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Research Article

Drying investigation of coriander seeds in a photovoltaic thermal collector with solar dryer

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ABSTRACT

This present work deals with experimental investigation of photovoltaic thermal collector design and development with solar dryer (PVTCSD). An solar experimental investigation is done on coriander seeds by natural, forced and open sun drying to estimate different parametric investigations such as solar radiation intensity, removal of moisture and the air outlet in the collector. Solar radiation is utilized as a source of energy to propel the photovoltaic thermal collector dryer; which was analysed in a drying testing chamber temperature in the range of 32°C to 59°C to dry 4 kg of coriander seeds. From the experimental study, it was understood that coriander seeds posses much more starting moisture 68% by weight and also the results proved that final moisture content has been decreased by 9% by weight during six bright days in the month of May 2021. The PVTCSD was used during the 9 a.m. to 4 p.m. In terms of understanding PVTCSD, solar sun drying with the forced convection achieved superior results than other two modes of operation.

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INTRODUCTION

At the same time, the photovoltaic thermal system creates power and low heat. This can be successful for both domestic and mid-level applications. In addition, low-grade thermal energy could also favour for electrical appliances for application of heat and power generation. The notion of PV/T-campaigns which may also be created from the panel was introduced for the first time by Wolf [1]. In the solar thermal collector, Kern and Russed [2] offered the innovative notion of water/air as a fluid medium. It is observed that electrical efficiency is increased upto 0.5% if silicon is used as an medium in the temperature of the solar panel by 10°C [3, 4]. In the photovoltaic thermal hybrid system, Srimanickam et al. [5] analysed several air canals. It was observed that thermal, thermal equivalent and thermal efficiency were 18.9%, 36.5% and 48.8%, respectively. Yadav et al. [7] has added rectangular ruggedness to achieve the area of the heat transfer on surface of absorber in air channel. Srimanickam et al. [7] examined solar solar thermal hybrid single-glazing flat plate. He determined that the efficiency of electrical and electrical thermal systems was 12.40% and

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34.43%. The performance of the V-groove solar collector has been investigated. The author argued that V-groove was better than standard geometry [8–12]. Different geometric rugosity was investigated to identify blurs on absorber plate, which performs better results than without blurring [13–19]. Srimanickam et al. [20] evaluated the different performances of the electrical, thermal and exercise thermal photovoltaic thermal hybrid system. Sawhney et al. [21] examined the roughness of several wave vortexes in the absorber plates and detected thermos hydraulic performance. Dongxu Jin et al. [22] investigated various geometric form and from him studies it is understood that absorber plate is modified with V-shaped ribs for achieving high thermal performance. Srimanickam et al. [23] from him detailed experimental studies it is understood that maximum thermal efficiency is achieved 4 to 12% at a mass flow rate of 0.008kg/s by exergy principle. Five varieties of mild steel air channels have been carried out experimental by srimanikam et al. [24] and two kinds of mass flow. The studies indicated that 14.27% and 20.81% respectively were electrical and thermal efficiencies. Adam et al. [25] examined circular ring turbulators with varied hole geometries. Deep Singh Thakur et al. [26] examined the hyperbolic artificial roughened ribs as conducting medium in the absorber flat plate; for investigation process to measure numerous arc-shaped rugged aluminium wire on the platform was examined by Anil et al. [27]. Omer and Zala et al. [28] experimentally researched PVT system and he has found enhanced flow rate from 0.024 to 0.057 m^3/s was achieved by 20 percent, respectively by 44 percent. Slimani et al. [29] investigated air flow by absorber surfaces to generate algiers higher thermal energy. Hasanuzzaman et al. [30], from him conclusion it is observed that temperature boosts the power output in photovoltaic system. This means that the PV system may achieve the greatest electrical energy by extracting heat from the air, water or both. The arc rib roughness geometry effect on absorber plate is evaluated by Hans et al. [31]. Several researchers had done investigations to evaluate the thermal performance, by changing the geometrical dimensions of dryer and collectors. In our research study we focused on photovoltaic system was to be developed for measuring the overall removal moisture content of coroindor seeds with better geometrical size of dryer. PVTD method with open drying method was tooked in our experimental investigation and also compared PVTD with open sun drying method, results proved that sun drying method was better than PVTD method for better removal of moisture content. It was neccessory to monitor the temperatures with the aid of sensors; inorder to investigate the performance and thermal storage behaviour of the solar pv with respect to phase change materials Kumar et al. [41]. It was neccessory to examine some deformations with the help of simulation software like computational fluid dynamics and ansys work bench to evaluate the dynamic performance of the system Karthickeyan et al. [42].

