ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 4, July-August 2012, pp.301-310

Study of Moisture Depletion Pattern of Spinach in Hot Air Oven

A.K.Upadhyaya [1], Bhupendra Gupta [2], Sanjeev Garg [3], Mohan Singh[4], Mukesh Pandey[5]
[1]Student of ME, Mechanical Engineering (Heat power), JEC Jabalpur,
[2]Faculty of Mechanical Engineering Department, JEC Jabalpur,
[3,4]Faculty of Post Harvest Process and Food Engineering, JNKVV Jabalpur,
[5]Dean (Academics) and Professor, Department of Energy, RGPV, Bhopal

ABSTRACT

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, we can easily conclude that for prediction about drying nature, we need an experimental setup and results and each result are unique one. In present work, spinach for drying in blanched and unblanched condition with loading densities 3kg/m^3& 3.5 kg/m^{3}in a cabinet air dryer in which drying nature validates the exponential model of drying has selected.

Keywords: (M_e) Equilibrium Moisture Content, Moisture Content (MC), (MR) Moisture Ratio, Treated (Blanched), Untreated (Unblanched)

1. INTRODUCTION

In this, spinach with 3kg/m^3 & 3.5 kg/m^3 loading densities in blanched and unblanched condition with temperature range 55 ^{0}C, 65^{0}C, and 75^{0}C, has 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 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 to 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 that is sufficient to keep relative humidity low inside the dryer. In our curves, drying occurs majorly in falling rate of drying.

2. EXPERIMENTAL METHOD

2.1. Materials

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

2.2. Experimental method

Drying experiments 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^{3}and 3.5kg/m^3 and placed in a stainless steel mesh tray of size 0.0123m^2 and 0.0168 m^{2}giving equivalent sample weight of 70g and 80g corresponding to different loading densities. Table 1 shows the details of equipment used for the experiment. Figure 1, figure 2 and figure 3, shows the universal hot air oven, sample of spinach, and dried product respectively.

Table.1 Specification of experimental apparatus

Apparatus	Specification	Make
Balance electronic	Capacity-210 g	Mettler
	Least Count:0.001g	
Hot Air Oven	Heater :1200 W	Tradevel Scientific Industries.
	Voltage :220-2300 V	
	Temperature :50-250^{0}C	
	Least count :1^{0}C	
Desiccator	Diameter :150 and 300 mm	Brosil
Petri dish	Glass	Brosil
	Disposable	Tarsons
Refrigerator	310 litre	Kelvinator

Fig 1 Universal hot air oven

Fig 2 Primary sample image of spinach

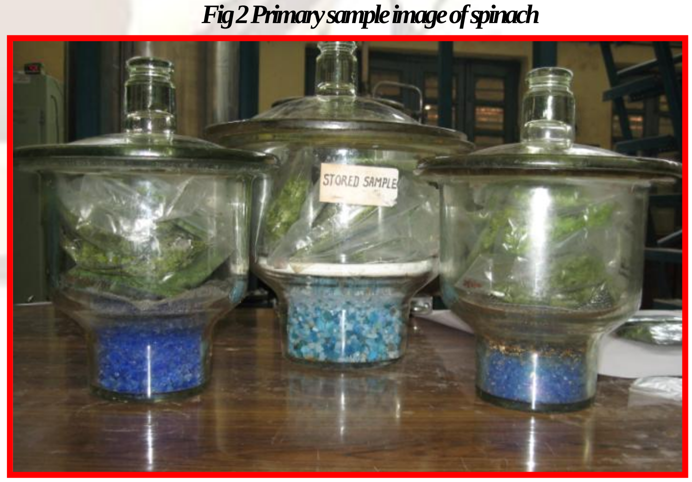

Fig 3 Dried stored sample of spinach

Method recommended by Ranganna (1986) was use 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°C,65°C,and 75 °C) and two level of loading density (3.0 and 3.5 kg/m^3) .The sample were dried for a minimum of eight hours of drying. Weights of the samples recorded after every hour during drying process. The dried samples cooled under laboratory conditions after each drying experiments, and kept in airtight jars. The experiments were triplicate and average of the moisture ratio at each value used for drawing the drying curves.

3. RESULTS AND DISCUSSIONS

It was attempt 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 calculated by the help of equilibrium moisture content, which is calculated by the method developed by Henderson and Perry (1976)

$$MR = \frac{M - M_e}{M_o - M_e}$$

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 used mentioned in table2.

Table.2 Model equations developed for drying process

S.No.	Model Name	Model Equation	References
1	Page (1949)	$MR = \exp(-kt^n)$	Page
2	Henderson and pabis (1969)	$MR = a.\exp(-kt)$	Henderson and Pabis
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)	$MR = a.\exp(-k_o t) + b.\exp(-k_1 t)$	Sharaf-Eldeen et al.
6	Midilli (2002)	$MR = a.\exp(-kt^n) + bt$	Midilli et al.

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. In first experiment, the following curves for spinach observed.

