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# DESIGN AND FABRICATION OF DOUBLE MODE SOLAR AIR HEATER TO ENHANCE THE EFFICIENCY BY USING DIFFERENT PARAMETER

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*Abstract:* The solar drying system Uses the solar heat energy to heat up air and to dry food substance loaded, which is useful in reducing wastage of agricultural product and helps in preserving of agricultural product and food product. The limitations of the natural sun drying e.g. exposure to direct sunlight, liability to pests and rodents lack of proper monitoring, and the escalated cost of the mechanical dryer, a solar is therefore developed to cater for this limitation. This project presents the design, construction and performance of a mixed-mode solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying cabinet was up to 74°C.The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

In the present work a comparative analysis is presented to show the effect of non coating of black color, with coating of black color and rough surface and result evaluated on that basis in the month of May-2021.

*Index Terms* - solar dryer, solar collector, rough surface, double mode, transparent glass cover.

## I. Introduction

Drying is one of the methods used to preserve food products for longer periods. The heat from the sun coupled with the wind has been used to dry food for preservation for several thousand years. Crop drying is the most energy consuming process in all processes on the farm. The purpose of drying is to remove moisture from the agricultural produce so that it can be processed safely and stored for increased periods of time. Crops are also dried before storage or, during storage, by forced circulation of air, to prevent spontaneous combustion by inhibiting fermentation. It is estimated that 20% of the world‘s grain production is lost after harvest because of inefficient handling and poor implementation of post-harvest technology, says Hartman‘s (1991).

Grains and seeds are normally harvested at a moisture level between 18% and 40% depending on the nature of crop. These must be dried to a level of 7% to 11% depending on application and market need. Solar drying may be classified into direct and indirect solar dryer. In direct solar dryers the air heater contains the grains and solar energy which passes through a transparent cover and is absorbed by the grains.

For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of Drying involves the application of heat to vaporize moisture and some means of removing water vapor after its separation from the food products. It is thus a combined and simultaneous heat and mass transfer operation for which energy must be supplied. The removal of moisture prevents the growth and reproduction of microorganisms like bacteria, yeasts and molds causing decay and minimizes many of the moisture-mediated deteriorative reactions. It observed that reduction in

weight and volume, minimizing packing, storage, and transportation costs and enables storability of the product under ambient temperatures. These features are especially important for developing countries [4].
Solar energy is inexhaustible, ample and free of cost available all over the world. Due to this the attention has been gradually diverting to utilize the renewable energy for a number of applications. Open sun drying was followed in rural areas to dry agricultural products. In recent days solar dryers are used which protect farming produce from insect, dust and rain. Solar drying is economical as compared to artificial drying methods. Fruits and vegetables are easily contaminated because they contain water more than 80%. In developing countries loss of 30-40% fruits and vegetables produce, and more than US$1.5 billion/year of Loss of worth in India. Open air and uncontrolled sun drying is still the most common method used to preserve and process Agricultural product. But these methods cause serious problem of wind born dust, infestation by insect, product may be seriously degraded and become market valueless and resultant adverse economic effects on domestic and international market34. India is blessed with 300–330 sunny days in a year and solar radiation around 4–7 kWh/m2-day. Thus, it is one of the most promising sources of energy, unlike fossil fuels and nuclear energy, it is an environmentally clean source and freely available energy.[5]

### 1.1 Problem Statement

Food scientists have found that by reducing the moisture content of food to between 10 and 20%, bacteria, yeast, mold and enzymes are prevented from spoiling it. The flavor and most of the nutritional value is preserved and concentrated [16]. Wherever possible, it is traditional to harvest most grain crops during a dry period or season and simple drying methods such as sun drying are adequate. However, maturity of the crop does not always coincide with a suitably dry period. Furthermore, the introduction of high-yielding varieties, irrigation, and improved farming practices have led to the need for alternative drying practices to cope with the increased production and grain harvested during the wet season as a result of multi-cropping.

