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RED CHILI DRYING IN FORCED CONVECTION VTC SOLAR DRIER WITH THERMAL SOURCE

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Abstract:

For drying red chilies, the major focus of current work is to show the dry pattern in forced convection vacuum tube collector (VTC) solar drier in Pune. It has been noted that the exit air temperature of VTC is considerably higher (97-32.9^{0}C) than the outside air temperature of environment. In the drying chamber (DC), this enhances the specific moisture extraction ratio of red chilies. Dissimilar to solar drying with no thermal source, that requires 1.4days, red chilies, takes merely 1.1days to achieve its equilibrium moisture ratio under solar drying with thermal source. The dried red chilies are viewed to be of superior class. Solar drier is considered as toxic free due to no need of conventional energy.

Keywords: *Red Chili, Exit Temperature, VTC, Forced Convection Solar Drier.*

1. Introduction

Protecting agricultural produce is the foremost issue to be overcome by each progressing states. In post-harvest stage, many agricultural produce bears abundant percentages of water due to which produce perish [1]. Conservation is a more essential practice for agricultural protection in a long term. Dehydration is often employed conventional system to save agricultural produce [2-3]. It is usually stated as the utilization of both mass and heat transfer for carrying off humidity from the produce. Dehydration is an earliest practice to decrease micro-organism growth that is widely employed in retaining the dietary worth [4]. It also stretches the existence phase in humid produce for using till its extended time [5].

In recent time, major commercial driers often utilize heated air in industrial drying practice [6]. Meanwhile the foremost problem for the commercial drier is that it is expensive and also requires more fuel energy. Due to above challenges in several states, drier based on solar energy are the better preference than the commercial drier [7]. This answer has resulted in growth for adaptable system of solar drying in the little past decade.

Chilies are the frequently cultivated and famous spice globally. They are the essential nutritional produce containing enough quantity of mineral and fiber. Chilies are viewed as valuable produce for human meal and a single biggest worldwide spice full of micro-nutrients. A dried chili is the most popular food additive and is used for healing ulcer [8].

Khawale et al. showed the experimental and mathematical work to dry chilly utilizing solar dryer with reflector [9]. Gupta et al., have analysed the experimental and theoretical performance for a solar dryer and open sun drying of chilli. From the test, moisture content of chilli was dried to 1.15g water/g dry matter and 0.45g water/g dry matter in open sun drying and solar dryer respectively from its initial content of 4g water/g dry matter [10].

Akintunde examined the effect of pretreatments and methods on drying quality and drying time of chilli pepper. Osmotic sugar and blanching pretreatments were employed before drying. The test reveals that pretreated sample has a significant effect on drying quality than untreated sample. The drying time of osmotic dehydrated sample is lowest compared to the blanching pretreated sample [11]. Haron et al. conducted hydrodynamic study of swirling fluidized bed dryer to dry pepper. It is observed that swirling fluidized bed dryer needs relatively short drying time for pepper compared to conventional sun drying method [12].

Ganiy et al. inspected the impact on osmotic dehydration of chilli varieties. Varieties were osmotically dehydrated in sucrose solution of variable concentration and binary mixture at different processing time. The osmoses chilli variety with higher sugar concentration gives better result while the osmoses chilli variety with lower processing time gives improved solute gain [13]. Anoraga et al. studied the influence of steam blanching pretreatments on chilli drying to that of hot water blanching pretreatments [14].

Artnaseaw et al. assessed the drying parameter of vacuum heat pump dryer to dry chilli. The outcome proved that the rise in drying temperature or a fall in drying pressure reduces the drying time of chilli thus smoothing the surface structure of dried chilli [15]. Kumar et al. investigated the impact of reflector on outlet temperature of one ended evacuated tube solar air collector. The trial was conducted on collector with and without reflector. The finding reveals that case with reflector gives higher outlet temperature than case without reflector [16].

Salve et al. developed the indirect solar dryer with flat plate collector to find the moisture removal rate of chilli drying. The dryer was integrated with phase change material for uninterrupted drying. The outcome reveals that, this method needs less time for drying chill than open sun drying method [17]. Waewsak et al. investigated the mathematical modeling of hot air drying to dry agricultural products. The finding demonstrated the drying air velocity at 1.34m/s and the drying air temperature from 60 to 80°C respectively [18].