EXPERIMENTAL PROCEDURE

A diversified kind of heat exchange devices is a photovoltaic thermal system with dryer (PVTCSD). Hence solar panel transfers solar radiation energy, wave energy converted into thermal energy, often sunshine. The experimental readings were taken from 9 a.m to 4 p.m for six bright days for this investigation to measure the intensity of solar radiation. The intensity of radiation is a measure to evaluate the performance of this system, hence the rays emitted during maximum radiation gives better performance (moisture removal rate). This method was adopted by solar glazing process to receive the solar intensity and converts that intensity into heat energy for removal of moisture.The available heat energy is transferred by fan to dryer for the removal of moisture. The Figure 1 illustrates the experimental installation setup incorporated with solar air collector and dryer. The system is comprised of components such as solar air collector, ventilator, drying chamber and air vent roof, fan e.t.c. The moisture of the coriander seeds was evaporated by the available maximum heat energy that glazed from solar radiation, which transfers the heat to drying chamber,. Consequently, the moisture of the coriander seeds was eliminated, which then turns into dry chilli Purohit et al. [39]. For this entire set up PVTD and sun drying the final scope of this doing experimental set up and analysis was to measure the removal of moisture content of coriander seeds subjected to different temperatures and pressures and also the thermodynamic properties such as relative humidity, humidity ratio and moisture

Figure 1. Experimental setup with coriander seeds.

Table 1. Description of PVTCSD

S.no	Description	Operating parameters
1	Entry Air Velocity (*v*)	1.1 & 1.9 m/s
2	Sk temperature (Ta)	308 - 317 K
3	Area of the panel, A	0.7471 m^2
4	Fan power	18 Watts
5	Drying Chamber height in Metres	1.050 m
6	Drying chamber Length	0.700 m
7	Length of the panel	1.115 m
8	Solar panel Circute voltage at opening, Voc	18.98 V
9	Solar Panel Short circuit, Isc	5.26 A
10	Solar panel Slope at surface	130
11	Solar radiation (G)	400-1100 W/m^2
12	Thickness of the panel	0.035 m
13	Chamber width	0.700 m
14	Width of the panel	0.670 m

absorbing efficiency also evaluated in this process. The solar panel inclination at an angle of 130 degree was to be designed to capture more energy from the intensity of the incident sunlight. The measurements of the hybrid collector were modelled as 1115 mm x 670 mm and the whole set up was installed at the north chennai (Avadi) for measuring the performance of the system.The table 1 illustrates description of PVTCSD with dimensions that tooked for this investigation.

METHODOLOGY

Product Moisture Content

The moisture level of coriander seeds is studied by the following equations for initial and final stage moisture as follows

$$M_o = \frac{m_i - m_d}{m_i} \tag{1}$$

$$M_f = \frac{m_s - m_d}{m_s} \tag{2}$$

$$M_t = \frac{m_t - m_d}{m_t} \tag{3}$$

M_i represents initial mass commodity in kg

M_d represents dry matter mass in kg

M_s represents dried commodity mass of the solar dryer in Kg

Mt represents sample mass with respect to time kg

Equation 1 represents the available initial mass to be absorbed subjected to different temperatures to be dry in kg.

Equation 2 represents the mass of the fluid that to be dried, when the coroindor seeds were to be dried in solar dryer with respect to kg.

Equation 3 represents the sample mass to be mosistured with respect to kg.

Performance in terms of Electrical Efficiency

The performance in terms of Electrical Efficiency is calculated by [23] and [24]

$$\eta_{el} = \frac{V_{mp} I_{mp}}{AG} = \frac{\dot{E}_{el}}{AG} \tag{4}$$

Where, $\dot{E}_{el}$ is an outlet electrical power (W), G = solar radiation, W/m^2, A = PV module area in m^2.

Perfomance in terms of Thermal Efficiency

Thermal efficiency depends upon generation of heat in kilojoules and the dimensional area of the panel measured in square metre in addition to the intensity of solar radiation by refereing [11, 20, 23] and [26], Hence mass flow rate of air related by

$$m = \rho * A * v \tag{5}$$

m = mass flow rate of air expressed in kg/s

ρ = density of air in kg/m^3

A = cross Sectional area of the air to be flow in m^2

V = Air velocity in m/s

$$Q_u = \dot{m}\, Cp\, (T_{out} - T_{in}) \tag{6}$$

Q_u is the heat gained with the help of system and C_p denotes the capacity specific heat .

