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# Performance Analysis of PVT Based Hybrid Type Solar Dryer for Drying Food Products

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Study Area: Bhubaneswar, Odisha
Coordinates: 20.29.61°N, 85.82.45°E

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## Abstract

The initiative was taken for drying the food products such as potato, ginger, and tomato maintaining hygienic and fast drying. Quadruple DC blowers were coupled at inlet and outlet of flat plate collector for proper circulation of heated air inside the drying chamber as well as exhaust purpose. They were operated by a Solar panel, battery, and charge controller. The two numbers of transparent cover plates were provided by maintaining a proper gap in between them for increasing transmittance. Baffles were provided in order to increase the turbulence effect. The absorbing plates with an attachment of fins were provided after being analyzed and modelled by using ANSYS software. By providing amount heat flow in the bottom face of the absorbing plate and film coefficient or convective heat transfer coefficient on the top of the face steady-state thermal analysis was done. The analysis of temperature, overall thermal energy and exergy, heat flux with confirmation of results in the laboratory, the Hybrid Type Solar Dryer proved thermally efficient and can be used as a competent unit for domestic and industrial uses.

## Introduction:

Preservation of products during peak yields for long term use in lean seasons for retention of flavour, appearance, and quality is the age-old practice in India and the world. From ancient times, driers for drying food grains were carried out by direct sun rays, firewoods, fossil fuels, and coals causing carbon nexus. Those solar driers (called Chula's in India) were of low cost, easy to construct, light in weight, easy to operate maintain, and control but losses colour, decay of leftover tissue's chlorophyll, and above all deteriorates the environment. Later they were improved from direct cabinet driers, simple solar crop dryers, and forced convection dryers but all the arrangements for the drying process were thermally inefficient. After the development of clean and renewable energy set up, innovations in dryers have been for better thermal efficiency and optimal use with modern materials and technology (Gaur *et al*., 2017; Gupta *et al*., 1982; Udomkun *et al*., 2020).

India demands an increase in clean energy generation for attaining a better quality of life. Due to erratic electric supply, and issues for centralized grid-based power warrant clean energy technology as an alternative solution. To address the issue, a number of social enterprises are focusing their efforts on the last-mile delivery of energy solutions. There is a need for an existence of a supportive ecosystem; an ecosystem with a greater flow of information in order so that the diffusion of clean energy products can take place rapidly in India. Such an ecosystem can promote the large-scale replication of clean energy solutions. Solar drying technology is an alternative and clean energy technology which aim is to dry the food products in an unhygienic method of drying the food products and quick process of drying as a comparison to the traditional method of drying. Various types of solar dryers are designed as per heated air drive inside the drying chamber such as direct and indirect types.

Tarigan (2018) had done a CFD simulation for drying agricultural food products in the drying chamber which was integrated with the thermal storage device and got temperature analysis. Rabha et al., (2017) had done experimental work for drying chilli pepper and sliced ginger in a forced convection solar tunnel dryer. Thermal analysis was done. Chauhan et al. (2017) had done thermal analysis on a PV integrated solar dryer by using a collector and without using the collector. The heat losses were reduced by using insulation and double-layer coating was provided inside the collector to increase heat energy. Sebaii & Shalaby (2019) had done mathematical regression

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analysis by drying thymus and mint in a forced convection dryer which was installed according to the latitude of the location.

Manjunath *et al.* (2019) had done CFD simulation on flat plate collector and found due to the presence of pin fin heat transfer rate increased. Tedesco *et al.* (2019) had done experimental analysis on the passive indirect solar dryers and got a coefficient of performance of 0.87. Behera *et al.* (2020) had done a performance evaluation of a Hybrid type of solar Dryer for drying various food products. This was used in both day and night time. The instantaneous efficiency, overall loss coefficient, coefficient of performance was evaluated. Behera *et al.* (2020) had done a thermal analysis of the absorbing plate by using ANSYS software. The temperature profile, total heat flux and directional heat flux were determined. These SPVT dryers are economical, saves overall thermal energy and exergy fuel, electricity, higher removal of moisture, and reduce drying time when compared to other drying arrangements and are better suited to North East India Climates (Patil *et al.*, 2020; Gupta *et al.*, 2020; Norton, 2012; Gupta *et al.*, 2020; Tiwari, 2014; Chow, 2010; Diwania *et al.*, 2020; Veeramanipriya & UmayalSundari, 2021)

