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Solar drying characteristics on commercial crop of Red chilli in Tamilnadu

E Murali[1], P Sivamurugan[2], B Srimanickam[3*]
[1,2,3*]*Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology,*
Chennai – 62, INDIA.
*srima1980@gmail.com**

Abstract

This article deals with the design and fabrication of flat plate hybrid collector with dryer (FPHCD). The FPHCD was concededvarious analysis on commercial crop of Red chilli which was performed three modes of operation such as solar sun drying with forced convection, solar sun drying with natural convection and open sun drying. Numerous parametric studies also handled in this article such as solar radiation intensity, moisture removal, outlet air temperature from the collector. In general, solar radiation was provided a sources of generating energy to drive a solar dryer. The FPHCDhas been provided the electrical and thermal energy to run a solar dryer.The solar dryer was tested by 14 kg of red chilli in the drying air temperature in the range of 32^0C – 59^0C. The initial moisture content of the red chilli was 73% (weight basis) and was reduced to the final moisture content of 11% (weight basis) in 6 days with clear sunny days in the month of July 2020. The FPHCDwas operated between 9 hrs to 16 hrs. Finally, comparative study was also handled for better understanding in FPHCD, in which solar sun drying with forced convection mode attained better results than other two modes of operations.

Keywords: flat plate hybridcollector, commercial crop, red chilli, electrical and thermal efficiency.

1. Introduction

Agriculture is a primary sector in Indian Economy. Variety of crops in India such as food crops, cash crops, commercial crops, horticulture crops and other related crops. Among the crops, Red chilli is a predominant crop in food system of India. This article shows various drying kinetics of red chilli which can be compared with conventional form of drying. Kern and Russell [1] presented the pioneering concept of water or air as a fluid medium on the photovoltaic thermal collector. Wolf [2] proposed the concept of PV/T collectors for the first time which can also be generated heat energy from the panel.The enhancing the solar panel temperature by 1^0C was known to cause 0.5 % decrement in electrical efficiency for silicon cells [3– 4].Srimanickam et al. [5] analysed the various air channels in photovoltaic thermal hybrid system. It concluded that thermal, equivalent thermal and overall thermal efficiency were found to be 18.9 %, 36.5 % and 48.8 % respectively. Yadav et al. [6] enriched the heat transfer area in the air channel with rectangular roughness on the absorber surface. Srimanickam et al. [7] assessed the performance of single glazing flat plate solar photovoltaic thermal hybrid system. It concluded that electrical and electrical thermal efficiency have been attained 12.40 % and 34.43 %, respectively.

Investigated the performance of solar collector with V-groove. Author claimed that V-groove is more efficient than traditional geometrical roughness. [8 – 12].Investigated various geometrical roughness with baffles on the absorber plate which claimed better performance than without baffles [13 – 19].Srimanickam et al. [20] studied the various performances of photovoltaic thermal hybrid system such as electrical, thermal and exergy.Sawhney et al. [21] investigated various wavy winglet vortex roughness on the absorber plate and found the thermohydraulic performances.Dongxu Jin et al. [22] Performed the different geometrical shape of V shaped ribs on the absorber plate and attained better thermal performance.Srimanickam et al. [23] have investigated energy and exergy efficiency of various air channels configurations with two types of air mass flow rates through experimentally. The results show that electrical, thermal and exergy efficiency were obtained 13.9 %, 25.9 % and 49.4 % respectively.

Srimanickam et al. [24] have performed five types of mild steel air channels with two kinds of mass flow rates by experimentally. The results were found that electrical and thermal efficiencies were attained 14.27 % and 20.81 % respectively**.** Adem et al. [25] investigated circular ring turbulators with various hole geometries on the absorber plate of the solar air collector.Deep Singh Thakur et al. [26] studied the artificial roughened hyperbolic ribs such as rectangular, triangular and semi-circular on the absorber plate of the solar air heater.Anil et al. [27] investigated the multiple arc shaped aluminum wire roughness on the absorber plate. Omer and Zala. [28] Investigated air based PVT collector by experimentally. Author ascertained that electrical and thermal efficiency was attained 20 %, 44 % respectively when the mass flow rate was enhanced in the range of 0.024 to 0.057 m3/s.