T_{in} and T_{Exit} represents inlet and outlet fluid air temperatures of the photo voltaic thermal collector respectively and heat efficiency obtained from this experimental setup is expressed in equation 7. Further, The generation of thermal energy through forced convection with the help of fan is expressed in equation 8

$$\eta_{ther} = \frac{Q_u}{AG} \tag{7}$$

$$\eta_{ther} = \frac{Q_u}{(AG + P_{fan})} \tag{8}$$

ηt_{her} = Thermal efficiency of fan

P_{fan} = Power output of the fan expressed in watts,

Here power generated through fan has been utilized for generation of thermal energy for drying solar commodity applications.

RESULTS & DISCUSSIONS

Photovoltaic thermal system with dryer (PVTCSD) tests had be conducted on coriander seeds and from investigation it is found that performance has been improved in clear sky medium, and also and from this analysis it is notified that conventional drying form of removing moisture content from coriander seeds is effective in comparison with solar drying as compared with natural and forced convection.

Figure 2 represents intensity of solar radiation vs temperature with respect to time, From the above results it is observed that maximum intensity of radiation 1048 W/M^2 is achieved at 12 p.m with ambient temperature of 40°C, Further it is observed that the minimum intensity of radiation 467 W/m^2 occurs during evening time 16 p.m with ambient temperature of 32°C, Hence the study reveals that maximum solar radiation is very high at 12 p.m and minmum intensity occurs at 16 p.m and we have conducted this test for all six bright days and experimentally finded the same values without any error.

From Figure 3 represents electrical efficiency vs glazing temperature from the studies it is observed that when the glazing surface temperature were increased electrical efficiency is significantly dropped as per the above illustration it is noted that electrical efficiency was attained by 7% with respect to glazing surface temperature reached at 58°C.

Figure 4 represents thermal efficiency vs outlet temperature of air. The maximum thermal efficiency 58% is achieved during midnoon 12 p.m with respective outlet temperature of air is 42°C from the experimental studies it is understood that the minimum thermal efficiency is occurred during 9 a.m with an thermal efficiency of 28% Figure 5 represents thermal efficiency vs power of the fan with respect to thermal efficiency of PVTCSD and from the plotted results it is observed that thermal efficiency of PVTCSD and the thermal efficiency of PVTCSD with fan power is gradually increasing with respect to 9 a.m and it is noted that the maximum efficiency is achieved at