## Methodology:

The PVT based Hybrid types of solar dryer consists of a solar flat plate collector, Drying Chamber, Solar Panel, Charge controller, battery, DC blower, Inverter, Electric Coil (Poonia *et al.*, 2018; Tiwari, 2014; Diwania *et al.*, 2020). The solar flat plate collector consists of two numbers of transparent cover plates having 5 mm thickness with a minimum gap of 3mm in between them and it is used to increase transitivity. The absorbing plate which was black coated (3mm thickness, Aluminium material) which was provided with fins in order to increase the heat transfer rate. The insulation (glass wool, 10 mm thickness) provided for reducing heat loss.

For better drying, wire mesh type of treys made up of stainless steel provided inside the drying chamber for even distribution of heated air and drying chamber made up of stainless steel. There were four numbers of DC blower provided at the inlet of collector, an outlet of collector and at the exhaust of drying chamber which was operated by a solar panel having 20 Watt, battery (12 Volt), charge controller (12 Volt, 10 amp) . It was operated by both PV system and Solar thermal flat plate collector.

The experimental set-up of the Hybrid type of solar dryer which was facing towards south and collector was tilted as per latitude of the Bhubaneswar location. The testing was carried out by taking food products such as ginger, potato, tomato and various parameters such as temperature, relative humidity and foodstuff quantity to be dried. The initial, final weight, moisture content, the Plate-1 shows the experimental set up of a Hybrid type of solar dryer which was facing towards south and collector was tilted as per latitude of the Bhubaneswar location. The Steady-state thermal Analysis of the Absorbing plate with the attachment of fins is shown in Fig-1. The testing was carried out by taking food products such as ginger, potato, tomato and various parameters such as temperature, relative humidity and food products quantity to be dried. The initial weight, final weight, moisture content, rate of weight reduction of ginger, potato and tomato were calculated, rate of weight reduction of ginger, potato and tomato were observed.

## Results and Discussion:

For testing the dryer it was placed in a shadow-free location where there is the maximum amount of solar radiation available. At a regular interval of time, parameters like temperature, Absolute humidity, wind velocity, the velocity of blowers at the inlet of the collector, on a glass plate, outlet of the collector, in the drying chamber and at the outlet of the drying chamber was measured.

The experiment was conducted by taking ginger, potato; tomato inside the drying chamber and various graphs was plotted at regular interval of time. At the bottom face of the absorbing plate the amount of heat flow conducted i.e. 10660 watts has been provided. The top face of absorbing plate and film coefficient or convective heat transfer coefficient =100 $W/mm^2\,^{o}C$. Temperature analysis and total heat flux were obtained by steady-state thermal analysis (Fig-1). The agri-products considered for experimental purposes before and after drying is shown in (Plate-2).

Plate-1: Experimental set up of Hybrid type of Solar dryer and testing of dryer

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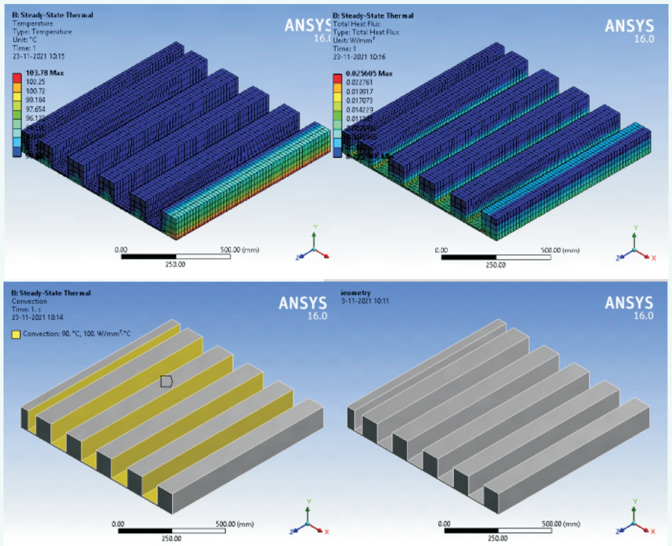


Figure-1: Steady-state thermal Analysis of Absorbing plate with attachment of fins

**The analysis Parameters (Drying of Ginger):** the absolute humidity, wind velocity, and temperature are the prime distinctive constraint that helps in expelling moisture, drying of the foodstuffs, and day-time exposure controls the energy intake.

