ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Study and Analysis of Drying Characteristics of Ginger using Solar Drier with Evacuated Tube Collectors

AR Umayal Sundari[1], P Neelamegam [2], and CV Subramanian[3]

[1]Department of Physics, A.V.V.M. Sri Pushpam College, Thanjavur - 613 503, Tamilnadu, India
[2]School of Electrical and Electronics Engineering, SASTRA University, Thanjavur - 613 402, Tamilnadu, India
[3]Department of Architecture, Periyar Maniammai University, Thanjavur – 613 403, Tamilnadu, India

ABSTRACT

In the present study, a solar drier is designed and fabricated with evacuated tube collectors and its performance is studied for drying ginger under the meteorological condition of Thanjavur district, Tamilnadu, India. Ginger is also dried separately by natural sun drying and is compared with the designed drier. Ginger is used in treating variety of ailments due to its high medicinal properties. The drier is employed with different air velocity flow rates (4 m/s, 4.25 m/s, 4.5 m/s, 4.75 m/s, 5 m/s). Drying of ginger in the designed drier reduces the average initial moisture content from 85.62% to a final moisture content of 0.92% in 6 hours. This is less than half the time taken by natural sun drying (13 hours). The efficiency of the drier varied from 31% - 40.4% for different air flow rates. The results show that the rate of drying is more if the air flow is more. It is also found that the quality of the dried ginger in the designed solar drier is high as compared to the one dried in natural sun drying. From the performance, quality and quick rate of drying it is evident that solar drier with evacuated tube collector is more compatible than other driers.

Keywords: Solar drier, Evacuated Tube Collector, Ginger, Air velocity flow rate, Moisture content, Efficiency.

Corresponding author

INTRODUCTION

Ginger or *Zingiber Officinale*, an herb found chiefly in Asia is believed to be a native of South East Asia. It is the most important cash crop of the world. The root which is a rhizome is the part used commonly. It is a tropical crop and is hot and dry in nature. It is spice which is used in cooking. It also has many medicinal values and is used in treating variety of ailments. Gingerol, an oleoresin in ginger accounts for the aromatic and pungent characteristics which makes it indispensible in the preparation of food, beverages and medicine. It is cultivated in India, China, Japan, Nigeria and Indonesia. India is the largest producer and consumer of ginger contributing about 32.75% (305900tons) of total world's ginger production [1]. It is grown almost in all the states of India. Ginger has been valued for its antibacterial properties for 1000s of years. Out of the total production about 50% is consumed as green ginger, 30% is converted into dry ginger and 20% as seed materials. Major share of the dry ginger produced is dried and exported due to its medicinal properties. Dried ginger is used in the treatment of stomach ache, nausea, indigestion, asthma etc. World trade in ginger is estimated to be $190 million per year [2].

This commercially important edible spice requires effective drying so as to attain a very low moisture content to minimize the wastage due to microbial and fungal attacks. There are different techniques used to dry different food products. The traditional natural sun drying has plenty of disadvantages. Natural sun drying is unhygienic and also takes long duration for drying which in turn reduces the quality of the product. Crops harvested during rainy season get spoiled due to poor weather condition. Drying is an excellent way to preserve food and solar food dryers are an appropriate food preservation technology for a sustainable world [3]. Solar drier with collector is one of the best drying techniques to dry edible fruits and vegetables.

Ezekoye et al designed, constructed and characterised a domestic solar dryer for agricultural applications which shows increased collector efficiency and dryer efficiency [4]. Thin layer solar drying of Cuminum Cyminum grains by means of solar cabinet dryer using flat plate collector reported by Mehdi Moradi et al shows that natural convection solar drying air flow rate in mixed mode is selected as the best method for drying Cuminum [5]. Mohanraj et al has reported that the drier with heat storage material enables to maintain consistent air temperature inside the drier [6]. Chanchal Loha et al have studied the thermal conductivity of ginger and have established a cubic polynomial expression to show that thermal conductivity decreases with decrease in higher hot air temperature rise and efficiency with short drying period for glass glazing as compared to polycarbonate sheet [7]. Ayyappan et al have developed and made experimental investigation on a natural convection solar tunnel dryer for drying bitter gourd under the meteorological conditions of Pollachi, India, in which the quality of the bitter gourd is good as compared to open sun drying [8]. Avadesh Yadav et al have observed that down flow configuration is more effective than up flow condition at all flow rates due to lesser losses in down flow in the experimental study made on evacuated tube solar collector for heating of air in India [9]. Darshit et al constructed a double shelf cabinet dryer and coupled with flat plate solar air heater for drying of green chillies and potato chips in hot and dry climate of Jaipur, India and have observed higher hot air temperature rise and efficiency with short drying period for glass glazing as compared to polycarbonate sheet [10]. Lamnatou et al have performed experimental investigation and thermodynamic performance analysis of a solar dryer using an evacuated tube air collector for apples, carrots and apricots [11].