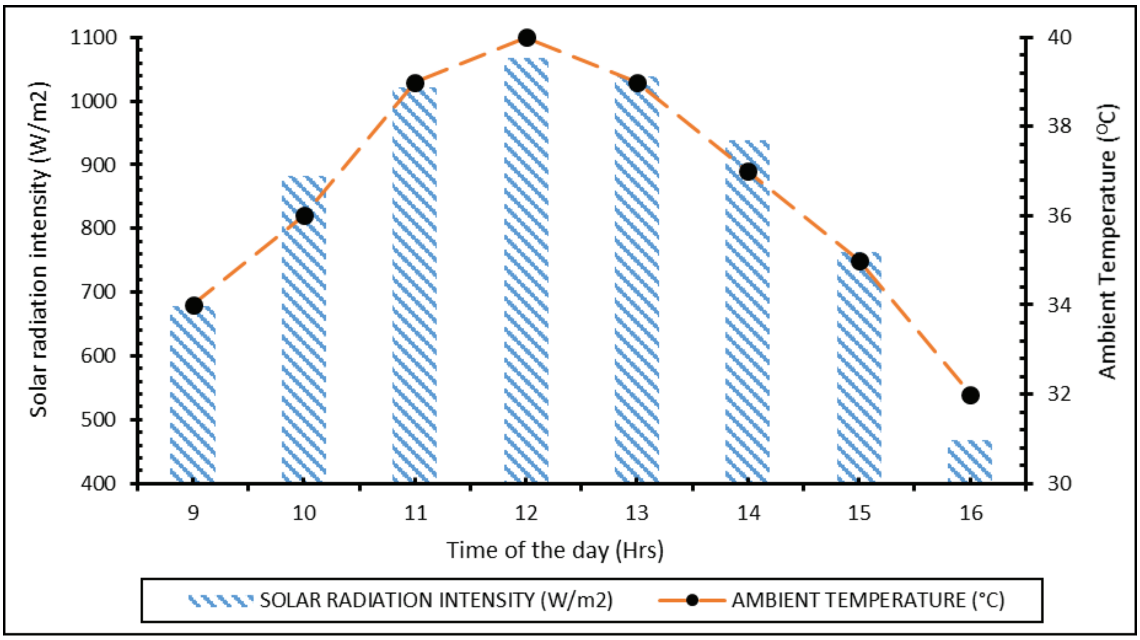

Figure 2. Solar radiation vs ambient temperature

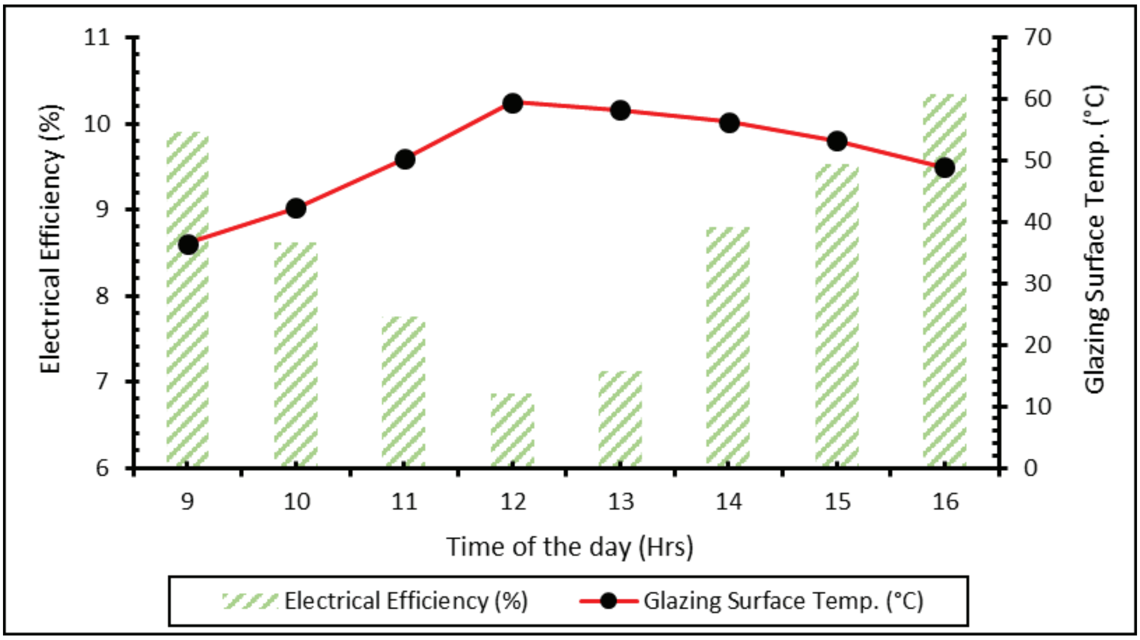

Figure 3. Electrical efficiency vs glazing surface temperature of PVTCSD.