### 1.2 Research Objectives

The objective of present study is to construct a double mode solar air dryer in which the grains are dried simultaneously by direct radiation through the transparent walls and roof of the cabinet and by the heated air from the solar collector. The problems of low and medium scale processor could be alleviated, if the solar dryer is designed and constructed with the consideration of overcoming the limitations of direct and indirect type of solar dryer. So therefore, this work will be based on the importance of a mixed mode solar dryer which is reliable and economically, design and construct a mixed mode solar dryer using locally available materials and to evaluate the performance of this solar dryer. This project presents the design, construction and performance of a mixed-mode solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying cabinet was up to 70% for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

## Literature Review

Solar drying may be classified into direct and indirect solar dryer. In direct solar dryers the air heater contains the grains and solar energy which passes through a transparent cover and is absorbed by the grains. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the grain bed. However, in indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the grain bed, while in the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls or the roof.

The unpredictable rise and frequent scarcity of fossil fuel accelerated the continuous search for an alternative power source. Solar is one of the renewable and sustainable sources of power that attracted a large community of researchers from all over the world. This is largely due to its abundant in both direct and indirect form. As such the development of efficient and inexpensive equipment for the drying of agricultural and marine products using solar power evolved thereby improving the quality of the products as well as improving the quality of life. The use of solar dryers in the drying of agricultural products can significantly reduce or eliminate product wastage, food poisoning and at the sometime enhance productivity of the farmers towards better revenue derived. A solar crop drying system does not solely depend on solar energy to function; it combines fuel burning with the energy of the sun, thus reducing fossil fuel consumption. In this paper a review of the solar dryer is presented. The various design of the solar dryer is reported in the literature thus far is presented [3].

Energy is important for the existence and development of human kind and is a key issue in international politics, the economy, military preparedness, and diplomacy. To reduce the impact of conventional energy sources on the environment, much attention should be paid to the development of new energy and renewable energy resources. Solar energy, which is environment friendly, is renewable and can serve as a sustainable energy source. Hence, it will certainly become an important part of the future energy structure with the increasingly drying up of the terrestrial fossil fuel. However, the lower energy density and seasonal doing with geographical dependence are the major challenges in identifying suitable applications using solar energy as the heat source. Consequently, exploring high efficiency solar energy concentration technology is necessary and realistic[24].

## DESIGN APPROACH AND METHODOLOGY

Solar drying refers to a technique that utilizes incident solar radiation to convert it into thermal energy required for drying purposes. Most solar dryers use solar air heaters and the heated air is then passed through the drying chamber (containing material) to be dried. The air transfers its energy to the material causing evaporation of moisture of the material.

### 3.1.1 Drying Mechanism

In this process of drying, heat is required to vaporize the moisture from the object and a flow of air helps in carrying away the evaporated moisture. There are two basic mechanism involved in the drying process: the extraction of moisture from the interior of an individual material to the surface, and the evaporation of moisture from the surface to the surrounding air. Drying process takes place in two stages first one happens at the surface of the drying material at constant drying rate and is similar to the vaporization of water into the ambient and second stage is according to properties of drying product with decreasing drying rate . Previously open sun drying is used for drying product. In this method, the crop is placed on the ground or concrete floors, which can reach higher temperatures in open sun, and left there for a number of days to dry. Capacity wise, and despite the very rudimentary nature of the process, natural drying remains the most common method of solar drying. This is because the energy requirements, which come from solar radiation and the air enthalpy, are readily available in the ambient environment and no capital investment in equipment is required. The process, however, has some serious limitations. The most obvious ones are that the crops suffer the undesirable effects of dust, dirt, atmospheric pollution, and insect and rodent attacks. Because of these limitations, the quality of the resulting product can be degraded, sometimes beyond edibility. All these disadvantages can be eliminated by using a solar dryer.[4]

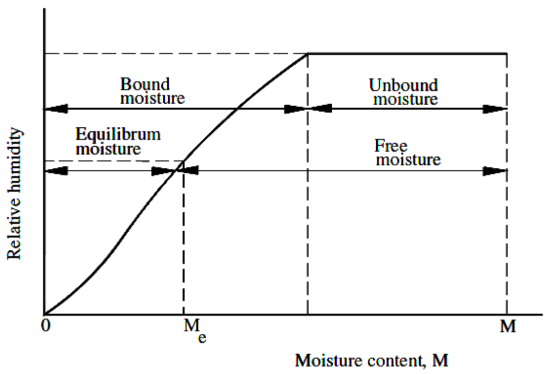



**Fig. Moisture in the Drying Material**

## Classification of drying systems

Solar dryers are available in a range of size and design and are used for drying of various agricultural products. Various types of Dryers are available in the market as per requirement of farmers. Primarily all the drying systems are classified on the basis of their operating temperature ranges that is High Temperature solar dryer and Low Temperature Solar dryer.

