Investigational Study Of Pv Powered Forced Circulation Solar Dryer

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***Abstract*—An indirect forced convection with photovoltaic powered forced circulation solar dryer has been built and experienced. The main parts are: a parabolic solar air collector, a scrap freeze as drying chamber, a battery and PV panel. The system is operated in one mode, sunshine hours. The dryer is used to dry 5 kg of ginger. Experiment were conducted on drying of ginger as drying of ginger is problem in north India and Mahatma Gandhi Institute for Rural Industrialization Wardha (MGIRI, A national institute under the ministry of MSME Government of India) asked to look into it and study the effect of drying as well the climatic and operational parameters on the dryer performance. The experiment was performed with and without reflective mirror at the Mahatma Gandhi Institute for the Rural Industrialization Wardha. The maximum collector outlet temperature was 66 0C and 81 0C without and with reflective mirror respectively. It was found that the average temperature inside the dryer without mirror was 63 0C which is below the maximum allowable temperature for ginger of 65 0C and with reflective mirror was above 65 0C which is higher than the maximum allowable temperature for ginger. Maximum instantaneous efficiency was found to be 58.4% and 78.39% and average was 51.14% and 59.18% without mirror and with mirror respectively. It is seen that the average efficiency of the collector is increased by 8.04% with reflector. The initial moisture content of ginger was 82.95% and it took 16 hours of day time to reach its equilibrium moisture of 12% when dried in solar dryer and took 48 hours in open sun drying with 8 hours of drying per day. The time of drying reduced in dryer by 66.7% and the quality of dried ginger was found well than open sun drying.**

Keywords*— *Parabolic solar air collector; Forced Convection; Ginger; Solar Module; Solar Radiation; PV Powered

I. INTRODUCTION

Agriculture is the main source of livelihood for the people in India. Fruits, vegetables, spice, grains are produced here in large quantities and the income derived from these products is normally minimal due to inadequate conservation and storage facilities and also lack marketing structures. Drying of agricultural products is still the most widespread preservation technique and it is becoming more and more an alternative to marketing fresh fruits since the demand for high quality dried fruits is permanently increasing all over the world [1].

Solar assisted drying system is one of the most attractive and promising applications of solar energy systems in tropical and subtropical countries. Traditionally all the agricultural crops were dried in the sun. Drying is one of an important post handling process of agricultural produce. It can extend shelf life of the harvested products, improve quality, it helps farmer to maintain relatively constant price of his products and reduces post-harvest losses. Direct sun drying Susceptible to contamination with foreign materials such as dusts, litters and are exposed to birds, insect and rodents. Hence, most agricultural produce that is intended to be stored must be dried first. Otherwise insects and fungi, which thrive in moist conditions, render them unusable. Other limitations were given by the availability of appropriate drying equipment which is technically and economically feasible and the lack of knowledge how to process agricultural products. Up to now only a few solar dryers who meet the technical, economical and socio-economical requirements are commercially available. The technical development of solar drying systems can proceed in two directions. Firstly, simple, low power, short life, and comparatively low efficiency-drying system. Secondly, high efficiency, high power, long life expensive drying system [2, 3]. Various solar dryers have been developed in the past for the efficient utilization of solar energy. Many studied have been reported on solar drying of agricultural products [4, 5]. Several studied have been done in the tropics and subtropics to develop solar dryers for agricultural products. Basically, there are four types of solar dryers [6], direct solar dryers, indirect solar dryers, mixed-mode dryers, and hybrid solar dryers, each having its characteristic advantages and disadvantages, with every drier developed and tested for different applications. The feasibility of the dryer depends largely upon the crop to be dried as well as the climatic conditions. The absence of control over drying temperature was acutely felt in open sun drying and the passive solar dryer, and then the later research tended to have a preference to the use of forced air circulation solar dryer. Several designs of forced convection solar dryers have been recently proposed for drying applications in developing countries and still a good deal of work is continuing in this direction [7–10]. Active solar dryers are designed incorporating external means like fans or blowers, for moving the solar energy in the form of heated air from the collector area to the drying beds.