Slimani et al., [29] studied the flowing of air behind absorber surface which generating better thermal energy in the Algiers climatic conditions. Hasanuzzaman et al. [30] studied as the glazing temperature upsurges the performance of electrical energy of the PV system recedes significantly. On account of this, maximum electrical energy of the PV system could be attained by extracting the heat through circulation of air, water or mixed of both.Hans et al. [31] executed the broken arc rib roughness geometry on the absorber plate which influenced better performance than nil roughness geometry.According to above reported literaturefew journals were given direct solar dryer. This article was established photovoltaic thermal system with dryer which can also be compared with open sun drying. Finally, solar sun drying has been produced better outcome than other two modes of drying.

2. Experimental procedure

The FPHCDis a diverse kind of heat exchangers. In general, sun shine falls on the solar panel that transforms solar energy or photo energy or light energy into heat energy. Top surface of solar panel absorbs the incoming solar radiation and convert it into heat energy and electrical energy simultaneously. Then heat energy transfers to a moving fluid that fluid travels from inlet duct to outlet duct of air passage. The experimental set-up is designed and tested at Chennai (13.0827° N, 80.2707° E). Chennai is situated in South India where has a grand potential of receiving solar energy due to its location in the tropical region. The external dimensions of hybrid collector is 1115 mm x 670 mm. The experimental setup of solar air collector with dryer is shown in Fig. x. This system consists of solar collector, fan, drying chamber and aluminium roof air venthot fluid air comes from the solar collector which feeds to the drying chamber with the help of small fan. The moisture of red chilli with in the drying chamber were evaporated with the help of thermal energy.

As a result, moisture were removed from the red chilli which makes into dry chilli subsequently. In this research work, moisture content, temperature of the red chilli, pressure of the drying chamber, air velocity and other related energy measurements were utilized for testing the complete setup.Relative humidity and temperature of red chilli in the drying chamber were monitored with the help of various sensors which were mounted at the selected location of the drying chamber. Solar panel were wedded with air channel medium which was tilted 13^0. The inclination of solar collector is designed in a way to extract more absorbed energy from the incident solar intensity. Experimental readings were taken between 9 am to 4 pm with a regular interval of 30 minutes for all the test days.

Fig. 1. Pictorialview of open sun drying and solar dryer drying on Red chilli.

Table 1. Detailed dimensions of the FPHCD.

Operating parameters & System parameters	
Air velocity at the entry of the channel (v)	1.2 & 1.8 m/s
Ambient temperature (T_a)	307 - 316 K
Area of the panel, A	0.7471 m^2
Fan power	18 Watts
Height of the drying chamber	1.050 m
Length of the drying chamber	0.700 m
Length of the panel	1.115 m
Open circuit voltage of solar panel, *Voc*	18.98 V
Short circuit current of solar panel, *Isc*	5.26 A
Slope of the solar panel surface	13^o
Solar radiation (G)	400-1100 W/m^2
Thickness of the panel	0.035 m
Width of the drying chamber	0.690 m
Width of the panel	0.670 m

3. Methodology

3.1. Moisture content of the product

The initial and final stage of moisture level of the particular commodity with respect to time t which were designed with the assistance of following equations as follows [32].

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

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

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

Where, mi, Initial mass of the commodity (kg), md, Mass of dry matter in the dryer (Kg), ms, Mass of the dried commodity in the solar dryer (Kg), mt, Mass of the sample at time t (kg).

3.2. Electrical Efficiency Performance

Electrical efficiency performance of a PV panel could be determined as a ratio of electrical energy output of the PV panel to the solar energy (or) light energy falls on the solar panel which is carried out as given below [23, 24, 33, 34, 35].

