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THIN LAYER DRYING OF SWEET NEEM, BASIL LEAVES AND MOTH BEANS

DR. SURENDRA R. KALBANDE[1], SNEHA D. DESHMUKH[2]

1. Head, Department of Unconventional Energy Sources and Electrical Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.
2. Ph. D Scholar, Department of Unconventional Energy Sources and Electrical Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

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Abstract: The study on thin layer drying of Sweet Neem, Basil leaves and Moth Beans was carried out at Department of Unconventional Energy Sources and Electrical Engineering., Dr. PDKV, Akola, using solar tunnel dryer. In order to select the appropriate drying model, seven mathematical drying models were fitted to the experimental data. Considering the statistical criteria (R^2, χ^2, SSE & RMSE) logarithmic model was found to be best fitted in order to describe the drying behaviour. 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 various drying temperatures with an R^2 = 1 and SE = 0.The coefficients of accepted models for the convective drying using solar tunnel dryer were determined by equations which are dependent on drying air temperature.

Keywords: Mathematical modelling, solar tunnel dryer, thin layer drying, moisture ratio, multiple regressions, sweet neem, basil leaves, moth beans.

Corresponding Author: DR. SURENDRA R. KALBANDE

Co Author: MS. SNEHA D. DESHMUKH

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INTRODUCTION

Basil (Ocimum Sanctum) is also known as holy basil and it is an aromatic plant. Moth bean is rich in protein (23.6 g), calcium (202 mg) which make it an excellent supplement to cereal diet. The removal of moisture prevents the growth of the micro-organisms responsible for the spoilage of the foods. This can be achieved by drying or dehydration for removal of water (responsible for many deteriorative) form a product. Natural sun drying has been used since time immemorial or agricultural product. In open sun drying the aroma and other volatile chemical compound of medicinal plants are loss due to direct solar radiation and other weather parameters. Hence drying characteristics evaluated and investigated.

Drying is the most widely used primary method of food preservation. The green colour of Basil leaves is due to the chlorophyll. The most common change occurs in the green colour vegetables during the thermal processing is the conversion chlorophyll to the pheophytin, causing a colour change from bright green to olive-brown, which is undesirable to consumer for a green vegetables, pre-treatment prior to the drying can aid the chlorophyll retain during the drying operation. Thin-layer mathematical drying models have been used to illustrate the drying behaviour of several agricultural products. (Oliveira et al., 2008) carried out characterisation of thin layer drying of spirulina which is a medicinal plant. According to (Demin et al., 2004) the change in moisture content the weight loss from the product were recorded at fixed interval. The data obtained from the drying test were applied to various well-known semi-empirical mathematical models of drying. The paper describes thin-layer convective drying behaviour of sweet neem, basil leaves and moth beans.

MATERIALS AND METHODS

The experimentation was carried out in solar tunnel dryer installed at Ramkrushana Agro. Vegetables and Fruit Products, Kodoli, Tal–Panhalla, Dist- Kolhapur which had been installed by Deptt. of Unconventional Energy Sources and Electrical Engineering, Dr. Panjabrao Deshmukh Agril. University, Akola, Maharashtra, India.

Raw Material- Fresh products namely, Fresh Basil leaves, sweet neem and sprouted moth bean were used for the experimentation. The drying experiment was conducted during sunny days on no load and full load condition in the solar tunnel dryer.

Study of Drying Characteristics

The drying mechanism depends on simultaneous heat and mass transfer phenomenon and factors dominating each process determined the drying behaviour of the product. The drying rates were computed from the experimental data and drying characteristics curves i.e. moisture ratio (db) vs. time, drying rate vs. time and moisture content (db) were plotted.

Determination of Moisture Content

Initial moisture content of sample was determined by the hot air oven drying method as recommended by (Ranganna, 1986). Samples were weighed using electronic weighing balance of least count 0.01g. The samples of Sweet Neem and Basil were placed in hot air oven at 70 ± 0.50 C for 12.00 h and the Sprouted Moth Bean at 100 ± 0.50 C for 18:00 h.

Determination of Moisture Ratio

The Moisture ratio of the product was computed by using following formula (Chakraverty, 1988).

Where, M = Moisture content (db), per cent

Me = EMC, (db), per cent

M0 = MC, (db), per cent

Determination of Drying Rate

The drying rate of product sample during drying period was determined as follows (Chakraverty, 1988).

