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Study of Drying Characteristics of Turmeric Slices in Solar-Biomass Hybrid Drying System

Ajinkya Deshpande [a++*], Chaitali Kulkarni [b#], N. N. Desai [c†], V. M. Modi [a‡] and U. D. Dobariya [a++]

[a] Department of Renewable Energy, CREEE, SDAU, SK Nagar, India.
[b] DAICT, SDAU, SK Nagar, India.
[c] Department of Agricultural Engineering, CREEE, SDAU, SK Nagar, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted for evaluation of solar-biomass and hybrid drying system for turmeric slice drying. The turmeric slices were dried in month of January. The experiment was concluded that the drying of turmeric slices of 3 mm thickness took 10 hours for drying on an average insolation rate of 1158 W/m². The temperature inside the dryer was higher near to heat exchanger and decreased as tray placed far away from heat exchanger. The thermal inertia of solar-biomass hybrid dryer was broken within 1.250 hrs. The full load performance was carried out with the same loading rate i.e. 67.42 kg per batch and dryer had 24 trays each tray containing 2.760 kg turmeric slice. The drying operation batch was completed in 8 hrs in day. The maximum temperature achieved inside the dryer was 55°C at 10 % relative humidity and 1158 W/m² solar insolation. For drying of turmeric

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[++] *Assistant Professor;*
[#] *Computer Programmer (Contractual);*
[†] *Assistant Professor & Head;*
[‡] *Associate Professor & Head;*
**Corresponding author: E-mail: ajinkyaagroneer@sdau.edu.in;*

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slices, initial moisture content 71.41% (w.b) and operation were stop at 0.2% (w.b.) moisture content. The maximum turmeric drying rate in solar-biomass hybrid drying system was observed 0.150 kg/hr at 13.00 hrs. The maximum drying efficiency of turmeric slice in solar-biomass hybrid drying system was recorded as 37.03%.

Keywords: Efficiency; solar-biomass hybrid dryer; moisture content.

1. INTRODUCTION

"Drying is an essential process used all over the world for the preservation of farm produce. It helps in reducing the water activity of the agro-produce to safe storage limit. There are many drying methods are used to dry different food produce at different drying conditions. The traditional mechanical dryers are more efficient and less time consuming than open sun drying. Traditional dryers also provide uniform high quality dried produce but such units are uncommon in rural areas having limited product volume and financial resources. Solar and biomass energy can be used in drying resulting reduction of drying time and specific improvement of the product quality in terms of color, taste and texture in comparison to open sun drying. Solar hybrid drying was observed to be a better option for drying of turmeric to improve its quality characteristics (Gill and Mittal 2019). A 25 kg capacity indirect solar drier has been constructed for the drying of fruits vegetables, seeds and medicinal plants. The drier works during clouds and after sunset resulting fast drying due to heating from bulbs provided in the solar air heater (Aggarwal 2011). In open sun drying, products are spread on ground in thin layer where they are exposed to direct sunlight and wind carrying dust. Considerable losses occur during this drying process because of influences such as rodents, birds, insects, rain and microorganisms" (Dhondge et al. 2019). "This causes degradation in produce quality and the product not to be marketable. The study indicated that different drying methods remarkably influence the physicochemical properties, essential oil yield and chemical composition of C. longa rhizomes. Turmeric (Curcuma longa) (Family: Zingiberaceae) is used as condiment, dye, drug, and cosmetic in addition to its use in religious ceremonies. India is a leading producer and Turmeric is an important spice grown in India since ancient times (Hegde and Bhat 2018). India is the largest producer, consumer and exporter of turmeric in the world. Solar drying, particularly hybrid solar drying technology, is a promising alternative that balances efficiency, cost, and environmental impact. Solar-powered biomass backup dryers address these issues and offer a more sustainable alternative (Mahajan et al. 2024). The effect of temperature on fluidized bed drying was evaluated at 50–80°C, finding that there were no significant differences in the curcuminoid content and antioxidant capacity of turmeric powder. Fluidized bed drying, producing a turmeric powder with a high content of bioactive compounds, when compared to convection oven and solar drying (Llano et al. 2022.