J.Mumbaet.al. [11] a solar maize dryer incorporating directly coupled photovoltaic (PV) powered D.C. Fan was developed and field-tested for small scale use in Malawi, central Africa. The dryer has a capacity of 90 kg. A main design constraint was that the drying air temperature should not exceed 60°C, which is the international drying standard for maize grain used for human consumption. The dryer was coupled to a solar air heater having a sun-tracking facility and optimized blackened sisal rope grids for improved energy collection efficiency of the order of 80%. Grain drying with this solar dryer technology, compared with sun drying, reduced the drying time by over 70%. M. Mohanraj and P. Chandrasekar [12] a forced convection solar drier was designed fabricated and tested for the drying copra under Indian climatic conditions. Drying copra in the drier reduced its moisture content from about 51.8% to 7.8% and 9.7% in 82 h for the trays at the bottom and top respectively. The thermal efficiency of the drier was estimated to be about 24%. V. Shanmugam et.al. [13] An indirect forced convection and desiccant integrated solar dryer is designed and fabricated to investigate its performance under the hot and humid climatic conditions of Chennai, India. The system consists of a flat plate solar air collector, drying chamber and a desiccant unit. The equilibrium moisture content is reached in 14 h at an air flow rate of 0.03 kg/m s.

The objective of this study is to develop an indirect forced convection with photovoltaic powered forced circulation solar dryer. The main parts are: a parabolic solar air collector, a scrap freeze as drying chamber, a battery and PV panel. Experiment were conducted on drying of ginger as drying of ginger is problem in north India and Mahatma Gandhi Institute for Rural Industrialization Wardha (MGIRI A national institute under the ministry of MSME Government of India) asked to look into it and study the effect of drying as well the climatic and operational parameters on the dryer performance.

II. Experimental Set Up

The experimental set up (Fig. 1) consists of an indirect forced convection solar dryer with a solar V-grooved air collector to increase the heat transfer rate between the absorber plate and the air. 12 V D.C.fan with an air flow rate up to 0.03816 kg/m2s an adiabatic section of double door Freeze of 300 liter capacity in scrap is used as drying chamber which avoid the fabrication cost and the complexity in fabrication of insulated drying chamber. The fan is running with the 12 Ah battery which is charged by 18 watt photovoltaic panel for the constant air flow rate inside the drying chamber. The solar air collector had dimensions of 2.05 m × 1 m GI sheet painted black was used as an absorber plate for incident solar radiation. It was oriented southward with a tilt angle of 23.70 degree. A 6 mm plain window glass is used as a transparent cover for the air collector to prevent the top heat losses. The frame is made of thick plywood of 18mm which for insulation, fine saw dust is used at the sides and bottom of the collector. The distance between the absorber plate and transparent covert is 0.0025 m, and the distance between the absorber plate and the bottom of the collector is 0.0025 m, the inlet of air has 9 holes each of diameter 0.01 m and the outlet duct has size 0.2 m × 0.04 m. a plane reflecting mirror of same size as that of the collector is also used. The reflector is placed facing north 36.4 degrees. With flat plate collector the usual practice is to use an array of north -facing reflectors only, since these are more convenient to handle and adjust than south – facing reflector.

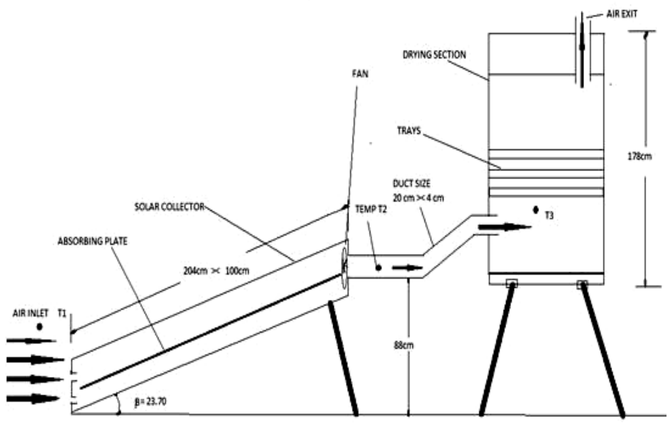

Fig. 1. Basic Schematic details of experimental set up.