Where,

ΔW = Weight loss in one h interval (gm/100gm bdm min.)

Δt = Difference in time reading (h)

Drying was carried out in solar tunnel dryer and the maximum temperature recorded inside the dryer was found to be 50-55 oC. The dryer was operated under unloaded condition to achieve a steady state condition. Then the samples (about 100 g) were spread on the tray in thin layer. The continuous weight loss was monitored and measured by digital electronic weighing balance. The initial weight loss of the samples was recorded at every 15 minutes for three hours and then measured after 60 minutes interval. Drying time was defined as the time required for reducing the moisture content of the product up to equilibrium moisture content.

Mathematical Modeling of the Drying Curves

In this study thin layer mathematical models were used to describe the drying kinetic of the products (Arun et al 2014). The drying curves were plotted and fitted with seven different moisture ratio models as given in table 1.

Table 1. Thin layer mathematical models

Model	Mathematical equation
Lewis	MR=exp(-a.x)
Page	$MR = exp(-a.x^b)$
Henderson and Pabis	$MR = a.exp(-b.x)$
Modified Henderson and Pabis	$MR=a.exp(b.x)+c.exp(-d.x)+e.exp(f.x)$
Logarithmic	$MR = a.exp(b.x)+c$
Two term	$MR= a.exp(-b.x)+c. exp(-d.x)$
Wang and Singh	$MR = 1+a.x+b.x^2$

Figure 1. Schematic view of solar tunnel dryer

RESULTS AND DISCUSSION

The drying characteristics of sweet neem leaves, basil and moth beans samples in natural convection solar dryer were studied. The different drying characteristics in terms of moisture content percent (db), drying rate (gm /100 gm bdm min) and moisture ratio were studied. It was observed that drying rate decreased continuously with decreasing moisture content. The curves indicate that drying process takes place in the falling rate period except very short unsteady-state initial and constant rate periods this result was in agreement of (Singh, 2012).

MODELING OF DRYING CURVES

The moisture content data obtained at various air temperatures were converted to dimensionless moisture ratio (MR) and then fitted in seven drying models (Table 1). Seven thin layer drying models were evaluated according to the statistical criteria, R2, χ2, and RMSE. By comparing the average values of these criteria, it is obvious that the logarithmic model had the highest R2 and the lowest χ2, and RMSE values.

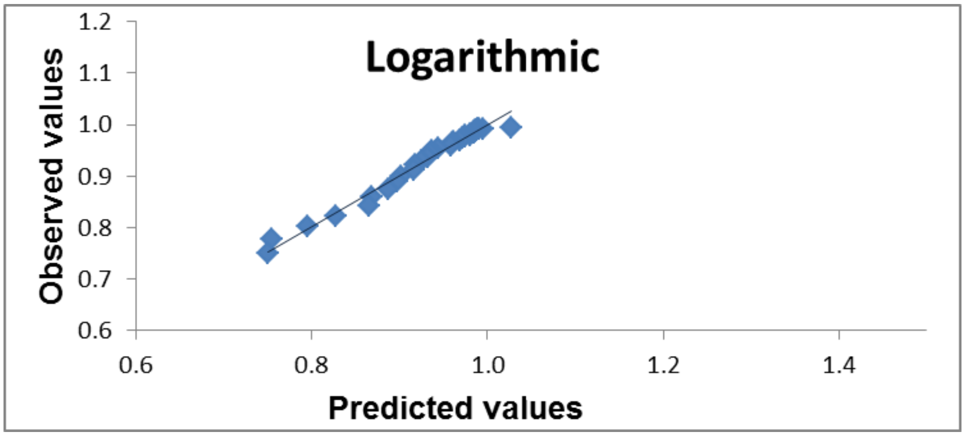

Fig 2. Observed verses Predicted values for moisture ratio for sweet neem leaves

Table 2. Results of thin layer drying model of sweet neem leaves sample dried in dryer.