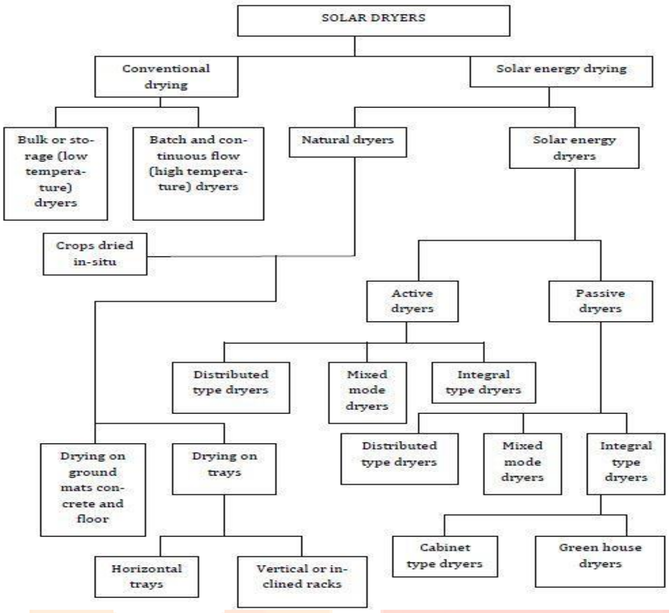



**Fig. Classification of dryer and drying mode [6].**

### Design Methodology

### Types of solar driers

Solar-energy drying systems are classified primarily according to their heating modes and the manner in which the solar heat is utilized. In broad terms; they can be classified into two major groups, namely [5]:

- Active solar-energy drying systems
- Passive solar-energy drying systems

Another Three distinct sub-classes of either the active or passive solar drying systems can be classified which vary mainly in the design arrangement of system components and the mode of utilization of the solar heat, namely [7]:

I. Direct solar dryers
II. Indirect solar dryers
III. Mixed-mode dryers
IV. Hybrid solar dryers

### Double mode solar dryer

The mixed-mode solar dryer has no moving parts so it is called the passive dryer. This type of dryer acquires energy from the rays of the sun that enters through the collector lustring. The inside surface of the collector is painted black and the sun rays are harnessed by trapping the heat f the air that is collected inside the chamber. This kind of solar dryer verified the accelerated drying process and its ability to dry agricultural products by quickly reaching better conditional moisture level, thus making it ideal for food preservation. This kind of dryer consists of a separate solar collector and a drying unit. A transparent cover is affixed on top of the dryer, the solar collector, and the drying unit. The collector receives the solar radiation. This kind of dryer is often used for drying crops in the wet season. Comparing the three kinds of dryers, the mixed mode dryer is the best of the three because it has the highest drying rate followed by the box dryer.

