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Drying behavior of spinach under various drying conditions

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Abstract
This study investigated, the drying behavior of spinach under open sun drying (OSD), natural convection single layer solar drying (SLSDNC), natural convection double layer (DLSDNC) and forced convention double layer drying solar drying (SLSDFC). Different drying models were examine with adequacy of fit between experimental and predicted by statistical parameters such as R^2 , χ^2, MBE and RMSE.

Keywords: Double layer, drying kinetics, forced convection, greenhouse solar dryer, natural convection

1. Introduction

Value addition to perishable fresh fruits and vegetables is done by drying process, greatly extend product shelf life and reduce postharvest losses, as well as it also contributes to great cost reduction in transportation and storage cost. Dried foods are good source of quick energy and wholesome nutrition, since the only thing lost during preservation is moisture. Dried nuts and seeds are good sources of protein for snack or meal. The food leather and chips provide plenty of energy. Drying of fruits and vegetables has been principally accomplished by convective drying (Nijhuis *et al* 1998) [5]. Fruits and vegetables are enriched with moisture and nutrients. These nutrients restrict the temperature to which the product can be raised during drying. The rate of drying also affects the end quality of dried product. Studies say that retention of vitamin C has been used as an indicator in the processed foods for the retention of other heat sensitive nutrients (Verma and Gupta 2004) [9].
Solar energy has been used for the preservation of agricultural produce since generations all over the world. Solar energy is low-grade energy but it is renewable and sustainable source of power and due to scarcity of fossil fuels it has got drive to use. India has tropical and temperate climatic conditions. In India here are plenty of sunshine hours. Hence, drying with the heat of sun is feasible and beneficial here. Open drying is an integral part of rural life for various horticultural produce, especially vegetable, fruits and spices which are produced in rural areas and have no scientific means of preserving such raw produce. Open sun drying is very much common between farmers due to various reasons especially economic viability (Paul and Singh 2013) [6].
Solar drying is proposed due to some shortcomings of open sun drying. It takes less time in drying of agricultural produce in solar dryer than open sun drying. Products dried in solar greenhouse dryer are found to be of superior quality than in open sun drying. (Prakash and Kumar 2014) [7]. Solar dryer uses direct energy without converting it into electricity. Greenhouse solar dryer can be used in both modes for drying natural convection and forced convection. Fan is used for forced convection that creates negative pressure to remove humid air (air containing moisture of crops during drying) from dryer. Hence, fan increases the rate of moisture removal from greenhouse solar dryer than natural convection.
Solar drying under forced convection is very much helpful. It reduces drying time for crops to attain required moisture content. Dried crops are of good quality in forced convection solar greenhouse dryer. In double layer forced convection greenhouse solar dryer roof covered with polyethylene sheet increases the drying rate. In present study drying behavior of spinach is evaluated for open sun drying (OSD), natural convection single layer solar

drying (SLSDNC), natural convection double layer (DLSDNC) and forced convention double layer drying solar drying (SLSDFC).

2. Materials and Method

2.1 Preparation of Sample

Spinach crop was collected from local market. The crops were washed thoroughly in fresh water to remove any dirt and dust as well as any residual chemicals sprayed on them. Washed crop was manually prepared for further process. Bunch of leaves of spinach were cut in 5 mm thick pieces.

2.2 Pretreatments

Cut pieces were blanched at 85 °C for 1 min. After blanching slices were dipped in 0.25% KMS solution.

A general flow process was explained for preparation of dried product in fig.

Bunch of spinach leaves
↓
Sorting and Cleaning
↓
Physical treatment (cutting 5mm thick pieces)
↓
Blanching
(1 min at 85 ^{0}C)
↓
Dipped in 0.25% KMS
↓
Loading on tray
↓
Drying

2.3 Drying Procedure

The different drying methods were open sun drying (OSD), natural convection single layer solar drying (SLSDNC), natural convection double layer (DLSDNC) and forced convention double layer drying solar drying (SLSDFC). The sample were recorded for their change in weight throughout drying process. The weight of samples were measured by using electronic balance of 10 kg capacity. The weights of the samples were noted down periodically at an interval of 30 min/ 60 min toward to end of drying.