S.N.	Model name	Model	Coefficients	R^2	χ^2	MBE	RMSE
1.	Lewis Model	*y=exp(-a.x)*	0.000072	0.7761	0.00123	-0.00929	0.0351
2.	Page Model	*y=exp(-a.x^b)*	0.0000	0.95061	0.00029	-0.0021	0.0173
			2.3411				
3.	Henderson and Pabis	*y=a.exp(-b.x)*	1.0348	0.8520	0.00084	0.000028	0.02914
			0.0001				
4.	Logarithmic	*y=a.exp(b.x)+c*	-0.00190	0.9960	0.00084	0.000028	0.02914
			-0.00299				
			1.000206				
5.	Two Term	*y=a.exp(-b.x)+c.exp(-d.x)*	0.458154	0.8520	0.000849376	0.000019	0.029144
			-0.000014				
			0.458336				
			-0.000004				
6.	Modified Henderson and Pabis	*y=a.exp(b.x)+c.exp(d.x)+e.exp(-f.x)*	0.344959	0.8520	0.00084	0.000026	0.0291
			0.000105				
			0.344959				
			0.000105				
			0.344959				
			0.000105				
7.	Wangh and singh	*y=1+a.x+b.x^2*	0.000059	0.9681	0.000194056	0.002011	0.01393040
			0.000000				

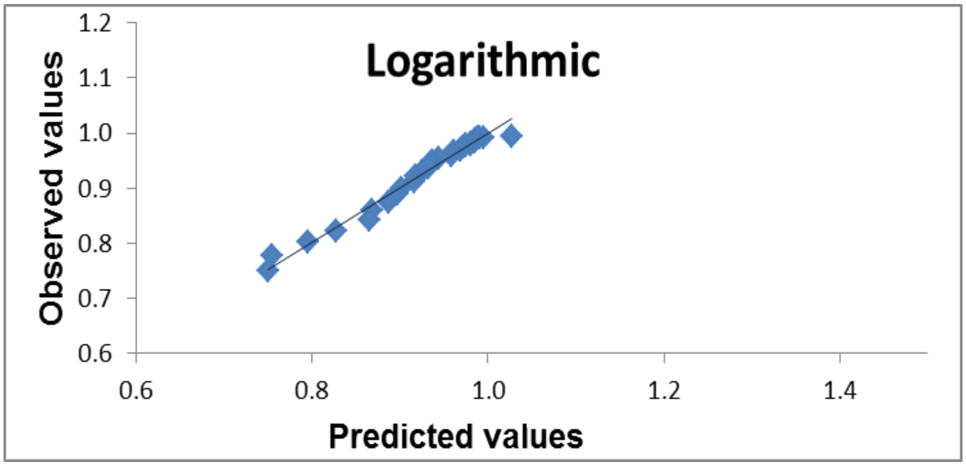

Fig 3. Observed verses Predicted values for moisture ratio for basil leaves

The non-linear least square regression analysis was used to estimate the parameters of the mathematical models (by fitting the model equations to experimental data). The coefficient of determination (R2), chi square (χ2) and the root mean square error (RMSE) were used as criteria for verifying the goodness of fit (Togrul, 2005; Sacilik and Elicin, 2006). The best model for describing the thin-layer drying characteristics was selected as the one with the highest value of R2 and the least values of χ2 and RMSE (Togrul, 2005). Then the relationships between coefficients of the best model and the drying parameters were determined using multiple regression analysis. All possible combinations of the different drying parameters were tested and included in the regression analysis (Togrul, 2005).

Table 3. Results of thin layer drying model of basil leaves sample dried in dryer.

S.N.	Model name	Model	Coefficients	R^2	χ^2	MBE	RMSE
1.	Lewis Model	$y=exp(-a.x)$	0.000078	0.8473	0.00077	-0.00670	0.0278
2.	Page Model	$y=exp(-a.x^b)$	0.000000	0.96088	0.00021	-0.00107	0.0145
			1.944811				
3.	Henderson and Pabis	$y=a.exp(-b.x)$	1.026680	0.8850	0.00059	0.000023	0.0244
			0.000103				
4.	Logarithmic	$y=a.exp(b.x)+c$	-0.006723	0.9935	8.92897E-05	0.000000	0.0094
			-0.002136				
			1.004333				
5.	Two Term	$y=a.exp(-b.x)+c. exp(-d.x)$	0.433633	0.8850	0.00059	0.000021	0.0244
			0.000014				
			0.433376				
			-0.000149				
6.	Modified Henderson and Pabis	$y=a.exp(b.x)+c. exp(-d.x)+e.exp(-f.x)$	0.342225	0.8850	0.00059	0.000022	0.02391
			0.000103				
			0.342225				
			0.000103				
			0.342225				
			0.000103				
7.	Wangh and singh	$y=1+a.x+b.x^2$	0.000030	0.9778	0.00012	0.002168	0.0069
			0.000000				