*(a) Absolute Humidity vs time:* the absolute humidity (g/m3), wind velocity, and temperature is recorded from the hygrometer, anemometer and the thermometer. Fig-3(a) explains comparisons between the humidity of atmospheric air and hot air circulated within the drying chamber while drying ginger. It was observed that humidity inside the drying chamber was more as compared to atmospheric air as it absorbs moisture content from the food products to be dried.

In Fig.-3(b); the Temperature profile of the hybrid type dryer was estimated at various points while drying ginger and the maximum temperature reached 72°C while the atmospheric temperature was 34.5°C. The temperature inside the drying chamber was 56.8°C and the temperature gradually decreases from 12 PM to 4 PM with respect to time period. Fig.-3© shows the velocity of air at different points such as the inlet of collector, the outlet of collector, at the outlet of drying chamber were measured by connecting 4 numbers of DC blowers operated by PV panel, charge controller and battery. It was observed that there was a slight difference in velocity of air with respect to time while drying ginger and a constant mass flow rate of heated air circulated inside the drying chamber.

**The analysis Parameters (Roasting of bread):** bread has become part to our daily food. It is tasty and palatable when it is roasted. The consumption of electricity in individually families is high and taxed upon the house head. The absolute humidity, wind velocity, and temperature have been observed in the solar dryer assembled (Plate-3).

Plate-2: The shape and colour of ginger before and after drying

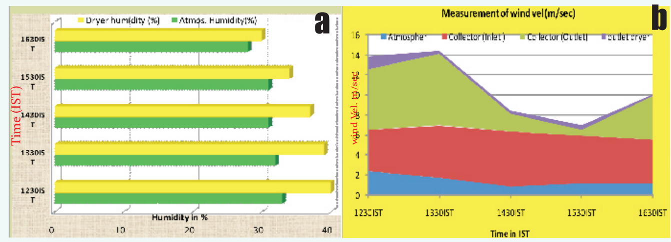


Figure-2: a) Abs. humidity vs. time during drying; b) Wind vel. vs Time during drying (ginger)

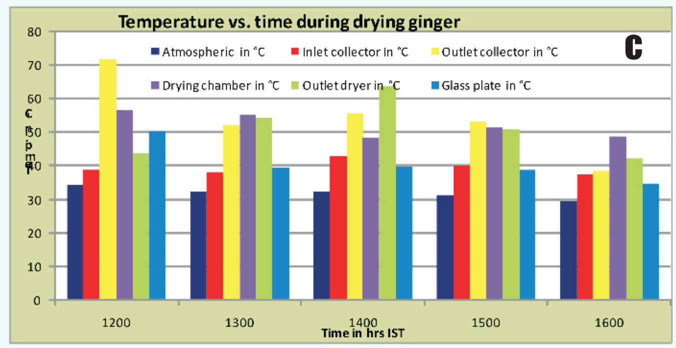


Figure-2: c) Temperature vs. Time during drying of ginger at various points

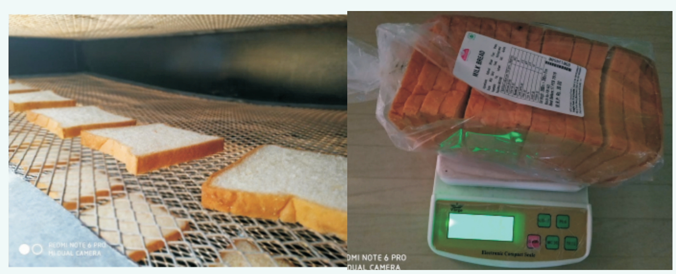

Plate-3: Showing the process of drying of bread prior and during roasting

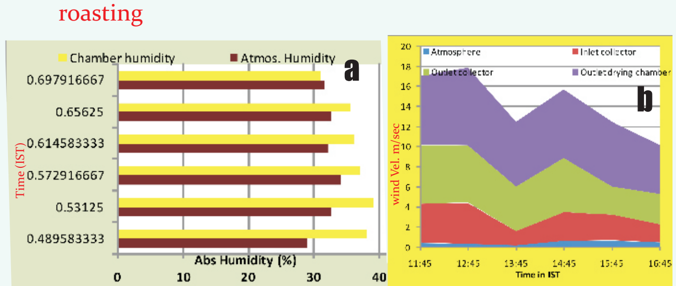


Figure-3: a) Abs. Humidity Vs Time; b): Time vs. wind velocity (m/sec) [Roasting bread)