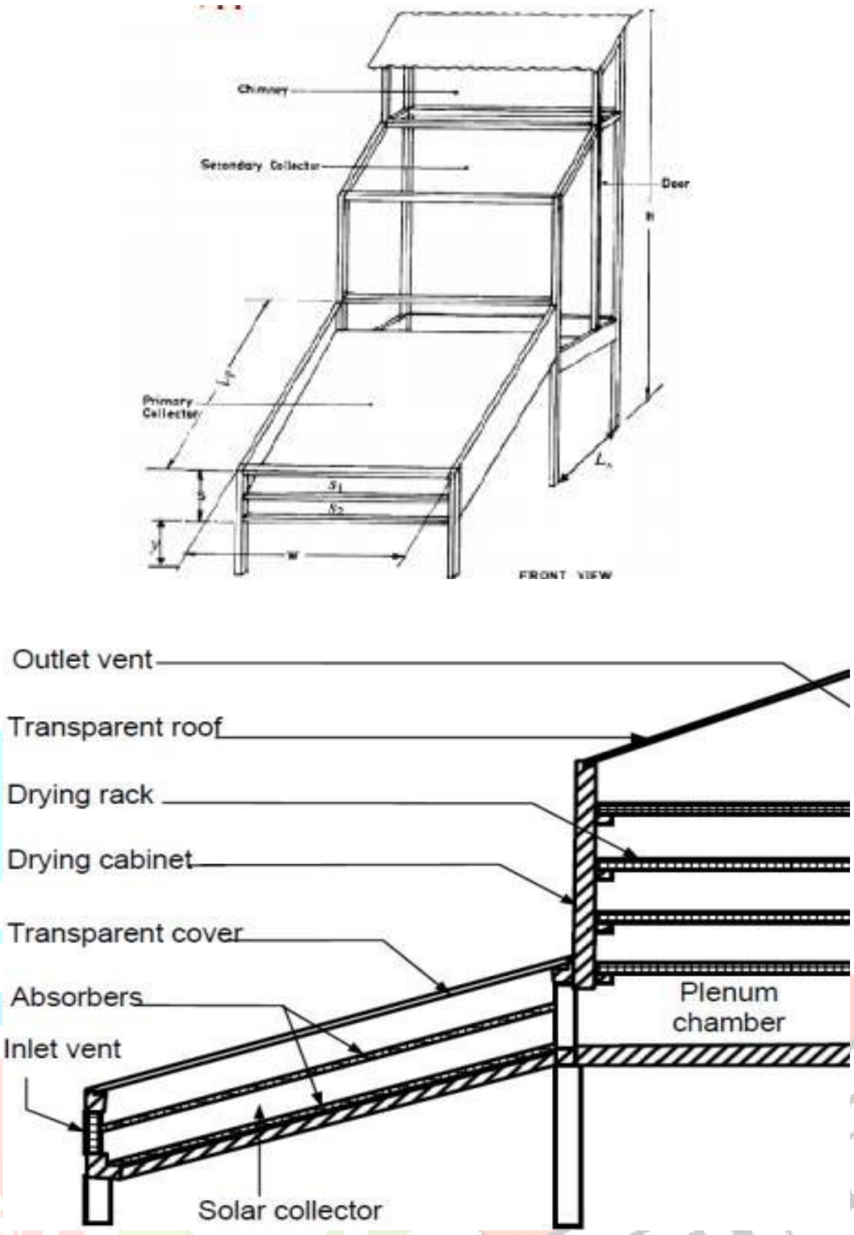



**Fig. Mixed Mode Type Solar Dryer**

## Applications of solar driers

The drying process has been experimentally studied and analyzed to simulate and design a drier. as drying is a process of removing moisture to a safe level, the equilibrium moisture content is defined as the moisture content in equilibrium with the relative humidity of the environment. The equilibrium moisture content is divided into, static and dynamic. While the static is used for food storage process, dynamic is used for drying process. The drying process is experimentally obtained and presented as moisture content on x-axis and rate of drying on y-axis. A deep bed of food grains is assumed to be composed of thin layers normal to the hot air flow direction. The equations for thin layer were written initially, using empirical, theoretical and semi theoretical equations. The conditions of the grain and air change with position and time during drying of a deep bed of grains. Logarithmic and partial differential equation models to simulate the deep bed dry modeling are dealt in detail.[16]

### DESIGN SPECIFICATIONS AND ASSUMPTIONS

Solar drying may be classified into direct and indirect solar dryer. In direct solar dryers the air heater contains the grains and solar energy which passes through a transparent cover and is absorbed by the grains. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the grain bed. However, in indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the grain bed, while in the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls or the roof. The objective of this study is to design a mixed-mode solar dryer in which the grains are dried simultaneously by both direct radiation through the transparent walls and roof of the cabinet and by the heated air from the solar collector.

