IJPPHT International Journal of Processing and Post Harvest Technology
Volume 3 | Issue 2 | December, 2012 | 278-282
RESEARCH PAPER

Study of moisture deplition pattern of spinach in hot air oven

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SUMMARY : Now a day it is evident from previous works on drying of food, fruits and vegetables by different scholars are that there are no as such exact theoretical laws or theoretical equations have developed. That can explain explicitly or implicitly the drying behavior of these biodegradable substances because there are many variables in these products. The major variables are biological conditions *i.e.* geographical condition as well as atmospheric condition. That varies from place to place and time to time. Other variables are Relative Humidity (RH), moisture content, drying medium temperature, air or gas flow velocity, conduction, convection, radiation and mass transfer mechanism. Apart from these some other factors are liquid diffusion such as (capillary flow, surface diffusion, hydrodynamics mechanics), vapor diffusion (mutual diffusion, knudsen diffusion, effusion, slip flow, hydrodynamic flow, stepan diffusion, evaporation, poiseuille flow) etc. Still searches are going on and nobody could assure that at any instance of time transfer of moisture has caused by above known mechanism. Due to these difficulties, it can be easily concluded that for prediction about drying nature, need of an experimental setup and results and each result is unique one. In present work, spinach for drying in blanched and unblanched condition with loading densities 3kg/m^2 and 3.5 kg/m^{2}in a cabinet air dryer in which drying nature validates the exponential model of drying has been selected.

KEY **W**ORDS: (M_e) Equilibrium moisture content (Me), Moisture content (MC), Moisture ratio (MR), Treated (blanched), Untreated (unblanched)

How to cite this paper : Upadhaya, A.K., Gupta, Bhupendra, Garg, Sanjeev and Singh, Mohan (2012). Study of moisture deplition pattern of spinach in hot air oven. *Internat. J. Proc. & Post Harvest Technol.,* **3** (2) : 278-282.

Research chronicle : Received : 08.06.2012; **Revised :** 07.09.2012; **Accepted :** 18.11.2012

In this, spinach with 3kg/m^2 and 3.5 kg/m^2 loading densities in blanched and unblanched condition with temperature range 55 ^{0}C, 65^{0}C and 75^{0}C, has been selected. Drying characteristic of spinach mostly controls by availability of moisture in it. For drying of spinach, a cabinet dryer with low Relative Humidity (RH), constant airflow and high temperatures has been selected. Blanching has done to improve final product quality and reduce process cost. It has observed that a temperature range in vicinity of 50^o C -70^o C was suitable for drying of spinach. Increase in air temperature significantly reduces the drying time. The air velocity during drying has taken 2.2 m/s^2 that is sufficient to keep relative humidity low inside the dryer. In our curves, drying occurs majorly in falling rate of drying.

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EXPERIMENTAL METHODS

Materials :

Fresh spinach leaves procured from local market everyday prior to the experiment. They were washed with tap water, the moisture on the wet sample surface was removed with filter paper .The average value of moisture content 93.41 per cent (w.b.) which shows that spinach leaves can be grouped under highly perishable vegetables. Spinach leaves were pre treated by blanching with distilled water. Treated sample were placed over filter paper (Whatman filter paper .size 41 A) for 1 minute to absorb excess water.

Experimental methods :

Drying experiments were performed in cabinet dryer (hot air oven, tradevel scientific industries, least count 1^{0}C) and installed in Department of Post Harvest Process and Food Engineering, College of Agriculture Engineering (JNKVV, JABALPUR). Sample were weighed in digital balance (METTLER, least count 0.001g)according to the loading density of 3.0kg/m^2 and 3.5kg/m^2 and placed in a stainless steel mesh tray of size 0.0123m^2 and 0.0168 m^2giving equivalent sample weight of 70g and 80g corresponding to different loading densities. Method recommended by Ranganna (1986) was used for determination of moisture content and for all experiments; the initial moisture content taken to be 1418.37 %(d.b.).The sample of both blanched and unblanched were subjected to uniform air velocity 2.2 m/s at specified three level of temperature (55.65,and 75 ^{0}C) and two level of loading density (3.0 and 3.5 kg/m^2) .The sample were dried for a minimum of eight hours of drying. Weights of the samples were recorded after every hour during drying process. The dried samples were cooled under laboratory conditions after each drying experiments and kept in airtight jars. The experiments were in triplicate and average of the moisture ratio at each value used for drawing the drying curves.