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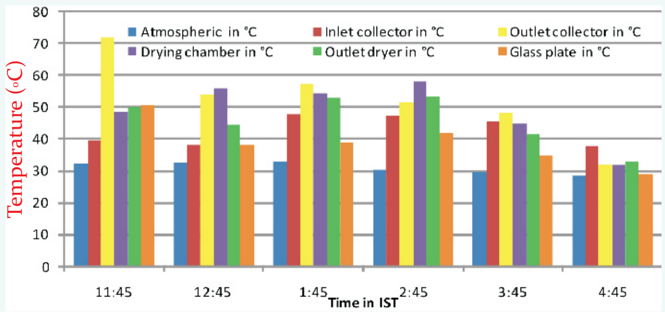


Figure-3: c) Temperature Vs Time during drying of bread at different places of drier

Plate-4: The colour and shape of fresh potato chips during drying

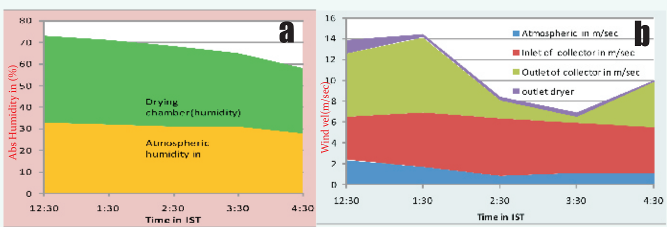


Figure-4: a) Absolute humidity vs. Time; b) Time vs. wind vel. at junctures during drying potato

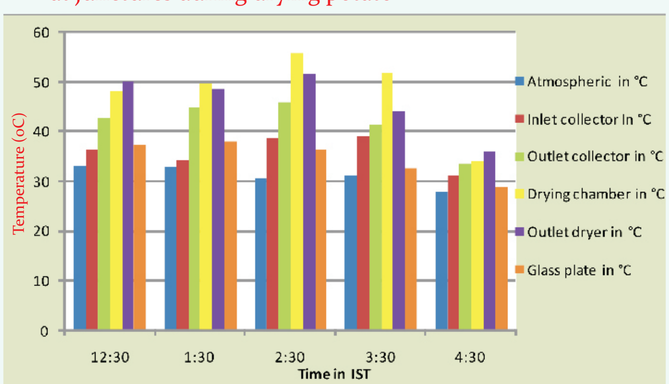


Figure-4: c) Temperature Vs Time at various points during drying of potato

Plate-5: During drying of tomato before and after within the dryer

Plate-6: The night mode of operation and observation of the solar dryer

Fig.-3 (a) depicts comparisons between the humidity of atmospheric air and heated air circulated inside the drying chamber was done while drying bread. Fig.-3 (b) shows the velocity of air at different points such as inlet of collector, the outlet of collector, at the outlet of drying chamber was measured by connecting 4 numbers of DC blowers operated by PV panel, charge controller and battery and constant mass flow rate of air was maintained while drying bread. Fig.-3 (c) narrates the temperature profile of hybrid type dryer was estimated at various points while drying bread and maximum temperature reached 71.8°C while the atmospheric temperature was 32.3°C. The temperature inside the drying chamber was 48.6°C and the temperature gradually decreases from 12 PM to 4 PM with respect to time period.

**The analysis parameters (dried potato chips):** fried potato chips are common and favourite crispy snacks in India. They usually practice is that the chips need to be sun-dried before frying. A lot of time is lost if it is dried from fresh potato and undergo a substantial amount of pilferage in the drying process. The wet and fresh potato chips can be dried by the solar drier at a low cost, within less time and maintaining the standard (Plate-4).

