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# Experimental Investigation of Solar Dryer in Climatic Conditions of Patan, Gujarat

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**ABSTRACT:** Solar food processing is the efficient and economical solution for addressing different food problems in the postharvest stage and also to the world's energy requirements. Solar dryer seems to be a very useful device in the point of view of energy conservation and environmental pollution. It saves quite an amount of energy or fossil fuel and also advantageous in the aspects of quality of dried products, space requirement, and capital cost.

In this present research work, the solar dryer has been fabricated with locally available materials and tested in climatic conditions of Patan, Gujarat, India. Generally in the solar dryer, sometimes the food would be overheated due to higher solar radiations during the peak hours, so controlling is required. The solar dryer with controlling arrangement developed and its performance analysis is investigated during the climatic conditions of Patan. This work also carried out the comparison between solar drying as well as open sun drying and concluded that solar drying is best as compared with open sun drying due to the higher moisture removal capacity in the solar dryer as compared with open sun drying.

**KEYWORDS:** Solar dryer, Drying, Moisture, Potato slices, Open sun drying.

## I. INTRODUCTION

The drying of foods grown from the ground is a very important subject. In the agriculture industry drying of agriculture products like fruits, vegetables, grains, etc has gained commercial importance. Most of the agriculture products like fruits and vegetables contain approximately 80% moisture which is extremely perishable. It is necessary to remove the moisture content to a certain level after harvest to prevent the growth of microbiological infection. The benefit of drying is that it can reduce post-harvest losses and thereby increases the availability of food products. Drying is a process practiced to preserve the agricultural product in the world. It is important to reduce the moisture content of a product to a safe level where deterioration could not take place. Also, drying ensures the quality of the product, long shelf life, and the market value of the product. The drying of agricultural products is carried out by burning fossil fuels. Fossil fuels have certain major limitations like high cost, negative impact on the environment, and destruction of natural resources. The limitations of conventional energy resources have directed the research towards non-conventional based sources. Non-conventional sources of energy are capable of solving the problems of energy supply and environmental sustainability. In agricultural-based countries, non-conventional-based energy sources play a very essential role in drying food products. Solar energy is famous as an energy-efficient and eco-friendly option for processing agricultural products compared to other non-conventional energy methods. Solar energy is an efficient alternative as it is more capable of drying agricultural material compared to industrial drying that makes use of conventional energy sources. In tropical and sub-tropical climates solar energy-based post-harvesting equipment is commonly used for processing agricultural products. Solar energy is richly available in India from a cost viewpoint. The traditional open sun drying is ancient technology. This technology is prone to losses by the influence of fungi, insects, birds and rodents, and other weather-related problematic incidents. Solar drying offers the advantages of faster drying than direct sun drying, greater preservation of quality, and market value of the product. The basic meaning of drying is to decrease the moisture content of the product to a safe level so that it prevents deterioration. The solar dryers are mainly classified into direct, indirect, and hybrid solar dryers. The working standards of such dryers generally depend upon the method of solar energy collection and its utilization to heat energy for drying. In general solar dryers are classified according to the method of air movement, mode of heat transfer, and type of drying chamber. [1]

In direct solar drying, the product directly absorbs the solar radiation through a transparent cover. Indirect solar drying consists of two major components such as the heat collection part and drying chamber. The hybrid solar dryer combines solar energy with an auxiliary energy source like gas, conventional fuels, or biomass. [2]

