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A STUDY ON THE DRYING BEHAVIOUR OF A LOCAL VARIETY (LALPAKRI) OF POTATO (*Solanum tuberosum* L.)

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Abstract

The study was carried out in the laboratory of the Department of Food Technology and Rural Industries, Bangladesh Agricultural University, Mymensingh during 2008-09 to analyze the drying behaviour of potato (var. Lalpakri) at variable air dry bulb temperature using a mechanical dryer. Fresh potatoes with 3, 5, 7 mm slices were used as raw materials for drying. The experiment showed that drying rate constant decreases with the increases in thickness and increasing loading density of potato slice, the rate of drying decreases but drying rate constant does not decrease proportionately. From the relationship between drying rate constant and thickness, the value of exponent 'n' of the power law equations was recorded 0.4586. It was observed that higher temperatures gave faster drying rate. From the exponential relationship between diffusion co-efficient (D_e) versus inverse absolute temperature (T_{abs}^{-1}), activation energy (E_a) for diffusion of water from local variety of potato (var. Lalpakri) was found to be 5.60 Kcal/gm-mole.

Keywords: Potato, drying behaviour, mechanical drying, arrhenious relationship and activation energy.

Introduction

In Bangladesh, Potato (*Solanum tuberosum* L.) is taken as a vegetable supplement to rice and this greatly improves the nutritive value of the diet. The total area and production of potato of the country in 2008-2009 was 3.96 million acre and 5.29 million tons, respectively (BBS, 2009). The per capita yearly consumption is only 24 kg in Bangladesh that is very negligible compared to Belarus (835 kg) and the Netherlands (415 kg) (Anonymous, 2008). Bangladesh Agricultural Research Institute (BARI) has developed more than 26 varieties of potato in Bangladesh. Besides these, local varieties like Lalpakri, Dolhazari, Lal Kaberi, Shilbilati, etc. produce acceptable yield and also play an important role in increasing the agricultural production in Bangladesh (Ahmed and Kader, 1981). Moreover, these indigenous potato varieties are highly priced and popular with the elite families. Potato can safely be used as a partial substitute of rice and wheat during the months from February to June at a reasonably low cost and as a

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vegetable round the year. With increased consumption, it should be able to remove pressure that is now there on rice and wheat. However, this bumper production of potato led to serious storage problem due to lack of cold storage facilities. The total number of cold storage is only 330 and the capacity is also only 20-22 lac ton of potato (Farooque, 2008).

A better solution would be the development of diversified proceed potato products like flakes, flour, chips, french fries, etc. in Bangladesh. Khurana *et al.* (1999) reported that many of the rural people in Bangladesh in the potato growing area, particularly the women folk, are now engaged in activities like making fried chips, dried chips from processed potatoes. It was reported that processed potato products are forecast to increase by 101 percent due to the rapid expansion of western style and fast food outlets (Westman, 2009).

McMinn and Magee (1997) found that drying of potato at air temperature of 60^0C with air velocity of 0.5 to 1.5 m/s, drying process appeared to be completely controlled by internal resistance to mass transfer. Temperature had the major influence on drying while flow rate showed a limited effect. Drying process was characterized by variable EMS; volumetric shrinkage of cylinders was affected mainly by air velocity and temperature had a negligible effect. Uddin and Islam (1985) developed self stable pineapple products by mechanical dehydration, sun drying and osmotic dehydration. At constant air conditions, decrease in thickness of slices gave increased drying rate while at constant thickness and constant airflow increase in temperature resulted in increased drying rate. Lewicki *et al.* (1998) dried 2 mm thick onion slices in different ways. Drying at 60^0C and it was demonstrated that increase in air temperature resulted in increased drying rate. Effective diffusivity increased with increasing temperature, but it was strongly dependant on water content. Energy of activation for diffusion was also strongly affected by water content, stepwise drying with infrared energy or assisting convective drying with microwave energy resulted in increased drying rates and thus substantial shortening of drying time. Considering the above factors and information, the present study was undertaken with the objective to analyze the drying behaviour of potato (var. Lalpakri) at low air dry bulb temperature using a mechanical (cabinet) dryer.

Materials and Method

Fresh potatoes of local variety "Lalpakri" grown in Mymensingh were used for drying process. Potatoes were sliced into 3, 5, and 7mm thickness and placed in trays as to form a single layer and drying commenced in a mechanical (Cabinet) dryer. Data on moisture content, moisture ratio at different time interval, rate of drying, etc. were recorded carefully.