# DESIGN PROCEDURE AND IMPLEMENTATION

## Design Procedures

In many parts of the world there is a growing awareness that renewable energy have an important role to play in extending technology to the farmer in developing countries to increase their productivity [19]. Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting [20]. Mix mode solar dryer is the combination of direct and indirect type of solar dryer. Product is dry by directly exposure to the sun light and also by hot air supplier on it. Air is heated in a collector and then this hot air is supplied to the drying chamber and drying chamber top is made up of glass cover. Which can directly absorbs solar radiation. In this way drying rate is higher as compared to direct solar drying. The governing equations were derived with respect of the drying air temperature, humidity ratio, product temperature and its moisture content [21]. It was found that inside temperature of drying chamber was up to 74% after 12 pm for about 3 hours. Drying rate obtained is 0.62kg/h and system efficiency obtained is 57.5% [23]. Tripathy and Kumar gives information of dryer in which flat plate collector placed in series. They used this dryer for drying potato slices of diameter 0.05m and thickness 0.01m [22].

## Result and Discussion

This project presents the design, construction and performance of a mixed-mode solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying cabinet was up to 74% for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

## Variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature.

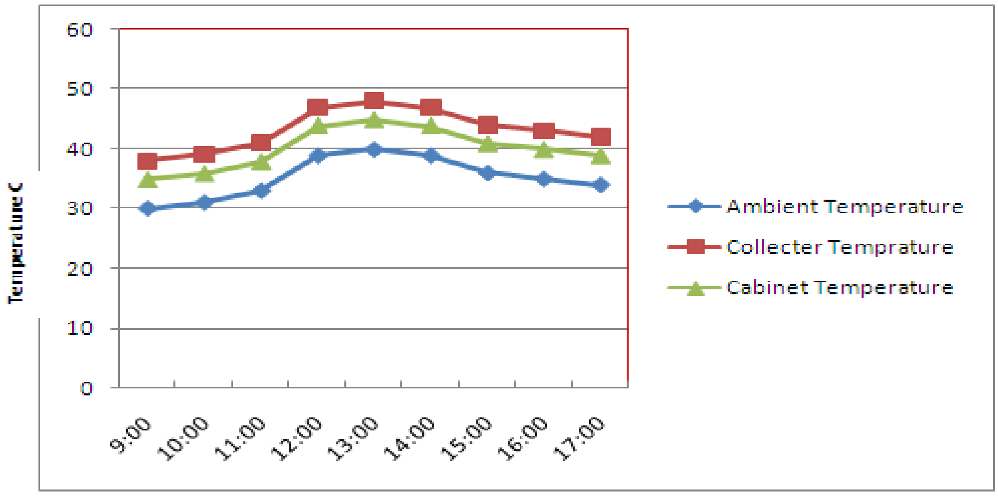
Table. 5.1 shows a typical day results of the hourly variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature. The dryer is hottest about mid-day when the sun is usually overhead. The temperatures inside the dryer and the solar collector were much higher than the ambient temperature during most hours of the daylight. The temperature rise inside drying cabinet was up to 8ºC for about three hours immediately after 12.00h (noon). This indicates prospect for better performance than open-air sun drying.

### WITHOUT BLACK PAINT ON SOLAR COLLECTOR

Table 5.1

| Sl. No. | Time | Ambient Temperature (°C) | Collector Temperature (°C) | Cabinet Temperature (°C) |
|---|---|---|---|---|
| 1 | 9:00 | 30 | 38 | 35 |
| 2 | 10:00 | 31 | 39 | 36 |
| 3 | 11:00 | 33 | 41 | 38 |
| 4 | 12:00 | 39 | 47 | 44 |
| 5 | 13:00 | 40 | 48 | 45 |
| 6 | 14:00 | 39 | 47 | 44 |
| 7 | 15:00 | 36 | 44 | 41 |
| 8 | 16:00 | 35 | 43 | 40 |
| 9 | 17:00 | 34 | 42 | 39 |