EXPERIMENTAL FINDINGS AND ANALYSIS

It was attempted to describe the drying process of spinach leaves by fitting the experimental data on selected exponential drying model for describing the moisture depletion pattern of spinach. The suitability of drying models was evaluated based on regression coefficient value (R^2), and the value of MR moisture ratio was calculated by the help of equilibrium moisture content, which was calculated by the method developed by Henderson and Perry (1976).

$$MR = \frac{M - Me}{Mo - Me}$$

where, M_o and M are the moisture content (% db) at time (θ) equal to zero and at any time (θ). To validate the experimental drying curves exponential mathematical models were used.

All these equations used the moisture ratio (MR) as dependent variable, which related the gradient of the sample moisture content in real time with the initial moisture content and equilibrium moisture content. The experimental drying data graphically analyzed. Variations of moisture content with time, variation in drying rate with drying time and variation in moisture ratio with drying time in terms of reduction in moisture content were drawn. The experimental data for drying of spinach leaves statistically and graphically analyzed with the help of spreadsheet (EXCEL) software packages on personal computer. From first experiments, the following curves for spinach observed.

From Fig.1 and Fig.2 it is evident that moisture depletion pattern of spinach was nearly same for two different loading densities at T=55^{o}C. Nearly same data were also observed for two loading densities at two other temperature ranges *i.e.* at T=65 ^{o}C and T= 75^{o}C those are given in Fig. 3 and 4.

From different plots, it is evident that total drying time considerably reduced with the increase in dry air temperature from 55^{o}C to 75 ^{o}C. The drying rate increased with increase in temperature and decreased with increase in time. For analyzing the pretreatment on drying of spinach, following curves have been plotted and are mentioned in Fig. 5-7.

From Fig. 5, 6 and 7, it is evident that pretreatment *i.e.* blanching did not affect the drying rate and it is preferable to do pretreatment in drying because it improves the drying quality of the spinach. Due to absence of a constant rate period found during the experimental drying of spinach, which validates exponential model that describe the phenomena of

Sr. No.	Model name	Model equation	References
1.	Page (1949)	MR= exp (-kt^n)	Page (1949)
2.	Henderson and Pabis (1969)	MR= ~. exp (-kt)	Henderson and Pabis (1969)
3.	Newton (1971)	MR= exp (-kt)	O'Callaghan *et al.*
4.	Modified Page(1973)	MR= exp [-$(kt)^n$]	Overhults *et al.*
5.	Two Term (1980)	MR= ~. exp (-k_ot)+b.exp (-k_1t)	Sharaf-Eldeen *et al.*
6.	Midilli (2002)	MR= ~. exp (-kt^n)+bt	Midilli *et al.*(2002)

