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# SOLAR POWER ACTUATED DRIER

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**ABSTRACT**

*The traditional method of drying is to keep the food grains in sunlight in open environment, which is not so hygienic due to contamination by dust, insects, bacteria and birds. Hence to overcome these problems, we thought of introducing a new method of drying using SOLAR POWER ACTUATED DRIER(SPAD), which derives the heat required for drying from the hot water stored inside the solar water heater. Hot water from the water heater is made to flow through the metallic jackets in different stages inside the suitable insulated drier cabin. Thus available heat over the metal jackets is sufficient to utilize for drying many food grains for maximum duration. Since this unit indirectly utilizes the solar energy it can be used as an indoor appliance. This project aims on utilizing the solar water heater as a multipurpose appliance along with better utilization of renewable source of energy. This can also emerge as a best solution for the present energy crisis.*

***Keywords:*** *Drier cabin, Solar water heater, Metal jackets, Temperature, Indoor home appliance.*

## I. INTRODUCTION

Drying is one of the excellent methods of food preservation which works by removing moisture from the food grains and also inhibits the growth of bacteria. Hence it has been practiced world-wide since ancient times to preserve food. There are variety of drier that uses non-renewable sources of energies such as electricity and gases. Even domestic solar drier are available which operates by absorbing solar radiation directly from sun and makes system to be kept under sunlight always. It might be very simple and inexpensive with the use of traditional methods of drying but, meanwhile it is very difficult to safeguard the items from environmental factors. When the things are exposed to sunlight in an open environment, they are affected by various factors such as humidity. It is also a great difficult to protect the things from birds and other animals. So totally it is very difficult to safeguard the things from blowing wind and other pollutants that often exists in atmosphere. Therefore it is very essential to dry the things in a safe and closed unit which is only possible by Solar drying system which is most efficient and eco-friendly.

In order to overcome these drawbacks, new technology for drying has been implemented by introducing solar driers. These driers are capable of providing efficient and safe drying since the unit is closed and isolated the things from being contact to the external environment. But even these solar driers have some demerits regarding its working. Solar driers works effectively only during the day time when there is sufficient sunlight is available. The intensity of solar radiation varies with respect to time and hence heat required for drying is not uniform throughout the day. Moreover during night it is not possible to dry anything using solar driers. Referring to all above mentioned aspects, there is a scope for introducing new method of drying which could overcome all the above problems associated with the traditional drying methods as well as normal solar driers. So the new method of drying could be implemented very easily at an economical cost by introducing SOLAR POWER ACTUATED DRIER.

SOLAR POWER ACTUATED DRIER (SPAD) is an indoor domestic drier that uses hot water from the solar water heater for drying food grains and other items. This is achieved by passing the hot water from the solar water heater through metallic jackets that are mounted inside the suitable insulated cabin. In this way it is possible to design and fabricate an effective, eco-friendly and hygienic indoor drier at an economical price. Solar water heater is the main source for tapping solar energy from sun and stores the heat energy in the form of hot water inside the insulated tank. Normally solar water is used to heat the water for domestic requirement mainly for bathing. But after the regular usage, water which is being continuously heated reaches to the maximum temperature when it is not utilized for rest of the day. Thus the heat contained in this water could be properly utilized for drying with use of Solar Power Actuated Drier. By using this system in parallel to the domestic usage we can make the solar water heater as a multipurpose appliance. This drier also provides the uniform temperature for the maximum duration in one complete day which is not possible with the use of traditional drying methods and other solar driers because the availability of solar radiation is only for a short duration and even intensity varies from time to time. Implementation of above method overcomes the difficulties involved in the other forms of driers.

## II. SYSTEM COMPONENTS

### 2.1 Solar Water Heater

There is variety of ways to convert sunlight into useful energy in which Solar water heater is one among them. It absorbs the heat from solar radiation falling on it and utilizes the same for raising the temperature of the water. Thus the available hot water is utilized for various domestic uses mainly for bathing and etc.

### 2.2 Drier Cabin

Drier cabin is a safe and closed unit inside which the items are kept and are dried for several days. It consists of several metal jackets through which the hot water is made to circulate. In order to maintain the temperature and keep the interior warm, the cabin must be provided with a thermal insulation


**Fig. 1: Solar Water Heater of ETC (left), Drier Cabin (right)**

### 2.3 Metal Jackets

Metal jackets are used to store the hot water during circulation as shown in figure. Material used for the jackets must have good thermal conductivity. In this regard galvanized iron (GI) is chosen as the material for jackets because of its good thermal properties and also availability of the material at an economical price. In this particular model four jackets are used which are inter connected by steel pipes using brazing joints.