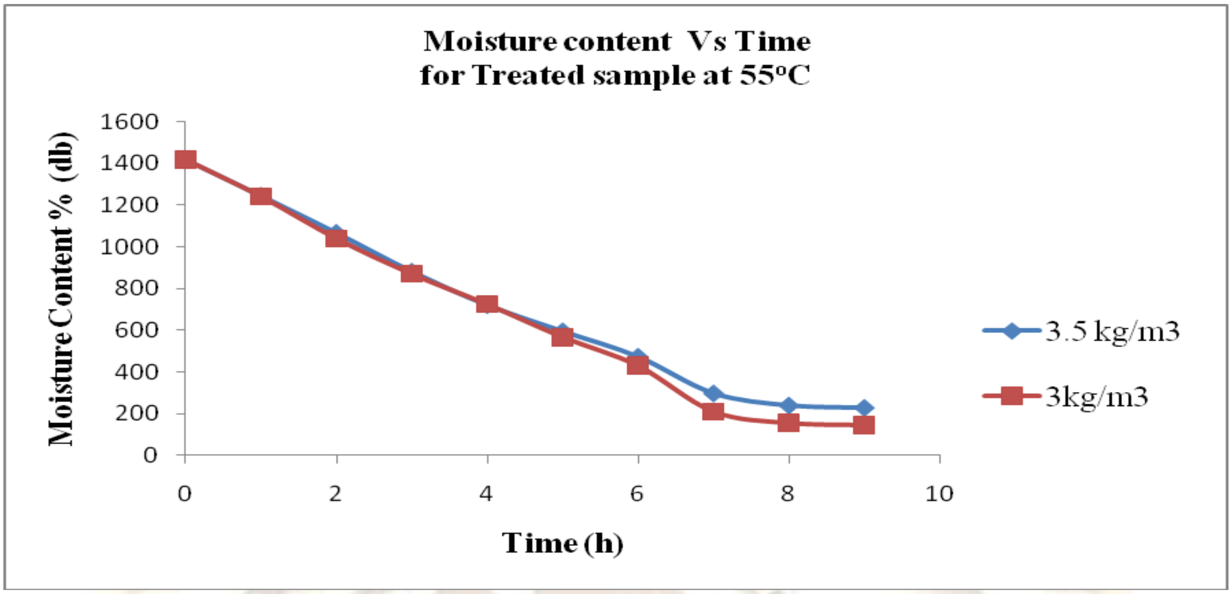

Figure 4 Blanched sample at T= 55°C plotted between Moisture content & Time.

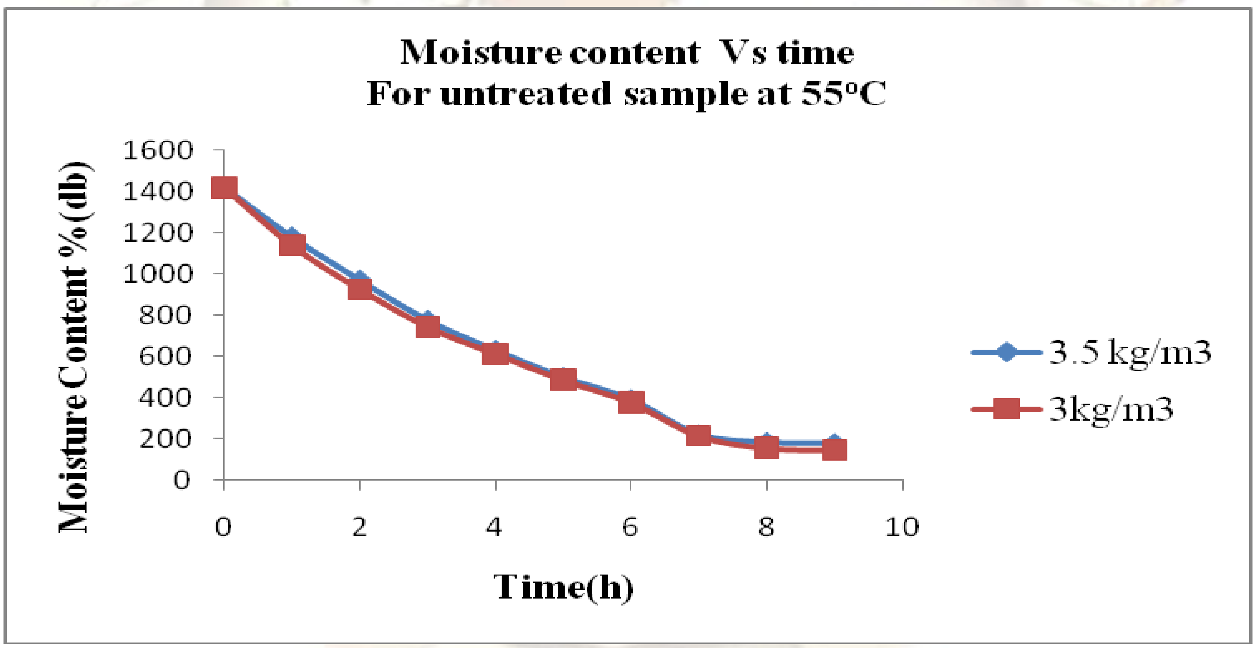

Figure 5 Unblanched samples at T= 55°C plotted between Moisture content & Time.

From above two figures Fig.4 and Fig.5 it is evident that moisture depletion pattern of spinach is nearly same for two different loading densities at T=55°C.Nearly same data also observed for two loading densities at two other temperature ranges i.e. at T=65 °C & T= 75°C those are given below.

