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EXPERIMENTAL INVESTIGATION OF SOLAR PHOTOVOLTAIC – THERMAL HYBRID DRYER FOR DRYING CASHEW NUTS

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ABSTRACT

The solar dryer is normally used to reduce the drying period and to get a safest drying free from said difficulties. The present study focusing on the usage of solar photovoltaic (PV) – thermal (T) hybrid system (combination of electrical and thermal components in a single area) for drying cashew nuts. One of the best methods for improving the efficiency of the Solar Photovoltaic – Thermal Hybrid system using the air as a coolant is to reduce the working temperature of solar cell. The hot air is used to dry cashew nuts and the PV panel produce the electrical energy to run the blower. Hence they are not dependent upon other external sources. Widely the drying of the cashew nuts is carried out by using steam and electrical drying processes (it needs 65-70°C, around 4-6 hours to reduce the moisture content). The mathematical model was developed for the relevant PV/T dryer considering various mass flow rate, solar intensity, spaces developed between the absorber plate and glass the cover for two different areas (CASE-I:0.5m² & CASE-II:2m²) of the collector. The thermal efficiencies were observed to be 36.11% & 27.58% for CASE-I & CASE-II respectively. The total efficiencies were observed to be 55.15% & 54.63% for theoretical and experimental.

INTRODUCTION

A Solar Photovoltaic Thermal System is a combination of solar photovoltaic technology and solar thermal technology, to produce both electricity and heat simultaneously. The absorption factor of a standard PV module should be above 80% for the PV/T collector to be financially competitive with individual systems. The PV/T technology is suitable for low temperature applications in the range of 25 to 40°C. The arrangement of a solar photovoltaic module and a solar thermal collector, along with the thermal insulation and wooden casing to make the solar PV/T collector[14].

Cashew has become one of the valuable commodities owing to the marketing prospect for domestic and even for export. Worldwide trading into two products which are cashee nuts in shells (CNS) and cashew (Nuts). In India contributes 17.3 and 39.47 % of total area and raw cashew production in the world, annually 7.52 lakhs tones of raw cashew nuts imported from African countries and exporting to US and UK. Normally drying of Cashew nuts is carried out by using steam and electrical drying process. Needs about 65 to 75 °C around 4 to 6 hours to reduce the moisture content[18]. Using solar energy as an alternative energy source for a dryer unit can prevent problems which occurs during the open sun drying, by using PV/T could reduce the drying time by a half. Increase the quality of CNS and at the end could emphasize the cost.

Quality of CNS in the market determined by some factors and the most comman are shape (amount/kg), moisture content (%), and losses (%). One of the most important post harvest handling is drying process. Drying process is very important to to reduce the moisture content to the level that save for storage[22]. The main objective of the present work is to study the dry characteristics of CNS such as moisture content, drying rate, efficiency and quality of the product increased at maximum level by using PV/T system.

FORMULAS

DRYING RATE (DR)

The Drying Rate (DR), kg/s is normally defined as the ratio between the mass of the moisture lost and the time taken during drying to achieve the said moisture loss.

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The drying rate is given as,

$$DR = \frac{m_i - m_f}{t_d} \quad (1)$$

where,

m_i Mass of sample before drying, kg
m_f Mass of sample after drying, kg
t_d Drying time duration, s

MOISTURE LOSS (ML)
The Moisture Loss (ML), kg is defined as the difference between the mass of sample before and after drying. The moisture loss is given by

$$ML = m_i - m_f \quad (2)$$

where,
m_i Mass of sample before drying, kg
m_f Mass of sample after drying, kg

EFFICIENCY OF SOLAR DRYING
The Thermal efficiency of the PV/T collector (η_{th})

$$\eta_{th} = \frac{q_u}{I \times A_p} \quad (3)$$

where,
q_u Useful heat gain, W
I Solar insolation, W/m²
A_p Area of the absorber plate, m²