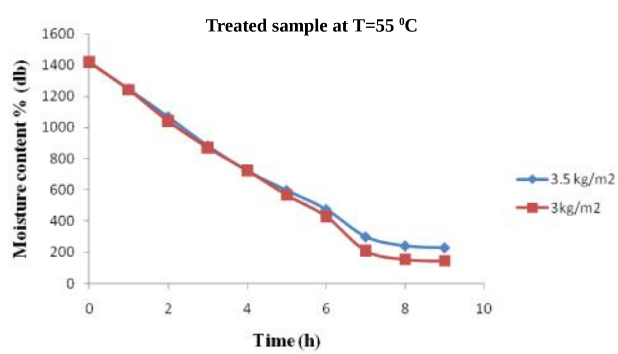

Fig. 1: Blanched sample at T= 55^{o}C plotted between moisture content and time

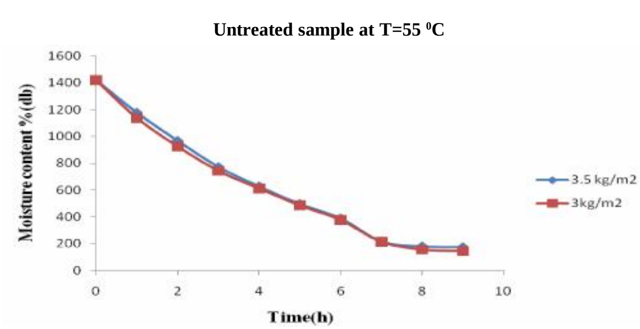

Fig. 2: Unblanched sample at T= 55^{o}C plotted between moisture content and time

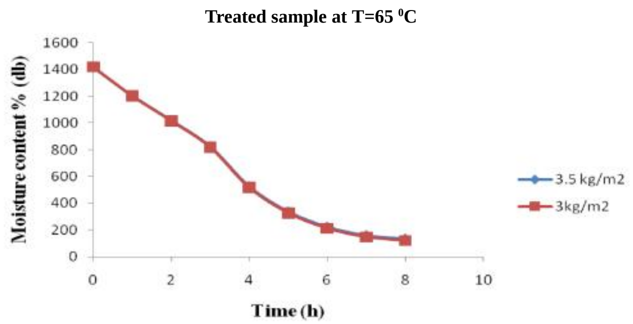

Fig.3: Blanched sample at T= 65°C plotted between moisture content and time

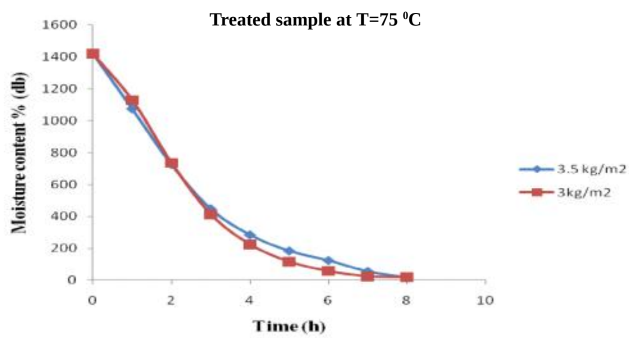

Fig. 4: Blanched sample at T= 75°C plotted between moisture content and time

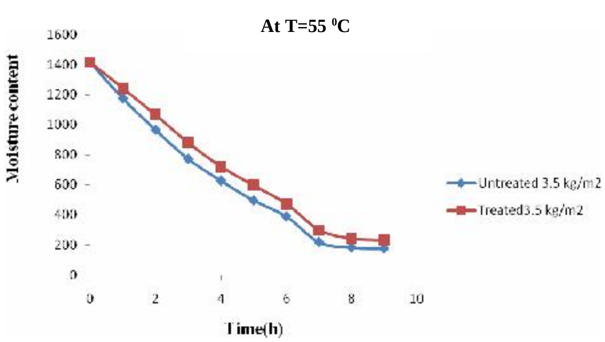

Fig. 5: For treated and unblanched sample at T= 55°C plotted between moisture content and time

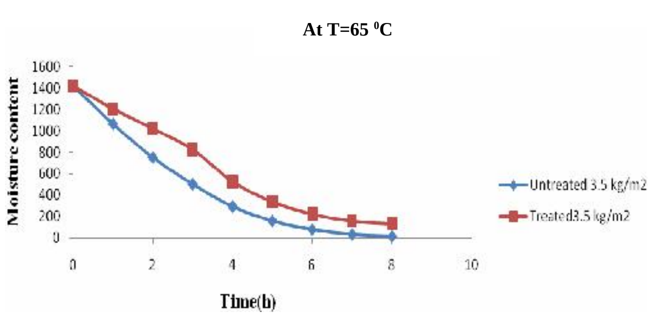

Fig. 6: For treated and unblanched sample at T= 65°C plotted between moisture content and time