Graph 5.1




**DATE 14-5-2021**

**WITHOUT BLACK PAINT ON SOLAR COLLECTOR**

**Table 5.2: Hourly Moisture Loss and Mass of the Potato**

| Time | Mass of Potato (g) | Moisture Loss (g) | % Moisture Loss | Total Moisture Loss (%) |
|---|---|---|---|---|
| 9:00 | 575 | 0 | 0 | 67.00 |
| 10:00 | 560 | 15 | 2.68 | 64.32 |
| 11:00 | 528 | 12 | 2.27 | 62.05 |
| 12:00 | 503 | 25 | 4.97 | 57.08 |
| 13:00 | 474 | 29 | 6.12 | 50.96 |
| 14:00 | 450 | 24 | 5.33 | 45.63 |
| 15:00 | 425 | 25 | 5.88 | 39.75 |
| 16:00 | 393 | 32 | 8.14 | 31.61 |
| 17:00 | 367 | 26 | 7.08 | 24.53 |

GRAPH 5.2 **Hourly Moisture Losses and Mass of the Potato**

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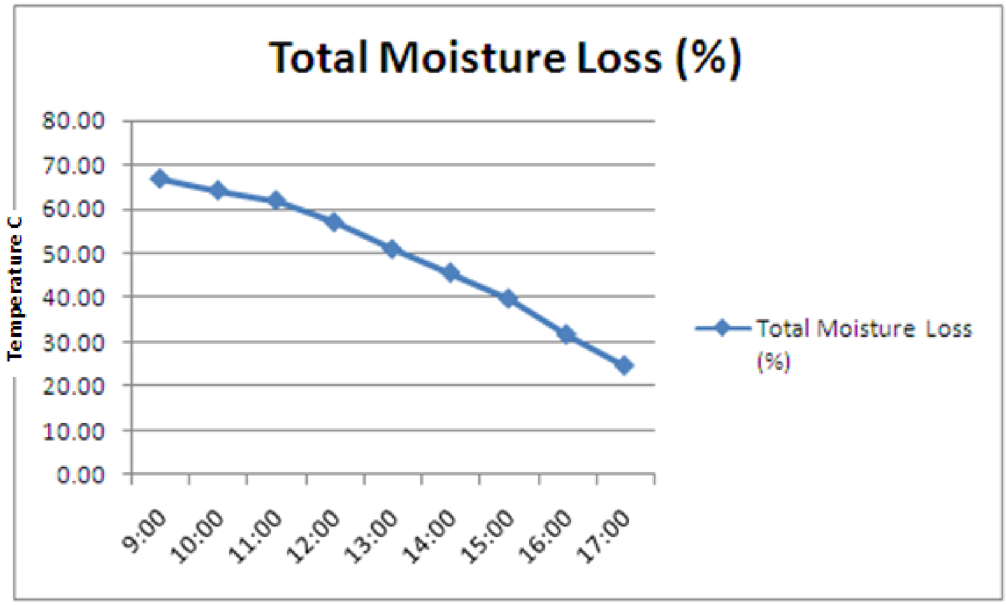
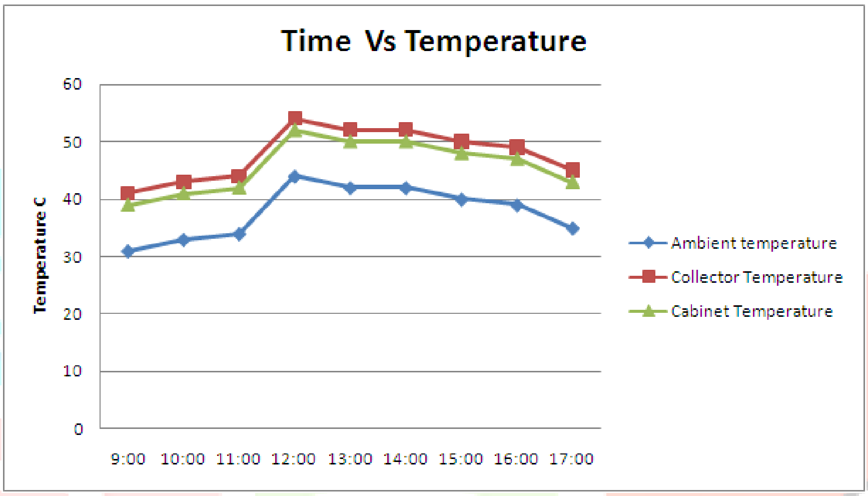