Arun et al. evaluated the drying kinetics of chilli utilizing solar tunnel drying method distinguished with the openl sun drying. The test reveals that the drying time decreased by 56% than that of open sun drying method [19].

Evacuated tube solar drier was developed and examined for spice such as garlic clove and herbs such as aloe-vera, bel and neem leaf by Malakar et al. [20] and Singh et al. [21].

From literature survey, it is known that the VTC solar drier works efficiently than the rest of solar drier. Furthermore, it has been noted as per the survey that VTC solar drier had not so far been utilized to dry red chilies. The recent study thus focus to examine the efficient working of drying with thermal source to solar dry red chilies meanwhile differentiate them with no thermal source drier.

2. Methodology

2.1 Experimental Process

Figure 2.1 illustrates the photo view for the forced convection VTC solar drier with thermal source. Air fan, vacuum tube collector, drying chamber, stones and chimney vent respectively are the necessary components of the forced convection VTC solar drier with thermal source.

Firstly, stones as a thermal source are evenly spread on the base portion of the drying chamber to get heated. Then new sample is distributed uniformly along the twin trays located inside the drying chamber to get dried. Once the air fan has started, the air gets moved inside the heater, rapidly become hot, and compelled to pass inside the dryer chamber containing red chilies and stones to gain heat. The red chilies start to decrease in weight using both hot air and lost stored heat from stone due to which the water begins to evaporate. Noting on hour basis of the red chilies weight is done starting from morning to till evening by the moment the sample achieve their equilibrium moisture ratio. Moreover complete test is performed in VTC solar drier with no thermal source.

2.2 Measuring Apparatus

The hourly sun intensity is calculated with a solari-meter on day basis. The anemometer meter is employed to note the wind velocity and surrounding temperature meanwhile

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humidity meter is employed to note the relative humidity. A thermometer is utilized to note temperature on several positions along the VTC solar drier. The weight of dried red chilies is found with electronic balance scale on hour basis. Sample pre, while and post drying in VTC solar drier with and with no thermal source is pictured in Figure 2.2 and 2.3 respectively.

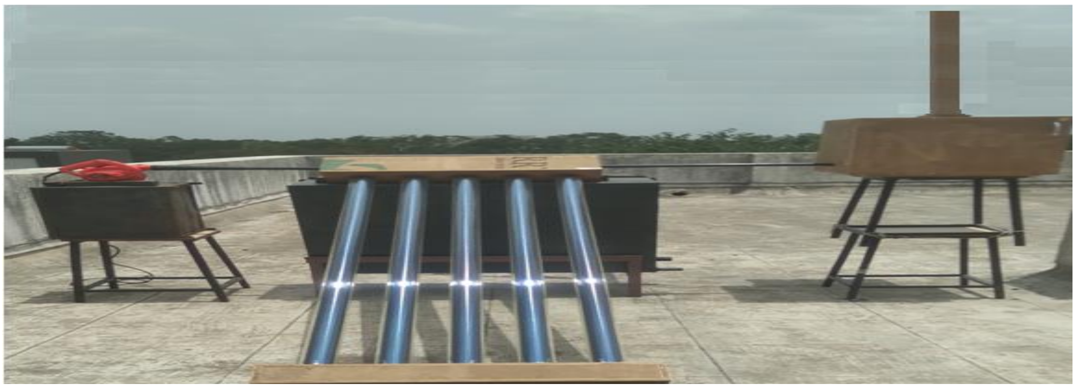

Figure 2.1: Photo of forced convection VTC solar drier with thermal source

Figure 2.2: Red chilies pre, while and post solar drying in VTC drier with thermal source

Figure 2.3: Red chilies pre, while and post solar drying in VTC drier with no thermal source

3. Data Determination

3.1 Moisture Loss

The moisture loss is calculated as [24],

$$ML = (M_i - M_f) \quad (1)$$

Where

M_f and M_i are hourly noted down final and initial mass of red chilies.

3.2 Moisture Ratio

The moisture ratio is determined as [22],

$$MR = MC / MC_i \quad (2)$$

Where

MC_i and MC are red chilies initial moisture content and moisture content at any time.