**Fig. 2: Metal jackets**

### 2.4 Metal Trays

To place the varieties of food grains inside the cabin, there is a need of proper container to hold. So the metal trays with good thermal conductivity and surface contact are required. Mainly Copper and Aluminum yields better results. With the use of trays it is quite easy to keep and remove the things in and out.

### 2.5 Plumbing System

#### 2.5.1 Pipes

Connecting pipes are required to carry the water from overhead tank to water heater and further hot water to drier. Water is initially drawn from overhead tank to water heater through PVC pipes. Hot water from storage tank of water heater is drawn through CPVC pipes to the jackets inside the cabin. Vent is provided using PVC pipes.

#### 2.5.2 Fittings and joints

FTA is the fitting used to reduce or extend the diameter of the pipe. It is mainly used at the inlet and outlet of solar water heater. At inlet FTA of PVC material is used whereas at Outlet FTA of CPVC material is used. Also end caps are made use at different position. Various joints such as Elbow, T-joint and Coupler are used to connect the pipelines at required places

#### 2.5.3 Valves

Ball valve is used to control the flow of water within the system and NRV (non-return valve) is used in between overhead tank and water heater to prevent backward flow of hot water from water heater to overhead tank. Pressure relief valve (PRV) is used in order to regulate water pressure from tank over the metal jackets.

#### 2.5.4 Overhead tank

This is the main source for water from which the water heater gets the sufficient quantity of water and also pressure to supply the hot water towards various tap points in a house.

## III. WORKING PRINCIPLE & IMPLEMENTATION

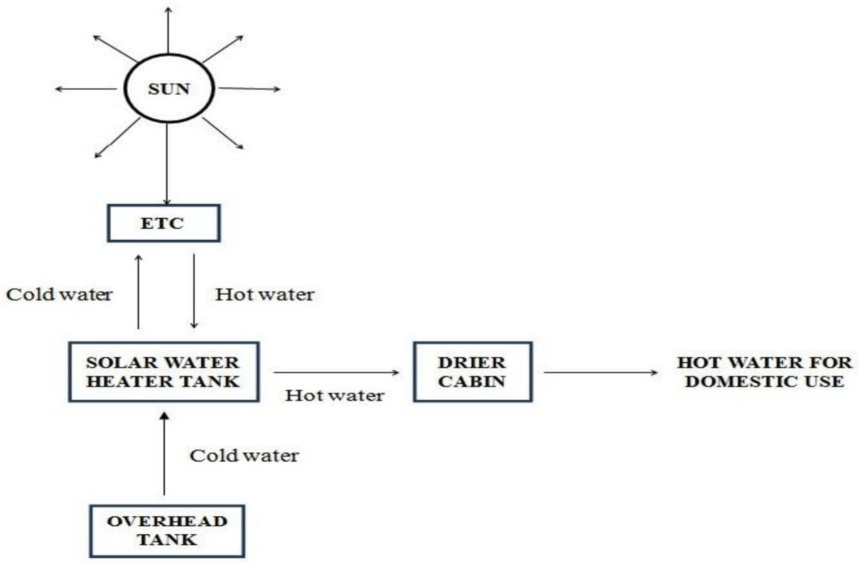


**Fig. 3: Flow chart of Solar Power Actuated Drier system**

### 3.1 Working

Solar is a main source of energy for solar water heater to work. Mainly it works according to Thermo-siphon principle where the water stored inside ETC (Evacuated Tube Collector) is heated up by absorbing direct solar radiation falling on it. By this the density of water reduces and thereby it becomes low weight and rises towards storage tank. Meanwhile the cold water stored inside the storage tank moves down to ETC due to elevation as well as high density. The process shown in Fig.3 continues until the solar radiation is present. Finally the storage tank will be completely filled with hot water.

In normal practice hot water is drawn for domestic use mainly for bathing. When the tap at bath room is opened, water is drawn from solar water heater due to pressure offered by overhead tank. The amount of hot water drawn is quickly replaced by cold water from overhead tank. Drier cabin design is in such a way that, it prevents the heat from being escape into external environment. So water inside the jacket can retain its heat to several hours and uses the same for effective drying.