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

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

3.3. Thermal Efficiency Performance

Thermal efficiency performance has been conducted with various parameters such as heat energy generation (KJ), area of the panel (m^2) and solar radiation intensity (W/m^2). The following equations were compiled the finding of thermal performance of solar hybrid collector as given below [11, 20, 23].

The equation of mass flow rate of air (Kg/s) is expressed by

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

Where, $\dot{m}$ = mass flow rate of air, kg/s, ρ = density, kg/m^3,A = PV module area, m^2,V = velocity of air, m/s.

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

Where, Q_u is gained from the system, Cp is a specific heat capacity of air (KJ/Kg K) and Tin and Tout shows input and output fluid air temperatures in the solar hybrid collector, respectively. Equation 7 describes the thermal efficiency has been generated from the FPHCD. Further, thermal energy were generated by forced convection through mini fan which has been included in the equation 8, as follows.

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

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

Where, Thermal efficiency (η_{ther}),P_{fan}, (W) is the fan power using to generate thermal energy or heat energy in the solar hybrid collector which can be used to dry the commodities in the solar dryer.

4. Results & Discussions

The FPHCDwasperformed various analysis on Red chilli. The performance tests were conducted on days with clear sky condition. In this study, various analysis were carried out such as electrical and thermal efficiency of FPHCD. In addition to that, removal of moisture from the Red chilli by conventional form of drying which were compared with solar drying in natural and forced convection mode of operation.

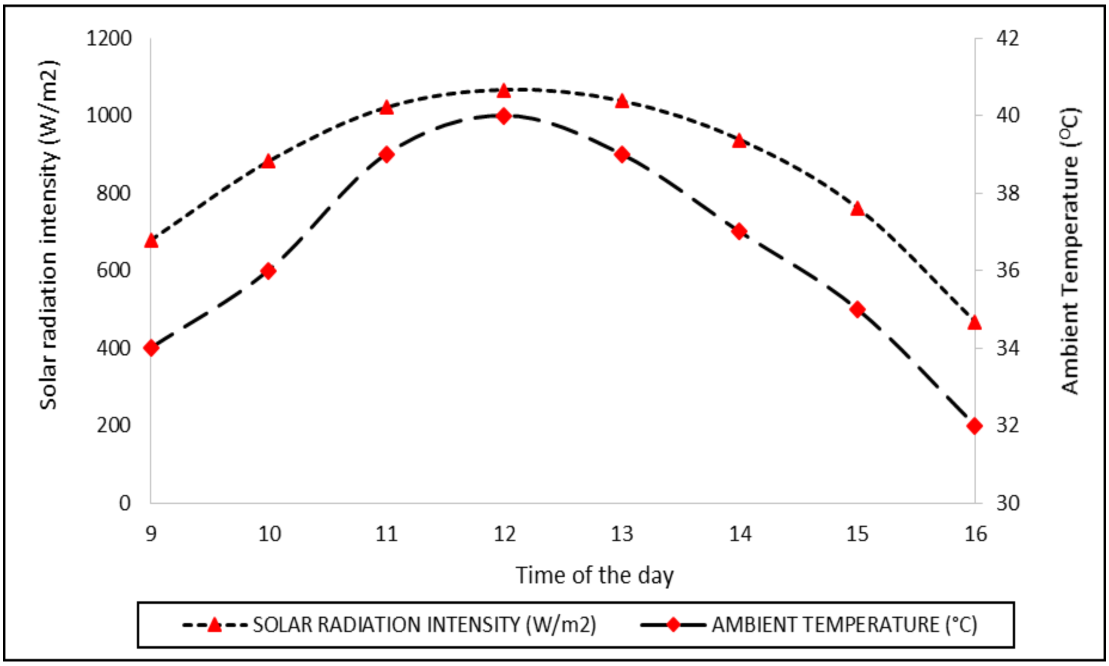

Fig. 2. Average solar radiation and ambient temperature with time (hrs).