## II. RELATED WORK

A.A. El-Sebaei et al. [3] had designed an indirect type natural convection solar dryer with storage materials. The drying experiment was carried for spherical vegetables like tomatoes, green peas and onions and also for spherical fruits like apples and figs. The experimental investigation was carried in the summer and winter weather conditions of Tanta, Egypt. The equilibrium moisture content for seedless grapes is reached after 60 h when system with storage material and 72 h without storage material. Sand was used as the storage material which reduced the drying process by 12 h. Shanmugam et al. [4] have developed a forced convection solar dryer with desiccant and investigated its performance for drying of green peas. They evaluated the performance under the hot humid climates of Chennai, India. The desiccant unit used in their work consists of 75 kg solid base desiccant. The final equilibrium moisture content was reached in 14 hours with an air mass flow rate of  $0.03 \text{ kg/m}^2 \text{ s}$ . The pickup efficiency and specific moisture extraction rate are notably improved in their work. J. E. Berinyuy et al [5] had designed and constructed a double pass solar tunnel dryer integrated with heat storage material. In their experiment the heat storage material used was Crushed basalt rocks. The temperature inside the dryer remained  $5^\circ\text{C}$  above the ambient temperature even at sunset. The dryer was capable of drying 17 kg of sliced cabbage from 95% moisture content wet basis down to 9% in five days. The dryer reduce the drying time of high moisture product by 30 to 50% depending on the product. S.M. Shalaby et al. [6] had developed an indirect type solar dryer employing PCM (Parafin wax) as heat storage material for drying medical plants. The Drying temperature of  $2.5\text{-}7.5^\circ\text{C}$  higher than ambient was achieved by PCM after sunset for five hours. They achieve final moisture content of *O. basilicum* and *T. nerifolia* in 12h and 18h in the case of implementing PCM. Padmanaban G. et al. [7] had studied the performance of a new desiccant assisted packed bed passive solar dryer for copra processing and compared with conventional passive solar dryer. They have carried out experimental testing under the meteorological conditions of Coimbatore city in India during March and April 2016. They evaluated that the copra was dried from initial moisture content of about 52% (wet basis) to the final moisture content of about 8% (weight basis) in 62 hours and also the drying time was reduced by about 44 hours when compared to the conventional passive solar dryer. They concluded that the packed bed absorber plate capable of retaining heat for long duration and the desiccant packed at the air heater outlet reduce the relative humidity at the dryer inlet. Nabnean S. et al. [8] had investigated the performance of direct forced convection low cost house hold solar dryer for drying banana. The dryer was designed with parabolic shaped flat plate collector with polycarbonate cover to reduce heat losses. They designed, constructed and tested the dryer at the Division of Physics, Faculty of Science and Technology, Thepsatri Rajabhat University, Lopburi in Thailand during the period of January - July 2019. During experiment the drying temperature achieved was varied between  $35^\circ\text{C}$  to  $60^\circ\text{C}$  from 8.00 am to 6.00 pm. The result shows that in 4 days the moisture content of 10 kg banana was reduced from an initial value 72% (wb) to a final value of 28% (wb) in the dryer compared to 40% (wb) in natural sun drying. The drying time was reduced 48% in dryer compared to natural sun drying. Vengsungle P. et al. [9] had investigated the thermal performance of photovoltaic-ventilated mixed mode greenhouse solar dryer with automatic closed loop control and also compared with open sun drying. They have carried out the experiment at Nakhonratchasima province in Thailand during the winter season of 2019 for *Ganoderma* drying. The air temperature inside the greenhouse solar dryer range from  $30^\circ\text{C}$  to  $52^\circ\text{C}$  compared to open sun temperature ranges from  $30^\circ\text{C}$  to  $40^\circ\text{C}$ . Also the relative humidity obtained inside the greenhouse solar dryer is always lower than that of open sun. From the experimental investigation, they concluded that the drying rate of the *Ganoderma* obtained from the greenhouse solar dryer with automatic closed-loop control is higher than that for the open sun traditional drying. Ankur Gupta et al. [10] had developed a hybrid photovoltaic-thermal (PVT) solar dryer for drying green chilis to investigate the performance at North East Indian climatic conditions. They fabricated and investigated the performance at the National Institute of Technology, Silchar, India: latitude  $24^\circ 83' \text{N}$  and longitude  $92^\circ 77' \text{E}$ . The drying experiment is carried out in the open sun and solar air dryer on 20<sup>th</sup> August 2018 from 9:00 AM to 5:00 PM. During 8 hrs of experiment the solar dryer removed moisture content of green chilis is 130% thermal efficiency and overall thermal efficiency of the PVT solar dryer was 12.29%, 18.81%, and 51.18% respectively. They concluded that the hybrid solar dryer is more effective in drying compared to the open sun drying method.



