals were the primary criterions for selecting the best equation to define the drying curves. In addition to R^2, the goodness of fit was determined by various statistical parameters such as reduced chi-square (χ^2), mean bias error (MBE) and root mean square error (RMSE) were defined by the equations 4 to 7 (Gomez and Gomez, 1983).

$$R^2 = \frac{\sum_{i=1}^{n}\left(MR_i - MR_{pre,i}\right).\sum_{i=1}^{n}\left(MR_i - MR_{\exp,i}\right)}{\sqrt{\left[\sum_{i=1}^{n}\left(MR_i - MR_{pre,i}\right)^2\right].\left[\sum_{i=1}^{n}\left(MR_i - MR_{\exp,i}\right)^2\right]}} \tag{4}$$

$$\chi^2 = \frac{\sum_{i=1}^{n}\left(MR_{\exp,i} - MR_{pre,i}\right)^2}{N-n} \tag{5}$$

$$MBE = \frac{1}{N}\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{\exp,i}\right) \tag{6}$$

$$RMBE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{\exp,i}\right)^2\right]^{\frac{1}{2}} \tag{7}$$

Where, $MR_{\exp,\ i}$ and $MR_{pre,\ i}$ are experimental and predicted dimensionless moisture ratios, respectively, N is number of observations and z is number of constants.

The best model describing the drying characteristics of samples was chosen as the one with the highest coefficient of determination, the least mean relative percent error, reduced chi-square and RMSE (Sarsavadia et al 1999, Madamba 2003, Saciliket al 2006). However, although these statistical indictors generally provide a reasonable procedure to compare models, they do not objectively indicate whether a model’s estimates are statistically significant, i.e. not significantly different from their measured counterparts.

Effective Moisture Diffusivity during Drying

The mechanism of moisture movement within a hygroscopic solid during the falling-rate period could be represented by effective moisture diffusion phenomenon (which includes liquid diffusion, vapour diffusion, vaporization-condensation, hydrodynamic flow and other possible mass transfer mechanisms) is used and represents an overall mass transport property of water in the material. During drying, it can be assumed that diffusivity, explained with Fick’s diffusion equation, is the only physical mechanism to transfer the water to surface (Dadali et al 2007; Dincer and Dost 1995; Wang et al 2007). Effective moisture diffusivity, which is affected by composition, moisture content, temperature and porosity of the material, is used due to the limited information on the mechanism of moisture movement during drying and complexity of the process (Abe and Afzal 1997). For the effective moisture diffusivity determination, potato mash layer were assumed to be infinite slabs. In addition, moisture movement during drying occurred only in the direction of material thickness. The external resistance to moisture transfer was negligible and the moisture distribution inside mash before drying was uniform. When the plot of logarithm of moisture ratio (ln MR) versus drying time is linear, the moisture diffusivity assumes an independent function of moisture content. In this case, the change of moisture content can be described by the following equation (Crank 1975):

$$MR = \frac{M_t - M_e}{M_0 - M_e} = \frac{M_t}{M_0} = \frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n+1)}\exp\left[-\frac{(2n+1)^2\pi^2\, D\, t}{4L^2}\right] \tag{8}$$

Where, D is the effective moisture diffusivity (m^2/sec) and MR is the moisture ratio. Since the top surface of mash was only exposed to hot air, the length, L, in Eq 8 was the thickness of the slabs. For long drying times; n = 1, then Eq. 8 can be written as;

$$MR = \frac{M_t}{M_0} = \frac{8}{\pi^2}\exp\left[-\frac{D_{eff}\pi^2 .t}{4L^2}\right] \tag{9}$$

Further simplified to straight line equation

$$In(MR) = In\left(\frac{8}{\pi^2}\right) - \left(\frac{D_{eff}.\pi^2}{4L^2}.t\right) \tag{10}$$

From Eq. 16, a plot of in MR versus drying time gave a straight line with a slope (S) of:

$$S = (\prod^2 /4L^2)\, D_{eff} * t \tag{11}$$

The effective moisture diffusivity was calculated using the method of slopes. When logarithm of MR values v/s drying time were plotted in accordance with Eq. 10, straight lines were obtained at all temperatures and sample thickness investigated. Linear regression analysis was employed to obtain values of diffusion coefficients for different drying conditions from the slope of the straight lines obtained.

