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Drying characteristics of *Byadagi* chilli (*Capsicum annuum* Linn.) using solar tunnel dryer

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■ ABSTRACT : Freshly harvested *Byadagi* chilli (*Capsicum annuum* Linn.) fruits were treated with dipsol, potassium nitrate and citric acid and dried in solar tunnel dryer (STD) and open yard sun drying (OYSD). A comparative study was conducted to evaluate two drying methods with respect to temperature and time combinations. It took 39 h to bring down the moisture content of chillies from 339.14% d.b. to 10.00% d.b. in STD as against 57 h under OYSD. The per cent time saved for drying chilli by using improved method of drying (STD) was found to be 31.57% in comparison with open yard sun drying. Drying took place in the falling rate period and the Newton model was found to be the best fit to describe the drying behavior of *Byadagi* chilli.

■ KEY WORDS : *Byadagi* chilli, Drying model, Moisture content

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Chilli (*Capsicum annuum* Linn.) is an important spice and vegetable crop used all over the world in one form or the other. It is also called as red pepper of capsicum and constitutes an important commercial crop used as condiment, culinary supplement or as a vegetable. Chilli is cultivated mainly in tropical and subtropical countries namely, Mexico, Africa, India, Japan, Turkey and USA. In India, among the spices consumed (per capita consumption), dried chilli contributes a major share (Pruthi, 1998).

Chilli, which contains high moisture content (300-400% d.b.) after harvest, is highly perishable and hence, its processing and storage are of considerable importance to the farmers as well as to the processors and consumers. Normally chilli with a moisture content of 11per cent d.b. is acceptable in the export market but Indian chilli sometimes contains up to 16 per cent d.b. moisture (Singhal, 1999). It is essential to reduce the moisture content and provide aeration to chilli after harvesting to avoid development of microflora and subsequent loss of quality or total spoilage (Singh and Alam, 1982).

Traditionally, the chilli is dried under sun in major production areas of the world but the major problem encountered in sun drying is that the chilli remains at intermediate moisture levels for longer periods resulting browning of the product besides the product being amenable to dirt, dust and microbial infection (Shrivastava *et al.,* 1990). Solar dryers have been reported to have higher drying efficiency (Tiris *et al.,* 1995). Chilli with higher colour value and less pungency are preferred in Europe and the West. Chilli is commercially important for two qualities, *i.e.*, its red colour due to the pigment capsanthin and its biting pungency due to capsaicin. Among these alkaloids, capsaicin and dihydrocapsaicin are the major alkaloids that contribute up to 80% of the total capsaicinoids (Bosland and Votava, 2000). The price that chilli powder fetches in the market is determined by its pungency and colour (Bandyopadhyay and Raghuram, 2007). Therefore, chilli needs to be dried quickly without impairing colour and pungency.

■ METHODOLOGY

The present study on drying of *Byadagi* chilli (*Capsicum annuum* Linn.) was carried out in the solar tunnel dryer (Fig. A) of one tonne capacity installed at the Department of Agricultural Processing and Food Engineering, College of Agricultural Engineering, Raichur, The dryer has tunnel shape made of semi cylindrical metallic (galvanized pipe) structure covered with UV-stabilized transparent thermic polyethylene sheet of 200 micron. Freshly harvested ripened chillies (cv. *Byadagi* kaddi) were procured from the field of a progressive farmer of Matamari village of Raichur district and brought to the laboratory within 5 h of harvesting. The chillies were washed in tap water to remove the soil and dirt adhered to the fruits. The chillies were pre-treated in selected emulsions and