### III. METHODOLOGY

The solar dryer was fabricated and installed in Patan. The experimental studies were carried out in the month of March 2021 to investigate the performance of Potato slices drying in a solar dryer. 2 kg of fresh potato for solar dryer and 1 kg of fresh potato for open sun drying were collected from the local market. They are properly cleaned with water after the purchase. The potatoes were chosen are of similar sizes for the experiment. The potatoes were weighed in the starting. To conduct the experiment potatoes were cut into slices. The solar dryer experiment was carried out from 9.00 am to 4.00 pm with a one-hour interval. The open sun drying experiment was carried out from 9.00 am to 7.00 pm with a one-hour interval. Proper measuring devices were used to record various values of parameters of interest. The parameters like temperature, relative humidity, the weight of the product are recorded at regular intervals of one hour during the experiment of the solar dryer.

The experimental setup of the solar dryer consists of a Solar dryer, Solar PV panel, DC Fan, PID controller. The drying chamber is covered on top by a transparent material. The Top cover is made from a UV filter Polycarbonate Unbreakable Sheet. The polycarbonate sheet traps solar energy and has also an insulation effect. The solar dryer is of inclined structure constructed with high-quality aluminium. The dimension of the drying chamber is 1.21 m x 0.91 m in cross-section and height 0.30 m. The chamber was insulated inside with glass wool of 10 mm thick. There is a provision of a castor wheel for the easy movement of the dryer. There are 2 aluminium perforated trays which are coated black. The trays can be easily removed to load and unload the drying product through the top cover. The excess solar radiations overheat and deteriorate the product placed inside the dryer. To maintain the desired temperature of the product the auto controlling system required in the dryer. For this purpose PID controller, Solar PV panel and 3 Dc fans are incorporated with the dryer. The performance of solar dryer evaluated by the procedure explained by Leon et. al. (2002). [11]

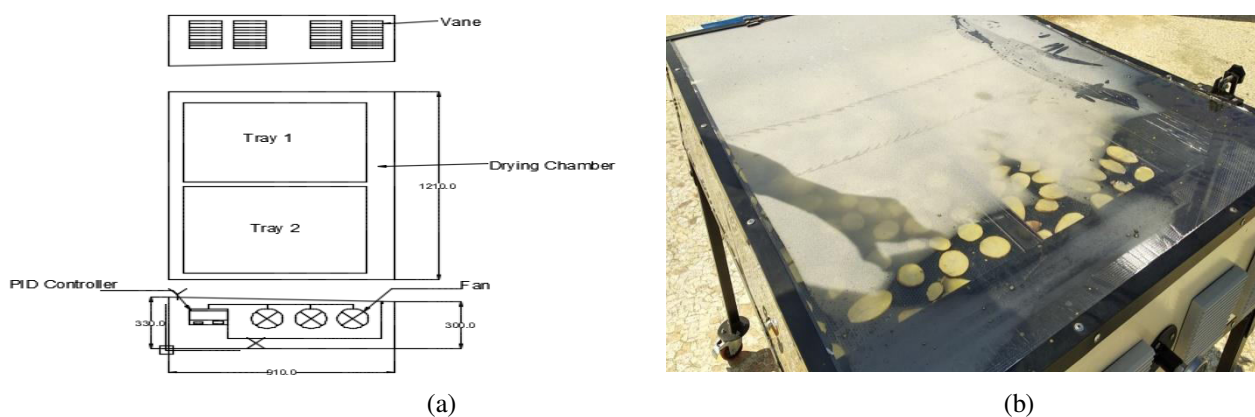
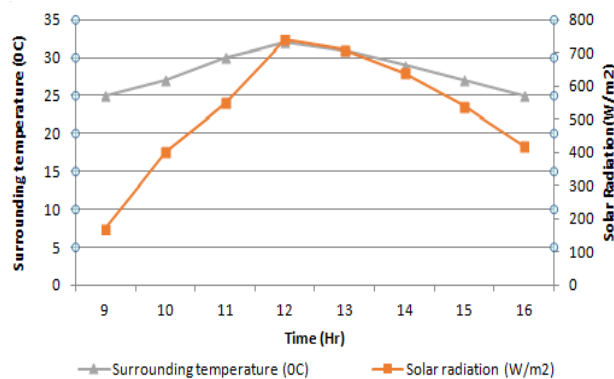