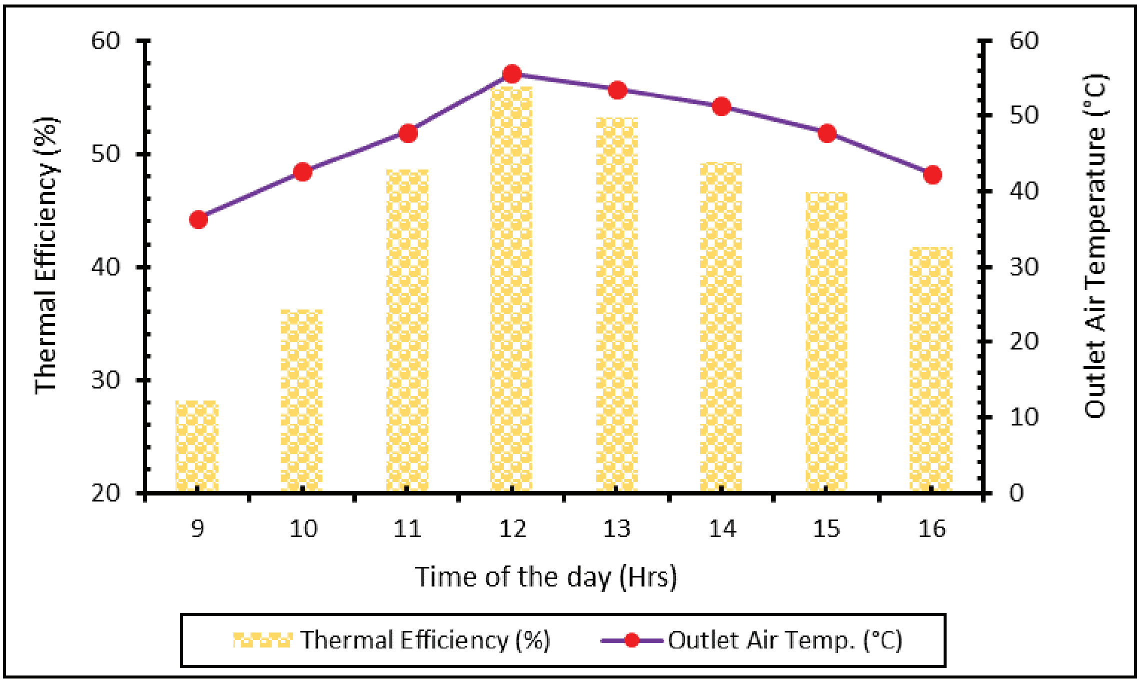

Figure 4. Thermal efficiency and outlet air temperature of PVTCSD.

forenoon 12 p.m, achieved upto 58% in terms of fan power it is achieved up to 45%. The electrical efficiency generated by the solar panel is 18 watts can be utilized by mini fan to complete the process.

Solar drying is an indication of removal of maximum moisture content of the product by the utilization of solar intensity that available from different glazing temperatures [35]. Figure 6 represents the comparative results obtained from open sun drying, solar drying along with natural and forced convection of PVTCSD. As per the average test days of the experimental study deals with various hours of drying in solar drying with forced convection, solar drying with natural convection and open sun drying 7 hrs 10 mins, 13 hrs 30 mins and 18 hrs 20 mins respectively. Open sun

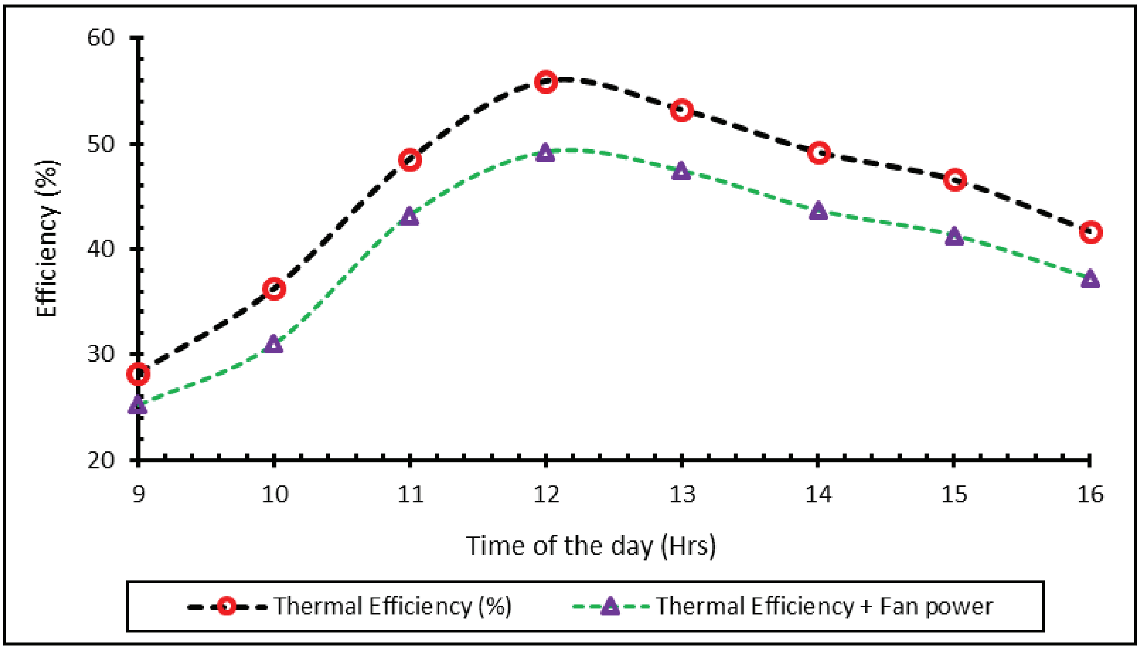

Figure 5. Thermal efficiency and Fan power with Thermal efficiency of PVTCSD.