3.3 Drying Efficiency

The drying efficiency of the VTC solar drier is evaluated as [25],

$$\eta D = M_w\, L \,/\, I_s\, A_c\, t \quad (3)$$

Where

I_s is solar intensity, A_c is collector‘s effective area, t is drying time, M_w is evaporated mass of water from the product; L is latent heat of water's evaporation.

3.4 Specific Moisture Extraction Ratio

The specific moisture extraction ratio of the VTC solar drier is evaluated as [23],

$$SMER = \mathrm{M} / P \quad (4)$$

Where

P and M are blower power and red chilies final mass at any time.

4. Results and Discussion

Hourly change in drying parameters like ambient temperature (T_a), relative humidity (RH_a), solar intensity (I_s) and wind speed (V) in the complete test is depicted in Table 3.1, and 3.2. During the February month in Pune, exit temperature (T_o) and entry temperature (T_i) of VTC whereas the chimney temperature (T_c), top tray temperature (T_t) and also bottom tray temperature (T_b) of DC in forced convection drying with thermal source is noted.

During the experiment, the solar radiation is noticed to fluctuate from 139.4 to 1109.3W/m^2. The DC's inside temperature and environment temperature together noticed to lie between 41.7 to 85.5^{0}C and 28.8 to 32.2^{0}C. It has been seen that the VTC's exit temperature lie between 61.7 and 129.2^{0}C. It is significantly hotter compared to the neighbor surrounding. This demonstrates that the drying rate of VTC solar drier with thermal source is greater in relation with VTC solar drier with no thermal source that minimizes the drying period in forced convection drying.

Moisture parameters which were establish to dry red chilies in VTC solar drier with and with no thermal source is represented in Table 3.3 and 3.4. Figure 3.1 and 3.2 depicts the fluctuation in moisture loss vs. drying period of red chilies by VTC drying with and with no thermal source. The moisture loss from red chilies by VTC drying with thermal source is large in 1.1days in relation with 1.4days VTC drying with no thermal source.

A plot among moisture ratio vs. drying period to examine the moisture ratio fluctuation of red chilies is shown in Figure 3.3 and 3.4. It is viewed that the moisture reduces firstly from its surface while at last within interior portion. The peak efficiency to dry red chilies is determined to be 36.14% whereas the peak specific moisture extraction ratio of VTC drying with thermal source is evaluated to be 0.3338kg/KWh. Besides this, the red chilies dried by drier with thermal source being superior in shade, aroma, shape and savor in relation to red chilies dried by drier with no thermal source.

Table 3.1: Hourly change of several parameters to solar dry red chilies (Day I)

Day Time (hrs:min)	Solar Intensity I_s (W/m^2)	Wind Speed V (m/s)	Relative Humidity RH_a (%)	Temperature at several positions					
				T_a (^0C)	T_i (^0C)	T_o (^0C)	T_b (^0C)	T_t (^0C)	T_c (^0C)
8:15	432.2	0.79	59.3	29.9	36.3	48	36.5	34.5	33.5
9:15	557.3	1.07	57.6	30.4	40.3	65	43.5	42.5	41.5
10:15	807.5	1.24	53.9	30.1	48.2	99.2	66.8	65	63.8
11:15	986.2	1.47	45.6	31.3	52.5	115.8	77.2	74.5	73.7
12:15	1078.5	0.79	38.9	32.2	53.8	125.5	82.3	81.5	79.8
13:15	1109.3	0.29	35	32.2	54.7	129.2	85.5	84.5	82.5
`14:15	1003.3	0.51	32.8	31.9	53	127.8	83.5	80.9	79.2
15:15	757.8	0.71	30.9	30.8	49.8	119.7	78.5	77.3	75
16:15	404.5	0.77	24.1	31	49.5	104.5	72.3	70.8	69
17:15	139.4	0.76	20.6	30.4	50.3	87.5	64.7	63.3	61.5

Table 3.2: Hourly change of several parameters to solar dry red chilies (Day II)

Day Time (hrs:min)	Solar Intensity I_s (W/m^2)	Wind Speed V (m/s)	Relative Humidity RH_a (%)	Temperature at several positions					
				T_a (^0C)	T_i (^0C)	T_o (^0C)	T_b (^0C)	T_t (^0C)	T_c (^0C)
8:15	459.8	1.39	61.1	28.8	35.5	47.1	33	31.5	30.5
9:15	545.8	1.52	59.6	29.9	39	61.7	42.7	41.7	41
10:15	717.9	1.39	56.5	30.1	46	91	62.3	60.2	59
11:15	906.6	1.45	50.3	30.7	49.5	108.8	72.5	70	69
12:15	1029.2	1.11	45.2	31.4	50	119.5	78.7	77	75.2