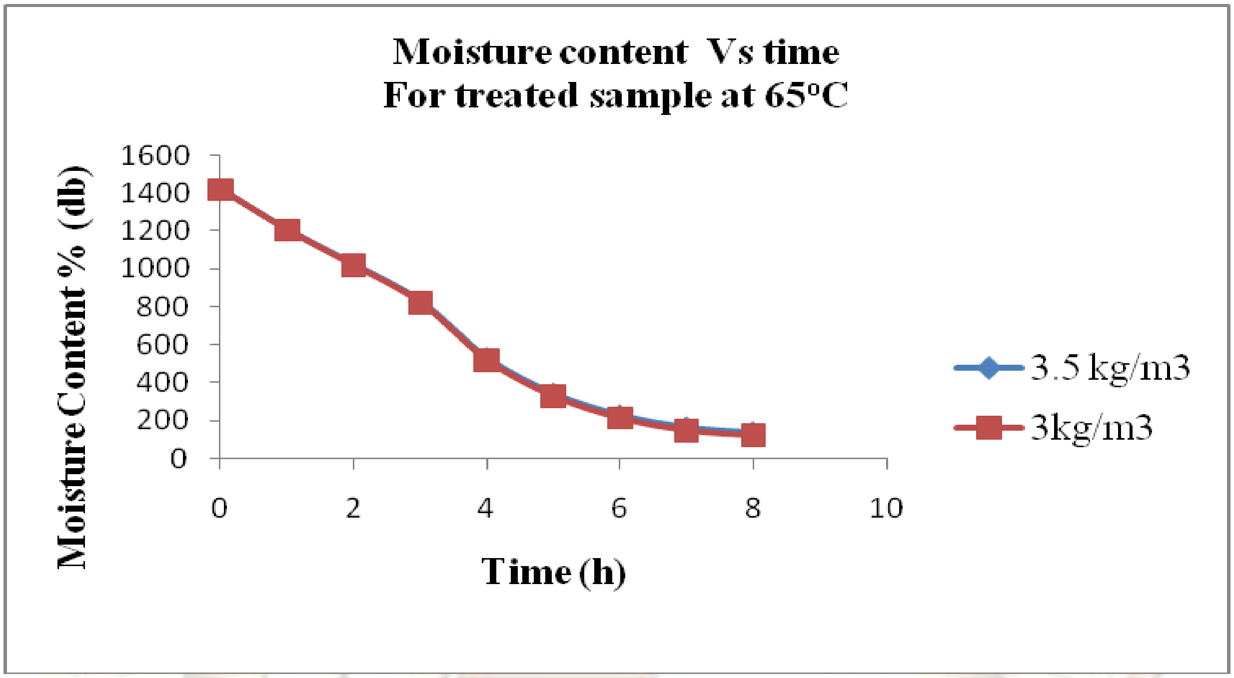

Figure 6 Blanched sample at T= 65°C plotted between Moisture content & Time.

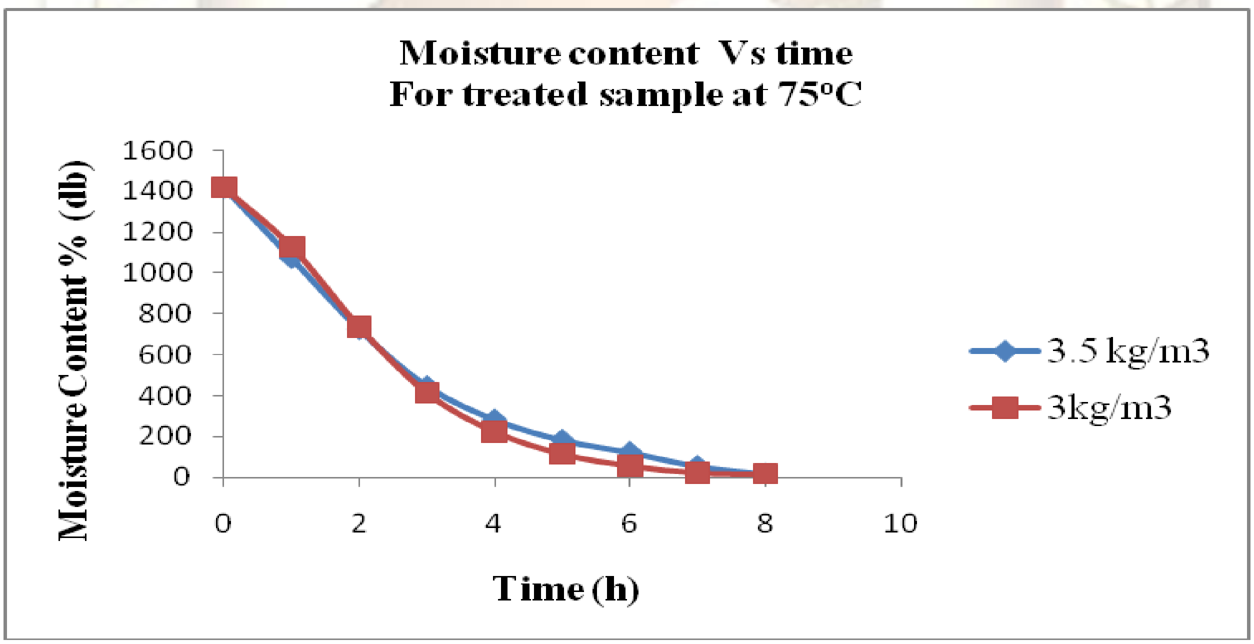

Figure 7 Blanched sample at T= 75°C plotted between Moisture content & Time.

ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 4, July-August 2012, pp.301-310

From figure 6 and 7, it is evident that total drying time considerably reduces with the increase in dry air temperature from 55°C to 75 °C. The drying rate increases with increase in temperature and decreases with increase in time. For analyzing the pretreatment on drying of spinach, following curves have plotted those mentioned in fig. (8-10).