**DATE 15-5-2021**
**With Black Paint on Solar Collector**
**TABLE 5.3**

| Sl. No. | Time | Ambient Temperature (°C) | Collector Temperature (°C) | Cabinet Temperature (°C) |
|---|---|---|---|---|
| 1 | 9:00 | 31 | 41 | 39 |
| 2 | 10:00 | 33 | 43 | 41 |
| 3 | 11:00 | 34 | 44 | 42 |
| 4 | 12:00 | 44 | 54 | 52 |
| 5 | 13:00 | 42 | 52 | 50 |
| 6 | 14:00 | 42 | 52 | 50 |
| 7 | 15:00 | 40 | 50 | 48 |
| 8 | 16:00 | 39 | 49 | 47 |

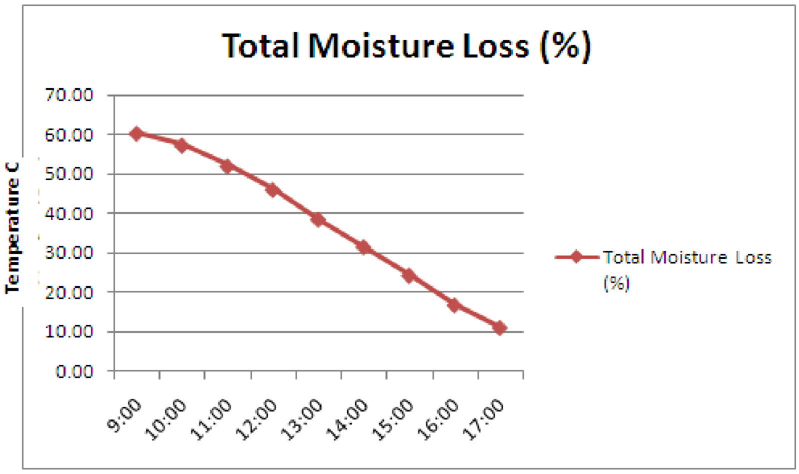



GRAPH 4.3 **Hourly Moisture Losses and Mass of the Potato**

**DATE 15-5-2021**
**With Black Paint on Solar Collector**
**TABLE 5.4**

| Time | Mass of Potato (g) | Moisture Loss (g) | % Moisture Loss | Total Moisture Loss (%) |
|---|---|---|---|---|
| 9:00 | 575 | 0 | 0 | 60.34 |
| 10:00 | 558 | 17 | 3.05 | 57.29 |
| 11:00 | 530 | 28 | 5.28 | 52.01 |
| 12:00 | 500 | 30 | 6.00 | 46.01 |
| 13:00 | 465 | 35 | 7.53 | 38.48 |
| 14:00 | 430 | 30 | 6.98 | 31.5 |
| 15:00 | 400 | 29 | 7.25 | 24.25 |
| 16:00 | 373 | 28 | 7.51 | 16.74 |
| 17:00 | 348 | 20 | 5.75 | 10.99 |

GRAPH 5.4 **Hourly Moisture Losses and Mass of the With black paint on solar collector**




## Conclusion

From the test carried out, the following conclusions were made. The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of agricultural crops. The product inside the dryer requires less attentions, like attack of the product by rain or pest (both human and animals), compared with those in the open sun drying. Although the dryer was used to dry Potato, it can be used to dry other crops like yams, cassava, maize and plantain etc. There is ease in monitoring when compared to the natural sun drying technique. The capital cost involved in the construction of a solar dryer is much lower to that of a mechanical dryer.

Also from the test carried out, the simple and inexpensive mixed-mode solar dryer was designed and constructed using locally sourced materials. The hourly variation of the temperatures inside the cabinet and air-heater are much higher than the ambient temperature during the most hours of the day-light. The temperature rise inside the drying cabinet was up to 24oC (74%) for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

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