III. Instrumentation

Copper constantan thermocouples are used to measure the temperature at various locations of the system. A solar power meter of range 1999 W/m2 is used to measure the solar radiation incident on the surfaces. A thermo hygrometer is used to measure the ambient air temperature and relative humidity of the air. The velocity of air is measured using vane type anemometer. An electronic balance of 0.001 g accuracy is used to measure the weight of the drying product. The moisture measurement is done in moisture analyzer by taking 5gms of drying products.

IV. Experimental Procedure

Experiments were conducted on drying of ginger as drying of ginger is problem in north India and Mahatma Gandhi Institute for Rural Industrialization Wardha (MGIRI, A national institute under the ministry of MSME Government of India) asked to look into it and study the effect of drying as well the climatic and operational parameters on the dryer performance. The system was oriented towards south to maximize the solar radiation incident on the V-grooved collector and kept free from shades in all directions. The experiment was performed at the Mahatma Gandhi Institute for the Rural Industrialization Wardha (MGIRI, under the ministry of MSME Government of India). The hot air from the solar collector was forced through the drying product and left through the exit. To estimate the system performance temperature, relative humidity, solar radiation were recorded at 1 hour interval and the moisture variation and change in weight of product is recorded after the interval of the 2 hours. Drying experiments were conducted for 5 kg of ginger loaded in the trays and same amount was kept in open sun. The loading density of the drying tray was 2.5 kg/tray size of the tray was 0.34 m × 0.5 m. before drying ginger was peeled, cored and sliced at 10 mm thickness. And also soaked in water for a night. Drying process was continued until the product achieved its equilibrium moisture content. For ginger, the initial and equilibrium moisture contents are 82.95 and 7-13% respectively In order to have high efficiency of solar collector for practical applications, the air flow rate should be as high as possible. Hegazy [14] and Pawar et al [15] used the air flow rate for conventional solar flat plate collector of constant flow operation in the range of 0.01– 0.03 kg/m2 s. In this study the flow rate of air through the solar flat plate collector is kept around 0.03 kg/m2s. The experiments were conducted with and without reflective mirror for collector, also the use of reflective mirror results in increase of drying air temperature averagely above 65 0C in drying chamber during the sunshine hours, which is not suitable for drying ginger Therefore, the results obtained using reflective mirror increases the efficiency of the collector but drying was not done properly. Hence the drying characteristic with mirror was not studied here.

V. CALCULATIONS

Weller and Bunn [16] used the weight change over time to calculate the moisture change over time A drying rate constant 'k' was derived by fitting moisture content and time to a thin layer drying equation of the form moisture ratio (MR).

$$MR = \frac{M_t - M_e}{M_o - M_e} = e^{-kt} \qquad \text{------------} \quad (1)$$

Where,Mt, Mo, Me is the moisture content in the product in % at any time t, at initial and at equilibrium respectively and k is the drying constant t is the drying time.

The main characteristics, which are generally used for performance estimation of any solar drying system are drying rate, dryer thermal efficiency [17]. The drying rate should be proportional to the difference in moisture content between the material to be dried and the equilibrium moisture content [18]. Mathematically, it can be expressed as thin layer equation drying rate,

$$\frac{dM}{dt} = -k(M_t - M_e) \qquad \text{----------------} \quad (2)$$

The instantaneous thermal efficiency of the solar air heater was estimated by using equation (3) according to (Kadam and Samuel) [19].