Analysis of Different Quality Parameters

Colour is one of the important parameters, which is an indicative of the commercial value of the product. The basic purpose was to get an idea of the comparative change in colour of fresh and dried material. Colour was determined using Hunter Lab Miniscan XE Plus Colorimeter. Before measuring the colour parameters, colorimeter was calibrated using standard white and black plates provided with the instrument. The colour is described by tristimulus value of L, a, b with the positive value of a, b indicating red and yellow colour and negative values indicating green and blue colour respectively. Values of a, b closer to zero indicates grey colour. L indicates the intensity of colour i.e. lightness which varies from L=100 for perfect white to L=0 for black.

For determination of colour, calorimeter was put on the sample and the values of L, a, b were measured. The sample was filled in petridish provided with no light is allowed to pass during the measuring process. The colour change was determined using the formula:

Colour change $\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$ (12)

Where ΔL, Δa and Δb are deviations from 'L','a' and 'b' values of fresh sample.

ΔL = L dried sample – L fresh sample;

+ ΔL means sample is lighter than fresh, - ΔL means sample is darker than fresh.

Δa = a dried sample- a fresh sample;

+ Δa means sample is redder than standard, - Δa means sample is greener than standard

Δb = b dried sample –b fresh sample,

+ Δb means sample is yellower than standard, - Δb means sample is bluer than standard

RESULTS AND DISCUSSIONS

Engineering Properties of Fresh Kufri Pukhraj

Engineering properties of Kufri Pukhraj and Kufri Jyoti potato viz. moisture content, TSS, reducing sugar, colour and starch content were measured using standard methods and are shown in table 3

Table 3: Engineering Properties of Fresh Kufri Pukhraj

Sr. No.	Engineering Properties	Quantity
		Kufri Pukhraj
1.	Moisture content (% db)	79.80 ± 0.50
2.	TSS (^{o}Brix)	3 ± 0.80
3.	Reducing sugar (%)	0.50
4.	Colour (L)	68.2 ± 0.07
5.	Starch content (%)	16.16 ± 0.13

Moisture content of potato was about 77.8% (wb). The potato mash after soaking had moisture content about 84% (wb) and it was dried at different thickness of 5, 6 and 7 mm and at varying temperature of 50, 60 and 70^{o}C in mechanical tray dryer. The data were obtained by weighing the samples after an interval of 30 min until a constant weight was reached. Three replications of each drying experiment were taken and the data collected was analyzed to obtain different drying parameters as discussed. Moisture content of the dried samples was then determined and the moisture content at different drying time was calculated using standard method.

Processing of Potato Mash

The quantity of raw potatoes taken was about 3 kg and about 700 g was wasted as peel. Then the potatoes were boiled and mashed. The quantity of mash obtained was 2250g. This mash was allowed to dip in water for 1 hour and the mash gained 300 g weight and the final weight was 2550g. This treatment reduced the reducing sugar percentage from 0.5 to 0.18. There was a 13.6-14 % recovery of potato flour.

Drying Behaviour of Raw Potato

Effect of Drying Methods on Moisture Ratio at Different Thickness of Potato Mash

The trends of change in moisture profile with respect to drying time for various thicknesses as affected by drying methods are presented in terms of moisture ratio versus drying time as shown in figure 3. The data for moisture ratio and drying time for different drying methods were shown. It was observed from the figure that the moisture ratio v/s time relationship is non linear, the decrease in moisture ratio being larger initially as compared to later part of drying. It was observed that the moisture ratio decreased with increase in drying time at all temperatures of mechanical drying.