From the literature, it is found that most of the driers make use of flat plate collectors. But the new evacuated tube collector has many advantages compared to flat plate collector which shows improved efficiency and better performance even in bad weather.

Thus, in this research work, an attempt has been made to design and develop a novel solar drier with evacuated tube collector and study its performance on ginger at different air velocity flow rates (4 m/s, 4.25 m/s, 4.5 m/s, 4.75 m/s, 5 m/s) and compare it with natural sun drying in Thanjavur, Tamilnadu, India.

MATERIALS AND METHODS

Design Calculations

Declination (δ)

The angle between the sun's direction and the equatorial plane is given by [4], [12] as,

$$\delta = 23.45 \sin [0.9863(284 + n)] \text{ -----------------------(1)}$$

Where (n) is the day in the year which varies from n = 1 to n = 365.

Optimum Collector Slope (β)

The optimum collector slope is determined by [4], [12] as,

$$\beta = \delta + \phi \text{ -----------------------(2)}$$

Where (δ) is the angle of declination for Thanjavur, Tamilnadu, India and (ϕ) is the latitude of the location.

Design Parameter (R)

The design parameter of the drier is given by [3] as,

$$R = SA / V \text{ -----------------------(3)}$$

Where (SA) is the surface area of the glazing of the collector and (V) is the volume of the drying chamber. If the ratio is equal to or greater than three then the design of the drier is said to be good.

Experimental Set-Up

The novel solar drier mainly consists of a drying chamber, Evacuated Tube Collector (ETC), a blower and a chimney. The size of the drying chamber used for study is 18’ x 18’ x18’ which is made of stainless steel sheets of thickness 25mm and insulated on all sides with rock wool slab of thickness 50mm compressed to 40mm to prevent the loss of heat. The chamber consists of three Aluminium perforated trays to place the product for drying. It consists of six evacuated tube air collectors with a copper header for heat exchange. The twin glass evacuated tube collector is made of borosilicate of 1.6mm thickness and the gap between the glass tubes is evacuated. The inner tube of the collector is coated with a three layer magnetron sputter coating (SS – Al N/Cu). Heat loss due to convection, conduction and radiation is thus minimized and it can withstand high temperature due to this technology. The length, inner diameter and outer diameter of each tube are found to be1500mm, 37mm and 47mm respectively. The collector is placed at optimum tilt in accordance with the latitude of Thanjavur district (10°45’ N), Tamilnadu along N-S direction, facing south so as to track maximum solar radiation throughout the day. This collector which is used as heat source is connected to the drying chamber with the help of EPDM (Ethylene Propylene Diene Monomer) rubber hose.

A blower motor of 0.335 KW, 1300rpm with a regulator to control the rate of flow of air is attached at the inlet of the solar collector to blow air into the collector. A chimney of height 100cm made of SWG (Standard wire gauge) GI (Galvanised) sheet is used at the top of the chamber which increases the air flow rate inside the chamber under the convective principle of hot air rising up.

Measuring Instruments and Devices

Temperature at various locations (Inlet and outlet temperature of the collector, temperature of all the trays inside the chamber, temperature of the chimney) is measured with the help of RTD (Resistance Temperature Detector) PT100 sensor (6 nos.) connected to SELEC 303 temperature controller and display unit. The ambient temperature, relative humidity and wind speed are measured using a digital anemometer (MASTECH MS 6252B). Solar insolation is measured using a solar power meter (TES-1333). A digital electronic balance is used for weighing the samples (D-Sonic Digital scale: $\pm$ 0.1g accuracy). Regulator in the blower motor is used to vary air velocity flow rates.

Experimental Procedure

Solar drying and natural sun drying experiments are carried out for ginger at different air velocity flow rates. Fresh ginger is cut into thin slices and the initial moisture content is measured using hot air oven, maintained at a temperature of 105°C for 24 hours by taking 200g sample.

Ginger is then spread uniformly on three trays for solar drying and one tray for natural sun drying. The blower motor is then switched on. The air that is passed through the evacuated tube collector gets heated up and is made to flow into the drying chamber where ginger is loaded in three trays. Using the regulator in the blower motor, the air velocity flow rate is adjusted to 4m/s, 4.25m/s, 4.5m/s, 4.75m/s and 5m/s . The entire experiment is repeated and the performance of ginger is studied for different air velocity flow rates.