Instantaneous efficiency,

$$\eta = \frac{m\,Cp\,(To - Ta)}{AI} \times 100 \qquad \text{----------------} \quad (3)$$

Where, m = mass flow rate Kg/s, Cp = specific heat of air KJ/Kg-k, To = outlet collector temperature, Ta = ambient air temperature, A = area of collector m2, I = solar intensity W/m2.

Some structural changes take place on drying because of weight loss and the most important structural variation appeared on crop is the mass shrinkage ratio expressed as [20].

Shrinkage ratio,

$$SR = \frac{Wt}{Wi} \qquad \text{----------------} \quad (4)$$

Where, Wt is the weight of product at time t and Wi is the initial weight of product.

VI. RESULTS AND DISCUSSION

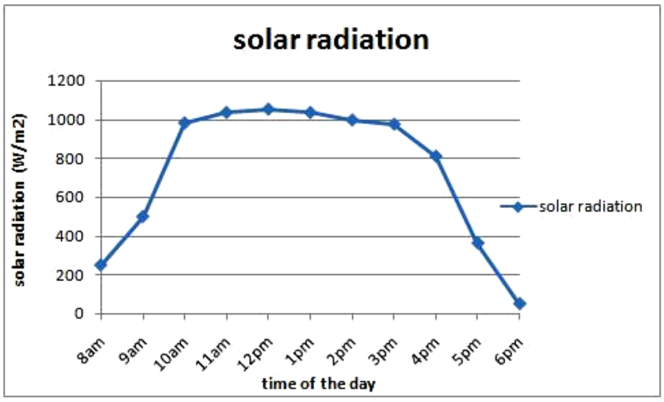

Fig. 2. Hourly variation of solar radiation.

Figures 2 and 3 shows the hourly variation of the measured solar radiation and relative humidity during the typical experimental run, which are employed for calculations As the time of day goes first it is seen that the intensity of solar radiation goes on increasing and it reaches to its maximum value of 1054 w/m2 at 12 pm. Then it starts decreasing as the time passes. The relative humidity which is measured to know the moisture absorbing capacity of the air. As the lower percentage of the relative humidity shows the higher capacity of the moisture absorption of air. The relative humidity goes on decreasing as solar radiation increases and reaches to its minimum value of 22% at 2 pm and then it starts increasing and it at its maximum value of 33% at 6 pm.

Figures 4 and 5 shows the variation of the Ambient air temperature (Ta), collector outlet temperature (To), and temperature inside dryer (Td) without and with reflective mirror respectively. It can be seen that the collector outlet temperature increases to a maximum of 660C and 810C at 12.00 PM without and with reflective mirror respectively and starts decreasing as the solar radiation decreases. It can be seen that the average temperature inside the dryer with reflective mirror above 650C which is higher than the maximum allowable temperature for ginger though the efficiency of dryer increases. Hence the drying characteristic of ginger without reflective mirror studied further.

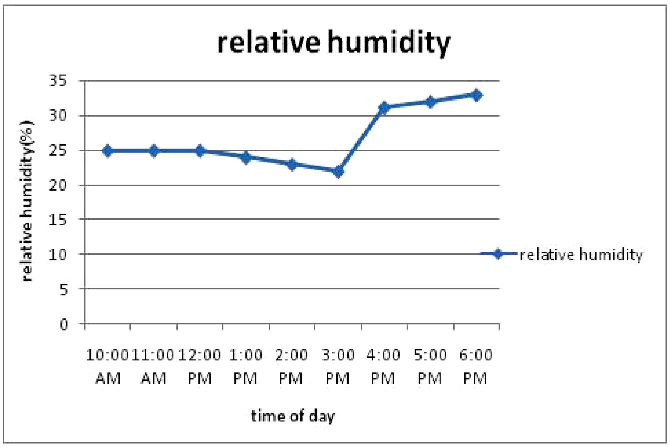

Fig. 3. Hourly variation of ambient relative humidity.