There were significant reductions in drying time with increase in drying temperature. Experimental results showed that drying air temperature is effective parameter for the drying of potato. As the air temperature increased, other drying conditions being same, moisture removal increases thus resulted into substantial decrease in drying time. Several authors reported similar findings for various vegetables (Sobukola et al, 2007 and Doymaz I and Pala M, 2002).

The drying time at 50, 60 and 70^{o}C drying air temperature were 1290, 1200 and 900 min for 5mm thickness sample of potato mash. As seen from figure of drying time v/s moisture ratio plot, sample of 5mm thick potato mash dry very fast at 70^{o}C drying temperature. The drying time in mechanical drying at 50, 60 and 70^{o}C temperature were 1440, 1230 and 990 min, respectively for 6 mm thickness prepared sample of potato mash and 1590, 1290 and 1050 min, respectively for 7 mm thickness.

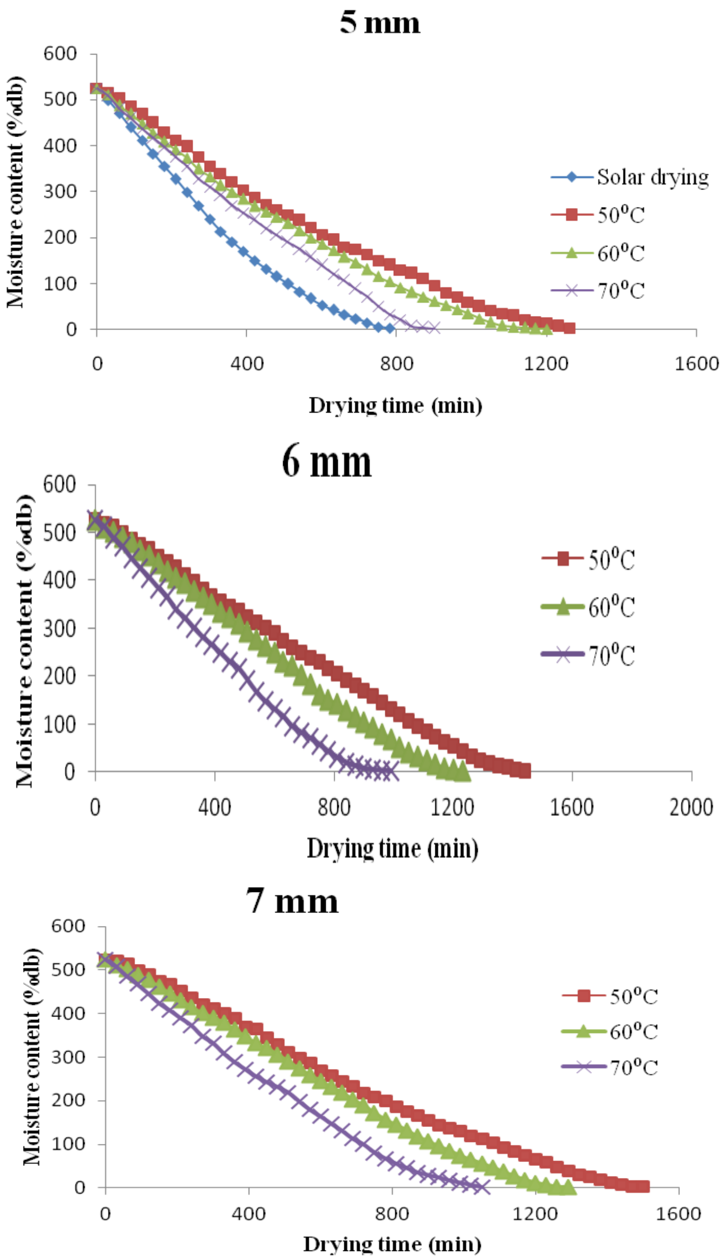


Figure 3: Variation of Moisture Content of Potato Mash with Time with Respect to Thickness