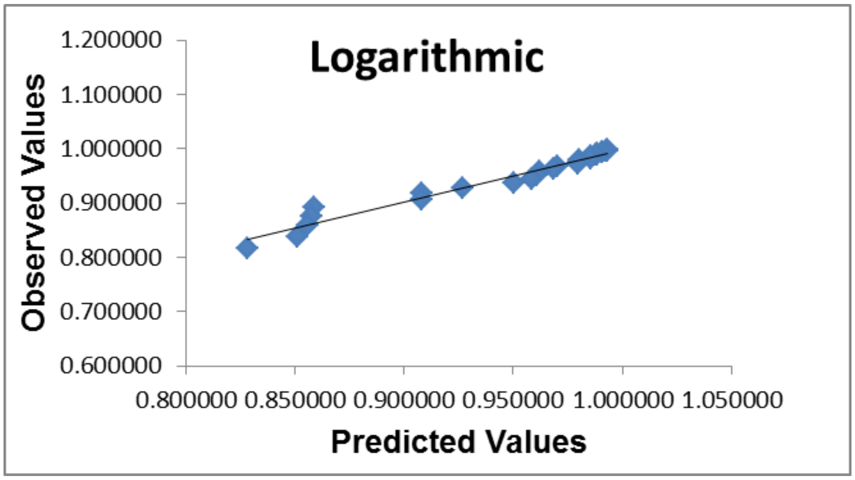

Figure 4. Observed verses predicted values of moisture ratio for moth beans

Table 4. Results of thin layer drying model of moth beans samples dried in dryer.

S.N.	Model name	Model	Coefficients	R^2	χ^2	MBE	RMSE
1.	Lewis Model	*y=exp(-a.x)*	0.000031	0.8531	0.00020	-0.00267	0.014303
2.	Page Model	*y=exp(-a.x^b)*	0.000000 1.870620	0.9309	0.0001	0.001294	0.010011
3.	Henderson and Pabis	*y=a.exp(-b.x)*	1.010557 0.000038	0.8748	0.00017	0.000003	0.013281
4.	Logarithmic	*y=a.exp(b.x)+c*	-0.000963 -0.002155 0.992106	0.9954	3.79845E-05	0.000000	0.006163
5.	Two Term	*y=a.exp(-b.x)+c. exp(-d.x)*	0.505266 0.000038 0.505266 0.000038	0.8748	0.00017	-0.000003	0.013281
6.	Modified Henderson and Pabis	*y=a.exp(b.x)+c. exp(-d.x)+e.exp(-f.x)*	0.336852 0.000038 0.336852 0.000038 0.336853 0.000039	0.8748	0.00017	0.000003	0.013281
7.	Wangh and singh	y=1+a.x+b.x^2	0.000002 0.000000	0.9388	8.91608E-05	0.001179	0.009442

Accordingly, the logarithmic model was selected as the suitable model to represent the thin layer drying behaviour of all the samples. The coefficients of the models were shown in Tables. Variation of experimental and predicted moisture ratio by logarithmic model with drying time (min) are shown in figures. It is clear that the logarithmic model provided a good agreement between experimental and predicted moisture ratios. Similar results were reported for drying of plum in tunnel dryer (Goyal et al., 2006) which indicated that in all cases the R2 values for the mathematical models were greater than 0.90, indicating a good fit. In order to taken 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 R2value, were finally included in the selected model. The coefficients of accepted models for the convective drying using solar tunnel dryer were determined by equations. The coefficients of models for the drying of sweet neem leaves, basil and moth beans in solar tunnel dryer are given in above tables. The coefficient depends on drying air temperature. These are presented in tables for sweet neem, basil and moth beans, respectively.

CONCLUSIONS

Drying air temperature affected the drying rate and drying time of sweet neem, basil leaves and moth beans. The drying rate increased with increase in the drying-air temperature and followed falling rate period. Logarithmic model was found to be adequate and best suited for describing the thin-layer drying behaviour of sweet neem, basil leaves and moth beans. The drying parameters a, k, n and b in logarithmic model can be expressed as a linear function of the temperature with an R2 value of 1 and SE of 0. Logarithmic thin layer drying equations represented thin layer drying behaviour of sweet neem, basil leaves and moth beans.

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