The Electrical efficiency of the PV/T collector (η_{el})

$$\eta_{el} = \frac{P_{\max}}{I \times A_p} \quad (4)$$

where,
P_{max} Maximum power produced from PV panel, W

The Total efficiency of PV/T collector (η_T)

$$\eta_T = \eta_{th} + \eta_{el} \quad (5)$$

Top Loss Coefficient (U_t)

$$U_t = \left(\frac{M}{\left(\frac{c}{T_{pm}}\right)\left(\frac{T_{pm} - T_a}{M + f}\right)^{0.33}} + \frac{1}{h_w} \right)^{-1} + \left(\frac{\sigma\left(T_{pm}^{\ 2} - T_a^{\ 2}\right)\left(T_{pm} + T_a\right)}{\frac{1}{\varepsilon_p + 0.05M\left(1 - \varepsilon_p\right)} + \frac{(2M + f - 1)}{\varepsilon_c} - M} \right)$$

where, (6)
M Number of glass cover
T_a Ambient temperature, K
T_{pm} Plate mean temperature, K
V wind velocity (m/s)
c = 365.91 (1-0.00883β+0.0001298β²)
f = $(1-0.04h_w+0.0005h_w^2)(1+0.091M)$
h_w = 5.7 + 3.8 V

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4.6.2 Bottom Loss Coefficient (U_b)

$$U_b = \frac{k_i}{\delta_i} \quad (7)$$

where,
k_i Thermal conductivity of the insulator, W/mk
δ_i Insulation thickness m

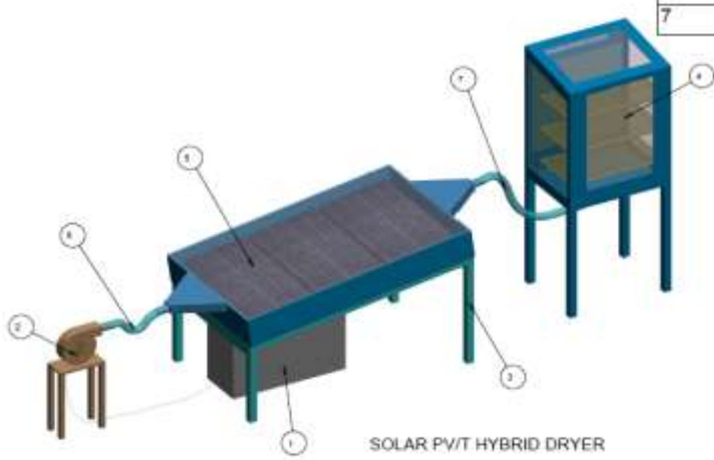
USEFUL HEAT GAIN (q_u)

$$q_u = A_p F_R \left[I(\tau \times \alpha)_e - U_o (T_i - T_a) \right] \quad (8)$$