Table 4: Total Drying Times Required for Drying of Pukhraj Potato Mash at Varying Thickness

Sr. No	Drying Method		Drying Time (Min)		
			5 mm	6 mm	7 mm
1	Mechanical drying	50°C	1290	1440	1530
		60°C	1200	1230	1290
		70°C	900	990	1050

Evaluation of Model Parameters

In order to evaluate the performance of convective models, the values of statistical parameters for all the experiment runs were compared and model coefficients for each model were calculated by using non-linear regression techniques of SPSS version 11.5. The best model chosen was one having the highest R^2 and the least (χ^2), mean bias error (MBE), root mean square error (RMSE). These models coefficients and the results of statistical analyses are presented given in table 5. From the drying models, the drying rates were determined. Five drying models were fitted to experimental data. All the models showed the higher R^2 value >0.90 for all thickness. The highest R^2 value was observed 0.999 at

50^{o}C of 5-7 mm thickness sample for log model and the least R^2 value were 0.90 at 50^{o}C of 6mm sample thickness for newton model. The least χ^2 value was observed 0.000108 at temperature 50^{o}C of 5 mm sample thickness for log model and the highest χ^2 value was 0.472288 at 60^{o}C of 5mm thickness sample for two term exponential model. At constant thickness, the highest R^2 value and least χ^2 value, MBE value and RSME value was observed at 50, 60 and 70^{o}C temperature for log model. Same results were observed by (K Rayaguru and W Routray 2012). At varying thickness, the R^2 value was increased with increase in thickness potato mash sample.

Table 5: Parameters of Various Drying Models of Kufri Pukhraj Variety of Potato and Related Statistical Indicators

Drying Methods	Newton Model						
	Thickness 5mm						
	R^2	Chi ^{2}	MBE	RMSE	k		
50 ^{0}C	0.908	0.0179	0.075	0.133	0.001		
60 ^{0}C	0.953	0.0049	0.013	0.069	0.002		
70^{0}C	0.938	0.007	-0.025	0.082	0.002		
Solar drying	0.956	0.005	0.0002	0.066	0.003		
Thickness 6 mm							
50 ^{0}C	0.900	0.012	-0.031	0.106	0.001		
60 ^{0}C	0.911	0.018	0.09	0.132	0.002		
70^{0}C	0.932	0.008	-0.03	0.090	0.002		
Solar drying	0.967	0.004	0.027	0.06	0.003		
Thickness 7 mm							
50 ^{0}C	0.921	0.009	-0.023	0.093	0.001		
60 ^{0}C	0.921	0.017	0.085	0.13	0.002		
70^{0}C	0.942	0.006	-0.002	0.08	0.002		
Solar drying	0.979	0.004	-0.042	0.06	0.002		
Logarithmic Model							
60^{0}C	0.999	0.0011	0.029	0.030	0.001	1.56	-0.55
70^{0}C	0.999	0.091	0.27	0.297	0.001	2.45	-1.45
Solar drying	0.998	0.005	0.066	0.070	0.002	1.44	-0.410
Thickness 6mm							
50 ^{0}C	0.999	0.0001	-0.0003	0.012	8.7E-6	84.03	-83.008
60^{0}C	0.997	0.43	-0.57	0.65	0.000	4.15	-3.12
70^{0}C	0.996	0.004	0.052	0.061	0.001	1.86	-0.82
Solar drying	0.999	0.008	0.08	0.089	0.002	1.39	-0.36
Thickness 7mm							
50 ^{0}C	0.999	0.41	-0.55	0.63	0.00	3.87	-2.84
60^{0}C	0.997	0.45	-0.58	0.66	0.00	2.69	-1.66
70^{0}C	0.998	0.01	0.09	0.101	0.001	1.83	-0.810
Solar drying	0.999	0.006	0.07	0.079	0.002	1.25	-0.23
Pabis and Henderson Model							
Drying Methods	R^2	Chi ^{2}	MBE	RMSE	k	a	
50 ^{0}C	0.936	0.015	0.074	0.12	0.002	1.14	
60^{0}C	0.965	0.004	-0.026	0.0597	0.002	1.102	
70^{0}C	0.953	0.547	-0.659	0.73	0.002	1.102	
Solar drying	0.970	0.004	-0.041	0.063	0.003	1.105	
6mm							
50 ^{0}C	0.927	0.018	0.103	0.131	0.001	1.14	
60^{0}C	0.936	0.009	0.034	0.095	0.002	1.140	
70^{0}C	0.951	0.64	-0.72	0.789	0.002	1.13	
Solar drying	0.977	0.002	-0.007	0.046	0.003	1.09	
7mm							
50 ^{0}C	0.948	0.013	0.09	0.11	0.001	1.140	
60^{0}C	0.944	0.009	0.036	0.09	0.002	1.14	
70^{0}C	0.957	0.006	-0.05	0.08	0.002	1.11	
Solar drying	0.986	0.007	-0.07	0.08	0.002	1.07	
Drying Methods	Two Term Exponential						
	5mm						
	R^2	Chi ^{2}	MBE	RMSE	k	a	
50 ^{0}C	0.907	0.37	-0.52	0.599	4.63	0.00	