During the experiment, ambient temperature, relative humidity and wind velocity, solar insolation, inlet and outlet temperature of the collector, temperature of all the trays inside the chamber, temperature of the chimney are recorded on hourly basis from 9.00am to 5.00pm. During the experiment, all the drying trays are weighed on hourly basis until the product acquires constant weight that is equilibrium moisture content.

DATA ANALYSIS

Determination of Moisture Content

The initial mass (m_i) and the final mass (m_f) of the sample are recorded at an interval of 1hour till the end of drying using the balance. The moisture content on wet basis (M_{wb}) is given as

$$M_{wb} = \frac{mi - mf}{mi} \qquad \text{------------ (4)}$$

Determination of Moisture Ratio

Moisture ratio is given as

$$MR = \frac{M - Me}{M0 - Me} \qquad \text{------------ (5)}$$

Where M is the moisture content at any time, M_e is the equilibrium moisture content M_0 is the initial moisture content of ginger.

Determination of Drier Efficiency

Efficiency of a solar drier is calculated as [4], [12]

$$\eta_d = \frac{ML}{IAt} \qquad \text{------------ (6)}$$

Where M is the mass of the water evaporated from the crop, L is the latent heat of vaporization of water, I is the solar insolation, t is the time of drying and A is the effective area of the collector.

RESULT AND DISCUSSION

To study the performance of the solar drier to dry ginger, the parameter SA/V is calculated using equation (3) and is determined to be 4.48 for the designed drier. As SA/V is greater than 3, the design of the drier is good.

At first, the designed solar drier is tested without any load. It is observed that the temperature inside the drying chamber is uniform under no load condition.

The initial moisture content of the ginger is 86.45% (wb), is determined by keeping 200gm of the sample in hot air oven at 105ºC for 24 hours. Ginger slices are dried in the designed solar drier at five different air velocities and natural sun drying. The different levels of air velocity rates under which the experiment is performed are 4 m/s, 4.25 m/s, 4.5 m/s, 4.75 m/s and 5 m/s. A series of tests are conducted and the results are discussed.

Time	Solar Insolation	Temperature (ºC)						
		Amb.	ETC in	ETC out	Tray 1	Tray2	Tray3	Chim.
9.00	322.3	31.8	38	40	33	32	33	32
10.00	689.6	29.7	57	88	59	55	56	57
11.00	912.7	29.7	51	107	70	63	67	69
12.00	1137	30.5	54	119	78	74	75	75
13.00	1170	30.8	62	128	87	78	83	81
14.00	1246	31.2	61	100	80	79	77	75
15.00	1071	31.3	60	123	86	80	83	82
16.00	850.6	31.8	48	126	82	81	79	79
17.00	499.7	32	45	109	75	74	72	72

Table 1: Variation of Solar Insolation, Ambient temperature, ETC inlet temperature, ETC outlet temperature, Tray1 (lower) temperature, Tray2 (middle) temperature, Tray3(upper) temperature and chimney temperature with time of the day for air velocity flow rate of 5 m/s recorded on 21.12.12

Variation of solar insolation, Ambient temperature (Amb), inlet and outlet temperature of the Evacuated tube collector (ETC in and ETC out), Temperature of Tray 1 (Lower tray), Tray 2 (Middle tray) and Tray 3 (Upper tray) are recorded on hourly basis during the entire experimental period. During the experimental period, the solar insolation varied from 88.2W/m^2 to 1309W/m^2; the ambient temperature and the temperature outlet of the evacuated tube collector varied from 29.6ºC to 34.5ºC and 39 ºC to 131 ºC respectively.

Solar insolation and the temperatures at various points recorded on 21.12.12 are shown in table 1. Variation of temperature at various points with respect to time of the day recorded on 06.12.12 is shown in fig.1

ISSN: 0975-8585

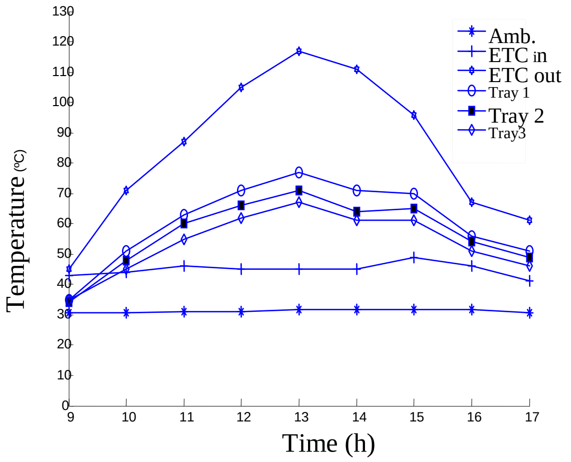

Fig. 1: Variation of Ambient temperature, ETC inlet temperature, ETC outlet temperature, Tray1 (lower) temperature, Tray2 (middle) temperature, Tray3(upper) temperature with time of the day for air velocity flow rate of 4 m/s recorded on 06.12.12