where,
Fr Heat removal factor
$(\tau \times \alpha)_e$ Transmittance of cover

MODELLING

S.NO	COMPONENTS
1	BATTERY
2	BLOWER
3	COLLECTOR-STAND
4	DRYING-CHAMBER
5	PV-T_COLLECTOR
6	TUBE1
7	TUBE2



SOLAR PV/T HYBRID DRYER

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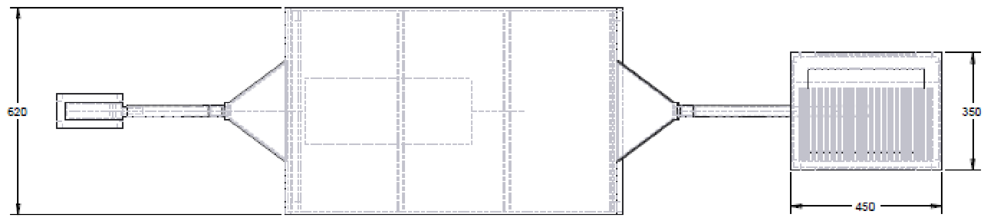
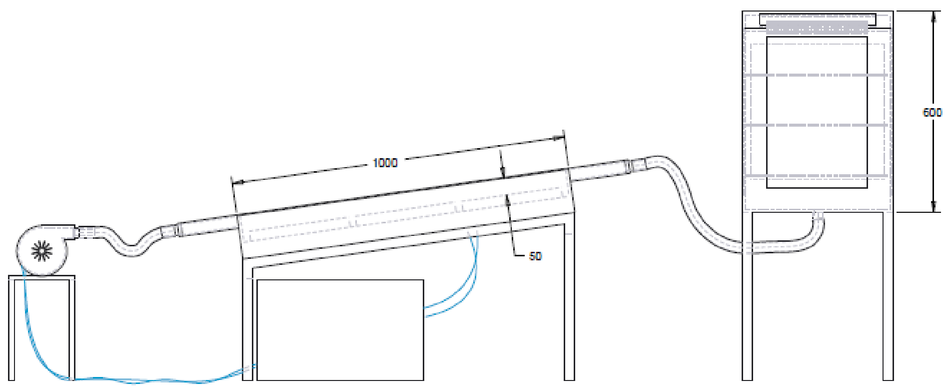


TOP VIEW



FRONT VIEW

RESULTS AND DISCUSSION

EFFECT OF MASS FLOW RATE ON USEFUL HEAT GAIN AND THERMAL EFFICIENCY

The figures 1 & 2 represent the variation in thermal efficiency and useful heat gain with respect to mass flow rate for Case-I and Case-II. Generally thermal efficiency and useful heat gain for both the collectors were increased with increase of mass flow rate. The heat gain of the Case-I was observed to be lower than Case-II. But it has higher efficiency than that of Case-II, because huge amount of heat gain was witnessed for Case-I (252W/m²) when compared with Case-II (193W/m²). The thermal efficiency values obtained were in the range of 27% to 41 % for Case-I and 16% to 34% for Case-II. The useful heat gain and thermal efficiency obtained at a mass flow rate of 0.03 kg/s was found to be optimum.

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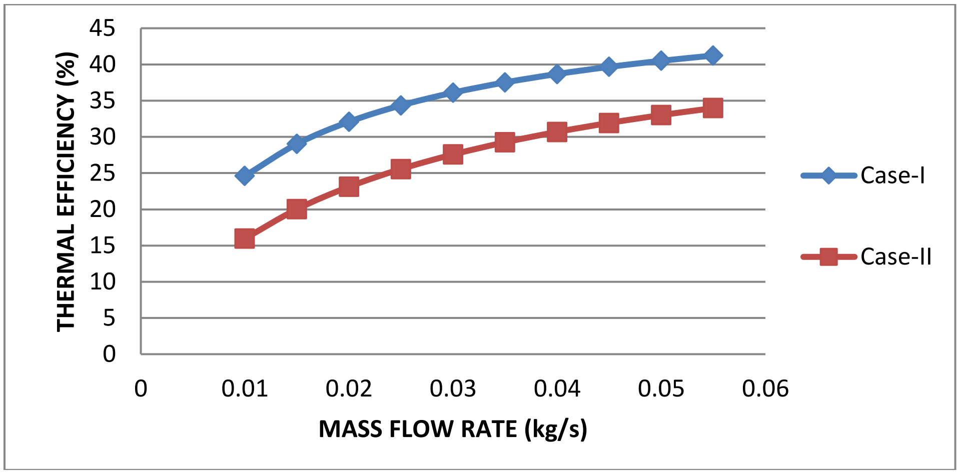