Typical hourly values of average solar radiation and ambient temperature since 9 hr to 16 hr is discovered in Figure 2. The maximum solar radiation was found to be 1068 W/m^2 at 12 hr and minimum solar radiation was found to be 467 W/m^2 at 16 hrs. Similarly, the maximum ambient temperature was found to be 40 °C at 12 hrs and minimum ambient temperature was found to be 32 °C at 16 hrs respectively. Solar radiation is always higher at midday and low in the morning and evening hours. On all test days, solar radiation range was from 467 W/m^2 to 1068 W/m^2. Evidently, thesolar radiation and ambient temperature from 9 hr to 16 hr seems to be existing a dome-shaped structure as shown in Fig.2.

Typical hourly values of electrical efficiency and glazing surface temperature of FPHCD since 9 hr to 16 hr is shown in Figure 3. Evidently, from 9 hr to 12 hr there was increase in glazing temperature and decreased electrical efficiency then vice versa till 16 hr. It was observed that when glazing surface temperature was maximum, electrical efficiency was minimum between 11 hr to 13 hr. Due to high glazing surface temperature, the electrical performance was very lower.

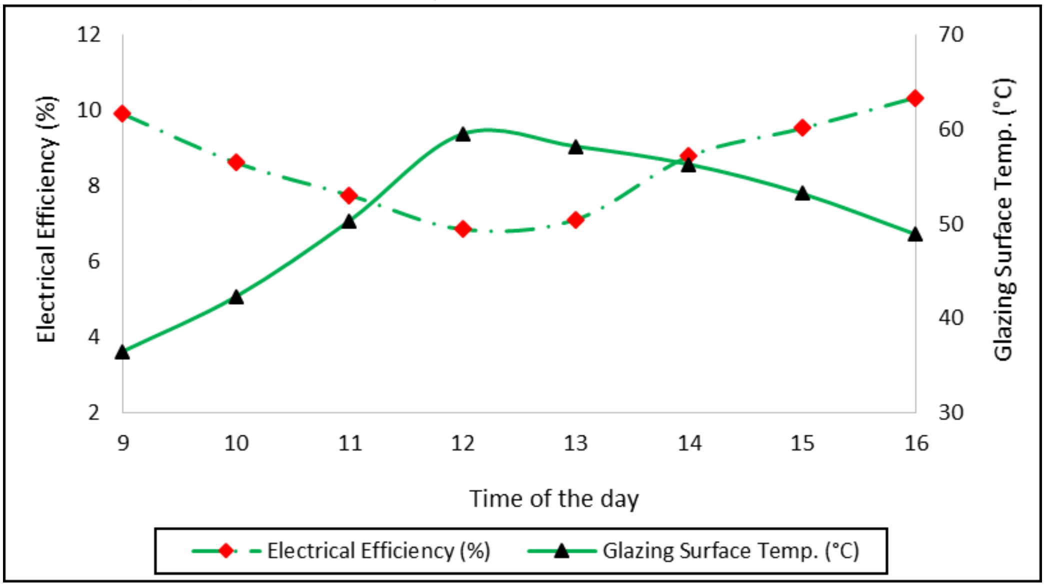

Fig. 3. Electrical efficiency and glazing surface temperature of FPHCD.