### 3.2 System Implementation

The best and easy way to implement Solar Power Actuated Drier is as explained previously that, to connect the drier cabin in lateral to the pipe line which carries hot water from solar water heater to the other domestic use. Below fig shows how the drier cabin can be implemented to a house for domestic use in an easy way.

Consider a two stores building shown in Fig. 4 in which the overhead tank and solar water heater are placed at top floor as shown above. Generally these are placed at the top floors in any buildings. At ground floor or first floor, bathroom is located where the hot water is actually needed. When we fix the drier cabin in middle of flow line, hot water first enters the metal jackets inside the cabin and then flows to bathroom or other taps. Without affecting the performance of water heater, we can make use of both hot water as well as drier.

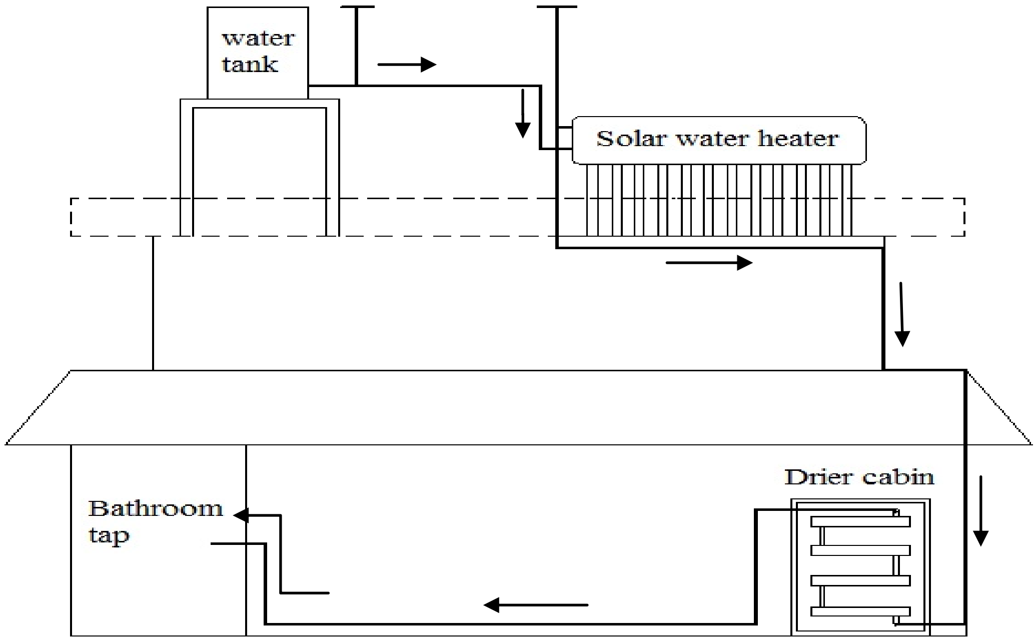


**Fig. 4: Schematic Diagram for Implementation of Drier Cabin in House**

### 3.2.1 Advantages

1. Very easy to install the drier cabin to the flow line.
2. Drier cabin can be placed at any part inside the house, hence maintenance is easy
3. Very convenient for the user to operate.