Figure 1 Thermal Efficiency with respect to Mass Flow Rate

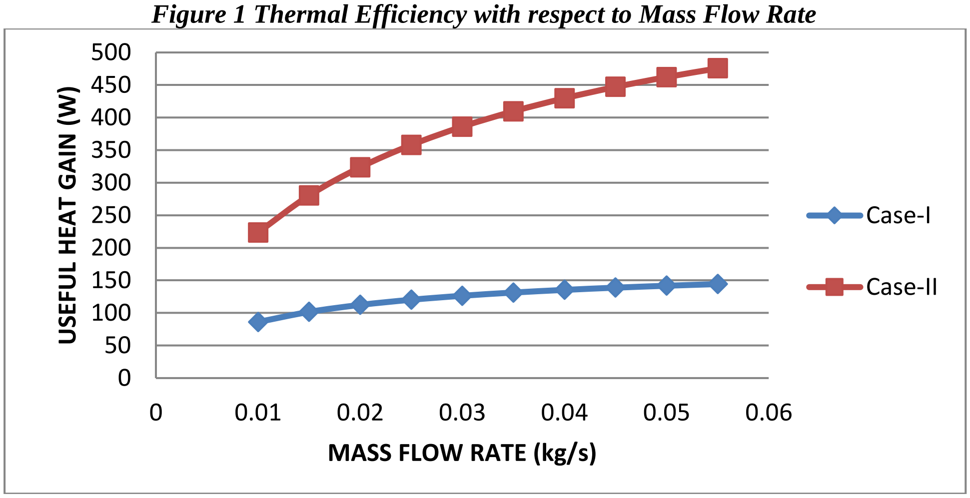

Figure 2 Useful Heat Gain with respect to Mass Flow Rate

EFFECT OF SOLAR INTENSITY ON USEFUL HEAT GAIN AND THERMAL EFFICIENCY

The figures 3 & 4 represent the variation in thermal efficiency and useful heat gain with respect to solar intensity for Case-I and Case-II.

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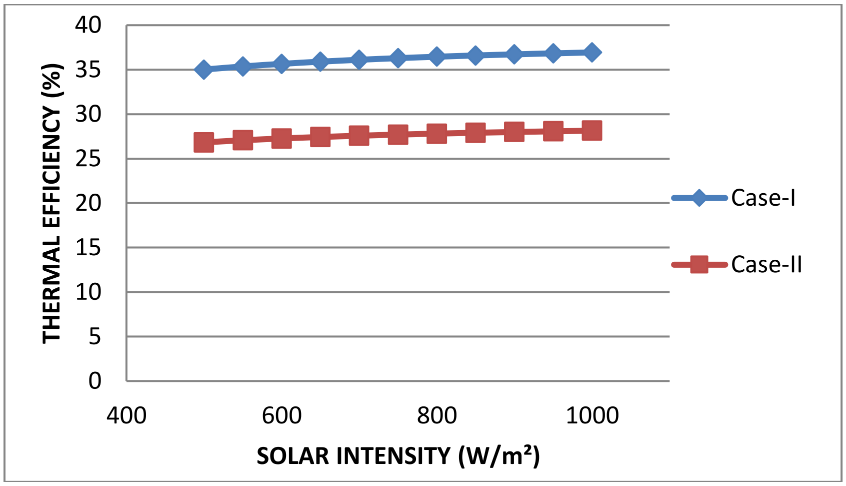