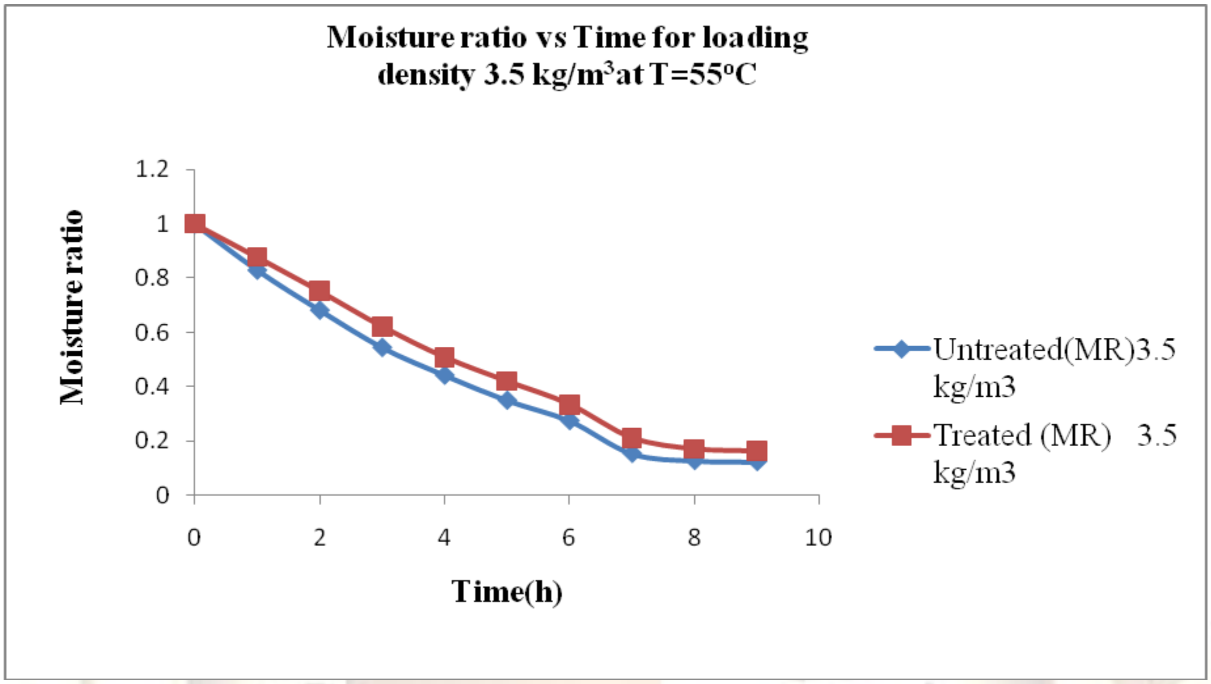

Figure 8 Treated & Unblanched sample at T=55°C plotted between Moisture content & Time.

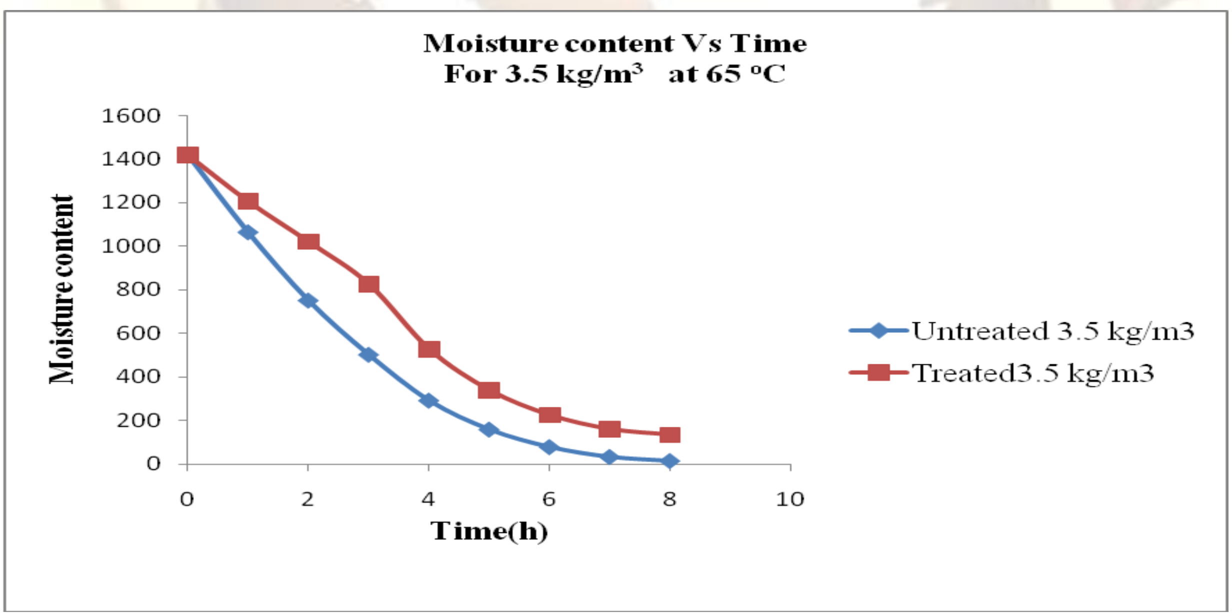

Figure 9 Treated & Unblanched sample at T=65°C plotted between Moisture content & Time.