2.4 Analysis of the drying data

2.4.1 Drying rate

Drying rate was determined by moisture content (%, db) decrease of the sample per unit time (min) as given by Brooker *et al* (1997).

$$\frac{dM}{dT} = \frac{(M_i - M_{i+1})}{(t_{i+1} - t_i)}$$

Where,

dM/dT = drying rate, recent moisture loss per min (%/min)

M_i = Moisture content (% db) of sample at time t_i

M_{i+1} = Moisture content (% db) of sample at time t_{i+1}

The temperature of ambient and exhaust air was measured with the help of standard mercury in-glass thermometer. The product temperature was measured using digital thermocouple.

2.4.2 Drying models

Thin layer drying mean to dry as one layer of sample or slices. Thin layer drying models (moisture ratio equations) describes that the drying phenomenon of agricultural materials mainly fall into three categories. First category is theoretical which take into account only internal resistance to moisture transfer while second category semi theoretical and third empirical model consider only external resistance to moisture transfer between product and air (Akpinar 2006) [1]. Among semi theoretical thin layer drying models, the Newton model, Page model, Henderson and Pabis model, the logarithmic model, The Two-term model, the two-term exponential, the Verma *et al*. model and Midilli – Kucuk model are used widely (Ismail and Ibn 2013) [4].

$$\text{M.R} = \text{Moisture ratio} = \frac{M_t - M_e}{M_i - M_e}$$

Where,

M_t, M_e and M_i are moisture contents (db) at any time 't', at equilibrium and at time t = 0, respectively.

K is drying constant.s^{-1}

a and c are model's parameters.

2.5 Adequacy of fit of various models

Modeling the drying behavior 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. Non-linear Regression analysis was conducted to fit the mathematical models by the statistical package for social sciences (SPSS version 22). Following are the drying model used in this study:

Table 1: List of drying models

S. No.	Name of model	Model equation
1.	Newton's model	M.R = Exp (-kt)
2.	Logarithmic model	M.R= a Exp (-kt) + b
3.	Henderson and Pabis model	M.R= a Exp (-kt)

Where,

k is drying constant.s^{-1}

a, b, and n are model's parameters.

3. Result and Discussion

3.1 Variation of moisture content with drying time

Open sun drying, single layer natural convection solar drying, double layer natural convection solar drying, single layer forced convection solar drying and double layer forced convection solar drying for spinach is shown in Fig.1. The drying time to reach less than 10% moisture content at various drying conditions of spinach 275– 540 min.

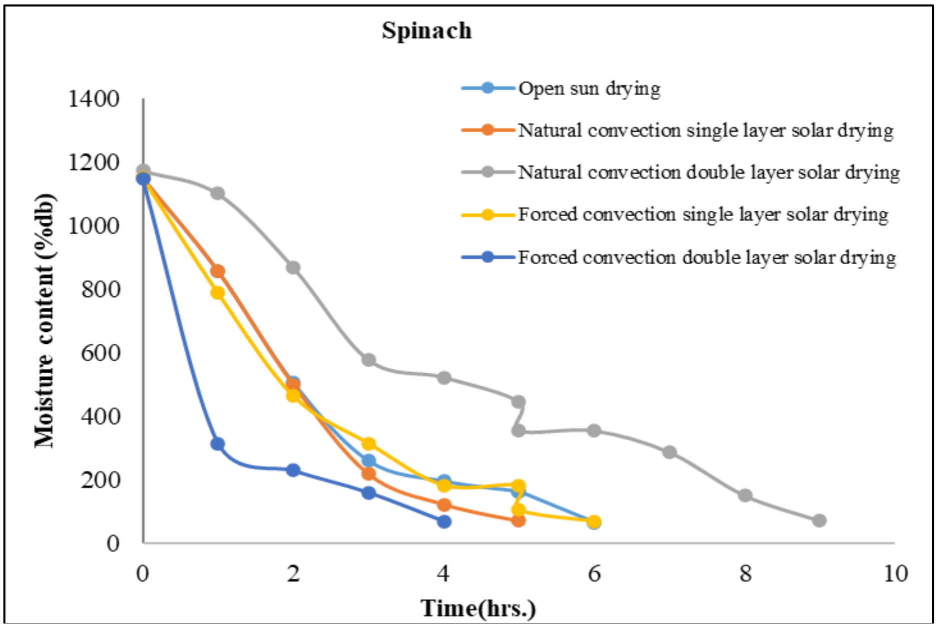

Fig 1: Variation of moisture content with respect to drying time at different temperature

Drying of crops under double layer solar dryer under natural convection took more time due to drop in temperature. Double layer solar dryer under forced convection took less time from all other conditions. When drying was done in double layer solar dryer under forced convection , the minimum drying time was obtained 275 min for drying of spinach from its initial moisture content (1145% db) to reach near desired moisture content less than 7 per cent.