Figure 3 Thermal Efficiency with respect to Solar Intensity

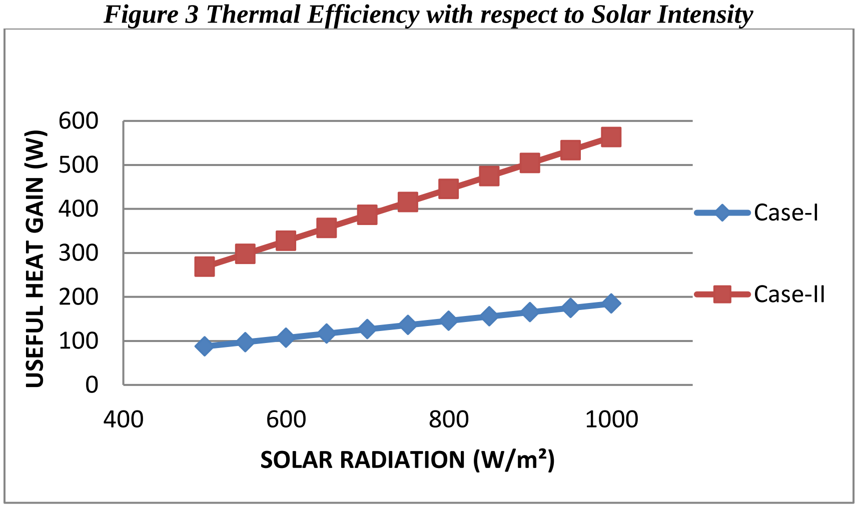

Figure 4 Useful Heat Gain with respect to Solar Intensity

EFFECT OF AIR FLOW THICKNESS ON USEFUL HEAT GAIN AND THERMAL EFFICIENCY

The figures 5 & 6 represent the variation in thermal efficiency and useful heat gain with respect to air flow thickness for Case-I and Case-II.

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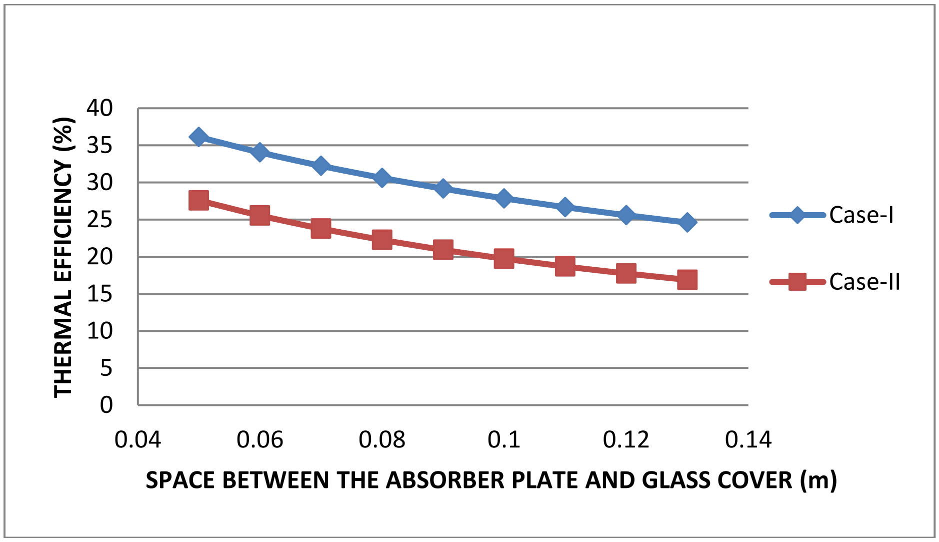