Table 3.3: Hourly change of moisture loss and moisture ratio of red chilies in VTC solar drier with and with no thermal source (Day I)

Drying Time (hrs)	Solar Drying with Thermal Source (VTC)			Solar Drying with No Thermal Source (VTC)		
	Mi (kg)	ML (kg)	MR	Mi (kg)	ML (kg)	MR
0	1.993		1.0000	1.993		1.0000
1	1.865	0.128	0.9220	1.885	0.108	0.9342
2	1.675	0.189	0.8058	1.744	0.141	0.8480
3	1.419	0.256	0.6491	1.575	0.169	0.7446
4	1.124	0.295	0.4686	1.369	0.206	0.6185
5	0.829	0.295	0.2881	1.126	0.243	0.4698
6	0.595	0.234	0.1450	0.884	0.242	0.3218
7	0.457	0.138	0.0604	0.690	0.194	0.2030
8	0.374	0.083	0.0097	0.578	0.112	0.1345
9	0.362	0.012	0.0024	0.469	0.109	0.0678

Table 3.4: Hourly change of moisture loss and moisture ratio of red chilies in VTC solar drier with and with no thermal source (Day II)

Drying Time (hrs)	Solar Drying with Thermal Source (VTC)			Solar Drying with No Thermal Source (VTC)		
	Mi (kg)	ML (kg)	MR	Mi (kg)	ML (kg)	MR
1	0.360	0.002	0.0012	0.394	0.075	0.0219
2	-	-	-	0.371	0.023	0.0079
3	-	-	-	0.365	0.006	0.0042
4	-	-	-	0.361	0.004	0.0018

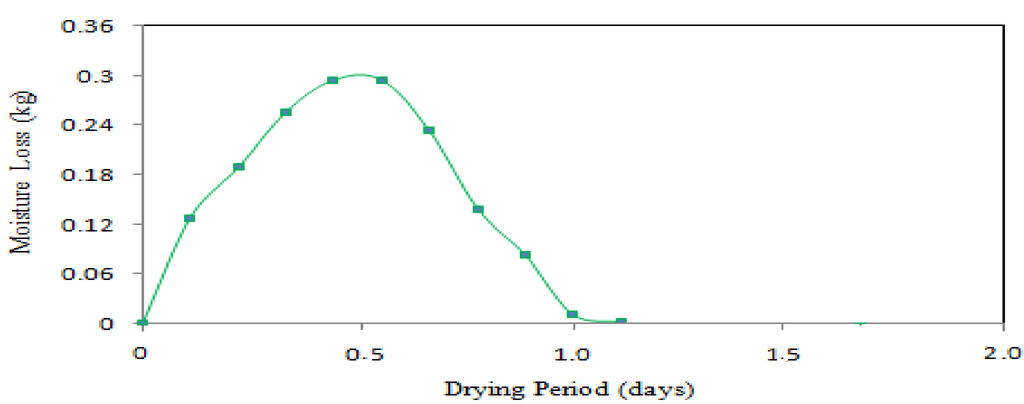

Figure 3.1: Change of moisture loss with drying period to dry red chilies in VTC solar drier with thermal source (Day I and II)