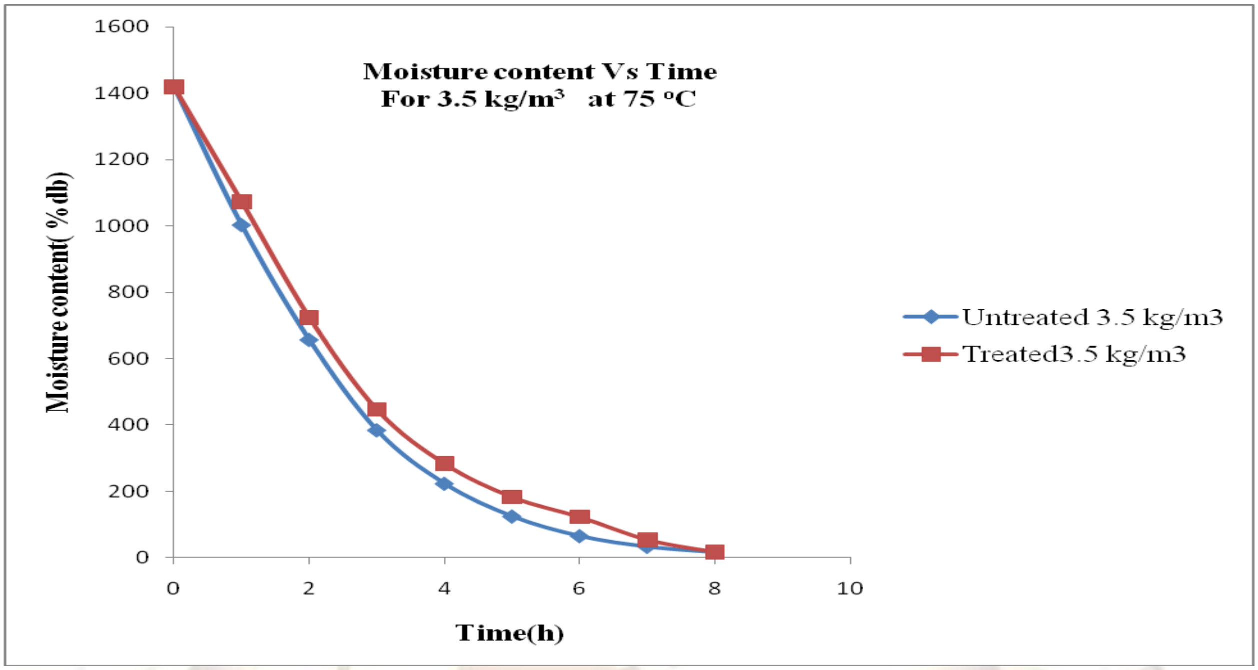

Figure 10 Treated & Unblanched sample at T= 75°C plotted between Moisture content & Time.

From above figure (8, 9, &10), it is evident that pretreatment i.e. blanching does 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 drying in falling rate period. The change of moisture ratio with time at different temperature of drying for various experiments has shown in Fig (11-13).

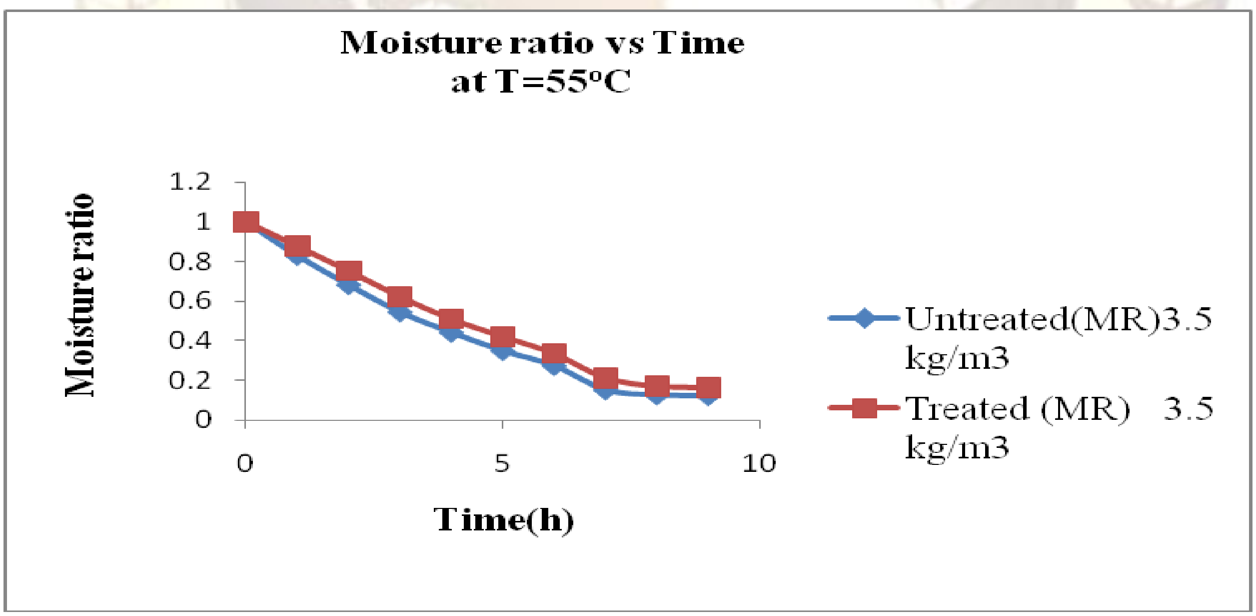

Figure 11 Validation of exponential model for treated and untreated sample between moisture ratio and time at temperature T=55 °C.