2. MATERIALS AND METHODS

2.1 No Load Testing

The no load test was conducted without the products in the drying chamber to estimate the performance of the developed system. The test was conducted from 9.00 AM to 5.00 PM. The variation in temperature, relative humidity and air velocity at different points of the drying chamber was observed to estimate the no-load performance of the system.

2.2 Full Load Testing

The solar conduction drying is a more energy-efficient process for the drying of turmeric rhizomes, but the drying time is much higher than that of air drying (Donde et al. 2020). "The full load testing of drying system was performed to estimate the performance in actual load conditions. In this testing, the drying unit was loaded fully to its designed product capacity of agriculture produce. The initial weight and moisture content of the samples were recorded. The sliced samples lost moisture rapidly as compared to whole rhizomes and had higher drying rates. In solar hybrid drying maximum drying rates were observed in solar drying with electrical backup as compared to solar drying without backup (Gill et al. 2018). One tray was weighed regularly after every hour to find out drying rate of product. The temperature and relative humidity at different points of the drying chamber and solar radiation were measured. The final moisture content of the product was measured to estimate drying rate" (Dhondge et al. 2019). The drying operations were conducted in batch wise manner. The full load of drying system was shown in Plate 1 and process flow chart was shown in Fig. 1.

Instrumentation and observations:

The following parameters were measured during the trials: solar radiation, mass of turmeric rhizomes, temperatures, relative humidity and biomass burnt. Initial and final moisture of the product was measured by Sartorius MA 160 moisture analyzer. The mass of the product and biomass fuel was measured with a physical balance.

1. Moisture content

Water content or moisture content is the quantity of water contained in a material, such as soil (called soil moisture), rock, ceramics, fruit, or wood. Moisture content inside food product promotes growth of bacteria, yeasts, and mold. The solar dryer was tested to study the behavior in terms of moisture removal pattern from Tomato slice at different temperature. Moisture content is expressed as a percentage of moisture based on wet weight (wet basis) or dry matter (dry basis). Wet basis moisture content is generally used.

Plate 1. Full load testing of drying system

Fig. 1. Process flow chart of turmeric slices drying

The Moisture content was calculated by the following formula:-

$$M_w(\text{wetbasis}) = \frac{w - d}{w} \times 100$$

$$M_d(\text{drybasis}) = \frac{w - d}{d} \times 100$$

Where,

w = Weight of sample product

d = Dry weight of sample product
M = Moisture content on a percent basis

2. Relative humidity

Relative humidity is the ratio of the partial pressure of water vapor in an air-water mixture to the saturated vapor pressure of water at a prescribed temperature. The relative humidity of air depends on temperature and the pressure of the system of interest.

$$RH = \frac{P_w}{P_{ws}} \times 100$$

Where,

RH = Relative humidity
P_{ws}= Saturation vapor pressure (hpa)
P_w= Vapor pressure

3. Drying rate

The moisture content data in each of experiments were analyzed to determine the Moisture lost by sample in a known time interval. The drying rate was expressed as g water/g dry matter- h.

The drying rate can be calculated as:-

$$DR = \frac{WML}{TimeInterval \times DM}$$

Where,

DR = Drying rate
WML = Weight of moisture loss
DM = Drying matter

4. Solar insolation

Solar insolation is the amount of electromagnetic energy (solar radiation) incident on the surface of the earth. This refers to the amount of sunlight shining down on the area under consideration.

3. RESULTS AND DISCUSSION

The research work was undertaken at the College of Renewable Energy and Environmental Engineering, S. D. Agricultural University, Sardarkrushinagar. The drying experiments were carried out in the month of January 2023. During no load and full load testing; moisture content, relative humidity, drying rate, solar insolation, temperature were recorded.

Full load performance was carried out with the same loading rate i.e. 67.42 kg per batch and dryer had 24 trays each tray containing 2.760 kg turmeric slice. The raw material and slices of turmeric were show in Plate 2 & Plate 3.