Table 5: Contd.,

60 ^{0}C	0.953	0.47	-0.61	0.68	4.03	0.00
70 ^{0}C	0.978	0.005	-0.05	0.07	0.003	1.947
Solar drying	0.956	0.49	-0.607	0.69	7.27	0.00
6mm						
50 ^{0}C	0.900	0.35	-0.50	0.57	3.82	0.00
60 ^{0}C	0.911	0.40	-0.54	0.63	4.33	0.00
70 ^{0}C	0.932	0.46	-0.59	0.67	6.50	0.00
Solar drying	0.967	0.47	-0.60	0.68	5.89	0.00
7mm						
50 ^{0}C	0.920	0.37	0.52	0.61	3.66	0.00
60 ^{0}C	0.921	0.42	-0.55	0.64	0.00	4.61
70 ^{0}C	0.941	0.45	-0.58	0.66	6.21	0.00
Solar drying	0.977	0.49	-0.63	0.69	4.72	0.00
Drying Methods	**Wang and Singh Model**					
	5mm					
	R^2	**Chi ^{2}**	**MBE**	**RMSE**	**k**	**a**
50 ^{0}C	0.998	0.34	0.49	0.58	0.00	-1.9E-8
60 ^{0}C	0.999	0.053	0.19	0.23	-0.001	3.9E-7
70 ^{0}C	0.999	0.06	0.199	0.23	0.00	-2.1E-7
Solar drying	0.998	0.003	0.044	0.057	-0.002	1.1E-6
6mm						
50 ^{0}C	0.999	0.30	0.46	0.54	0.00	-5.3E-8
60 ^{0}C	0.996	0.45	0.56	0.66	0.00	5.2E-8
70 ^{0}C	0.996	0.07	0.23	0.27	0.00	6.96E-9
Solar drying	0.999	0.0004	0.017	0.019	-0.002	9.3E-7
7mm						
50 ^{0}C	0.998	0.41	-0.54	0.63	0.00	2.7E-8
60 ^{0}C	0.997	0.53	-0.62	0.72	0.00	1.2E-7
70 ^{0}C	0.998	0.06	0.20	0.23	-0.001	3.8E-7
Solar drying	0.997	0.02	0.13	0.16	-0.002	7.7E-7

Effective Moisture Diffusivity for Drying Process

The effective diffusivity of the food material characterizes its intrinsic mass transport property of moisture which includes molecular diffusion, liquid diffusion, vapor diffusion, hydrodynamic flow and other possible mass transfer mechanics (Karathanos et al 1990). The effective moisture diffusivity was calculated using the method of slopes.