Mechanical drying of potato slices

Studies on dehydration of lalpakri potato, forced convection hot air type cabinet dryer were used for drying. The dryer consists of several chambers in which trays of samples were placed. A fan passed over a heater around the cabinet blew air over the samples undergoing dehydration. To determining the effect of temperature, thickness and loading density on the rate of drying, Lalpakri potatoes cut into different shape were taken for determination of moisture content. Fresh potatoes of known moisture content and desired size slices (3, 5, and 7mm) were placed in trays and drying commenced in the drier at constant air velocity ($0.6ms^{-1}$) and at a specific air dry bulb temperature (^0C). Moisture content at each time (0, 0.15, 0.30, 1, 2, 3, 4, 5, and 6 hr) interval was determined gravimetrically and weight loss was used as a measure of the extent of drying. For determination of the effect of temperature on the rate of drying potato slices of constant thickness were dried at different temperature, such as 45^0C, 50^0C, and 60^0C at constant airflow and extent of drying was determined as before.

Analysis of experimental data

Fick's law is applied for describing mass transfer during drying, as food dehydration is assumed to take place by diffusion. The expression is:

$$\frac{\delta M}{\delta t} = \Delta^2 D_e M$$

Where, M = Moisture Content (db), T = Time, and D_e = Effective diffusion co-efficient.

To find a solution of the above unsteady state diffusion equation for one dimensional transport for the case of initial uniform moisture distribution in the sample was derived by Brooker *et al*., 1974 and Islam, 1980.

$$\text{MR} = \frac{M_t - M_o}{M_o - M_t} = \frac{8}{\pi^2} \sum_{n=0}^{\alpha} Exp\left(\frac{-(2n+)^2 \pi^2 D_e t}{L^3} \right) \text{....................................} \quad 1$$

For low M_e values and for moisture ratio, MR<0.6 equation (02.1) reduces to:

$$\frac{M_t}{M_o} = \frac{8}{\pi^2} e \frac{-\pi^2 D_e t}{L^2} = \frac{8}{\pi^2} e^{-mt} \text{...} 2$$

Where, m = $\frac{\pi^2 D_e}{L^2}$ drying rate constant, sec^{-1}

Consequently, a straight line should be obtained when plotting ln MR versus time (t). The slope of the regression line is the drying rate constant, m from which the effective diffusion co-efficient, D_e is calculated.

The diffusion co-efficient, D_e has an Arrhenious type of relationship with drying air dry bulb temperature (abs.). The relationship is as follows (Heldman, 1974).

$$\text{InDe=InD}_0 - \frac{E_a}{RT^2_{abs}} \quad \text{..........} 3$$

Where, D_o = the constant of irrigation and is usually referred to as a frequency factor when discussion Arrhenious equation; E_a = activation energy of diffusion of water, cal/g-mole; R = gas constant, cal/g-mole, ^{0}K; and T_{abs} = absolute temperature, ^{0}K.

From the semi-theoretical equation as shown in equation (2), it may be noted that the drying rate constant, m is a function of thickness of the product dehydrated, as

$$m= \frac{\pi^2 D_e}{L^2} \quad \text{..........} 4$$

Symbolically, this may represent as: $m = A (L)^{-n}$

Or, Logm = LogA – nLog(L) 5

Where, $A = \pi^2 D_e$ and n = 2

The above relationship shows that if external resistance to mass transfer is negligible and if simultaneous heat and mass transfer effects are taken into account, the value of the exponent of the power law equation should be 2. But the above conditions may not be always satisfied and experimentally determined 'n' value is found to be less than 2 (Islam, 1980).

Results and Discussion

Effect of loading density on drying time

To investigate the influence of loading density on drying time, 1.2 kg/m^2 and 2.4 kg/m^2 potato slices of 8 mm thickness were dried at identical air dry bulb temperature (55^{0}C) at constant air velocity in a cabinet dryer. The data were analyzed by using equation 2 and moisture ratio (MR) versus drying time (hr) were plotted on a semi-log co-ordinate and the following regression lines were drawn (Fig. 1).

$MR = 0.9137^{-0.3724x}$ for loading density (1.2 kg/m^2), at 55^{0}C

$MR = 0.9134e^{-0.3229x}$ for loading density (2.4 kg/m^2), at 55^{0}C

From the Fig. 1 and above developed equation, it is seen that as loading density of slice increases, the rate of drying decreases but drying rate constant does not decrease proportionately. Using 1.2 kg/m^2 loading density, the rate constant was 0.372 hr^{-1} at 55^{0}C, whereas for twice the loading density at similar condition the rate was 0.323/hr.