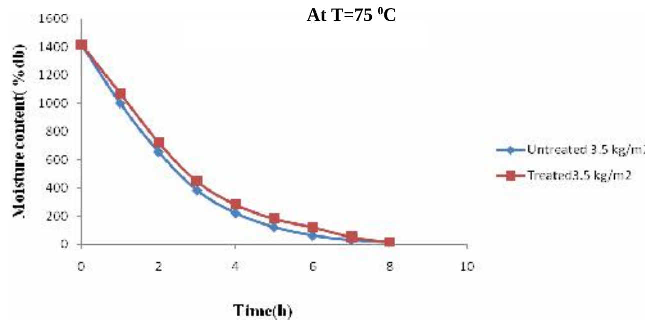

Fig.7: For treated and unblanched sample at T=75°C plotted between moisture content and time

drying in falling rate period. The change of moisture ratio with time at different temperature of drying for various experiments are shown in Fig. 8-10.

From the curves, it is evident that drying curve plotted between moisture ratio and time follows exponential law and pretreatment had insignificant role in drying of spinach in terms of moisture ratio. At beginning of drying moisture ratio was high *i.e.* one and at the span of time it decreased exponentially. To explain the effect of different temperatures with treatment condition at different loading densities are plotted in Fig.11-14.

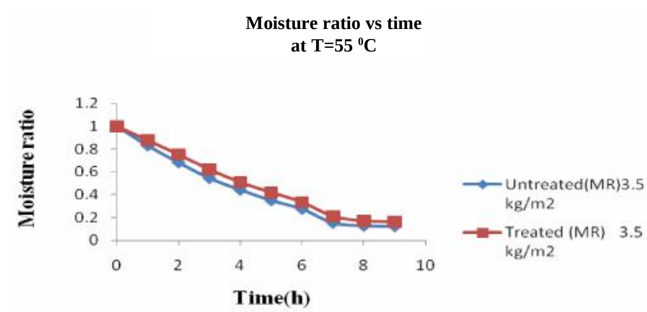

Fig.8: Validation of exponential model for treated and untreated sample between moisture ratio and time at temperature T=55 °C.

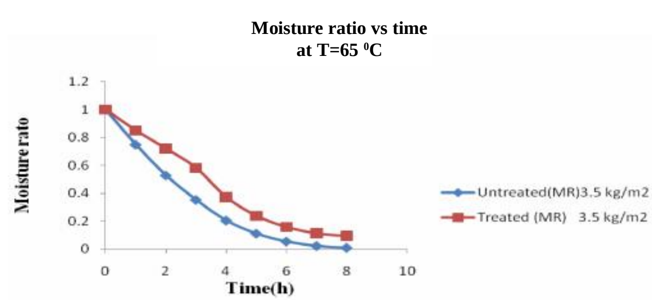

Fig.9: Validation of exponential model for treated and untreated sample between moisture ratio and time at temperature T=65 °C.

From different graphs, it is evident that treated and untreated samples with two different loading densities followed exponential law better at higher temperature *i.e.* 75 °C and 65 °C in comparison to 55 °C.

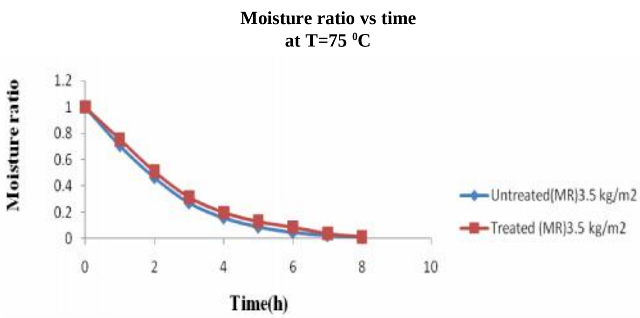

Fig.10:Validation of exponential model for treated and untreated sample between moisture ratio and time at temperature T=75 °C