When logarithm of MR values vs. drying time were plotted in accordance with Eq. 8**,** straight lines were obtained at all temperatures and drying bed thickness investigated. Linear regression analysis was employed to obtain values of diffusion coefficients for different drying conditions from the slope of the straight lines obtained. Values of D_{eff} for different conditions together with correlation coefficient of estimation for drying of are presented in Table 6.

Table 6: Effective Moisture Diffusivity (m^2/ Sec) For Drying of Kufri Pukhraj Potato Mash

Drying Methods	**Thickness (m)**					
	0.005 m		**0.006 m**		**0.007m**	
	D_{eff}x 10^{-10}	**R^2**	**D_{eff}x 10^{-10}**	**R^2**	**D_{eff}x 10^{-10}**	**R^2**
50^{o}C	1.43684	0.5427	1.70392	0.5583	2.2364	0.5407
60^{o}C	1.94396	0.6774	2.43418	0.5923	3.14752	0.6373
70^{o}C	2.40882	0.5793	3.40785	0.7021	3.89299	0.6295

The drying method has pronounced effect on drying rate and consequently it affects the value of the diffusion coefficient. The increase in temperature, the effective diffusivity increased due to the increase in vapor pressure inside the sample. Similarly, as the sample thickness increases the moisture diffusivity increased. The D_{eff} value increased from 1.43684×10^{-10} m^2/sec to 2.40882×10^{-10} m^2/sec as temperature increase from 50°C to 70°C. The higher D_{eff} value was

3.89299 ×10^{-10} m^2/sec of 0.007 mm thickness sample at 70^{o}c and lowest value was 1.43684 ×10^{-10} m^2/sec of 0.005 mm thickness sample at 50 °C.

Effect of Drying Air Temperature on Color (L Value) of Tray Dried Potato

The response surface and contour graphs were generated to study the Color (L value) of dried potato flakes.

Table 7: Experimental Data of Mechanical Drying of Potato Mash for Response Surface Analysis

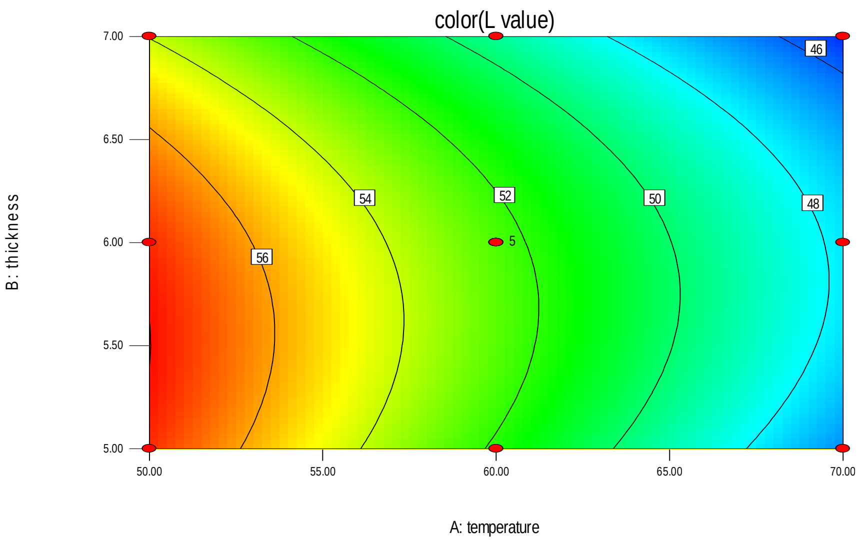
Temperature, X_2 (^{O} C)	Thickness (mm)	Color (L Value)
60.00	6.00	51.22
50.00	6.00	56.78
70.00	5.00	46.55
60.00	5.00	51.22
50.00	5.00	58.2
50.00	7.00	54.1
70.00	6.00	48.34
60.00	7.00	49.75
70.00	7.00	44.75

The color of tray dried pukhraj potato mash varied in the range of 44.75 to 58.2 with an average value of 51.475. The maximum color (58.2) was found at 50 °C temperature, and 5 mm thicknesss; while minimum color (44.75) was found at 70°C temperature, and 7 mm thicknesss.