This situation is also observed in case of cubes and french cut and may be attributed to more efficient utilization of the heat input in a thicker bed as noted by Islam and Flink (1982). This phenomenon can be advantageously used for increased dryer throughout. However, care should be taken not to increase loading density to such an extent as to increase drying time to a level at which the products are spoiled due to microbial growth.

Influence of thickness on drying rate

To ascertain the influence of thickness on drying behaviour of 3mm, 5mm, and 7 mm slices of potato of local variety were dried at a constant air dry bulb temperature of. The results were analyzed by using equation (2) and are shown in Fig 2. For three different thicknesses the developed equations are:

MR = $0.9605^{e-0.0808x}$ (for 3 mm slice; t = hr)
MR = $0.9289^{e-0.1115x}$ (for 5 mm slice; t = hr)
MR = $0.9693^{e-0.0553x}$ (for 7 mm slice; t = hr)

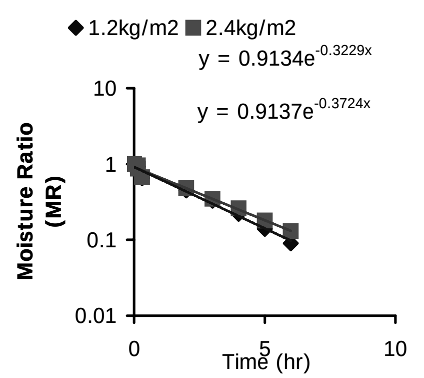

Fig. 1 Effect of loading density of Slice on drying rate at 55^{0}C

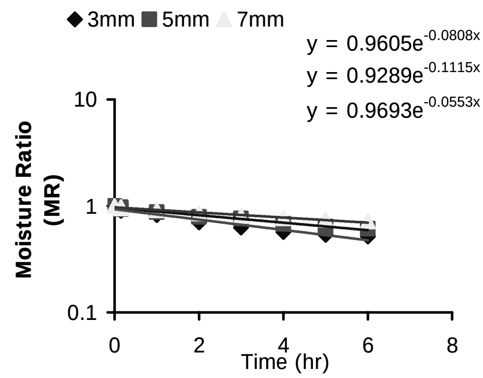

Fig. 2 Effect of thickness of Lalpakri (LV of Potato) on drying rate at 50^{0}C

The drying rate constants were determined by a regression analysis and were plotted against sample thickness on log-log coordinate. From the equations and Figure 2, it can be clearly seen that the thickness has profound effect on drying time and that as thickness of the samples increases the drying time to a specific moisture ratio also increases with the resultant decrease in drying rate constant and thus also diffusion co-efficient (Table 1).

The plot in Fig. 3 shows that the relationship between sample thickness and drying rate constant can be represented by power law equations which are as given below:

$m = 0.1549L^{-0.4586}$ for local variety

Where, m = drying rate constant (hr^{-1}) and L = Sample thickness (mm)

From the above equation, it is found that the value of exponent 'n' for Local Variety (LV) of potato (Lalpakri) is 0.4586 at 50^0C. It is seen that the value is lower than 2 as predicted by equation (5) and it indicates that the external resistance to mass transfer is highly significant under the given conditions and this also indicates that increase in airflow rates will give increased drying rates. Islam (1980) showed an 'n' value of 1.70 while drying of potato using higher airflow rates (2.5 m/s).

The above discrepancy of 'n' value is mainly due to airflow rate and thickness and demonstrates the relative importance of external or internal mass transfer resistance. However, product structure and composition and simultaneous heat and mass transfer effects also play important roles in this regard. Islam (1980) while working with potato, showed that by taking into account of the simultaneous heat and mass transfer effect value of 'n' could be corrected to 2 from 1.7.

Influence of temperature on drying time

To investigate the influence of temperature on drying time, potatoes were dried in the mechanical dryer at three different temperatures (45^0C, 50^0C, and 60^0C) using sample of constant thickness, 5mm slice. The experimental drying data were analyzed by using equation (2) and plots of moisture ratio versus drying time were made on semi-log scale and regression lines were drawn (Fig. 4) and the developed equations are given here under:

$MR = 0.934e^{-0.2196x}$ for 5mm slice at 45^0C

$MR = 0.9484e^{-0.078x}$ for 5mm slice at 50^0C

$MR = 0.9239e^{-0.2659x}$ for 5mm slice at 60^0C

From the figure 4 and also from the above equations, it is observed that the moisture ratio (MR) (hence moisture content) decreases with time and time to dry to specific ratio decreases with increasing temperature. Thus, higher temperature would give faster drying rate. At very high temperature and low humidity, drying rate may initially increase, but at drying progresses resultant case hardening would reduce drying rate drastically and deteriorate the quality of the product due to cooking instead of drying. High temperature also may scorch the product and thus selection of optimum temperature for drying is of significance during particularly, mechanical drying with counter current operation (Karel *et al.,* 1975, Potter, 1978).

