

# **A STUDY ON DRYING OF AMLA USING A HYBRID SOLAR DRYER**

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## **ABSTRACT**

In this work, Indian gooseberry or amla fruit which is the richest source of vitamin C among fruits were dried using a hybrid photovoltaic thermal (PV/T) dryer. An experimental hybrid solar dryer associated with a photovoltaic (PV) system was developed for the purpose. The experimental hybrid system consisting of a double pass arrangement produces both electric and thermal energy simultaneously. Drying process of amla samples using the hybrid system has been compared with open sun drying. The developed hybrid PV/T drying system produces better quality products in shorter time by the efficient use of solar energy.

## **NOMENCLATURE**

K	Drying rate (g/h)
M	Moisture content at any time (g)
$M_{db}$	Moisture content in dry basis (% wb)
$M_e$	Equilibrium moisture content
$M_o$	Initial moisture content (g)
MR	Moisture ratio
$M_{wb}$	Moisture content in wet basis (% db)
T	Time (h)
$W_d$	Bone dry weight of the sample (g)
$W_L$	Amount of moisture evaporated (g)
$W_o$	Initial weight of the sample (g)

## **1. INTRODUCTION**

Drying or dehydration is a popular preservation method of fruits and vegetables in which the moisture content is reduced to a level to keep the product at a relatively chemically stable state [1]. Vegetables and fruits are highly perishable in nature and available in plenty at particular seasons. Preservation of these

crops is a challenging task for farmers. Proper preservation techniques should be cost effective and least detrimental to the quality of the products. Lack of good post harvest processing facilities coupled with short shelf life results in huge revenue loss to the country. Suitable processing technologies are needed to preserve the produced crops in order to save the agrarian economy of the country. Electrical or fossil fuel powered dryers are not popular among the economically weak farmers even though these dryers offer faster drying performance. Solar dryers are increasingly becoming popular among farmers due to the low operating cost and better performance than open sun drying. It has an added advantage of maintaining the environment pollution free.

Indian gooseberry (*Phyllanthus emblica* Lim) or amla is indigenous in tropical South-East Asia. Amla fruit is the richest source of vitamin C among the fruits. The shelf life of amla fruits in atmospheric conditions without processing is very short. In tropical countries preservation of amla by solar drying is a common practice. But open sun drying has many disadvantages like contamination by insects and dust, need of a lot of man power etc. Drying rate and drying time are the significant parameters while drying of biological materials. Controlled drying using solar energy has many advantages in rural areas due to low running cost and good product quality.

Siporn Methakhup et al. [2] reported the effects of drying methods and conditions on drying kinetics and quality of amla flakes. Vacuum drying and low-pressure superheated steam drying of amla flakes were carried out at various drying conditions to monitor the drying kinetics and quality degradation of the product during drying. Verma and Gupta [3] dried amla on a solar dryer to investigate the effects of different treatments on the product quality. The pre-treatments under study were flaking; pricking; pricking + blanching; pricking + blanching + flaking etc. All the treatments were found to be significantly improving the product quality. Hossain and Bala [4] used a mixed mode type forced convection solar tunnel dryer to dry hot red and green chillies under tropical weather conditions of Bangladesh. An experimental closed-type dryer integrated with a photovoltaic (PV) system was developed by Ho- Hsien Chen et al. [5]. This system integrates a PV panel as an electric energy producing device and dehumidification system to remove moisture. They have reported that by using this system, loss of color and flavor are minimized. Mustafa Aktas et al. [6] determined the drying characteristics of apples in a heat pump and solar dryer. Both the heat pump and solar dryer were designed and fabricated. Drying of apples were experimentally analyzed and found that apples can be dried in a short time with the combination of both the dryers.

Only a small fraction of solar energy is converted by photovoltaic cells to electricity and the remaining is wasted. The wasted thermal energy can be recovered by photovoltaic/thermal (PV/T) technology and the recovered thermal energy can be utilized for further applications like drying. The PV/T collector offers superior way of exploiting solar energy due to improved overall efficiency. Recent studies were reported on different PV/T systems based on air and water as working fluids.