The effect of temperature and thickness on color of pukhraj potato flakes are presented in Table. From temperature and thickness contour map (Figure 4), it was observed that at a constant thickness (5mm) color (L value, lightness) decreased with increasing temperature from 58.2 to 46.55. At a constant temperature (50°C), the color decreased from 58.2 at 5 mm thickness to 54.1 at 7 mm thickness.

The results were corroborated from the Analysis of Variance (ANOVA) showing significant effect of quadratic term (p-value: 0.0002) of temperature and thickness on color at 5% level of significance. Final equation predicting color as affected by temperature and thickness is given below:

Color (L Value) =+53.37552-1.13815 * Temperature+17.19684 * Thickness +0.057500 * Temperature * Thickness+2.52069E-003 * Temperature^2 -1.82293 * Thickness^2



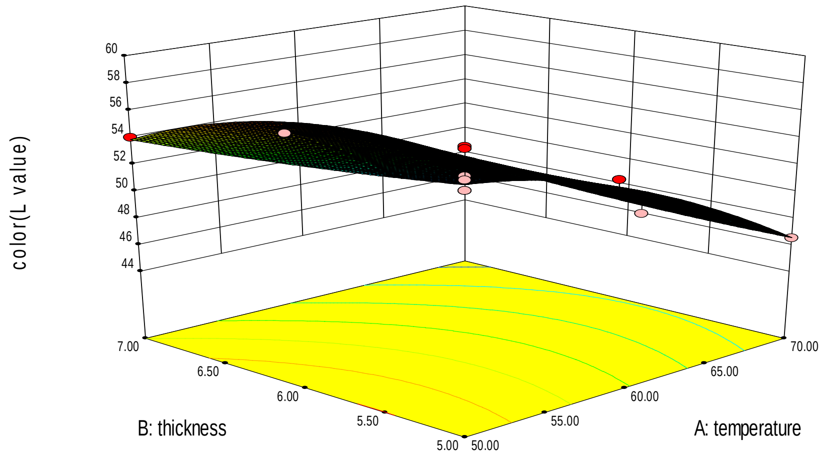


Figure 4: Contour and Response Surface Plots for Color during Thin Layer Drying of Potato at 50-70 ° C and 5-7 mm

The following conclusions were drawn from this study. Potato mash did not exhibit a constant rate drying period under the experimental conditions used in this study. Predictions by the logarithmic model are in good agreement with the data obtained from the convective drying experiment. Effective moisture diffusivity values ranged from 1.43684×10^{-10} m^2/sec to 2.40882×10^{-10} m^2/sec as temperature increase from 50°C to 70°C. Drying of 5mm thickness potato mash sample down to about 3.4 % (d.b.) moisture content by a convective dryer at 50^0C air temperature requires a drying time of about 900 minutes without any significant loss in the colour (L value, lightness) of the flakes.

CONCLUSIONS

The following conclusions were drawn from this study. Potato mash did not exhibit a constant rate drying period under the experimental conditions used in this study. Predictions by the logarithmic model are in good agreement with the data obtained from the convective drying experiment. Effective moisture diffusivity values ranged from 1.43684×10-10 m2/sec to 2.40882×10-10 m2/sec as temperature increase from 50°C to 70°C. Drying of 5mm thickness potato mash sample down to about 3.4 % (d.b.) moisture content by a convective dryer at 500C air temperature requires a drying time of about 900 minutes without any significant loss in the colour (L value,lightness) of the flakes.

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