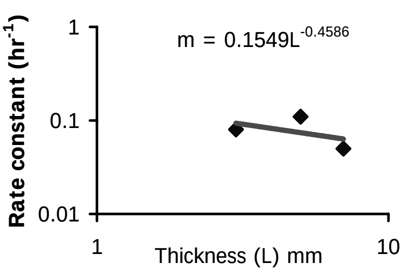

Fig. 3 Influence of thickness of Lalpakri on drying rate constant at 50°C

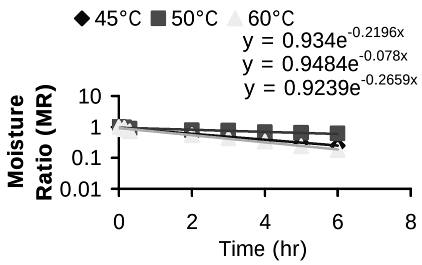

Fig. 4 Influence of temperature of Lalpakri on drying rate for 5mm slices

From the dying rates constant that are determined by regression equation, the diffusion coefficient was calculated (Table 1). Diffusion co-efficient (De) versus inverse absolute temperature (T_{abs}^{-1}) were plotted on a semi-log scale and regression lines were drawn (Fig. 5). From the slope of the resultant straight line, activation energy (E_a) for diffusion of water from local variety of potato was calculated and found to be 5.60 Kcal/gm-mole.

The calculated activation energy is lower than 12.50 Kcal/g-mole of activation energy for diffusion of water from potato by (Saravacos and Charm, 1962), that found by Iqbal (2003) for cucumber (8.50Kcal/g-mole) and cauliflower (7.76 Kcal/g-mole), for onion (26.83 Kcal/g-mole) found by Afjal Babu *et al.* (1997) but higher than that (4.4 Kcal/g-mole) found for mango by Islam *et al*. (1997). These differences in activation energy might result from differences in product characteristics, temperature employed for drying, etc. (Islam, 1980; Iqbal and Islam, 2005)

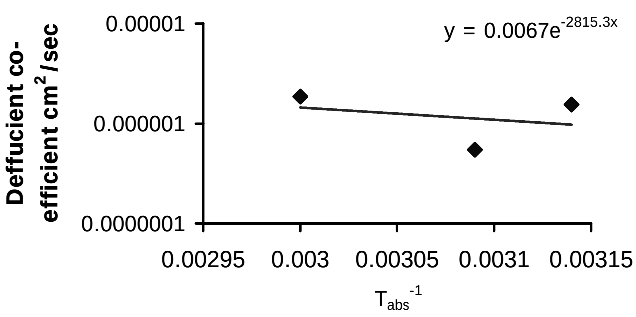

Fig. 5 Effect of temperature on diffusion co-efficient of local variety

The dependence of diffusion co-efficient on absolute temperature can be represented as:

$D_e = 0.006e^{-2815.3x}$

Where, D_e = Diffusion co-efficient (cm^2/s) and T_{abs} = Absolute temperature (^0K)

Table 1. Drying parameters of mechanical dried potato (Local variety-Lalpakri).

Variety	Thickness (mm)	Shape of object	Temperature	Slope (min^{-1})	Diffusion co-efficient (cm^2/s)	Value of exponent (n-value)	Activation energy (Ea) Kcal/gm-mole
Lalpakri (Local variety of potato)	8	Slice	55^0C	6.20×10^{-3}	6.71×10^{-6}	0.458	5.60
	8	Slice	55^0C	5.38×10^{-3}	5.82×10^{-6}		
	3	Slice	50^0C	1.34×10^{-3}	2.04×10^{-7}		
	5	Slice	50^0C	1.85×10^{-3}	7.85×10^{-7}		
	7	Slice	50^0C	9.21×10^{-4}	7.63×10^{-7}		
	5	Slice	45^0C	3.66×10^{-3}	1.54×10^{-6}		
	5	Slice	50^0C	1.30×10^{-3}	5.49×10^{-7}		
	5	Slice	60^0C	4.43×10^{-3}	1.87×10^{-6}		

Conclusion

From the study, it demonstrates that drying of local variety potato "Lalpakri" could conveniently be accomplished by forced convection hot air type cabinet dryer. However, it was observed that at the low air velocities present, drying occurs is highly significant, the external mass transport resistances. Results showed that drying rate constant decreases with the increases in thickness. The influence of loading density of potato on drying rate showed that drying rate constant decreases but not proportionately as bed thickness increases and this behavior can be advantageously used for higher dryer throughput. From the relationship between drying rate constant and thickness, the value of exponent 'n' of the power law equations was recorded 0.4586. The activation energy (E_a) from the exponential relationship for diffusion of water from the local variety of potato (var. Lalpakri) was found to be 5.60 Kcal/gm-mole. The informations generated here on drying behaviour of potato (var. Lalpakri) will be very much helpful for future research.