3.2 Variation in drying rate with drying time

The change in drying rate with drying time for spinach at various drying conditions is shown in Fig.2. The drying rate curves for the different drying conditions have different peak from each other. Generally the drying rate v/s drying time graphs clearly indicate that the drying rate uniformly decrease with increase in drying time. This loosely held water may be removed by use of centrifugal force. Double layer solar dryer under natural convection the drying rate initially obtained was 1.21 (%db/min) and then increased in 60 min upto 3.86 (%db/min) and then decreased upto 1.17 (%db/min).

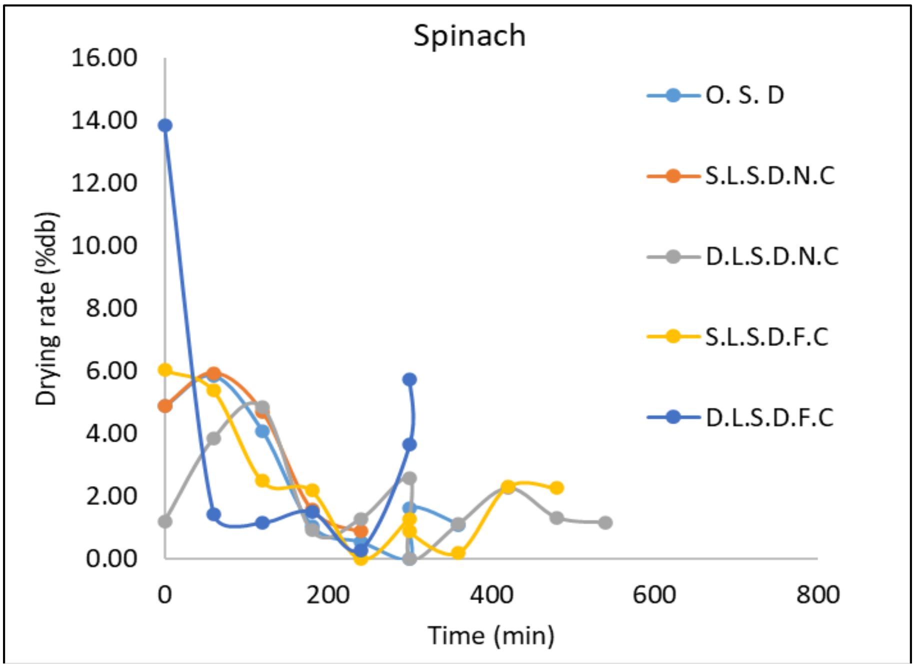

Fig 2: Variation in drying rate (%db/min) with respect to drying time (min) in different drying conditions

drying time is shorter when the temperature obtained was higher and humidity was lower as in double layer solar dryer under forced convection, which is explained by the increase in the drying rate. This increase is due to the increased heat transfer potential between air and product, thus favouring the evaporation of the water from the product. The effect of temperature and time on drying rate is well documented in the literature (Torgul and Pehlivan 2002 and Chiang and Petersen 1985) [8, 2].

Table 2: ANOVA on Average drying rates at different drying conditions

Drying condition	Average Drying rate (%db/min)
Open sun drying	2.40± 2.22
Single layer solar dryer under natural convection	3.60±2.23
Double layer solar dryer under natural convection	1.88±1.42
Single layer solar dryer under Forced convection	2.31±2.28
Double layer solar dryer under Forced convection	3.65±5.72

All data are the mean ± SD of duplicate readings.

3.3 Validation of various drying models

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 was calculated by using non-linear regression techniques of SPSS version 22. The moisture ratio data at different drying temperature were fitted to experimental data using Σ-Plot into the three thin layer drying models list. The best model chosen was one having the highest R2 and the least (χ2), mean bias error (MBE), root mean square error (RMSE). These models coefficients and the results of statistical analyses are presented in Table 3 -5.