## IV. EQUATIONS AND CALCULATION

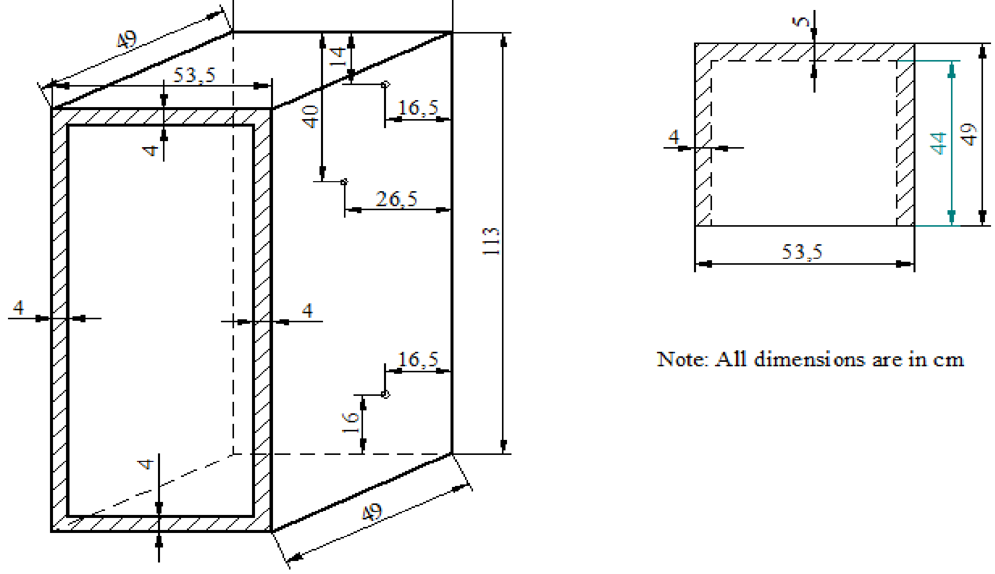


**Fig. 5: Cabin Dimensions**

## 4.1 Cabin Specifications

| | |
|---|---|
| Type of drier cabin | : Old refrigerator body. |
| Drier outer cabin | : Made of Sheet metal/ Aluminium. |
| Drier inner cabin | : Made of plastic liners. |
| Insulation provided | : Fiberglass or polyfoam. |
| Height | : 113cm. |
| Breadth | : 53.5cm. |
| Length | : 49 cm. |
| Wall thickness | : 4cm. |
| Drier door opening angle | : 180°. |
| Total no of holes | : 3(inlet, outlet, moisture relief) |

### 4.1.1 Total volume of drier cabin [capacity]

Total volume = [length × breadth × height] (1)

= (113 – 4 – 4) × (53.5 – 4 – 4) × (49-4)

= 210210 cm³

= 0.210 m³

## 4.2 Jacket specifications

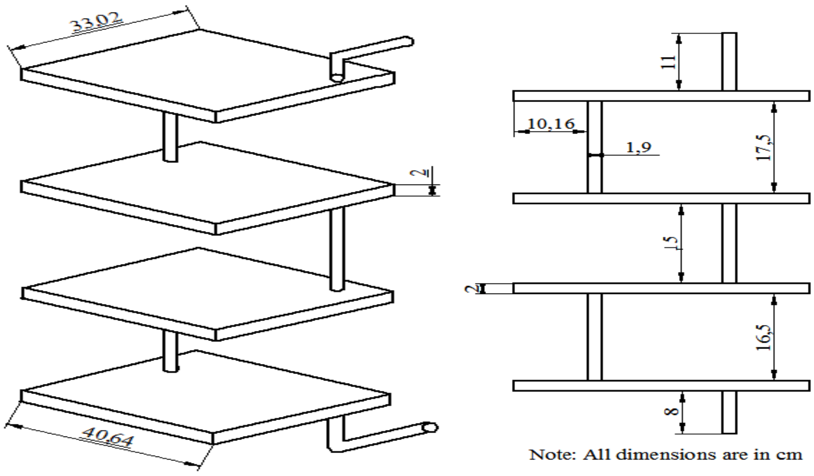


**Fig. 6: Jacket dimensions**

| | |
|---|---|
| Metal for the fabrication of jacket | : Galvanized iron (GI sheet) |
| Thickness of the sheet metal | : 22 gauge = 0.0643 cm. |
| Length (L) | : 40.64 cm |
| Breadth (B) | : 33.02cm |
| Height (H) | : 2cm |
| Density of the material | : 7850 kg/m³ |

### 4.2.1 Calculation of area

Area of the sheet metal required for single jacket = 2[(L×B) + (L×H) + (B×H)] (2)

= 2(40.64×33.02) +2(40.64×2) +2(33.02×2)

= $2978.50 cm^2$

= $0.2978\ m^2$

Therefore, total area required for all 4 jackets are = $4 \times 0.2978 = 1.1912 m^2$ of GI sheet

**4.2.2 Volume of sheet metal**

Total volume of material required for jackets = Area × Thickness (3)

= $1.1912 \times 6.43 \times 10^{-4}$

= $7.657 \times 10^{-4}\ m^3$

**4.2.3 Weight of sheet metal**

Mass of the material used for jackets = [density × volume] (4)