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References

Afzal Babu, S. M. M., Kowser Sarker, M. A. S. and Islam, M. N. 1997. Kinetics of mechanical, solar and drying of onion. *Bangladesh J. Agril. Engg.* **8** (1&2): 49-61.

Ahmed, K. U. and A. N. M. Kader. 1981. Indigenous potato varieties in Bangladesh. *Bangladesh J. Agril. Res.* **6**(1): 45-50.

Anonymous, 2008. "Bangladesh Potato Campaign 2008. Alu Khan Krishak Bachan" (souvenir). A conference on Potato Campaign (May 07-09, 2008) organized by Ministry of Agriculture, FAO and CSD, Bangladesh. at Bangladesh-China Friendship Conference Centre (BCFCC), Dhaka. p-18.

BBS (Bangladesh Bureau of Statistics). 2009. Year Book of Agricultural Statistics of Bangladesh, Statistics division, Ministry of Planning, Govt. of the People's Republic of Bangladesh, Dhaka. p-80.

Brooker, D. B., Bakker, E. W. and Hall, C. W.1974. Drying of Cereal grains. Theory and Simulation of cereal grain drying. The AVI Publishing Company. Inc. USA. p-185.

Farooque, A. 2008. "Bangladesh Potato Campaign 2008. Alu Khan Krishak Bachan" (souvenir). A conference on Potato Campaign (May 07-09, 2008) organized by Ministry of Agriculture, FAO and CSD, Bangladesh. at Bangladesh-China Friendship Conference Centre (BCFCC). Dhaka. p-8.

Heldman, D. R. 1974. Food Process Engineering. AVI Pub. Co. Inc. Westport. Connecticut, USA. pp: 10-18.

Iqbal, A. 2003. Processing and preservation of cauliflower and cucumber by dehydration and fermentation. M.S. thesis. Dept. of Food Technology and Rural Industries, Bangladesh Agricultural University, Mymensingh.

Iqbal, A. and Islam, M. N. 2005. Dehydration kinetics of cauliflower. *Bangladesh J. Crop Sci.* **16**(1): 113-122.

Islam, M. N. 1980. Use of Solar energy for development of self stable potato products. Ph.D. Thesis. Royal Veterinary and Agricultural University, Copenhagen, Denmark.

Islam, M. N. and J. M. Flink. 1982. Dehydration of potato. II osmotic concentration and its effect on air-drying behaviour. *Journal of Food Technology.* **17:** 387-403.

Islam, M. N., Uddin, M. B. and Islam, N. M. 1997. Development of self-stable dehydration mango products. *Bangladesh J. Agril. Engg.* **4** (1&2): 65-73.

Karel, M., Fennema, O. R., and Lund, D. B. 1975. Principles of Food Science, Part-II, physical principles of food preservation. Marcel Dekker, Inc. New York and Basel. Pp:133-139, 205.

Khurana, S. M. P., Shekhawat, G. S., Pandey, S. K. and Singh, B. P. 1999. Potato, global research and development. Proceedings of the Global Conference on Potato, New Delhi, India. vol.2 Pp:6-11.

Lewicki, P. P., D. Witrowa-Rojchert, and D. Nowak. 1998. Effect of pretrearment on Kinetics of convection drying of onion. *Drying Technology,* Poland **121**(1&2):83-100.

McMinn, W. A. M. and Magee, T. R. A. 1997. Quality and physical structure of a dehydrated starch-based system. *Journal of Drying Tech.* United Kingdom **6**(8): 1961-1971.

Potter, N. N. 1978. Food Science, CBS publishers and distributors, Shahdara, Delhi.p-78

Saravacos, G.D. & Charm, S.E. 1962. Fd Technol. 16, 78.

Uddin, M. B. and M. N. Islam. 1985. Development of shelf-stable pineapple products by different methods of drying. *J. of Int. of Engineers Bangladesh* **13** (1): 5-13

Westman, W. 2009. China, Peoples Republic of Frozen Potato Products: Potato and Frozen Potato Products Annual. USDA Foreign Agril. Service GAIN REPORT. Global Agric. Info. Net. pp:1-14.