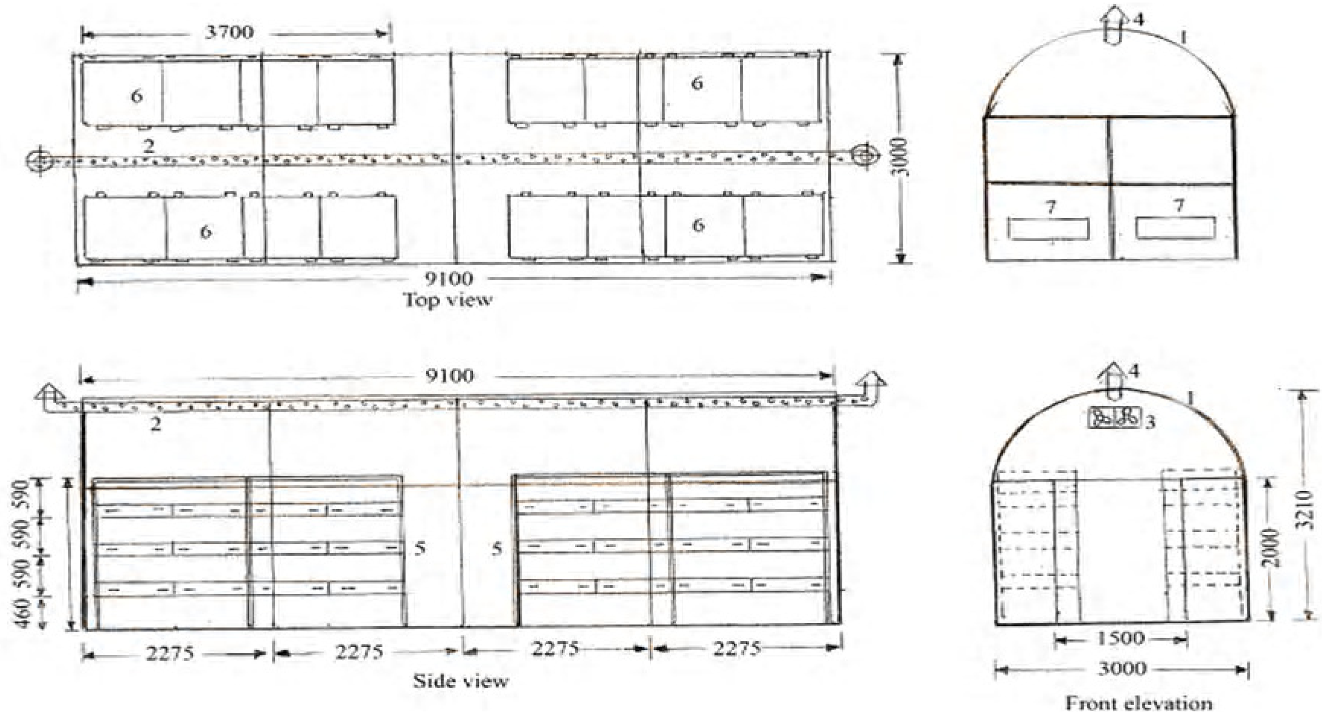

Fig. A: Schematic diagram of solar tunnel dryer

dried in STD and under OYSD. The treatment combinations were laid out in two factorial randomized block design with three replications.

The details of pre-treatments selected for the investigation are as given below.

T_0 – Control (without pre-treatment).

T_1 – Soaking chillies for 5 min in dipsol: K_2CO_3 (25 g)+gum acacia (1 g)+butylated hydroxy anisol (0.01 g)+refined groundnut oil (10 g) (CFTRI, 1979).

T_2 – Soaking chillies for 5 min in KNO_3 (25 g)+gum acacia (1 g)+butylated hydroxy anisol (0.01 g)+refined ground nut oil (10 g) (Papa kumari *et al.,* 2003).

T_3 – Soaking chillies for 20 min in 0.5 per cent citric acid (Tontand and Therdthai, 2009).

The chemicals used for pre-treatment of chilli were of analytical grade and procured from M/S. Industrial Laboratory Equipment (ILE), Bangalore.

The temperature and relative humidity of ambient air and air inside STD were recorded at an interval of one hour during drying period. Initial weight of chilli samples and hourly physiological loss in weight during drying period were taken to study the drying characteristics of chillies in STD and under OYSD. The experimental data were tested for fitting in two drying models.

The drying rate was calculated by using the following equation

$$\textbf{Drying rate (\% d.b. h}^{-1}\textbf{)} = \frac{dM}{dt} \qquad ......(1)$$

where,

dM = Difference in moisture content (% d.b.)

dt = Difference in drying time (h)

The mathematical models *viz.,* Newton and Page models were selected for fitting the experimental data. The models are expressed as follows.

$$\textbf{Newton model : } MR = \exp(-k\theta) \qquad ......(2)$$

$$\textbf{Page model : } MR = \exp(-k\theta^n) \qquad ......(3)$$

where,

$$MR = \textbf{Moisture ratio and it is denoted by} \left(\frac{M - M_e}{M_o - M_e}\right) \qquad ......(4)$$

where,

M_e = Equilibrium moisture content, % (d.b.)

M = Moisture content at any time θ, % (d.b.)

M_o = Initial moisture content, % (d.b.)