= $7850 \times 7.657 \times 10^{-4}$

= 6.0107 kg of sheet metal

= 6.0107 × 9.81

Weight of the sheet metal required = 58.9650 N

**4.2.4 Capacity of jacket**

Volume of water inside jacket = [No. of jacket × length × breadth ×height] (5)

= 4 × 40.64 × 33.02 × 2

= $10735.4\ cm^3$

= $0.0107 m^3$

= 10.735 liters of hot water

## V. RESULTS AND DISCUSSIONS

### 5.1 Heat Testing and Analysis-1

This analysis is carried out to find the rate of variation of surface temperature of water jacket inside a drier

**5.1.2 Initial observations**

1. Ambient temperature : 30˚c
2. Jacket normal temperature : 31.5˚c
3. Inlet water temperature : 60˚c
4. Surface temperature of jacket : 57˚c

**5.1.3 Procedure followed**

1. A digital thermometer is fixed to the jacket enables to measure the surface temperature of jacket.
2. Initially hot water is made to pass through drier cabin and surface temperature is noted down.
3. Take the readings of surface temperature for every half an hour and so on.
4. Tabulate the result and plot the graph of temperature profile.

**Table 1: Variation of surface temperature of water jacket inside a drier**

| SL.No | Time (in hours) | Jacket surface temperature (˚c) |
|---|---|---|
| 1 | 0.0 | 56.3 |
| 2 | 0.5 | 54.9 |
| 3 | 1.0 | 53.9 |
| 4 | 1.5 | 53.3 |
| 5 | 2.0 | 52.7 |
| 6 | 2.5 | 52.7 |
| 7 | 3.0 | 52.1 |
| 8 | 3.5 | 51.5 |
| 9 | 4.0 | 50.9 |
| 10 | 4.5 | 50.3 |
| 11 | 5.0 | 49.7 |
| 12 | 5.5 | 49.1 |
| 13 | 6.0 | 48.5 |
| 14 | 6.5 | 47.9 |
| 15 | 7.0 | 47.3 |
| 16 | 7.5 | 46.7 |
| 17 | 8.0 | 46.1 |
| 18 | 8.5 | 45.5 |
| 19 | 9.0 | 44.9 |
| 20 | 9.5 | 43.7 |

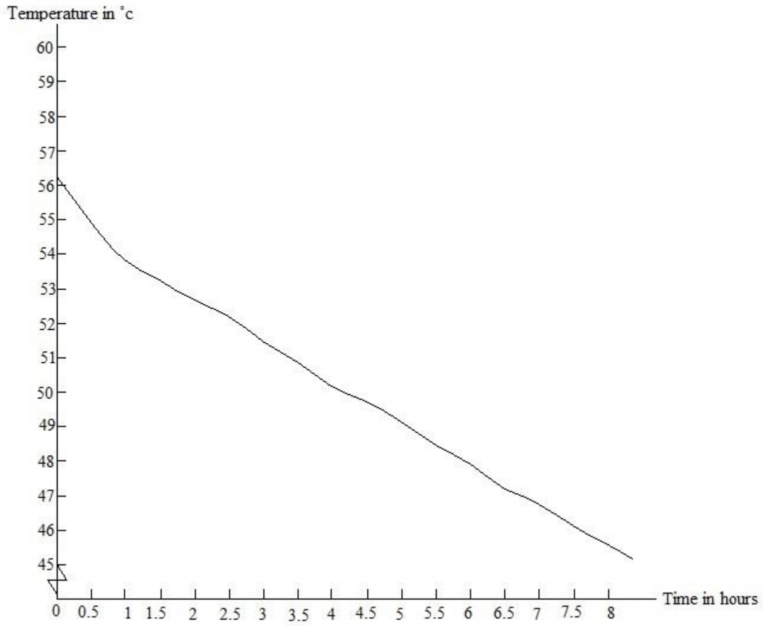


**Fig. 7: Variation of surface temperature of water jacket inside a drier**

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### 5.2 Analysis-2

To find the rate of decrease of temperature of hot water kept inside a drier, its variation and to plot the temperature profile graph.

#### 5.2.1 Initial observations

1. Ambient Temperature : 35˚c
2. Inlet water temperature : 60˚c
3. Surface temperature of jacket : 55˚c
4. Temperature of water sample kept inside drier : 60˚c

#### 5.2.2 Procedures followed

1. Initially take a glass of cold water of 250ml and heat it to temperature say 60˚c.
2. Keep the same inside the drier and note down the time and initial temperature.
3. Note down the temperature of the water for every half an hour and tabulate the result and plot the graph of temperature profile.