Figure 5 Thermal Efficiency with respect to Air Flow Thickness

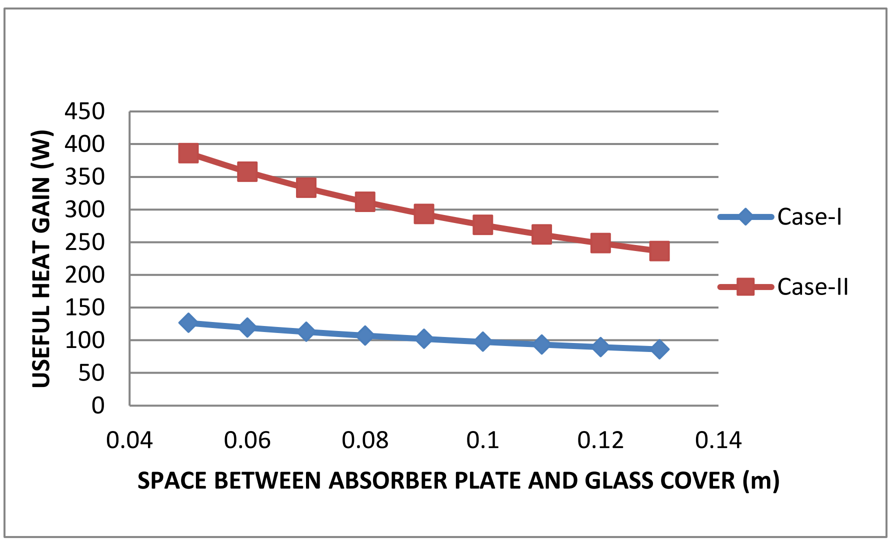

Figure 6 Useful Heat Gain with respect to Air Flow Thickness

Total efficiency of The PV/T collector
The conventional solar collector has only Thermal efficiency. But the Solar PV/T collector of the hybrid dryer, has both electrical and thermal efficiency. So the total efficiency of the system also establishes. Here obtained the thermal and electrical efficiencies were 36.11%, and 19.04% respectively. The total efficiency was observed to be 55.15% by used The Solar PV/T hybrid collector.

PV/T COLLECTOR
The table 1 shows the comparison of Theoretical and Experimental results for Case-I.

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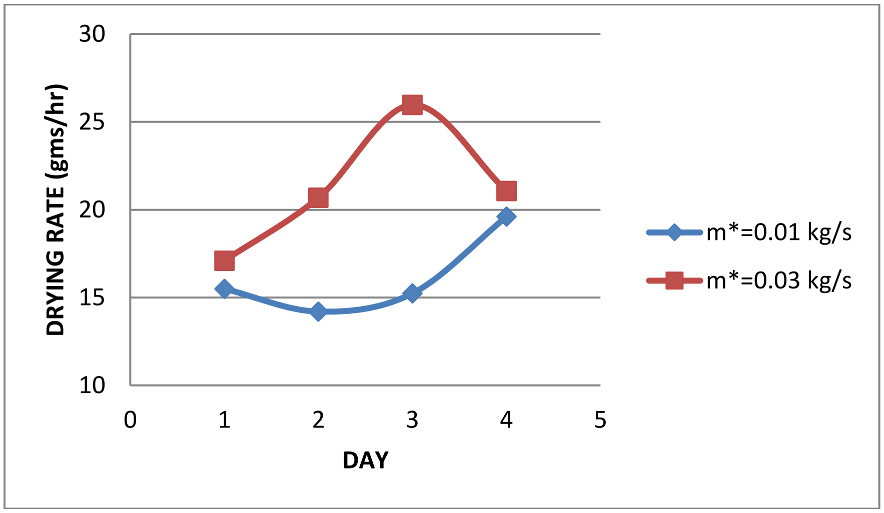
Table 1 comparison of Theoretical and Experimental Results

Parameter	**Theoritical**	**Experimental**
Nusselt Number	15.51	15.51
Collector efficiency factor	0.472	0.489
Heat removal factor	0.457	0.473
Useful energy gain	126.38 W	131.21 W
Thermal efficiency	36.11 %	37.49 %
Electrical efficiency	19.04 %	17.14 %
Total efficiency	55.15%	54.63 %

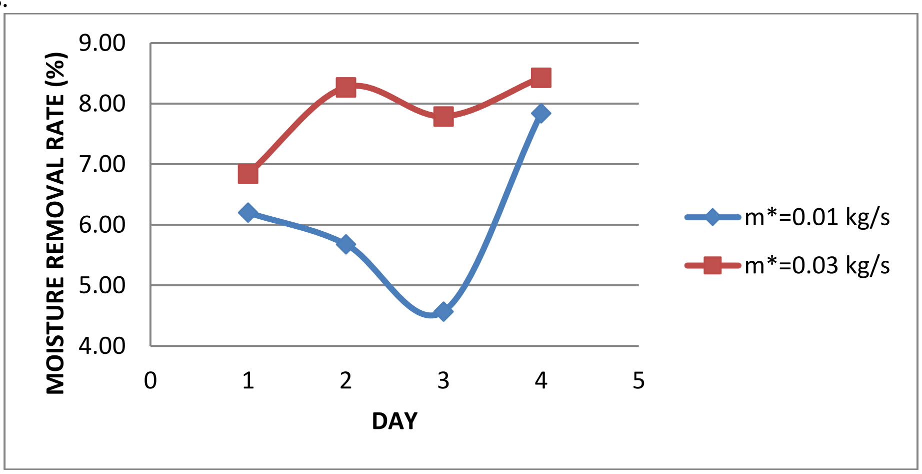
DRYING CHAMBER

The figures 7 represent the variation in drying rate with respect to various days (dates) for two different mass flow rates.