From table1 and fig.1, it is found that ETC out is very high as compared to ambient temperature. This indicates that the performance of solar drier is better than the performance of natural drying. It is also found that the temperature of tray1 (lower tray) is slightly higher than tray 2 (middle tray) and tray 3 (upper tray). Also, it is found that the solar insolation is high during mid-noon and the drier is hot during this period when the sun is overhead.

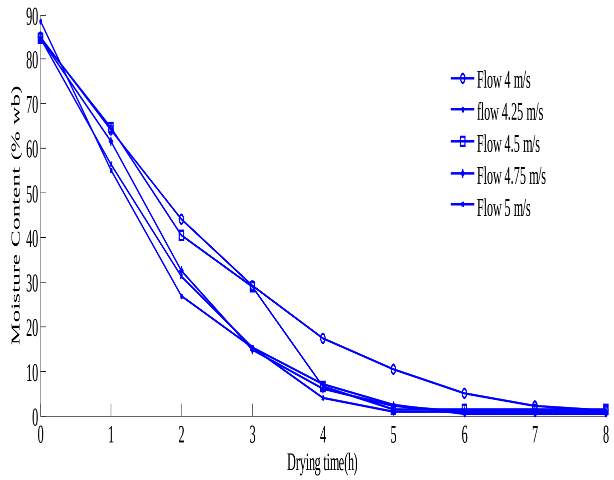

Fig. 2: Variation of Moisture Content (%wb) Vs Drying Time for different velocity air flow rates

Variation of Moisture content (%wb) with respect to drying time for different air flow rates is shown in fig. 2. The initial moisture content varied from 84.8% - 88.6% whereas the final moisture content varied from 0.5% to 1.4% and the corresponding drying time varied from 8 hours to 5 hours for different air velocity flow rates from 4m/s to 5 m/s.

From Table 2 it is observed that the drying time for natural sun drying of ginger is 13 hours whereas the average drying time is 6 hours to dry ginger in the drier. Also it is observed that ginger in tray 1 (lower tray) reaches equilibrium moisture earlier than tray2 (middle tray) and tray 3 (upper tray).

ISSN: 0975-8585

Table 2: Variation of moisture content (% wb) of solar dried ginger in tray 1(lower), tray 2 (middle), tray 3 (upper) and sun dried ginger vs time of the day

Day	Time	MC (%wb) Sun Drying	MC (%wb) Solar Drying		
			Tray 1	Tray 2	Tray 3
Day 1 (06.12.12)	9.00	85.10	85.10	85.10	85.10
	10.00	76.70	63.10	64.4	65.10
	11.00	67.60	42.30	43.70	46.30
	12.00	55.10	25.00	29.80	32.60
	13.00	45.50	15.00	17.80	19.50
	14.00	38.40	8.40	11.20	12.00
	15.00	32.30	2.80	7.0	5.20
	16.00	28.50	1.10	3.2	2.60
	17.00	26.00	1.10	1.10	1.10
Day 2 (07.12.12)	10.00	17.70			
	11.00	12.50			
	12.00	9.00			
	13.00	7.00			
	14.00	1.60			

The efficiency of drier varied from 31% to 40.4% for different air velocity flow rates and sun drying efficiency varied from 10% to 12% on these days. From fig.3 it is observed that efficiency of the drier increases with increase in air velocity flow rates.

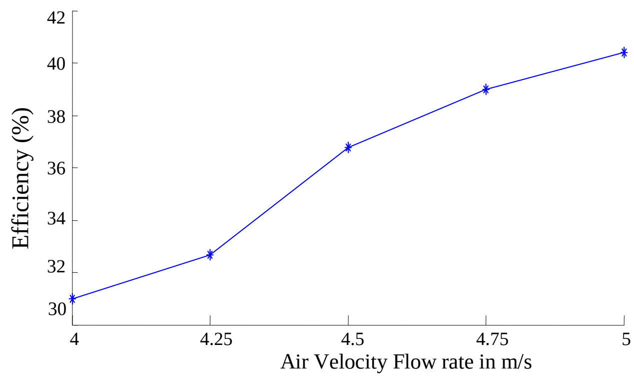

Fig. 3: Thermal efficiency of the solar drier with evacuated tube collector at different air velocity flow rates

Variation of Moisture ratio with drying time is shown in fig.4. It is seen that moisture removal is higher initially and then gets reduced exponentially. This is because of the removal of moisture from the surface first followed by the movement of moisture from internal part of the product to its surface.