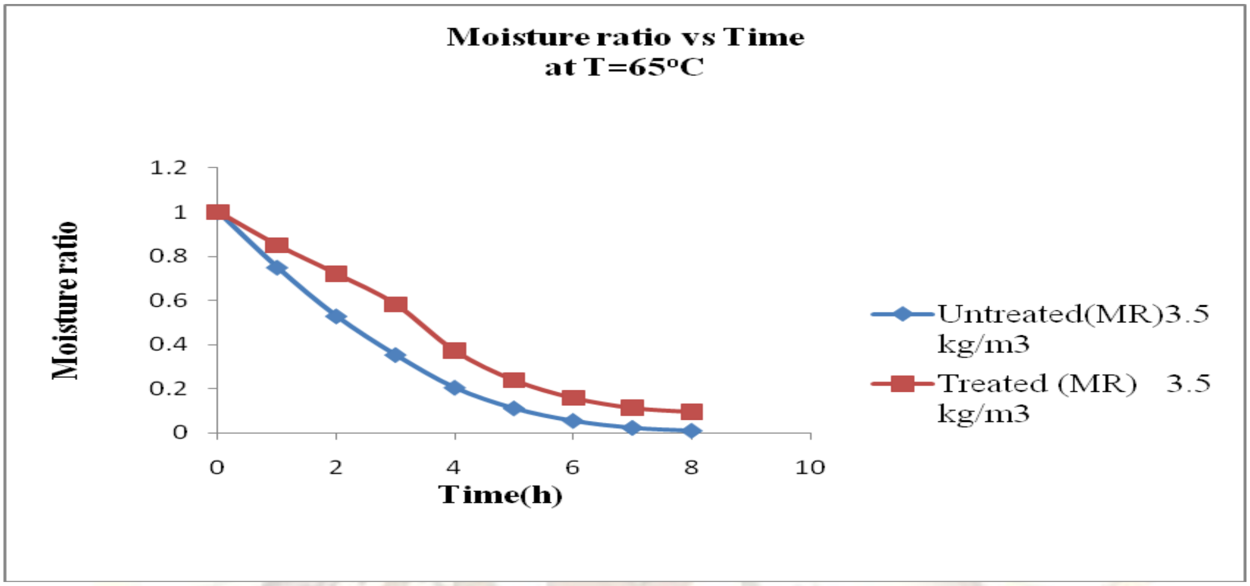

Figure 12 Validation of exponential model for treated and untreated sample between moisture ratio and time at temperature T=65 °C.

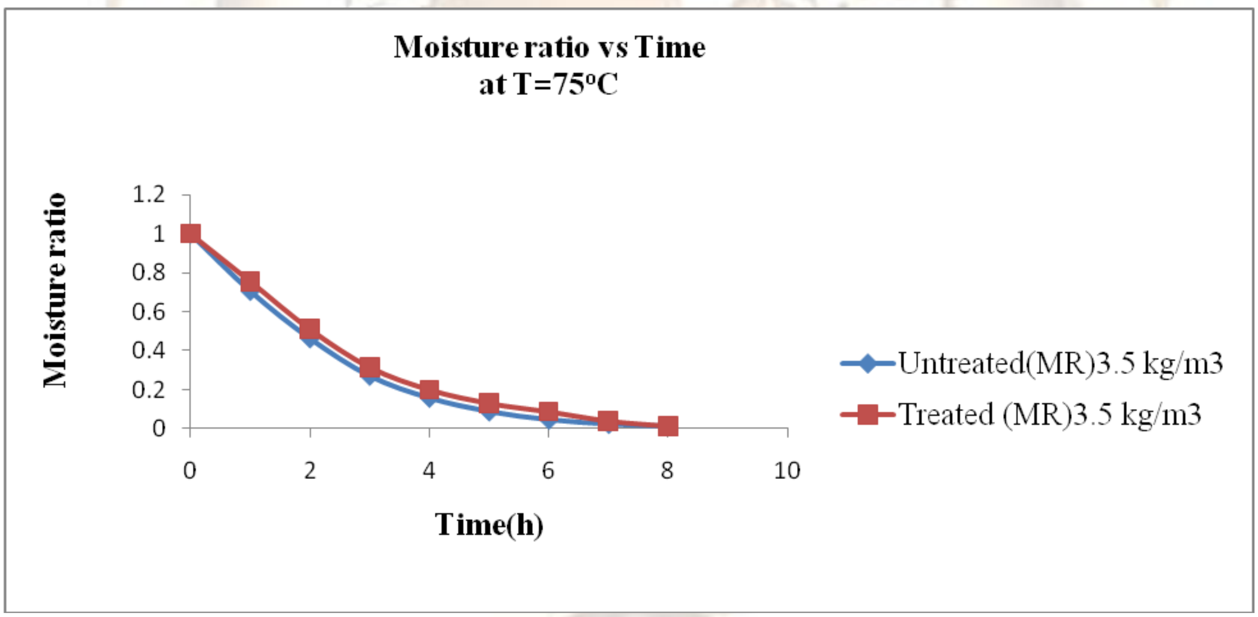

Figure 13 Validation of exponential model for treated and untreated sample between moisture ratio and time at temperature T=75 °C

From above curves, it is evident that drying curve plotted between moisture ratio and time follows exponential law and pretreatment has insignificant role in drying of spinach in terms of moisture ratio. At beginning of drying moisture ratio is high i.e. one and at the span of time it decreases exponentially. To explain the effect of different temperatures with treatment condition at different loading densities have plotted in fig (14 -17).