**Table 2: Decrease of temperature of hot water kept inside a drier**

| SL. No | Time (hrs) | Temperature (˚c) |
|---|---|---|
| 1 | 0 | 60 |
| 2 | 0.5 | 54 |
| 3 | 1 | 52 |
| 4 | 1.5 | 51 |
| 5 | 2 | 50 |
| 6 | 2.5 | 48.5 |
| 7 | 3 | 47 |
| 8 | 3.5 | 46.5 |

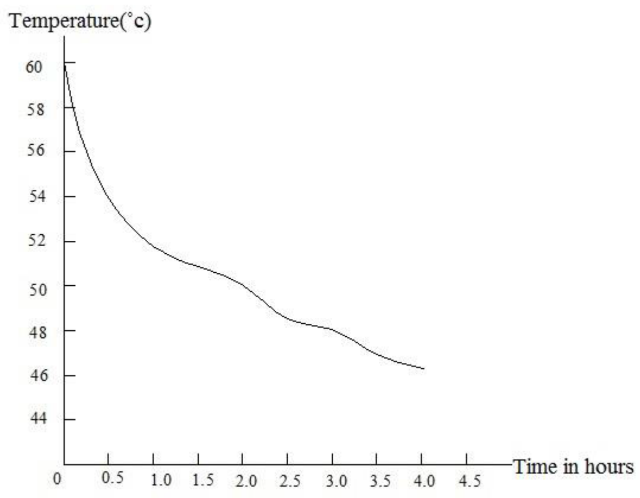


**Fig. 8: Decrease in temperature of hot water kept inside drier**

### 5.3 Analysis-3

To find the rate of increase of temperature of cold water kept inside a drier, its variation and to plot the temperature profile graph.

#### 5.3.1 Initial observations

1. Ambient temperature : 35˚c
2. Inlet water temperature : 60˚c
3. Surface temperature of jacket : 55˚c
4. Temperature of water sample kept inside drier : 29˚c

#### 5.3.2 Procedures followed

1. Initially take a glass of cold water of say 29˚c.
2. Keep the same inside the drier and note down the time.
3. Note down the temperature of the water for every half an hour

**Table 3: Increase of temperature of cold water kept inside drier**

| SL. No | Time (hrs) | Temperature (˚c) |
|---|---|---|
| 1 | 0 | 29 |
| 2 | 0.5 | 42.5 |
| 3 | 1 | 48 |
| 4 | 1.5 | 50 |
| 5 | 2 | 50 |
| 6 | 2.5 | 49 |
| 7 | 3 | 47.5 |
| 8 | 3.5 | 46.5 |

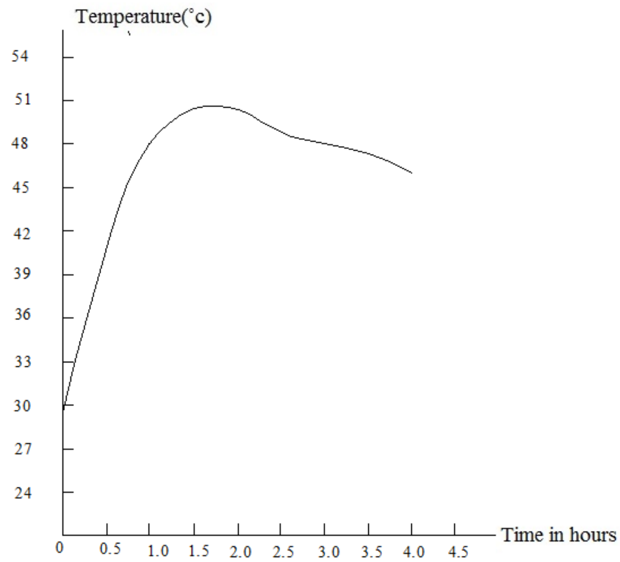


**Fig. 9: Increase in temperature of cold water kept inside drier**

### 5.3 Comparison between Traditional drying and cabinet drying (Testing-1)

Two sets of known weight of a) green peace b) green chilly c) grapes are taken. One set is kept in the Solar Power Actuated Drier and other set is kept in direct sunlight. Above things are dried for the duration of 2 days and percentage of moisture removed is calculated