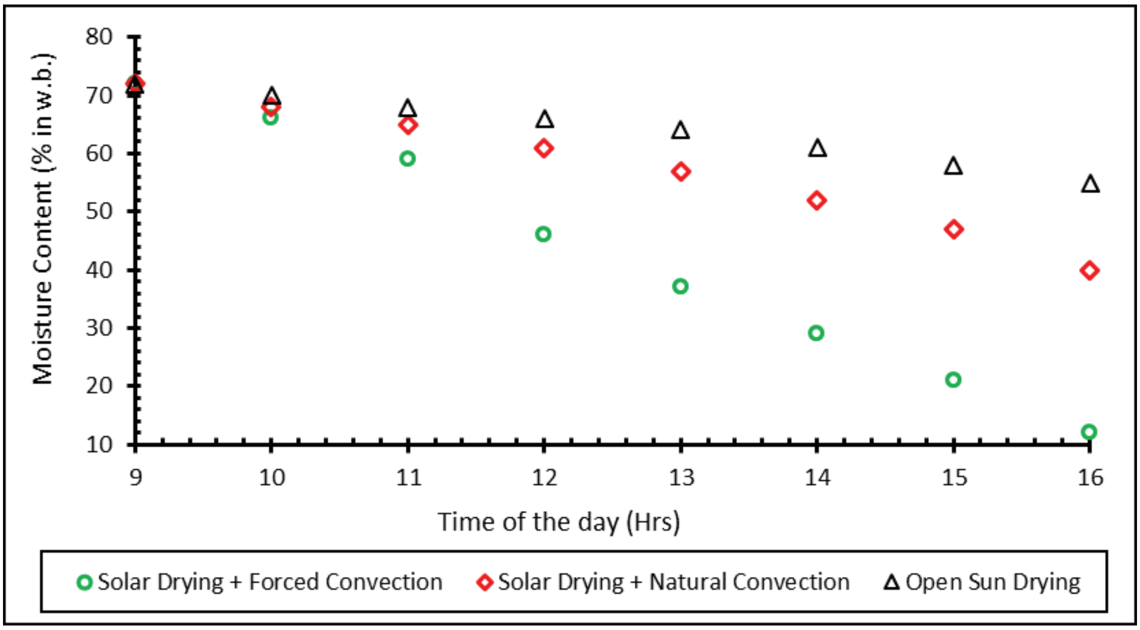

Figure 6. Comparative results on open sun drying, solar drying along with natural and forced convection of PVTCSD.

drying has many demerits such as product quality will deteriorate, contaminated items mixed together which made nil quality. This was due to the phenomenon of time consumption of open sun drying is more compared to other methods of removal of moisture content [39],[40].

Typical hourly values of solar radiation vs Thermal efficiency of PVTCSD is shown in Figure 7. When solar radiation has been enhanced thermal efficiency was increased. As per the diagram, 24.38% of thermal efficiency can be reached at 468 W/m^2, whereas 55.96% of thermal efficiency can be attained at 1037 W/m^2.

The intensity of solar radiation is the key factor to measure or evaluate the electrical efficiency of the system. Or in other words it is defined as the estimation of the propulsion of solar electrical current to measure the overall performance of the system [37]. Figure 8 represents the intensity of solar radiation with respect to the achieved electrical efficiency of PVTCSD system.From the figure 8 it