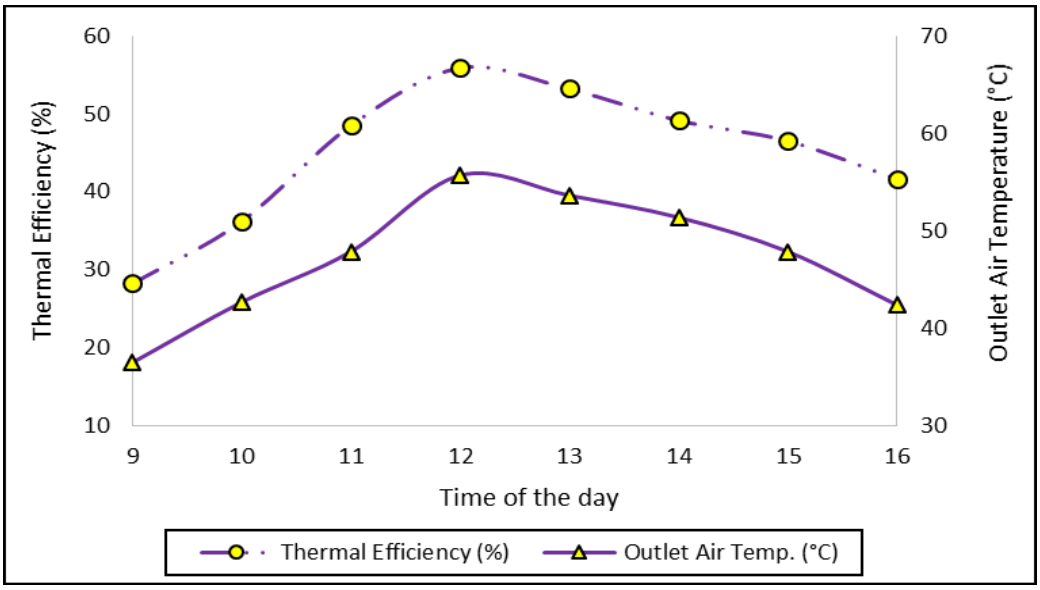

Fig. 4. Thermal efficiency and Outlet air temperature of FPHCD.

Typical hourly values of Thermal efficiency and Outlet air temperature of FPHCD is exposed in Figure 4. Thermal performance increased with increase in air mass flow rate and solar radiation. Extracted more heat energy from the tedlar side as a result better performance of the system. The hourly variations of thermal efficiency Vs outlet air temperature of FPHCD was calculated by using Eqs. 5 to 8. Evidently, outlet air temperature was maximum between 12 hrs to 14 hrs, due to maximum solar radiation available during those hours.

Typical hourly values of Thermal efficiency and Fan power with Thermal efficiency of FPHCD is shown in Figure 5. Forced convection can be generated by mini fan which was consumed by 18 watts. Figure 5 describes two kinds of results in which normal thermal efficiency and thermal efficiency along with fan power. Electrical efficiency was generated by the solar panel which can be utilized by mini fan at an energy of 18 watts.