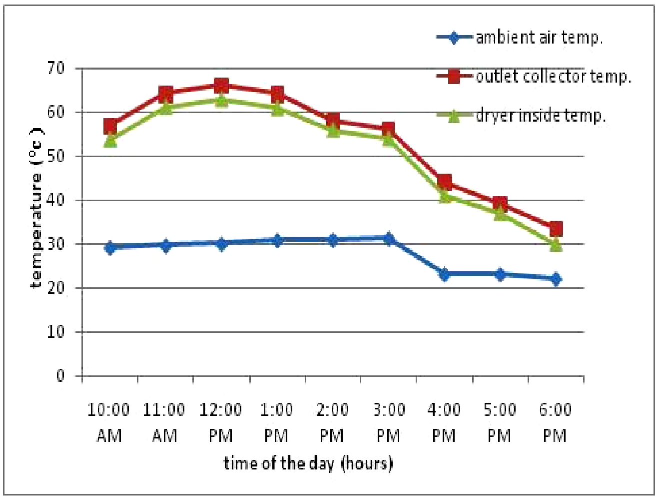

Fig. 4. Hourly variation, ambient temperature, collector outlet temperature and the temperature inside dryer without reflective mirror.

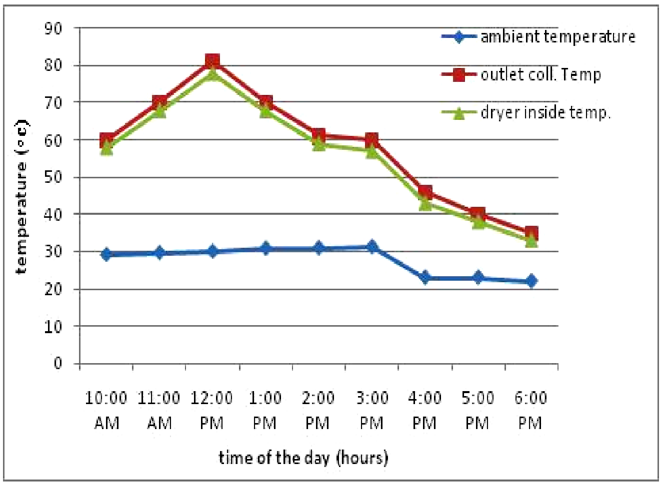

Fig. 5. Hourly variation, ambient temperature collector outlet temperature and the temperature inside dryer with reflective mirror.

The weight loss and the moisture content variation of the ginger with drying time are shown in Figs. 6 and 7, respectively. A weight loss of about 80% is achieved through solar energy. The plots indicate that the rate of moisture loss decreases as the drying time increases, until finally the ginger approach the equilibrium moisture content (MR=0). The drying mainly occurs in the falling rate period which indicates a diffusion-controlled type of mechanism of drying. The moisture content of ginger reached to 12% from 80.95% in 16 h of drying during day while it took 48 hours in open sun drying with 8 hours of drying per day. The time of drying reduced in dryer by 66.7%. Weight loss of product is initially faster because of the free moisture content in the surface of the product.

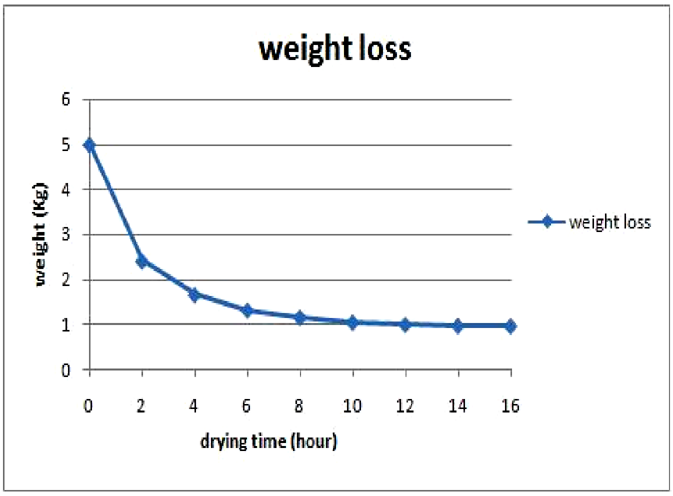

Fig. 6. The weight loss of product during solar drying.