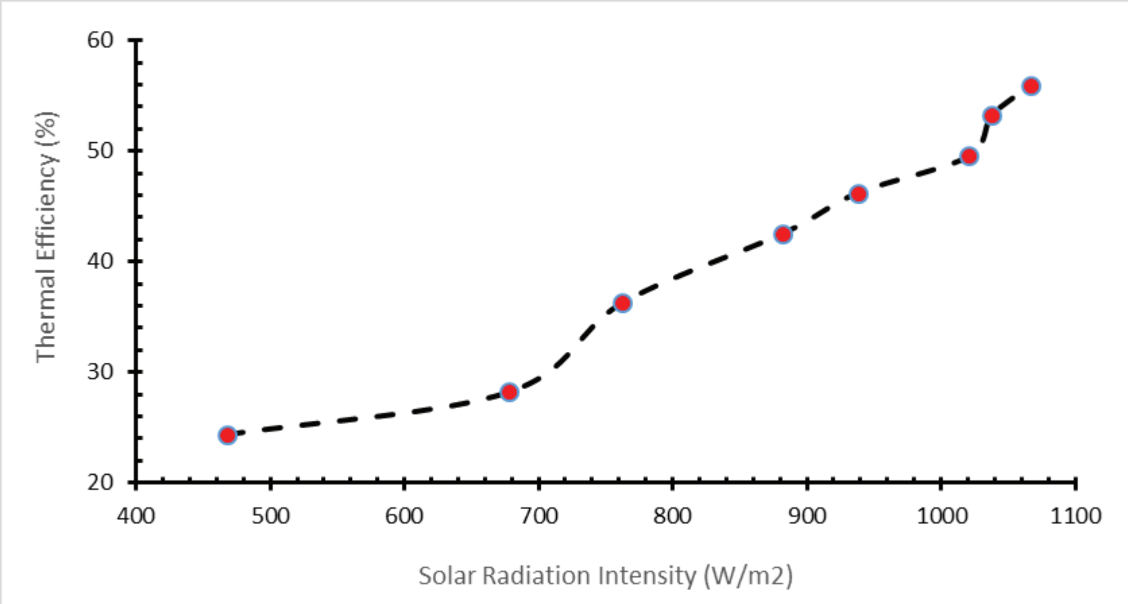

Figure 7. Solar radiation intensity vs Thermal efficiency of PVTCSD.

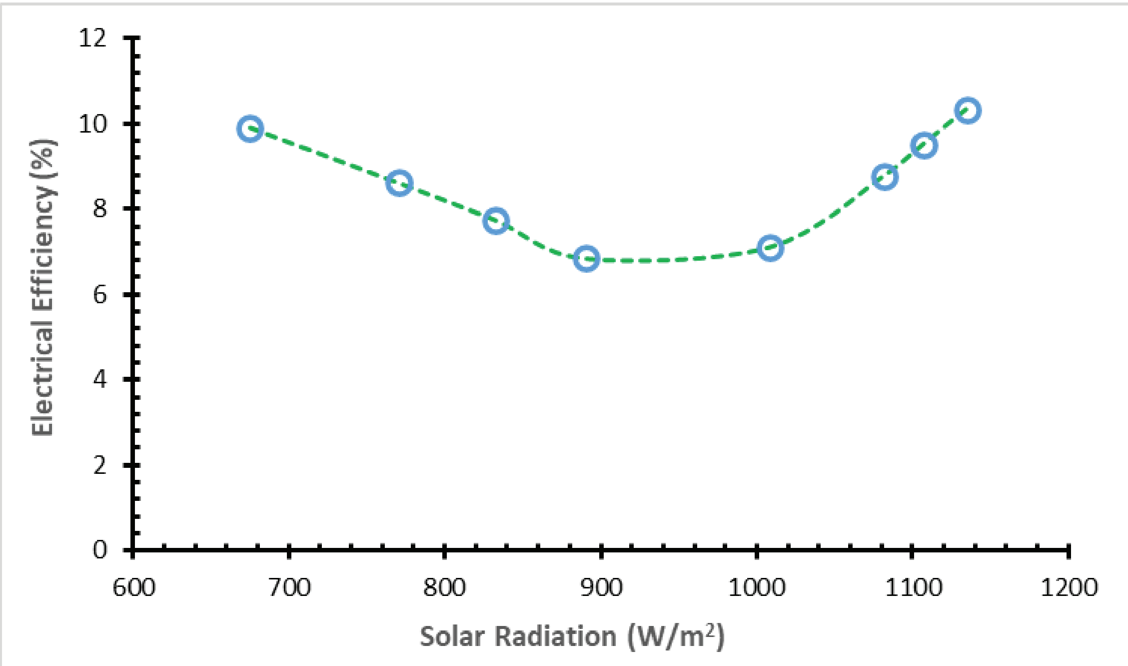

Figure 8. Solar radiation intensity vs Electrical efficiency of PVTCSD.

was observed that the be 6.86% of thermal efficiency can be reached at 890 W/m^2, whereas 10.34% of thermal efficiency can be attained at 1135 W/m^2. This is due to the phenomenon of maximum electrical efficiency was subjected to glazing temperatures and maximum intensity of solar radiations. The phenomenon of solar radiation has a significant predominant enhanced parameter to measure the electrical efficiency of the system [38].