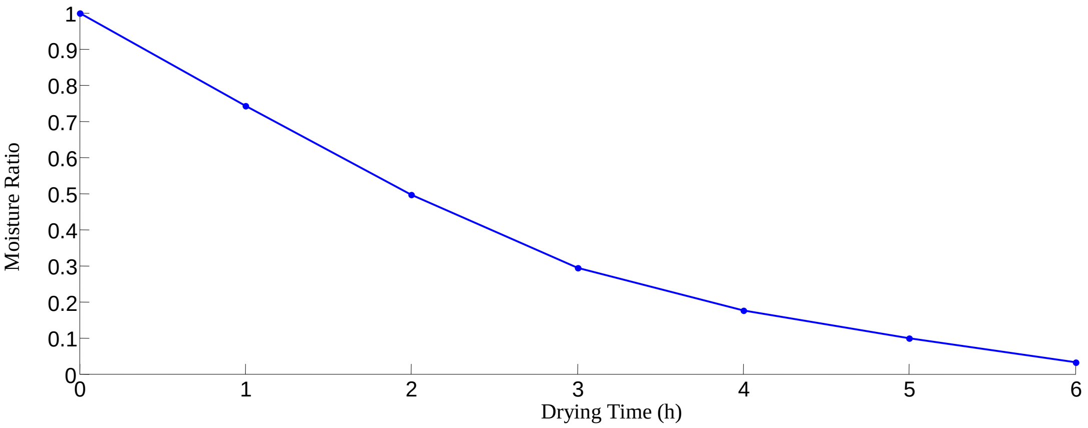

Fig. 4: Variation of Moisture Ratio Vs Drying Time for solar drying of ginger

The natural colour and the appearance of ginger are maintained more when dried in a solar drier as compared to the sun dried one. Also, the odour and flavour of the solar dried ginger is more satisfactory than the natural sun dried ginger. The quality of the solar dried ginger is high as compared to the sun dried one as solar drying is free from dust and contamination and is also protected against rain, birds and insects. The labour required in solar drying is also less as compared to sun drying.

CONCLUSION

The newly designed solar drier with evacuated tube collector reduces the drying period of ginger considerably. The time taken by the solar drier is less than half the time taken by natural sun drying. The efficiency of the solar drier is higher than the natural sun drying. Also the efficiency of the drier is higher for higher air velocity flow rates. The quality of the solar dried ginger using the designed drier is high in terms of colour, flavour and appearance as compared to the natural sun dried one. As the drier makes use of evacuated tube collector, it can perform better during winter season and off-sunshine period than the drier that makes use of flat plate collector. Another advantage of the designed drier is that the drying process can be controlled. Also this drier can be used to dry any agricultural products and products that cannot be dried under natural sun drying. So, it is evident that the newly designed drier with evacuated tube collector is better than any other drier.

REFERENCES

[1] Aggarwal RK. Asian J Agric Rural Develop 2(2): 201-205.
[2] Abubacker ATN. Export Potential of Ginger. 2009; Available: http://top5ofanything.com/index.php?h-7a31105c.
[3] Dennis Scanlin. 1997; Available: http://www.scribd.com/doc/8392821/Home-Dried-Food.
[4] Ezekoye BA, Enebe OM. The Pacific J Sci Technol 2006; 7(2): 185-190.
[5] Mehdi Morali, Ali Zomorodian. American-Eurasian J Agric Environ Sci 2009; 5(3): 409-413.
[6] Mohanraj M, Chandrasekar P. J Eng Sci Technol 2009; 4(3): 305-314.
[7] Chanchal Loha, Reeta Das, Biplab Choudhury , Pradip K Chatterjee. J Food Proc Technol 2012; 3(6).

ISSN: 0975-8585

[8] Ayyappan S, Mayilsamy K. J Sci Industr Res 2010; 69: 635-638.
[9] Avadhesh Yadav, Bajpai VK. World Academy Sci Eng Technol 2011; 79: 81-86.
[10] Darshit Parikh, Agrawal GD. Int J Renewable Energy Res2011; 1(4): 224-231.
[11] Lamnatou Chr, Papanicolaou E, Belessiotis V, Kyriakis N. Applied Energy; 2012; 94: 232-243.
[12] Ahmed Abed Gatea. J Agric Biotechnol Sustainable Develop 2011; 3(4): 65-71.