Table 3: Data for model coefficients and statistical parameters for Logarithmic Model

Drying Method	Logarithmic Model						
	R^2	Chi^2	MBE	RMSE	k	a	C
Open sun drying	0.987	0.0025	0.0043	0.041	0.323	1.252	-0.224
Single layer solar dryer under natural convection	0.975	0.0020	0.0032	0.038	0.399	1.054	-0.029
Double layer solar dryer under natural convection	0.985	0.0033	-0.0016	0.045	0.150	1.299	-0.256
Single layer solar dryer under Forced convection	0.987	0.023	-0.0028	0.009	0.925	1.019	-0.01
Double layer solar dryer under Forced convection	0.989	0.012	-0.0033	0.070	0.998	0.831	-0.169

The parameters k, a and b have been determined for each temperature for each crop using SPSS Version 22. The values of K were found in range of 0.123 to 0.459 for Newton model, 0.140 to 0.480 for Henderson and Pabis and 0.042 to 1.001 for logarithmic model in different drying conditions. The value of a found in range 0.996 to 1.150 for Henderson and Pabis model and for logarithmic model value was observed 0.831 to 2.69. The value of b in logarithmic model was from -1.208 to -0.013. The χ^2 value indicates the relative error of the predictions and low values are indicative of reasonable good fit for most practical purpose for predicting moisture ratio.

Table 4: Data for model coefficients and statistical parameters for Newton model

Drying Method	Newton Model				
	R^2	Chi^2	MBE	RMSE	K
Open sun drying	0.969	0.0041	-0.0206	0.061	0.459
Single layer solar dryer under natural convection	0.975	0.0023	-0.0186	0.040	0.416
Double layer solar dryer under natural convection	0.904	0.0044	-0.0122	0.061	0.211
Single layer solar dryer under Forced convection	0.972	0.006	-0.0195	0.024	0.432
Double layer solar dryer under Forced convection	0.986	0.0007	-0.0184	0.067	1.001

In all cases, the value of R^2 was > 0.90 indicating a good fit (Erenturk *et al* 2005). The range of R^2 for spinach varied from 0.904 to 0.986, from 0.932 to 0.987 and from 0.979 to 0.989 for Newton model, Henderson and Pabis and Logarithmic model respectively.

Table 5: Data for model coefficients and statistical parameters for Henderson and Pabis Model

Drying Method	Henderson and Pabis Model					
	R^2	Chi^2	MBE	RMSE	K	A
Open sun drying	0.977	0.0051	-0.0162	0.057	0.480	1.048
Single layer solar dryer under natural convection	0.975	0.0023	-0.0152	0.038	0.428	1.031
Double layer solar dryer under natural convection	0.932	0.0033	-0.0148	0.053	0.227	1.074
Single layer solar dryer under Forced convection	0.974	0.0007	-0.0011	0.0236	0.437	1.011
Double layer solar dryer under Forced convection	0.987	0.0008	-0.0010	0.068	0.981	0.980

4. Conclusion

The fast drying was observed in double layer greenhouse solar dryer under natural convection (275 min) while slowest drying was open sun drying (720 min). The logarithmic model showed higher adequacy of fit between experimental and predicted data for all selected vegetables because of maximum R^2 (0.985 to0.995) with least χ^2, MBE and RMSE are observed in this model.

5. References

1. Akpinar KE. Determination of suitable thin layer drying curve model for some vegetables and fruits. J Food Eng. 2006; 73(1):75-84
2. Chiang WC, Petersen JN. Thin layer air drying of French fried potato slices. J Food Technol. 1985; 20:67-78.

3. Elkhadraoui A, Kooli S, Hamdi I, Farhat A. Experimental investigation and economic evaluation of a new mixed-mode solar greenhouse dryer for drying of red pepper and grape. Renew Energ. 2015; 77:1-8.
4. Ismail MA, Ibn IEM. Mathematical modeling of thin layer solar drying of whole okra (Abelmoschus Esculentus) pods. Intl J Food Research. 2013; 20(4):1983-89.
5. Nijhuis HH, Torringa HM, Muresan S, Yukel D, Leguijt C, Kloek W. Approaches to improving the quality of dried fruits and vegetables. J Food Sci Technol. 1998; 9:13-20.
6. Paul B, Singh PS. A review of solar dryers designed and developed for chilli. Int J of Advent Res. 2013; 1(4):62-72
7. Prakash O, Kumar A. Environomical analysis and mathematical modelling for tomato flakes drying in a modified greenhouse dryer under active mode. Int J of Food Eng. 2014; 16(4):669-81.
8. Togrul IT, Pehlivan D. Mathematical modelling of solar drying of apricots in thin layers. J Food Eng. 2002; 55:209-16.
9. Verma RC, Gupta. Effect of pre-treatments on quality of solar dried amla. J Food Eng. 2004; 65:397-402.