The experiment was conducted in batch and experimental data such as temperature, relative humidity and solar insolation were recorded at 10 minute sampling intervals and weight of marked trays were noted in every passing hour. The temperature of drying chamber was set to 55ºC and dried slices as shown in Plate 4.The effects of hot air drying (HAD) and direct solar drying (DSD) on drying kinetics and properties of turmeric. Thermogravimetric analysis confirmed lesser weight loss of curcuminoids for DSD (42.60%) in comparison with HAD (44.77%) (Sharma et al. 2021).

Table 1. Moisture content of row and dried turmeric slices

Sr. No.	Samples	Row turmeric slice (% w. b.)	Dried turmeric slice (% w. b.)
1	Sample 1	71.41	0.1
2	Sample 2	65.00	0.3
3	Sample 3	60.12	0.2
	Average	**65.65**	**0.2**

Plate 2. Row material of turmeric

Plate 3. Row material of turmeric Slice

Plate 4. Turmeric slices after drying

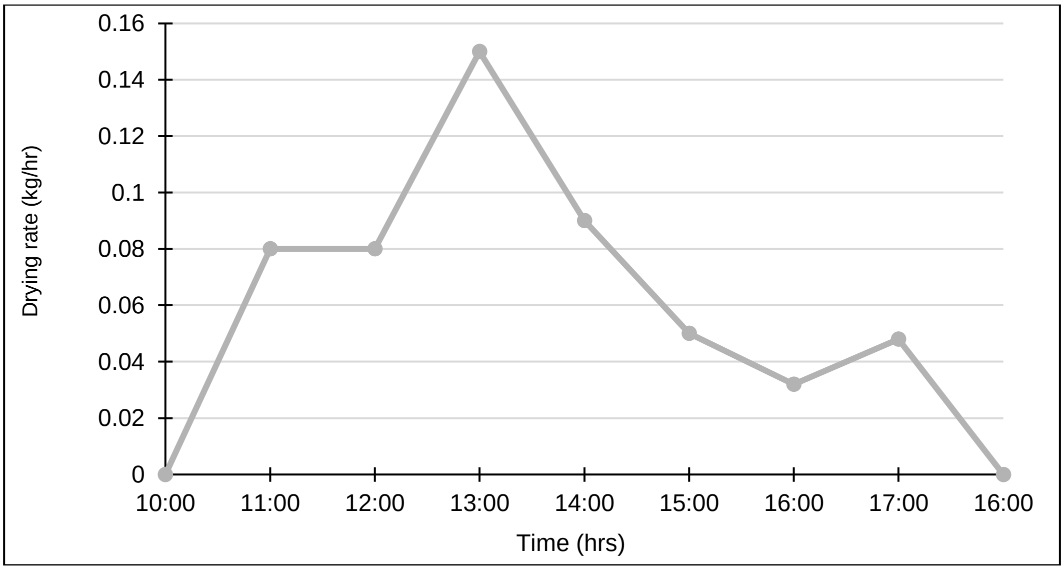

Fig. 2. Drying rate of turmeric slices during full load test

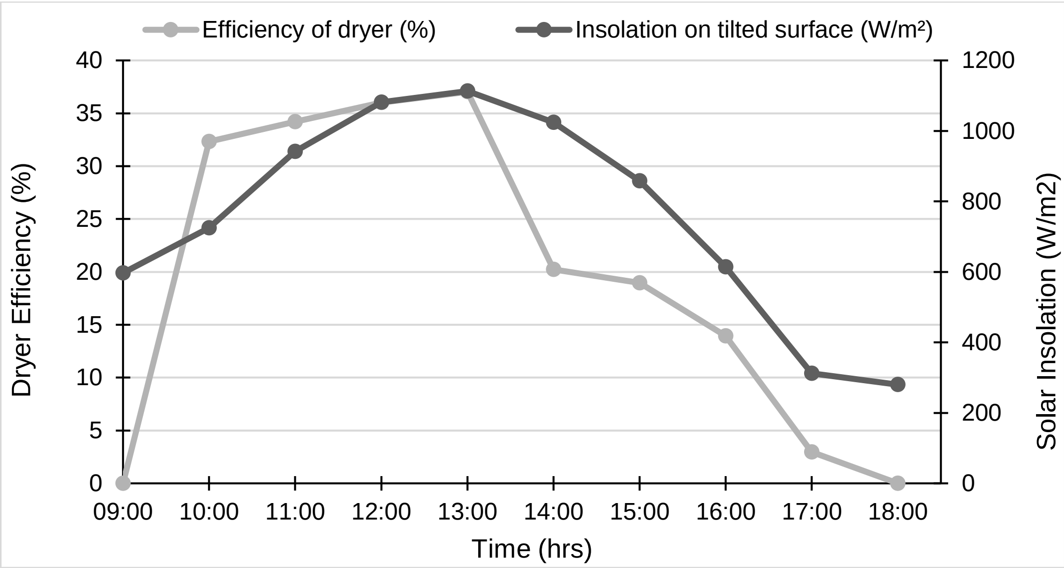

Fig. 3. Drying efficiency curve for turmeric slice drying

The moisture content of turmeric slices were measured before and after drying operations. The total drying time of 8 hours was required to dry turmeric slice in solar-biomass solar drying system in one batch. The moisture content of turmeric slices were recorded with help of Sartorius MA160 moisture analyser. The moisture content on % wet basis were tabulated in Table 1.

3.1 Drying Rate of Turmeric Slices in Dryer

The weight observation of single tray was recorded for calculation of drying rate turmeric slice drying. The graph of time vs drying rate and insolation was represented in Fig. 2 showed that as the drying rate was increased till 13.00 hrs and then gradually decreased. The maximum drying rate 0.150 kg/hr was observed at 13.00 hrs.

3.2 Drying Efficiency Variation

The drying time was 6.00 h in solar greenhouse dryer (GHD) under FC3 case and 11.50 h in OSD for ginger and 6.50 h in GHD under FC3 (0.107 m^3/s) case and 12.50 h in Open sun drying (OSD) for turmeric. The drying efficiency for ginger and turmeric under the FC3 case was 34.13–37.17% and 30.71–33.28%, respectively (Borkakot et al. 2021).