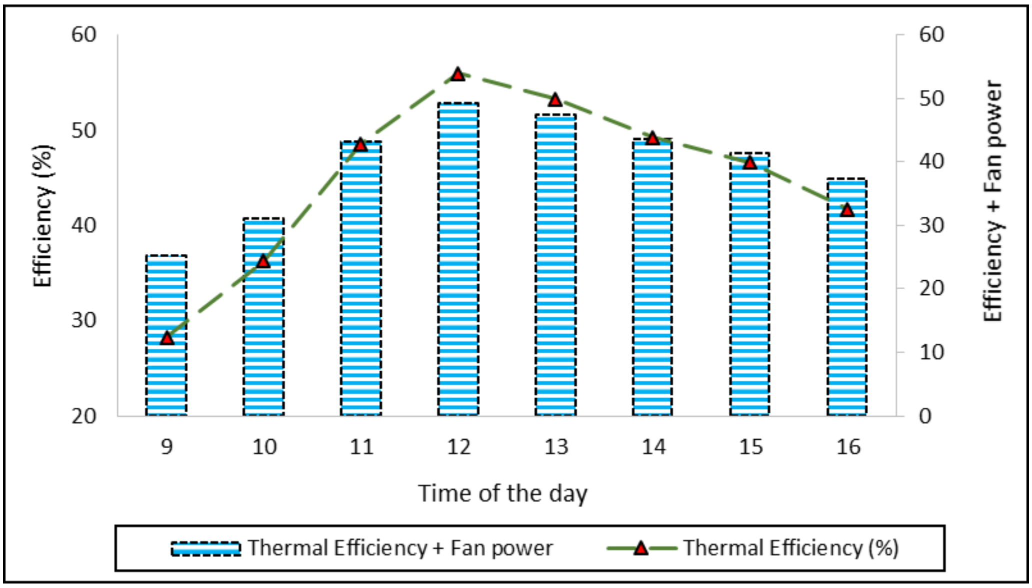

Fig. 5. Thermal efficiency and Fan power with Thermal efficiency of FPHCD.

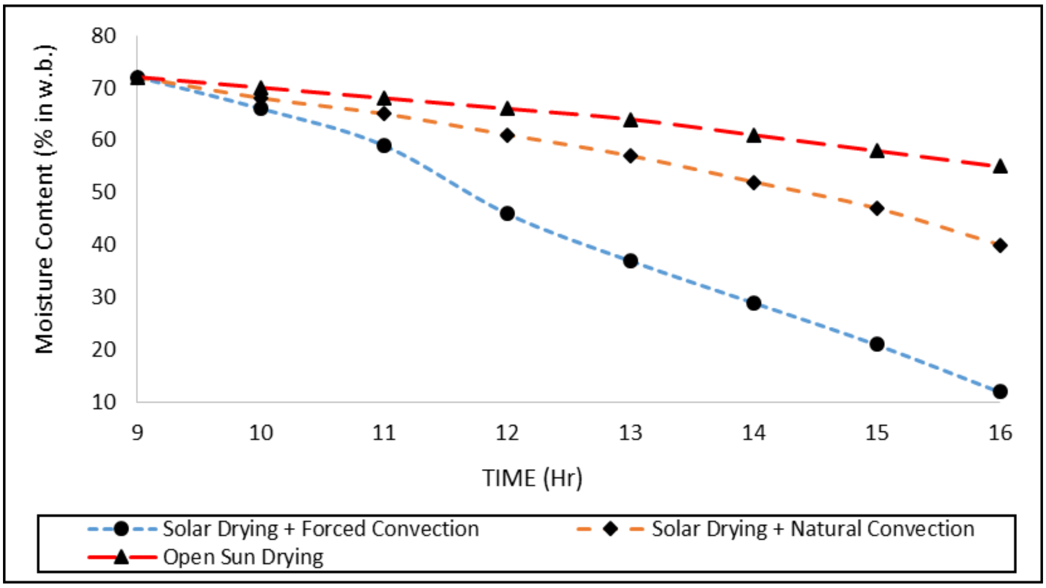

Fig. 6. Comparative results on open sun drying, solar drying along with natural and forced convection of FPHCD.

Fig. 6.Shows the comparative results of open sun drying, solar drying along with natural and forced convection of FPHCD. 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 drying has many demerits such as product quality will be deteriorated, contaminated items mixed together which made nil quality. Whereas, the solar dried chilli was free from dirt and clean nature.