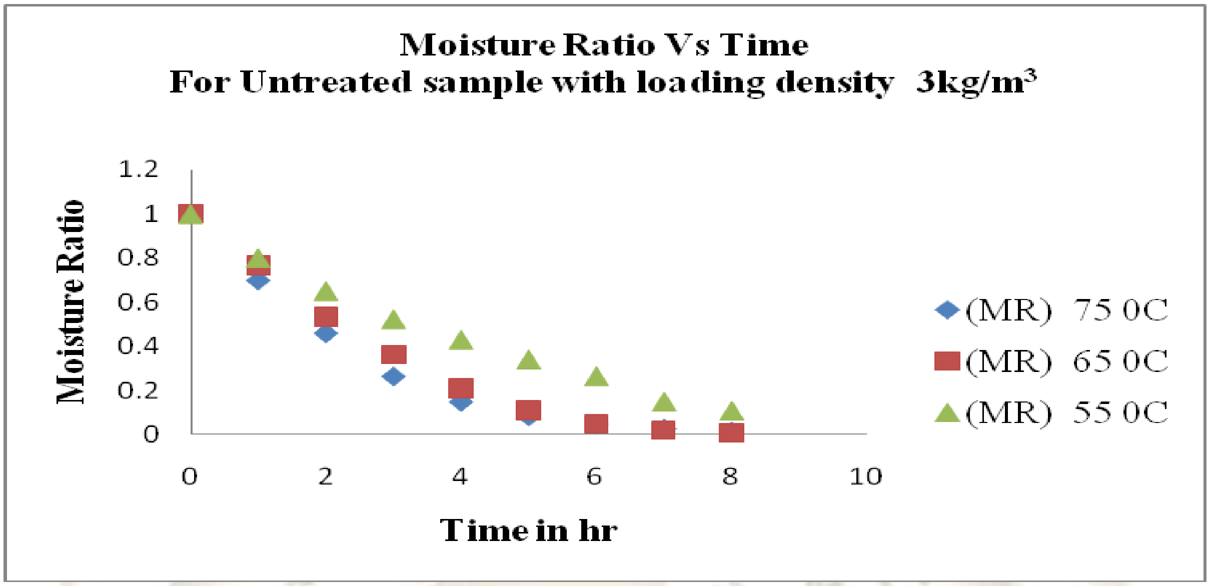

Figure 14 Untreated sample with loading densities 3kg/m^{3}plotted between

Moisture ratio & time

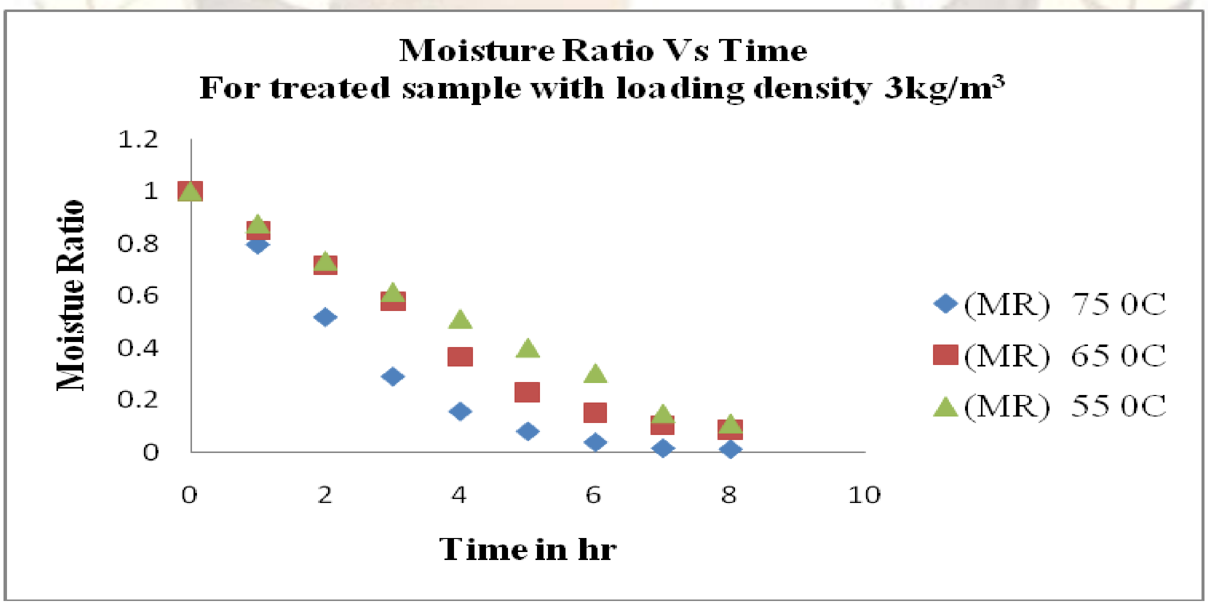

Figure 15 Treated sample with loading densities 3kg/m^{3}plotted between

Moisture ratio & time

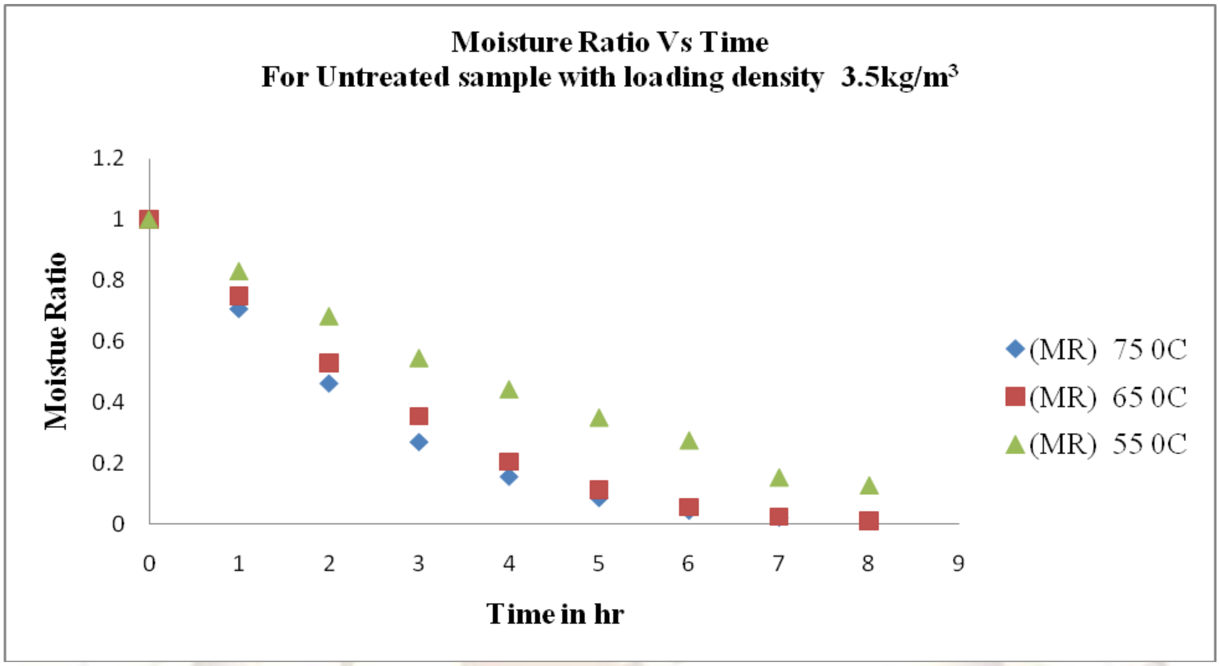

Figure 16 Untreated sample with loading densities 3.5kg/m^3 plotted between Moisture ratio & time

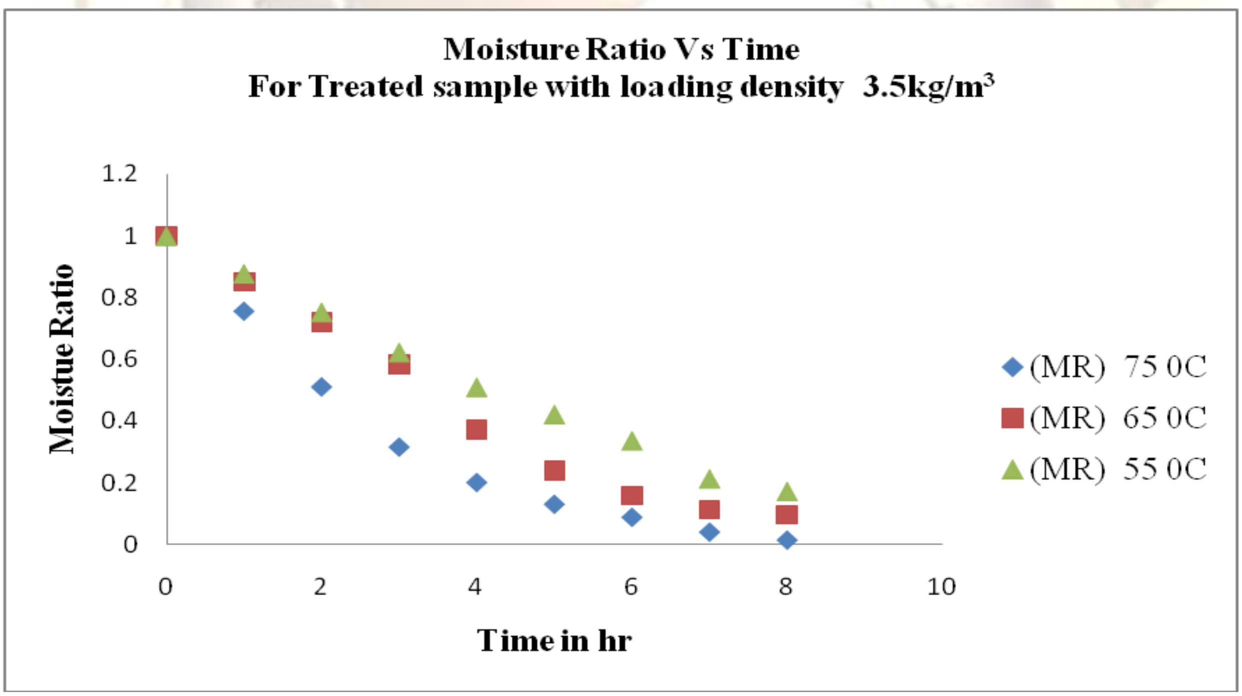

Figure 17 Treated sample with loading densities 3.5kg/m^3 plotted between Moisture ratio & time

From above graph it is evident that treated and untreated samples with two different loading densities follows exponential law better at higher temperature i.e. 75 ^oC & 65 ^oC in comparison to 55 ^oC.

4. CONCLUSION

- Total drying time considerably reduces with increase in drying air temperature from 55^oC to 75 ^oC.
- 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^oC-75 ^oC.
- The value of experimental constants increases with increase in temperature.

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