#### 5.3.1 Observations

| | |
|---|---|
| Ambient temperature | : 35˚c |
| Temperature inside the drier | : 50˚c |
| Duration of available solar radiation | : morning 9.00 AM to evening 5.00 PM |
| Duration of available heat inside drier | : throughout the day (24×7) |
| Time duration of drying | : 2 days |

**Table 4: Weights of various samples taken for testing (before and after drying)**

| SL. No | Items for drying | Initial weight Before drying (g) | Weight after Traditional drying (g) | Weight after cabinet drying (g) |
|---|---|---|---|---|
| 1 | Green peas | 70 | 40 | 36 |
| 2 | Green chilly | 100 | 58 | 18 |
| 3 | Grapes | 100 | 76 | 50 |

#### 5.3.2 Inference

By comparing fourth and fifth column in the table 4, we can see difference in between these two methods with respect to weight after drying. Hence it is concluded that the cabinet drying is more effective than that of traditional drying.

#### 5.3.3 Percentage moisture removed

$$\text{Percentage of moisture removed} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100 \quad (6)$$

**Table 5: Percentage moisture removed**

| SL. No | Items Dried | Traditional drying | Cabinet drying |
|---|---|---|---|
| 1 | Green peace | $\frac{70-40}{70} \times 100 = 42.85\%$ | $\frac{70-36}{70} \times 100 = 48.57\%$ |
| 2 | Green chilly | $\frac{100-58}{100} \times 100 = 42\%$ | $\frac{100-18}{100} \times 100 = 82\%$ |
| 3 | Grapes | $\frac{100-76}{100} \times 100 = 24\%$ | $\frac{100-50}{100} \times 100 = 50\%$ |

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## VI. PHOTOGRAPHS

**Fig. 10: Comparison of traditional drying (left) and cabinet drying (right) for green chilly**

**Fig. 11: Comparison of traditional drying (left) and cabinet drying (right) for grapes**

**Fig. 12Mango paste product before and after drying**

**Fig. 13: Coconuts (copra) before and after drying**

**Fig. 14: Mango peel before and after drying**

**Fig. 15: Drier cabin interior**

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## VII. CONCLUSION

Solar energy refers to energy from the sun. The sun has produced energy for billions of years hence it is a renewable source of energy unlike non- renewable sources such as fossil fuels. The main benefit of solar energy is that it does not produce any pollutants and is one of the cleanest sources of energy. The only limitation that solar energy possess is that it cannot be used at night and amount of sunlight that is received on earth is depends on location, time of day, time of year, and weather conditions.

But in case of SOLAR POWER ACTUATED DRIER, this limitation has been overcome by using the refrigerator body as drier cabin. Polyurethane rigid foam (polyfoam) material used along the inner walls of the refrigerator is an insulator and hence resists the heat inside the cabin from flowing outside. Thus the hotness inside the cabin is maintained throughout the day irrespective of the presence of solar energy and constant temperature is also achieved. Similarly, PUF insulation provided along the cylindrical wall of water heater enables to withstand the high temperature of water for several hours. So by this, the presence of solar energy (sunlight) will not have a much impact on the performance of the drier.

Solar Power Actuated Drier forms a pure indoor home appliance for drying various kinds of food grains and other household items. Apart from drier, it also forms an indoor kitchen appliance and keeps the cooked food items hot and fresh. So such delicious foods are very safe and hygienic to keep inside the cabin. Cabin interior, metal jackets can establish a warm space with an average surface temperature of 70ºC which is sufficient enough to keep the dishes hot. Effective use of this system can avoid the reheating of dishes and thereby saves the fuel and electricity.

Warm cabin interior is well suited for the storage of grain flours such as rice, wheat, maize etc which are often subjects to the microbial and other moisture attack when kept in open space. With this it also functions like a safe storage unit for various kinds of edible flours, sugar and any items that are highly sensitive to moisture. Along with inhibiting the bacterial growth, it also avoids the attacks of insects over the items inside the cabin.

SOLAR POWER ACTUATED DRIER highlights and encourages the use of solar energy. It has also increased the scope for the use of solar water heaters by making it a multipurpose home appliance. This research work aims on well utilization of renewable source of energy like solar energy and to emerge as a solution to the present energy crisis.

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