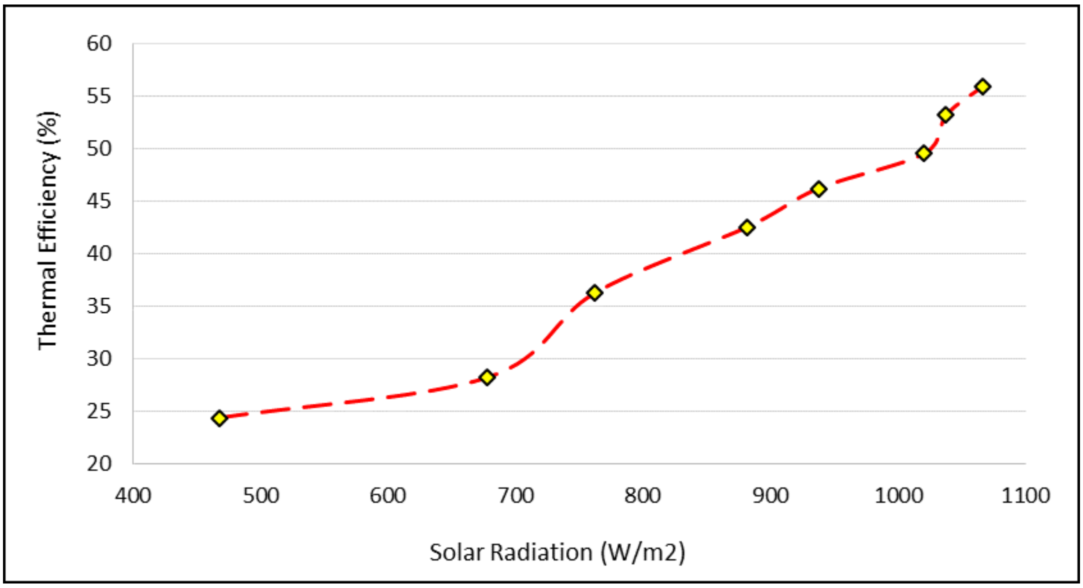

Fig. 7. Solar radiation intensity vs Thermal efficiency of FPHCD.

Typical hourly values of solar radiation vs Thermal efficiency of FPHCD 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.

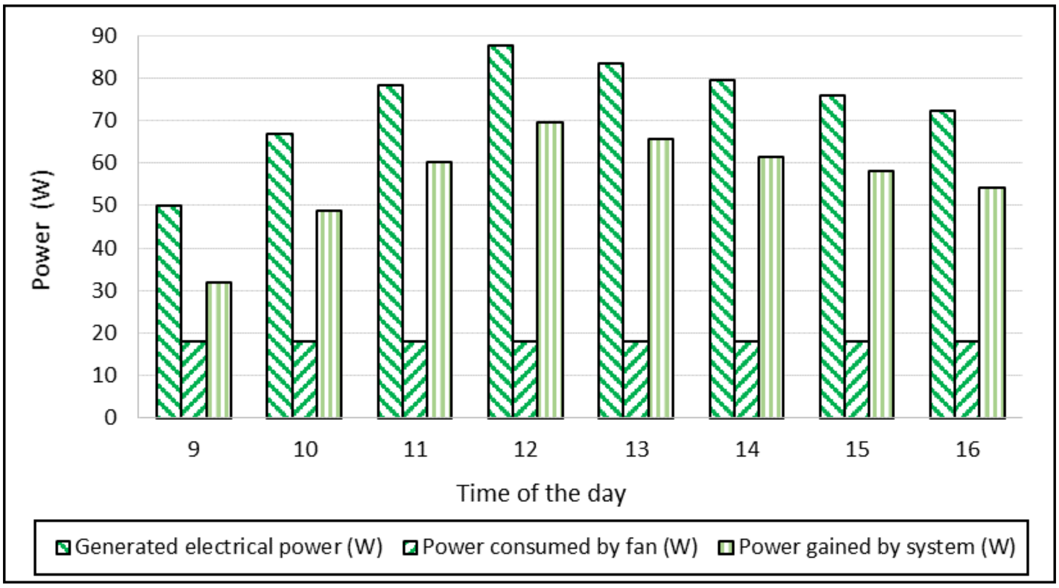

Fig. 8. Generated electrical power, power consumed by fan and power gained by the system.

Typical hourly values of Generated electrical power, power consumed by fan and power gained by the system is revealed in Figure 8. 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 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.

5. Conclusion

Major conclusions can be drawn as given below.

- ❖ Electrical and thermal efficiency were achieved by FPHCD such as 11.12 %, 56.48 %, respectively.
- ❖ Commercial crop of Red chilli 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.
- ❖ Mass flow rate of air can be enhanced better heat energy generation and thermal efficiency. As a result, drying time will be reduced significantly in the forced convection mode of drying.

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