Figure 1: (a) Schematic diagram of solar dryer (b) Potato slices before drying

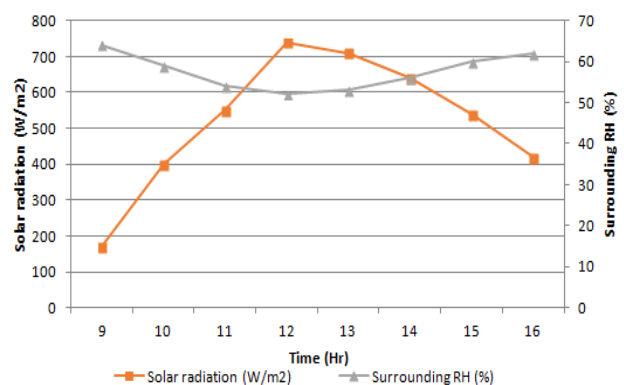
### IV. EXPERIMENTAL RESULTS

Figure 2(a) shows the variations of the surrounding temperature, solar radiation versus the time during the typical experimental day. It is clearly seen that, as the solar intensity raises from the morning 09 am to 01 pm noon, the surrounding temperature is also increasing and then reduces as the day passes. It means that, there is proportionality between the solar intensity as well as surrounding temperature. As the day passes, then the solar rays intensity remains also increasing, also the surrounding air also takes the solar rays, therefore the surrounding air temperature also increasing. Figure 2(b) shows the variations of the solar intensity, surrounding Relative humidity versus the time for typical experimental day. It is clearly visible that, there is inverse proportionality between the solar intensity as well as surrounding relative humidity. For the given mass of the water vapour present in the atmosphere, the increase in air temperature always reduces the Relative humidity. It is the main reason behind the lower the relative humidity as the solar radiations increases. Earlier graphs, it has been already depicted that, there is a proportionality between the solar insolation as well as surrounding air temperature. So as the solar intensity is increasing, then the surrounding air

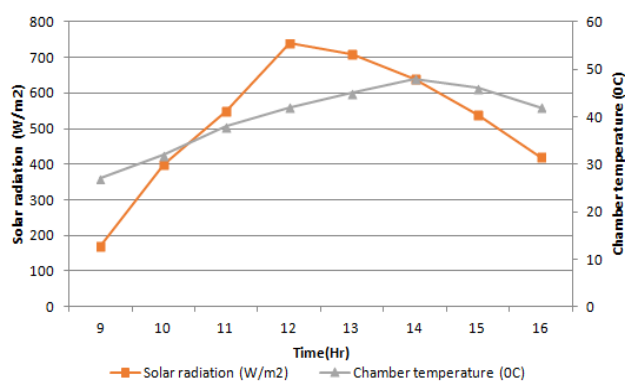
temperature increase and at same time the relative humidity reduces. It is highest during the starting of the experimentation, and least at 01 pm and the increases. Figure 2(c) shows the fluctuations of chamber temperature during varying the solar radiations on the day of experimentation. Actually in the case of solar drying, it is pretty interesting to know about the chamber temperature, because it directly affects the drying rate inside the chamber. Higher temperature leads to higher heat accumulation and the drying will be faster and vice versa. From the graphs, it is clearly seen that the curves are similar trends and not perfectly aligned with each other. The reason is the uncertainty as well as various climate factors like water vapour, dust, and many more. The highest temperature reaches at 02 pm and highest solar radiation at 12 o'clock. The mismatch reason is due to the heat capacity of the drying material as well as air present in the drying chamber too. Figure 2(d) and (e) shows the moisture content of product in solar dryer and open sun drying during the experimental days respectively. It is obviously seen from the both graphs that the moisture content remains higher in the case of open sun drying as compared with the solar drying. In the case of open sun drying, after reaching the thermal equilibrium, the temperature of the atmosphere as well as drying product found same, then the drying will be reduced. So the moisture content will be higher in the case of open sun drying. Figure 2(f) shows the relation with the moisture ratio and drying time during the experimental day for open solar drying and sun drying. It has been found that the moisture ratio remains lower for the solar drying as compared with the open sun drying. It is also shown that, as the time passes the moisture ratio reduction remains for the solar drying and remains higher for the open sun drying. The reason behind the lower moisture ratio is a good heating and removal of the water present in the food present in the solar dryer.