K = Drying rate constant

θ Drying time (min)

N = Dimensionless empirical co-efficient

The difference between observed and predicted moisture ratio values at various drying times under different drying methods and chemical treatments were defined as residuals. The residuals were plotted against predicted values of moisture ratios. A model was considered acceptable if the residual values fell in a horizontal band centered around zero, displaying no systematic tendencies (*i.e.*, random in nature) towards a clear pattern. If the residual plots indicated clear pattern, the model was not considered acceptable (Chen and Morey, 1989).

The constants of the selected models were estimated by non-linear regression. The parameters of all the models were estimated by using Origin 7.5 software package (Origin Lab Corporation, Northampton, USA). The fit quality of the proposed models on the experimental data was evaluated using linear regression co-efficient (R^2), mean relative per cent deviation (P), sum of square error (SSE), root mean square error ($RMSE$), chi-square (χ^2)and the trend of residual plots.

The statistical parameters were calculated employing the following equations.

$$P = \frac{100}{N}\sum_{i=0}^{N}\frac{MR_o - MR_P}{MR_o} \quad ......(5)$$

$$RMSE = \sqrt{\frac{\sum_{i=0}^{N}\left(MR_o - MR_p\right)^2}{df}} \quad ......(6)$$

$$SSE = \frac{1}{N}\sum_{i=1}^{N}(MR_o - MR_p)^2 \quad ......(7)$$

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_o - MR_p)^2}{N - z} \quad ...... (8)$$

where,

MR_o = Observed moisture ratio

MR_P = Predicted moisture ratio

df = Degrees of freedom

N = No. of data points

z = No. of constants

RESULTS AND DISCUSSION

During the drying process maximum air temperature recorded in STD was 55.5°C for the maximum ambient air temperature of 45°C. Reduction in moisture content of *Byadagi* chilli (treated and untreated) dried in STD and under OYSD is shown in Fig. 1. The moisture content of chilli got reduced exponentially. Among the pre-treatments, dipsol treated chilli dried in STD took minimum drying time of 39 hours from its initial moisture content of 339.14 %(d.b.) to the final moisture content of 9.41% (d.b.) whereas it was found to be 57 hours under OYSD.

The drying rate of *Byadagi* chilli (treated and untreated) dried in STD and under OYSD is shown in Fig. 2. The drying of *Byadagi* chilli took place under the falling rate period. The drying rate of *Byadagi* chilli treated with dipsol, KNO_3, citric acid and control (untreated) dried in STD varied from 85.40, 76.32, 77.11 and 45.20 % (d.b.) h^{-1} during the first hour of drying to 0.015, 0.015, 0.835 and 0.249 % (d.b.) h^{-1} during the final stage of drying respectively. Similar trend was observed in case of pre-treated chilli dried under OYSD. It was due to the availability of high moisture during the initial stage of drying process. Similar results were reported by Phirke *et al.*(1992). Similar type of results were quoted in the case of red chilli dried in a waste fired dryer Phirke *et al.*(1992).

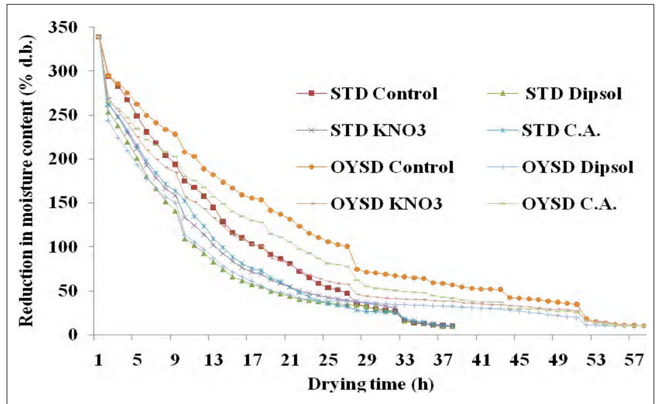

Fig. 1: Effect of different pre-treatments and drying methods on reduction in moisture content of *Byadagi* chilli

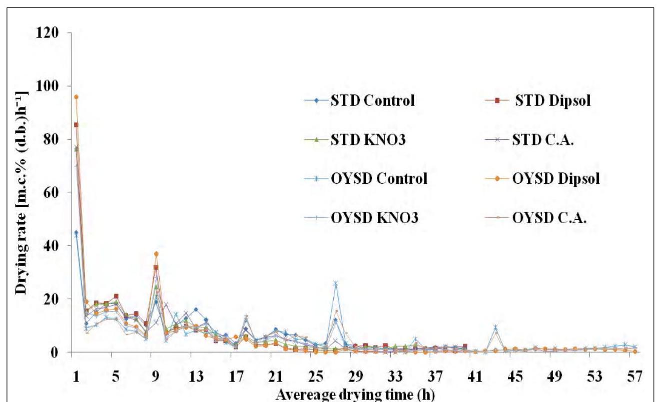

Fig. 2: Effect of different pre-treatments and drying methods on drying rate of *Byadagi* chilli