Typical hourly values of Generated electrical power, power consumed by fan and power gained by the system is revealed in figure 9. As electrical energy was increased power gained by the system also enhanced, however power consumed by the fan was used at a constant scale at 18 watts. According to the system that electrical power generated at a maximum quantity at 12 Noon, during this period power

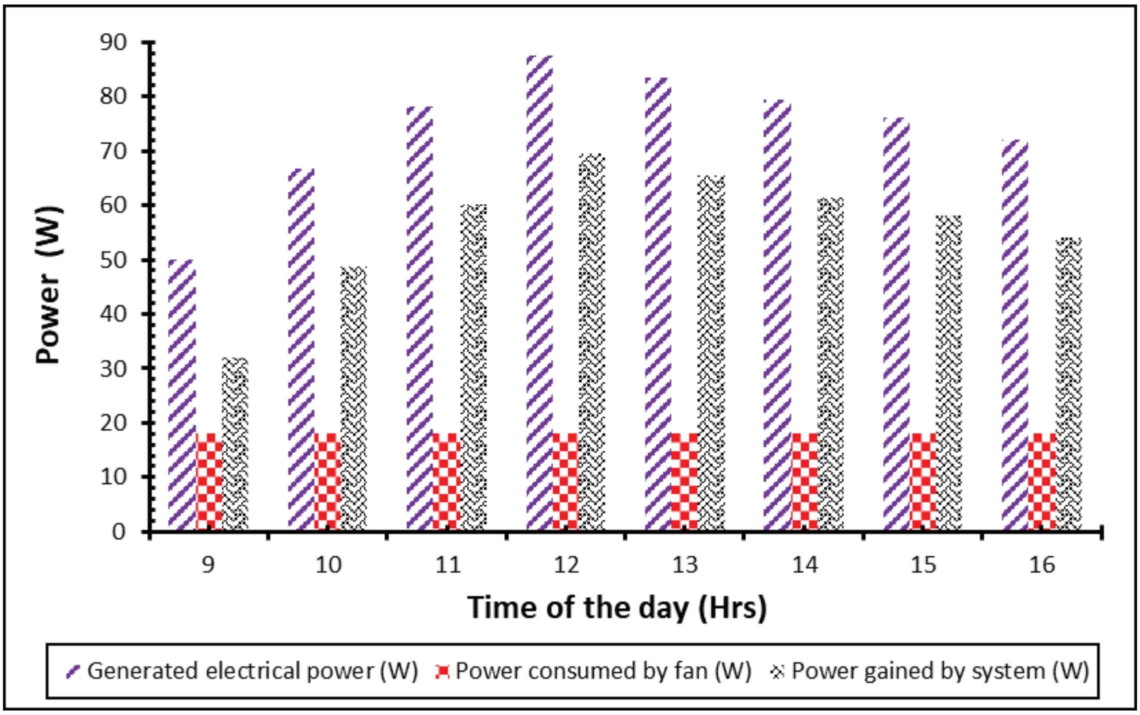

Figure 9. Generated electrical power, power consumed by fan and power gained by the system.

gained by the system was reached at 69.55 watts. However, power consumed by the fan since 9 am to 4 pm 18 watts only.

CONCLUSION

From the experimental analysis it is found that

- ❖ Coriander seeds has been dried at all three modes, among this forced convection has significantly produced better results. However, open sun drying was performed at a poor level.
- ❖ Air flow rate has been increased which induced better thermal efficiency. As a result, drying time will be reduced significantly in the forced convection mode of drying.
- ❖ Electrical and thermal efficiency were achieved by PVTCSD such as 10.34 %, 55.96 %, respectively.

NOMENCLATURE

A	Cross Sectional area of the air to be flow in m^2
A	PV module area in m^2
Cp	Specific heat in kg/kgk
$\dot{E}_{el}$	Outlet electrical power in watts,
G	solar radiation in W/m^2
m	Mass flow rate of air expressed in kg/s
ηt_{her}	Thermal efficiency of fan
P	Power in watts.
P_{fan}	Power output of the fan expressed in watts
PVTCSD	Photovoltaic thermal collector design and development with solar dryer.
Qu	Heat gained by the system in watts.
Tin	Inlet Temperature in °C
Tout	Outlet Temperature °C
W	Power gained by system in Watts.
ρ	Density of air in kg/m^3

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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