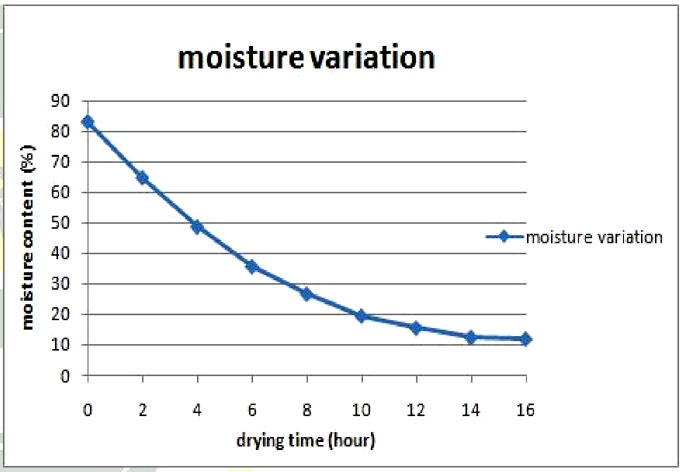

Fig. 7. The variation of moisture change with drying time.

Fig. 8 shows the influence of drying time on moisture ratio. The moisture ratio decreases significantly with decreased drying time. Fig. 9 presents the variation of mass shrinkage ratios with the drying time and is calculated using equation Wt/Wi given by Midilli [20]. To determine the mass changes during drying, it is significant to determine the mass shrinkage of the drying products.

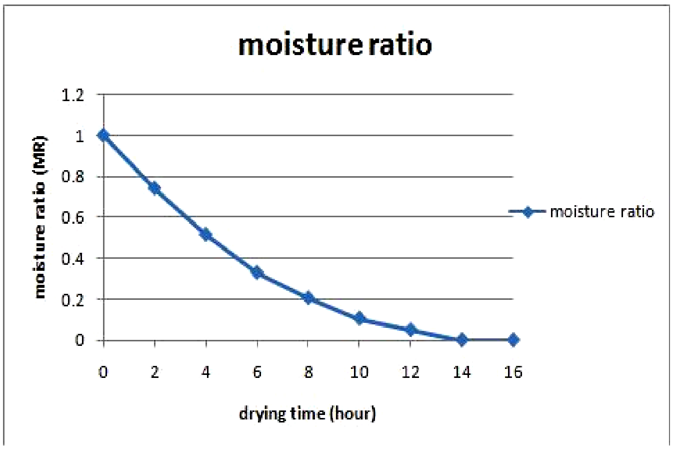

Fig. 8. The variation of the moisture ratio with drying time.

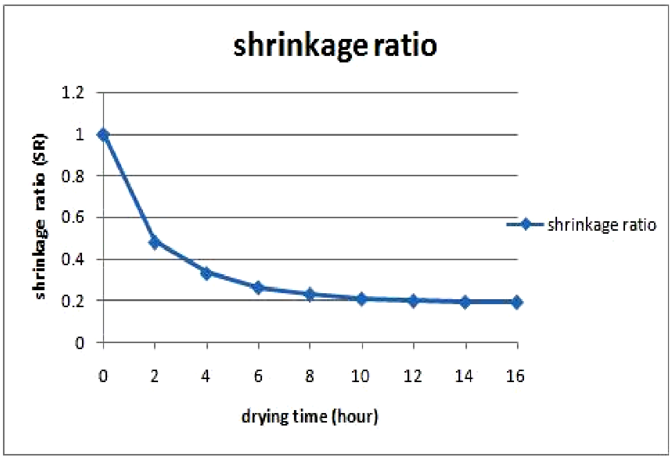

Fig. 9. The variation of the shrinkage ratio with drying time.