The PV/T technology has been evolved over the last three decades and widely published. A detailed review of available literature on PV/T collectors were given by Charalambous et al. [7]. Arwind Tiwari [8] presented energy metrics analysis of a hybrid photovoltaic module. In that paper energy pay-back time, electricity production factor and life cycle conversion efficiency of a PV module were analyzed. It has been observed that the energy pay-back time was considerably reduced due to the increase in annual energy availability of the thermal energy in addition to electric energy. Low cost performance improvements of air cooled PV/T solar collectors were suggested by Tonui and Tripanagnostopoulos [9]. Their study investigates the performance of two low cost improvements of heat extraction in the channel of a PV/T system to attain higher thermal output and PV cooling. Niccolo Aste et al. [10] presented the details of design, development and performance monitoring of PV/T air heater. The simulation model developed by them predicted the thermal and electrical performance of a PV/T with reasonable accuracy. Joshi and Tiwari [11] have conducted exergy analysis of a hybrid PV/T air heater. The hybrid systems are

more economical than the stand alone systems. Analytical expression for electrical efficiency of PV/T hybrid air collector was presented Dubey et al. [12].

The present work deals with amla fruits dried by a hybrid solar photovoltaic thermal (PV/T) dryer and the performance was compared with that of open sun drying.

## 2. MATERIALS AND METHOD

The experimental hybrid system consists of a photovoltaic panel, a blower and a drying chamber. The hybrid system has been designed and fabricated in such a way that it enabled the combined production of electric energy and thermal energy from the photovoltaic panels. A photovoltaic (PV) panel of a rating of 100 W was placed on a frame made of mild steel angles. Bottom and side walls were covered with galvanized iron sheets. On the top of the frame, a glass cover was provided. Polystyrene sheet (thermocool) of thickness 0.05 m was used for insulation. A cabinet type solar dryer (dimensions 0.75 m x 0.45 m x 0.35 m) was fabricated using galvanized iron sheets (SWG 20) along with a door for loading the dryer.

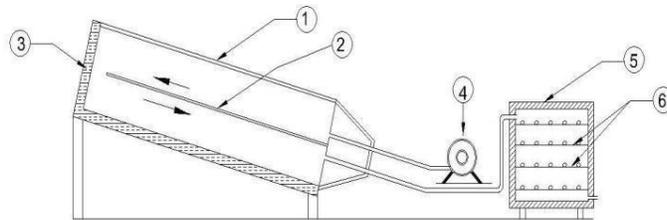


FIGURE 1. EXPERIMENTAL SET UP

(4) Top glass cover (2) Photovoltaic panel (3) Insulation Blower (5) Solar dryer (6) Trays

The dryer has four trays to keep the crops. The outer surface of the dryer was insulated with plywood to reduce heat losses. A blower was employed to increase the heat transfer rate.

The experiments were conducted at the Solar Energy Laboratory of NIT Calicut, Kozhikode. The experiments started at 8.00 am and terminated at 5.00 pm. The drying time is defined as the time in which the crop is dried. Drying started from 8.00 am. About 3 kg of amla was collected from the market near the institute. Among these, good quality uniform sized samples were sorted out for the experiment. Further samples were pricked and cut into slices. Two sets of samples (1 kg each) were used for the experiment. A set of sample was spread on a galvanized iron sheet for open sun drying. Another sample was spread on a mesh tray of hybrid solar dryer.

Moisture content of the samples was found by the oven drying method. Samples of the product were weighed using an electronic balance. Then samples were placed in moisture boxes which were kept in oven at a temperature of 105 °C for 24 hours. These samples were again weighed and their moisture content was determined on the wet basis method.

Moisture content in wet basis (%)

$$M_{wb} = \frac{(W_o - W_d) \times 100}{W_o} \quad (1)$$

Moisture content in dry basis (%)

$$M_{db} = \frac{(W_o - W_d) \times 100}{W_d} \quad (2)$$

W<sub>o</sub>: Initial weight of the sample (g)  
W<sub>d</sub>: Bone dry weight of the sample (g)  
Moisture ratio (MR)

$$MR = \frac{M - M_e}{M_o - M_e} \quad (3)$$

M : Moisture content at any time (g)  
M<sub>e</sub>: Equilibrium Moisture Content  
M<sub>o</sub>: Initial Moisture Content (g)

$$\text{Drying rate } K = \frac{W_L}{T} \quad (4)$$

Where W<sub>L</sub>: Amount of moisture evaporated, g T : Time taken, h

### 3. RESULTS AND DISCUSSION

The experiments were done at the Solar Laboratory of NIT, Calicut on 2 days of December, 2012. The samples were subjected to drying from 8.00 am to 5.00 pm. Generally, drying of fruits depends on the temperature and humidity of the drying air. Figure 2 shows the variation of ambient temperature with time. Figure 3 shows the variation of solar radiation with time. Maximum solar radiation obtained on day 1 and 2 were 838 W/m<sup>2</sup> and 788 W/m<sup>2</sup>, respectively at around 1.00 pm.