The drying efficiency of the dryer was very important parameter for evaluation of dryer. The variation of drying efficiency with drying time and solar insolation was graphically represented in Fig. 3. The drying efficiency of turmeric slices drying was increased with increased the solar insolation. The drying efficiency was increased in the initial hours of drying time and then fall as shown in Fig. 3. The maximum drying efficiency of turmeric slice in solar-biomass hybrid drying system was recorded as 37.03%. The zero drying efficiency indicated that the product was dried up to its bone dry condition so further drying of the product was not possible.

4. CONCLUSIONS

Solar tunnel drying method is an effective alternative to traditional open sun drying, where retention of curcumin, volatile oil and oleoresin was high, with less drying time (Jose and Joy 2009) The developed solar-biomass hybrid dryer is capable of producing the optimum air temperature for dehydration of turmeric rhizomes. During no load performance, the thermal inertia of solar-biomass hybrid dryer was broken within 1.250 hrs. The drying operation batch was completed in 8 hrs in day. Which is more than the traditional drying i.e., open sun drying had taken 11 days to dry the rhizomes while solar biomass drier took only 1.5 days and produced better quality produce (Prasad et al. 2006). The efficiency of the whole unit obtained was 28.57%. The maximum temperature achieved inside the dryer was 55°C at 10 % relative humidity and 1158 W/m^2 solar insolation. For drying of turmeric slices, initial moisture content 71.41% (w.b) and operation were stop at 0.2% (w.b.) moisture content. The maximum turmeric drying rate in solar-biomass hybrid drying system was observed 0.150 kg/hr at 13.00 hrs. The maximum drying efficiency of turmeric slice in solar- biomass hybrid drying system was recorded as 37.03% which is more than overall dryer efficiency of mixed mode (MFSCD) is 26.5% (Lakshmi et al. 2019).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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