The drying rate curve is shown in Fig. 10. The results show that the drying occurs in the falling rate period with a steep fall in moisture content in the beginning and is very slow in the later part. This is due to the fact that in the later part, the drying occurs through diffusion of moisture within the product and also, the shrinkage of the product may offer a resistance against moisture movement. The better quality of product is obtained by the slow drying rate because the temperature is a major factor in determining the quality of the dried product. Constant rate period is not observed during drying possibly due to the thin layer of product that does not provide a constant removal of moisture.

Figure 11 shows the variation in efficiency of collector with time .it is seen that the efficiency of collector goes decreasing as time of the day passes this is because of the decreasing solar radiation. Maximum instantaneous efficiency was found to be 58.4% and 78.39% and average was 51.14% and 59.18% without mirror and with mirror respectively. It is seen that the average efficiency of the collector is increases by 8.04% with reflector.

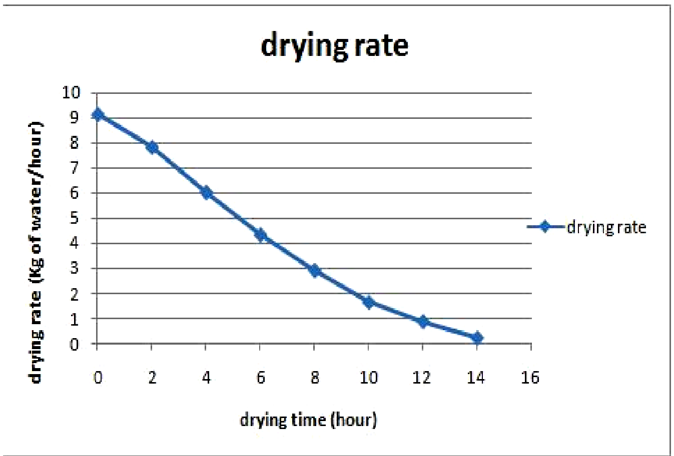

Fig. 10. The variation of drying rate as a function of drying time.

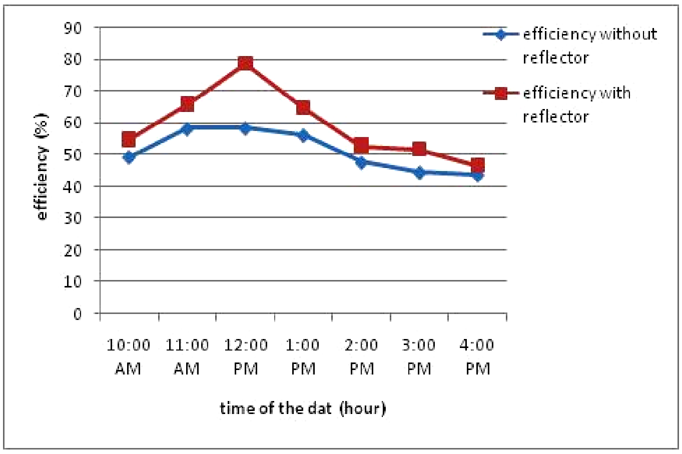

Fig. 11. variation in efficiency with time.

CONCLUSIONS

The maximum collector outlet temperature was 660C and 81 0C without and with reflective mirror respectively. It was found that the average temperature inside the dryer without mirror was 63 0C which is below the maximum allowable temperature for ginger of 65 0C and with reflective mirror was above 65 0C which is higher than the maximum allowable temperature for ginger. Maximum instantaneous efficiency was found to be 58.4% and 78.39% and average was 51.14% and 59.18% without mirror and with mirror respectively. It is seen that the average efficiency of the collector is increased by 8.04% with reflector. The initial moisture content of ginger was 82.95% and it took 16 hours of day time to reach its equilibrium moisture of 12% when dried in solar dryer and took 48 hours in open sun drying with 8 hours of drying per day. The time of drying reduced.

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