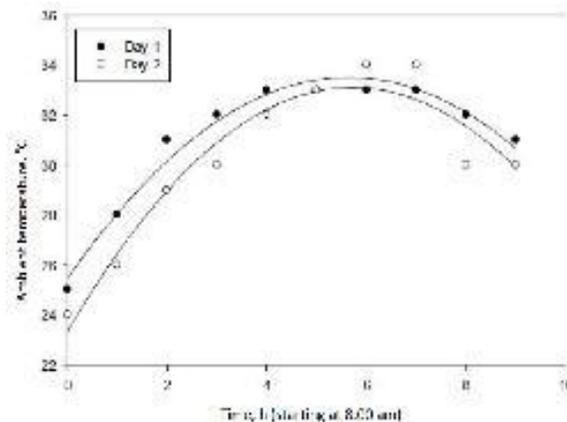


FIGURE 2. VARIATION OF AMBIENT TEMPERATURE AGAINST TIME

Figure 4 demonstrates the variation of moisture loss of the sample during the drying period. It is clear from the graph that photovoltaic thermal dryer removes more moisture than the open sun drying during the same drying period.

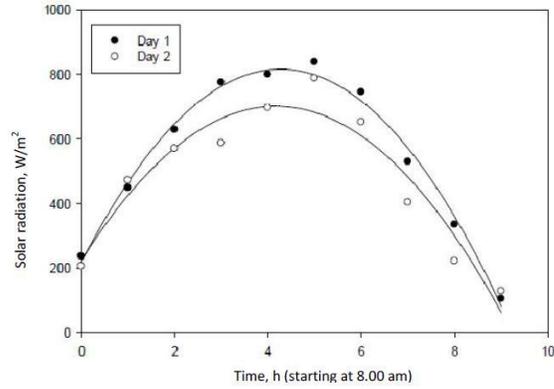


FIGURE 3. VARIATION OF SOLAR RADIATION AGAINST TIME

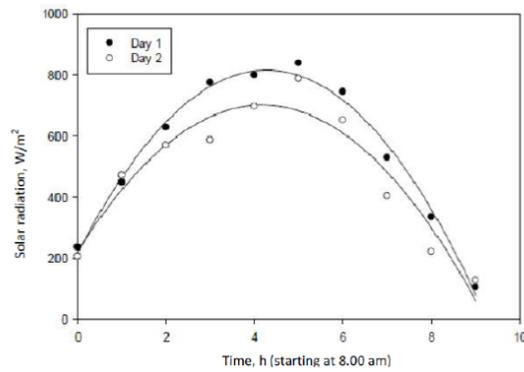


FIGURE 4. REDUCTION IN MOISTURE CONTENT WITH DRYING TIME

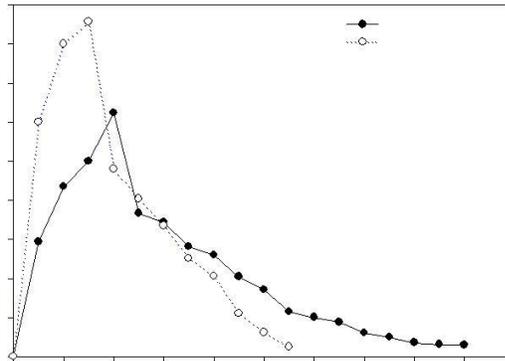


FIGURE 5. VARIATION OF DRYING RATE WITH DRYING TIME

Figure 5 shows the variation of drying rate with drying time for open sun drying and hybrid solar drying. Initially the drying rate was high and then slowly decreasing. Only a small quantity of energy is required to evaporate the surface moisture so the drying rate was high during the initial period. The energy requirement is more after the evaporation of the surface moisture. Figure 4 & 5 clearly demonstrate the effectiveness of the hybrid solar dryer compared to the open sun drying of the amla fruit. A water pressure gradient has to be established for the moisture removal from the fruits. In traditional open sun drying due to the intake of high humid air, a water vapor pressure gradient cannot be attained. Consequently more time is required to dry the product in open sun drying. Controlled drying using a

hybrid dryer improves product quality by reducing the drying time.

#### 4. CONCLUSION

In this study, the performance of a hybrid photovoltaic thermal (PV/T) drying system which produces both thermal and electric energy simultaneously using a solar panel of rating 100 W was investigated. The thermal energy produced was used for the controlled drying of amla. By using this hybrid system, better drying performance was obtained compared with open sun drying. The closed nature of the system prevents many typical short-comings of open sun drying such as microbial contamination and exposure to humid environment.

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