The effect of different pre-treatments on moisture ratio of *Byadagi* chilli dried in STD and under OYSD is shown in Fig. 3. Moisture ratios at the end of drying in STD were 0.010, 0.009, 0.012 and 0.006 in dipsol, KNO_3, citric acid and control samples, respectively. Similar trend was observed in case of OYSD during final stage of drying. It is evident from Fig. 3 that the moisture ratio of chilli dried in STD was appreciably lower than the chilli dried under OYSD (Kaleemullah and Kailappan, 2006).

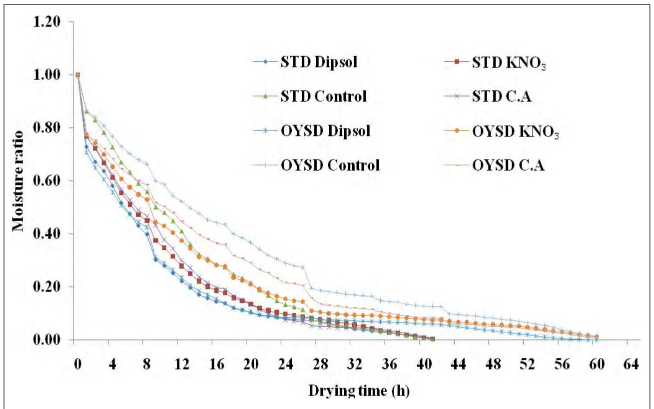

Fig. 3: Effect of different pre-treatments on moisture ratio of *Byadagi* chilli with two drying methods

Newton and Page models were fitted to the experimental data. The residuals of the moisture content of Newton and Page models at different drying methods and different pre-treatments of *Byadagi* chilli were computed. The constants obtained in drying models are presented in Table 1. The Newton and Page equations adequately described the chilli dried under STD over selected pre-treatments. The co-efficient of determination was greater than 0.806 and standard errors were less than 0.2861 in all cases of Page model. In case of Newton model the coefficient of determination was greater than 0.907 and standard errors were less than 0.5919. Gupta *et al.* (2002) reported that the Page model adequately described the convective drying of red chillies over selected range of drying air temperatures.

Statistical results such as the mean relative per cent deviation modulus (*P*), sum of square error (*SSE*), chi-square (χ^2), root mean square error (*RMSE*) and the pattern of residual plots for these fitted models are presented in Table 2. It is evident from the Table 2 that, the Newton model gave the best fit to the experimental data with higher R^2 value of 0.990 and

Table 1 : Constants of drying models

Method	Pre-treatment	Newton	Page	
		k	k	n
STD	T_1	-0.099	-0.055	-0.580
	T_2	-0.102	-0.059	-0.762
	T_3	-0.101	-0.060	-0.798
	T_4	-0.109	-0.075	+1.300
OYSD	T_1	-0.065	-0.033	-0.248
	T_2	-0.064	-0.036	-0.583
	T_3	-0.061	-0.041	-0.821
	T_4	-0.052	-0.044	+1.147

T_1= Dipsol, T_2= KNO_3, T_3=Citric acid and T_4 =Control

Table 2 : Estimated values of statistical parameters of newton and page models employed for two drying methods

Models	Methods	Pre-treatment	R^2	P	RMSE	SSE	χ^2	Residuals
Newton	STD	T_1	0.968	0.078	0.044	1.90×10^{-3}	2.00×10^{-3}	Random
		T_2	0.938	0.151	0.096	9.10×10^{-3}	9.30×10^{-3}	Patterned
		T_3	0.975	0.060	0.039	1.50×10^{-3}	1.57×10^{-3}	Random
		T_4	0.957	0.107	0.083	6.82×10^{-3}	7.00×10^{-3}	Patterned
	OYSD	T_1	0.907	0.163	0.121	1.43×10^{-3}	1.46×10^{-2}	Patterned
		T_2	0.977	0.037	0.039	1.48×10^{-3}	1.51×10^{-3}	Random
		T_3	0.990	0.016	0.019	3.60×10^{-3}	3.70×10^{-4}	Random
		T_4	0.988	0.019	0.027	7.70×10^{-3}	7.80×10^{-4}	Random
Page	STD	T_1	0.875	0.304	0.172	2.90×10^{-2}	3.05×10^{-2}	Patterned
		T_2	0.908	0.056	0.035	1.20×10^{-2}	1.30×10^{-3}	Random
		T_3	0.907	0.226	0.145	2.97×10^{-2}	2.18×10^{-2}	Patterned
		T_4	0.934	0.165	0.128	1.60×10^{-2}	1.69×10^{-2}	Patterned
	OYSD	T_1	0.806	0.304	0.252	6.26×10^{-2}	6.48×10^{-2}	Patterned
		T_2	0.849	0.244	0.255	6.39×10^{-2}	6.61×10^{-2}	Patterned
		T_3	0.924	0.124	0.147	2.13×10^{-2}	2.20×10^{-2}	Patterned
		T_4	0.907	0.150	0.216	4.62×10^{-2}	4.77×10^{-2}	Patterned