Figures 7 Drying Rate with respect to various Days

The figures 8 represent the variation in moisture removal rate with respect to various days (dates) for two different mass flow rates.



Figures 8 Moisture Removal Rate with respect to various Days

The figures 9 represent the variation in temperature with respect to various time (hours).

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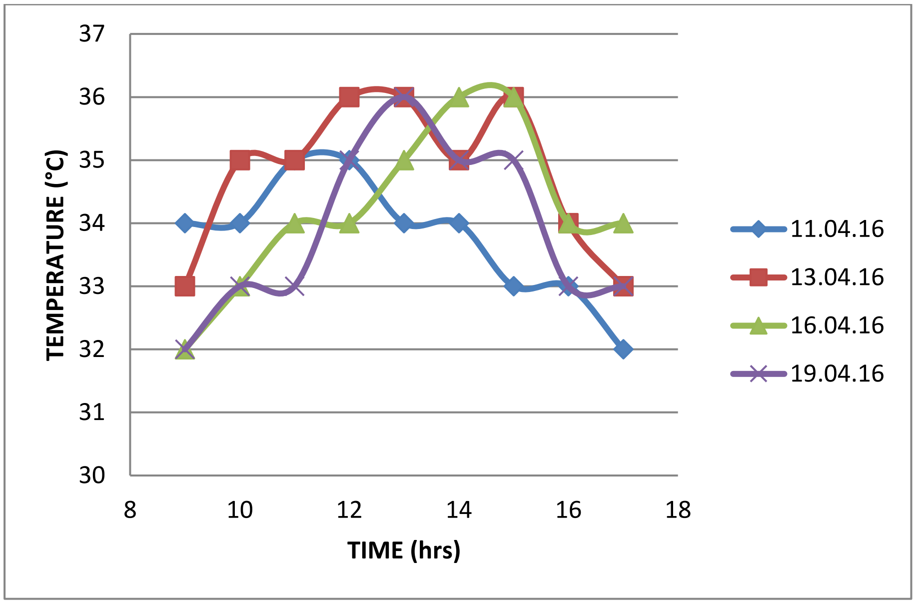

Figures 9 Temperature with respect to various Times (hour)

CONCLUSIONS

Based on this work results obtained from the theoretical & Experimental calculations and the related discussion briefed in the previous section the following conclusion are arrived,

- On comparing Case-I and Case-II considered the two different PV/T collectors in this study the two different PV/T collectors, were delivered the total efficiencies of 36.11% and 27% respectively for the absorber areas $0.5m^2$ (1m x 0.5m) and $2m^2$ (2m x 1m). Hence, it is observed that there is about more than 8% total efficiency was obtained for Case-I than that of Case-II.
- In summary the maximum total efficiency achieved by The PV/T was about 55.15% for a mass flow rate of 0.03 kg/sec, and the corresponding thermal and electrical efficiencies were about 36.11% and 19.04% respectively.
- The theoretical and experimental values of total efficiency were obtained 55.15 % and 54.63% for PV/T collector.
- The drying rates were varied from 14.2 g/hr to 19.6 g/hr and 17.1 g/hr to 25.97 g/hr for 0.01 kg/s and 0.03 kg/S mass flow rate respectively.
- The moisture removal rates were varied from 4.57 % to 7.84 % and 6.84 % to 8.43 % for 0.01 kg/s and 0.03 kg/S mass flow rate respectively.

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