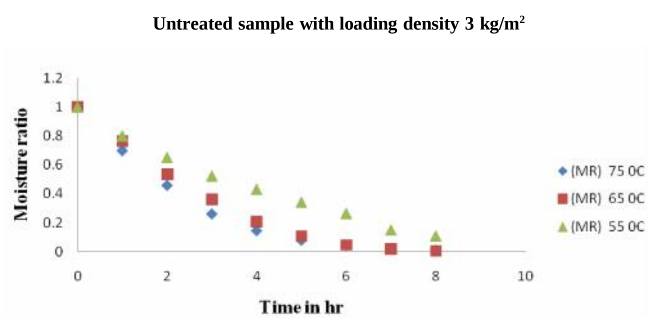

Fig.11:For untreated sample with loading densities 3kg/m²plotted between moisture ratio and time

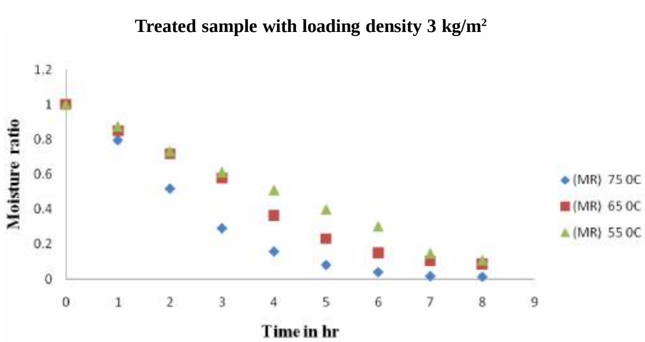

Fig.12:For treated sample with loading densities 3kg/m²plotted between moisture ratio and time

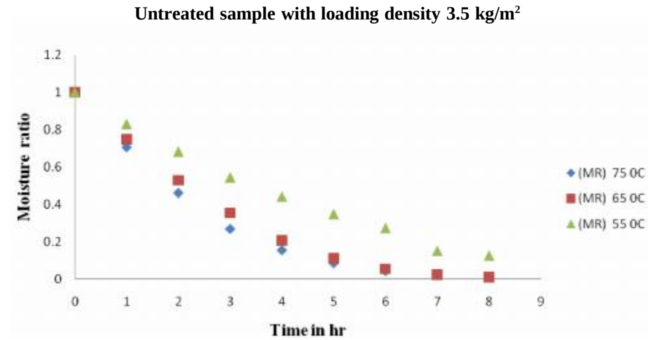

Fig.13:For untreated sample with loading densities 3.5kg/m²plotted between moisture ratio and time

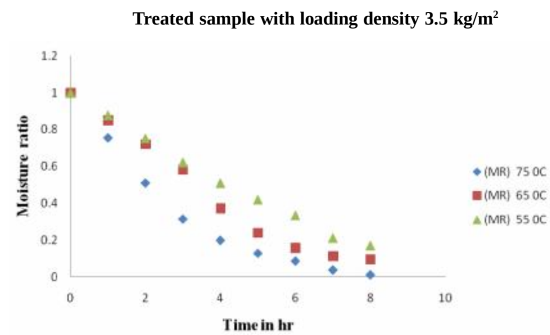

Fig.14:For treated sample with loading densities 3.5kg/m²plotted between moisture ratio and time

Conclusion :

– Total drying time considerably reduced with increase in drying air temperature from 55°C to 75 °C.
– Spinach does not initially dry at constant rate .The whole drying took place in falling rate period only.
– The drying rate increased with increased in temperature and decreased with increase in time.
– The loading densities had a small but insignificant role on the drying rate, especially at higher temperatures.
– Pretreatment had an insignificant role on the drying rate.
– Experiment validates the drying of spinach for exponential model at higher temperature and for better result; temperature must lies between temperature range 55°C-75 °C.

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