the lowest χ^2 value of 3.7×10^{-4}. The results are similar to the findings of Kaleemullah and Kailappan (2006). The trend of the residual plots for Newton model was random. This describes the adequacy of prediction of moisture ratio by Newton model. Newton model was found acceptable with lowest value of mean relative per cent deviation modulus of 0.016, lower *SSE* and *RMSE* values of 3.6×10^{-4} and 0.019, respectively. The Page model described a poor fit to the experimental data with lowest R^2, higher mean relative per cent deviation modulus, *SSE, RMSE,* χ^2 and the trend of the residual plots was patterned.

Conclusion :

The drying characteristics of *Byadagi* chilli in two drying methods with different pre-treatments were investigated. From the present investigation it is concluded that the chilli dried in STD was of good quality over OYSD. The time required for drying chilli from initial moisture content of around 339.14% (d.b.) to the final moisture content of around 10% (d.b.) was 39 and 57 hours for STD and OYSD, respectively. The Newton model was found to be the best fit to describe the drying behavior of *Byadagi* chilli.

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■ REFERENCES

Bosland, P.W. and Votava, E.J. (2000). *Peppers: Vegetable and spice Capsicums*. CABI Publ, CAB Int, Walingfort, UNITED KINGDOM.

Bandyopadhyay, T. and Raghuram (2007). Chilli in soup, *Vikalpa*, **32**(3): 107-121.

CFTRI (1979). Technical note on sun drying of chilli. *Indian Cocoa Arecanut Spices*, **3**:16.

Chen, C. and Morey, R.V. (1989). Comparison of four EMC/ERH equations. 303 *Trans. ASAE*, **32**: 983-990.

Gupta, P., Ahmed, J., Shivahare, U. S. and Raghavan, G. S. V. (2002). Drying characteristics of red chilli. *Agric. Engng. Abs.,* **20**(10): 1975-1987.

Kaleemullah, S. and Kailappan, R. (2006). Drying kinetics of chillies in deep-bed dryer. *J. Food Sci. & Technol.,* **43**(4): 420-424.

Papa kumari, D., Ravishankar, C., Satyanarayana, V. V. and Rao, B. V. (2003). Effect of chemical treatment and drying methods on drying time, pod length and pod damage of chilli (cv. LCA 235). *J. Food Sci. &Technol*., **40**(2): 233-235.

Phirke, P.S., Umbarkar, S.P. and Tapre, A.B.(1992). Development and evaluation of a waste fired dryer for red chilli. *Indian J. Agric. Engg*., **2**: 176-180.

Pruthi, J. S. (1998). Chillies or Capsicums. In: *Major spices of India. Crop management and post-harvest technology*. ICAR, NEW DELHI, INDIA pp: 180-243.

Singhal, V. (1999). Chillies In: Indian Agriculture, Indian Economic Data Research Centre, NEW DELHI, INDIA pp: 420-425.

Singh, H. and Alam, A. (1982). Techno-economic study on chilli drying. *J. Agric. Engg.,* **19**: 27-32.

Shrivastava, M., Ngomidir, M. and Pandey, P. H. (1990). Design and development of a low cost solar dryer. In: Proc. Int. Agric. Engg., Conference and Exhibition, Bangkok, Asian Institute of Technol. BANGKOK, pp: 505-515.

Tiris, C., Tiris, M. and Dincer, I. (1995). Investigation of the thermal efficiencies of a solar dryer. *Energy Conv. Mgmt.,* **36**: 205-212.

■ WEBLIOGRAPHY

Tontand, S. and Therdthai, N. (2009). Preliminary study of chili drying using microwave assisted vacuum drying technology, *http://iat.sut.ac.*

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