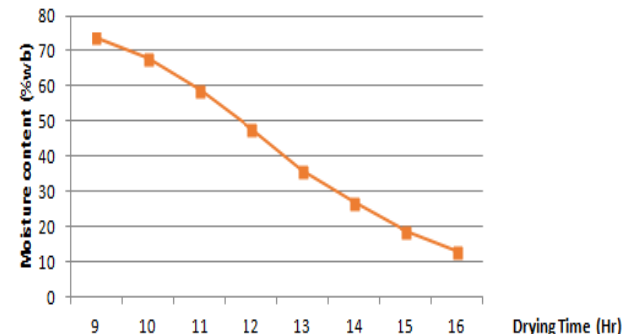
(a)



(b)



(c)



(d)

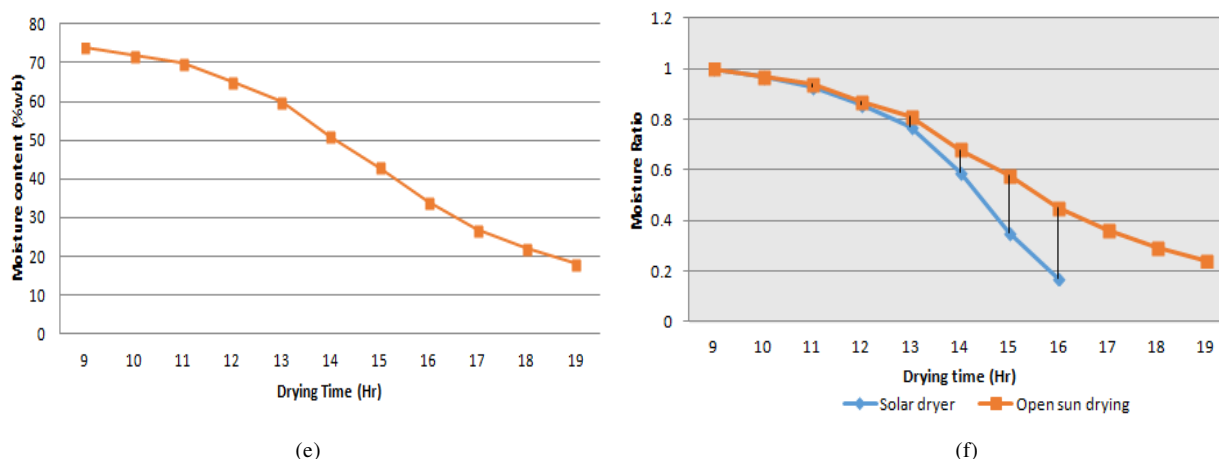


Fig. 2 (a) Fluctuation of Temperature at different solar radiation (b) Fluctuation of Relative Humidity at different solar radiation (c) Fluctuation of Chamber temperature at different solar radiation (d) Variation of Moisture Content with Drying time (Solar dryer) (e) Variation of Moisture Content with Drying time (Open sun drying) (f) Moisture ratio patterns obtained from Experimental data

## V. CONCLUSION

The solar dryer is considered one of the most important solar energy operated devices that are used for the drying of food and vegetables. Higher solar heat accumulation during peak hours is a problem for the solar dryer. Because the accumulation of heat creates the overheating of the food or grains inside the solar dryer. The content of the moisture for the open sun drying conditions remains higher during the experimental day. The content of the moisture inside the solar dryer remains lower as compared with the open sun drying during the experimental day. The relative humidity is a prime factor for solar drying and it reduces when the surrounding temperature increasing. It is concluded by the research study that solar drying has reduced the moisture content of the potato slice from 74 % wet basis to 13% wet basis in 7 hrs in comparison of the open sun drying has reduced the moisture content of the potato slice from 74 % wet basis to 18% wet basis in 10 hrs.

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