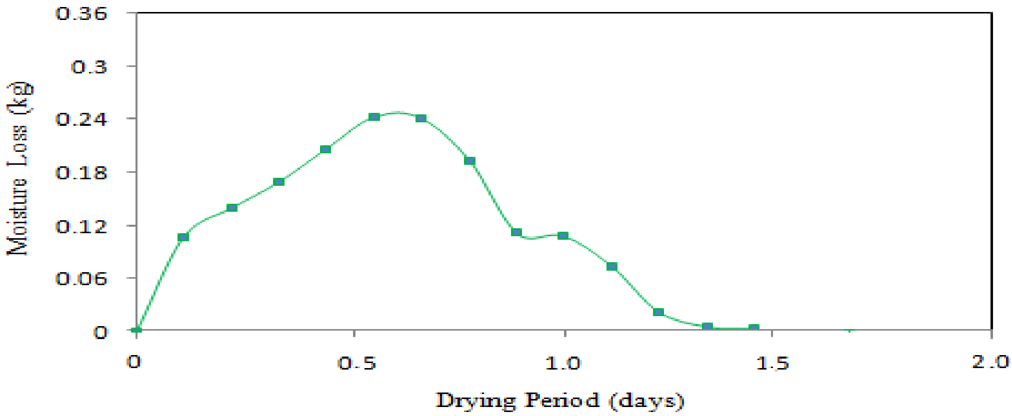

Figure 3.2: Change of moisture loss with drying period to dry red chilies in VTC solar drier with no thermal source (Day I and II)

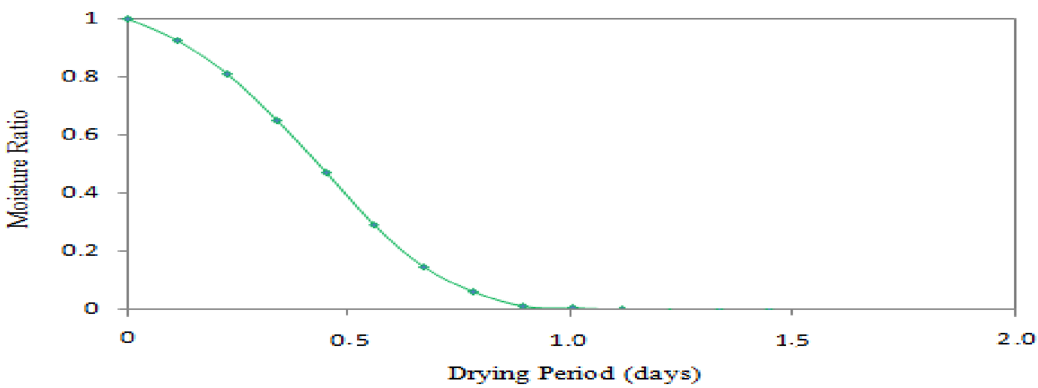

Figure 3.3: Change of moisture ratio with drying period to dry red chilies in VTC solar drier with thermal source (Day I and II)

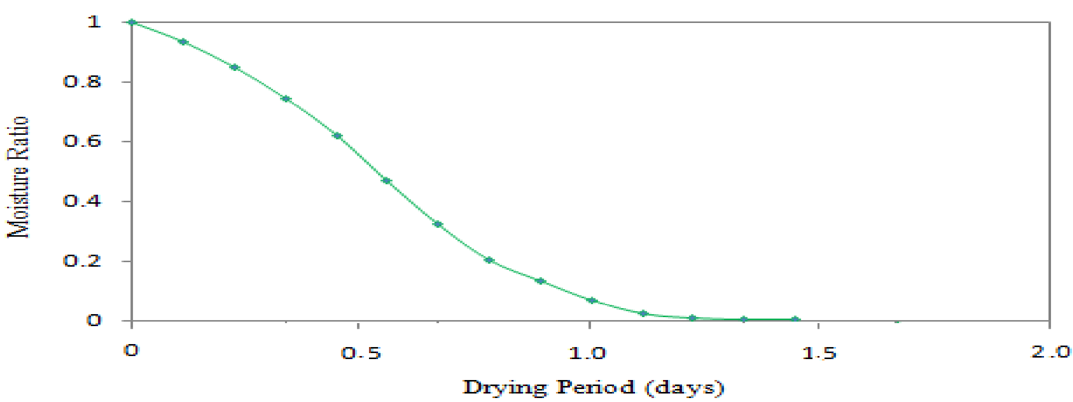

Figure 3.4: Change of moisture ratio with drying period to dry red chilies in VTC solar drier with no thermal source (Day I and II)

5. Conclusion

The testing on solar drier with thermal source assisted with VTC is conducted for the reason of drying red chilies meanwhile it is differentiated from solar drier with no thermal source. The drying period of red chilies is decreased with this drier. The incorporation of DC builds its inlet air temperature considerably high in relation with the environment air temperature. This VTC drier is determined of being 36.14% capable to dry red chilies. Many types of agricultural produce possibly dried with this eco friendly drier. Beside this, there being many chances to preserve the conventional energy. By means of VTC drier, the produce being dried can be send overseas meanwhile huge profit can be gained from it.

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