Fig.-4 (a) depicts comparisons between the humidity

Table- 1: Drying Parameters (Humidity, Wind vel. & Temp. at various points for drying Tomato chips

| Time | Abs. Humidity (%) | | Wind velocity (m/sec) | | | | Temperature ( in at various segments | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (IST) | a | b | c | d | e | f | g | h | I | j | k | l |
| 11:20 | 30.5 | 40 | 0.89 | 1.96 | 4.31 | 4.92 | 32.4 | 39 | 61 | 39.4 | 43.3 | 44 |
| 12:20 | 33 | 38 | 0.18 | 1.69 | 6.83 | 6.12 | 28.6 | 41.1 | 57.9 | 48.6 | 50.4 | 45.2 |
| 13:20 | 31.5 | 38.5 | 1.52 | 2.2 | 4.17 | 6.52 | 30.2 | 38.2 | 56.9 | 62.8 | 63.3 | 41.7 |
| 14:20 | 34.5 | 37 | 0.57 | 1.78 | 3.05 | 4.96 | 31.3 | 38.6 | 58.6 | 47.1 | 47.4 | 42.1 |
| 15:20 | 31 | 34 | 1.78 | 1.94 | 3.18 | 7.08 | 29.5 | 45.2 | 42.7 | 42.7 | 43.1 | 35.7 |
| 16:20 | 29.5 | 30.5 | 0.25 | 2.24 | 3.71 | 3.88 | 28.7 | 35.7 | 34.7 | 34.7 | 30.2 | 29.1 |

a- Atmospheric (%); b-Drying chamber (%); c-Atmosphere; d-Collector inlet; e-Collector outlet; f-Dryer outlet; g-Atmosphere; h-Collector Inlet; i-Outlet collector; j-Drying chamber; k-Dryer outlet; l-Glass plate of atmospheric air and heated air circulated inside the drying chamber was done while drying potato. Fig.-4 (b) narrates the temperature profile of hybrid type dryer was estimated at various points while drying potato. And it was observed that temperature gradually decreases from 12 PM to 4 PM with respect to time period.

Various parameters during drying of tomato Slices: in Table-1, the velocity of air at different points such as inlet of collector, the outlet of collector, at the outlet of drying chamber was measured by connecting 4 numbers of DC blowers operated by PV panel, charge controller and battery and constant mass flow rate of air was maintained while drying tomato. Operation of drying during the night: the Hybrid type dryer was also tested during the night period for drying bread and temperature represented in Table 1 by taking a heated coil (50W, 5A) which was operated by 100W inverter (Plate-6).

The temperatures obtained from the experiment are shown in Table -2.

Table 2: Temperature for night observation of various food stuffs

| Sl n. | Time | Chamber Temp. ºC | Room Temp. ºC |
|---|---|---|---|
| 1 | 19.30 | 45 | 28.2 |
| 2 | 19.45 | 50 | 28.2 |
| 3 | 20.15 | 55 | 28.2 |
| 4 | 20.30 | 60 | 28.2 |
| 5 | 20.45 | 65 | 28.2 |

Present research is the design; technical advances, performance evaluation and application of PVT based Hybrid Type Solar Dryer. They are used for parching various agri-products like vegetables, fruits, oil-seeds, spices and herbs during harvest (peak season) and consumption during the lean period (Zoukit *et al*., 2019). The problem associated with solar dryers is stowing heat. Innovations in heat storage arrangements are emerging to be a popular expanse of research with optimum thermal energy utilization. This leads to improved thermal efficiency, stability of energy availability, surges drying time, enhanced thermal conductivity and easy use during radiation deficient time. Researchers are carried to develop heat storage units for Agricultural, domestic and commercial uses. Such units shall be useful for industries, food processing units, dairy farms, construction sector, waste management, textile industries where regulated dry performance is required.

Conclusively, performance evaluation and thermal energy availability, efficient application produced from hybrid type solar dryers and modifications are made in the present research. Steady state thermal analysis for absorbing plate with attachment of fin was carried out for doing temperature analysis as well as heat flux. The maximum temperature at outlet of solar collector reached 70oC which was sufficient enough to dry the food products. The dryer can be used both in day and night purpose by providing heat which was operated by inverter and battery. It has been observed that the humidity of air increased inside the drying chamber as it absorbs maximum amount of moisture from the food products. The maximum rate of weight reduction for tomato was calculated as 95.8 by taking initial weight and final weight as 620.3 gm and 44.8 gm respectively. The present hybrid dryer can of produce standard qualitative, dried agro-products and food stuffs that can augment higher exporting and profitable.

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