DESIGN, TESTING AND ANALYSIS OF POP SOLAR DRYER

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Abstract: Drying is veryimportant process in the manufacture of POP (Plaster of Paris) Sheets which are usedfor false ceilings in households.Efficient drying of POP sheets gives proper finishing and consumes less time. Generally these POP sheets are dried in open atmospheric condition which takes long time to dry. The main aim of this project is to design, fabricate and test the solar dryer to reduce the drying time of the POP sheets.The project work is carried out based on the requirement of a small scale industry located at Piduguralla, Guntur district, A.P. which manufactures POP sheets. The design of a solar dryer consists of absorber plate made of GI sheet and reflector plate made of Steel sheet which is placed at the backside of the dryer.The test results gave temperature about 45^{O}C by modifying the experimental steps. The experiment conducted to remove the moisture by keeping the sheets inside the dryer. The test results have shown that the moisture removed was more than 50% when they are kept in the dryer compared with the drying in open atmosphere. The test results were compared by modifying the experimental setup by replacing steel sheet with clear polyvinyl sheet, to decrease the cost of solar dryer. The moisture removed from POP sheets with this setup is almost same as that of POP sheets dried in open atmosphere. Hence it is suggested to use a solar dryer with steel reflector at the backside.

***Index Terms* - Solar dryer, POP sheets, polyvinyl sheet**

I. INTRODUCTION

The technique of drying is probably the oldest method of food preservation practiced by mankind. The removal of moisture during drying prevents the growth and reproduction of microorganisms which cause decay and minimize many of the moisture deterioration reactions. Drying brings about substantial reduction in weight and volume thereby reducing packing, storage and transportation costs. It also enables the storability of the product under ambient temperatures.The basic function of a dryer is to supply the product more heat than is available under ambient conditions, thereby increasing sufficiently the vapour pressure of the moisture. In the process of drying, heat is necessary to evaporate moisture from the material and a flow of air helps in carrying away the evaporated moisture. There are two basic mechanisms involved in the drying process. They are migration of moisture from the interior of an individual material to the surface, and the evaporation of moisture from the surface to the surrounding air.The drying of a product is a complex heat and mass transfer process which depends on external variables such as temperature, humidity and velocity of the air stream. The importance of solar drying is increasing worldwide, especially in areas where the use of the abundant, renewable and clean solar energy is essentially advantageous. The supply of solar energy is abundant in most locations in India where solar heat is intense virtually all the year round.

I.METHODS OF SOLAR DRYING TECHNOLOGIES

a. Direct Solar Drying

Direct solar drying is the conventional way of drying the products. In this method the products are directly exposed to the solar radiation and reduce the moisture content to atmospheric air. The air movement is due to density difference. It is broadly classified into two categories:

(1) The outdoor open air solar drying.

(2) Through a transparent cover which protects partly the foodstuff from rain and other natural phenomena i.e. a passive solar drying method.

b. Indirect Solar Drying

Indirect solar drying or convective solar drying is the new technique of product drying. It is very efficient method than the direct type of solar drying. In this method the atmospheric air is heated in flat plate collector or concentrated type solar collector. The heating process is either passive or active. This hot air then flow in the cabin where products are stored. Therefore moisture from the product may lost by convection and diffusion. This method of drying is used to avoid direct exposing to the solar radiation. This method mainly reduces the disadvantages of direct solar drying.

c. Mixed Mode Solar Drying

It is combination of direct and indirect solar drying method. Product may dry with both direct exposure to solar radiation and hot air supplier on it. Air may heated in solar energy collector first then pass to the chamber where products are stored. In this process product may dry according to convective moisture loss. The same chamber is partially or totally covered with the transparent material to exposure the products to solar radiation**.**

II. OBJECTIVES OF SOLAR DRYING

Solar dryer is designed and fabricated to overcome the problems involved in drying of POP sheets. The following are the three major objectives of the solar dryer

1. To supply the product with a temperature more than which is available under ambient conditions.
2. To protect the pop sheets from rain as the solar dryer is a box like structure in which POP sheets are placed.
3. In winter the drying time of POP sheets can be reduced.
4. As POP sheets are dried in open air there is no control of temperature and sometimes due to high temperatures the sheets may break. Using solar dryer we can check the amount of moisture content removed and measure the temperature at which they are being dried.

III. Design of Solar Dryer

In order to reach the stated objectives, solar dryer for drying of POP sheets were designed according to the required specifications. The first job of any solar dryer is to receive the sun rays and to transmit it to the required place. Also, there should be a mechanics to absorb the sun rays which have been transmitted. Initially the frames were fabricated with the help of welding in order to accommodate the POP sheets. A support has been provided at the middle top of the frame to support the POP sheets. The complete frame is cover by the poly vinyl cover and at one side of the frame, GI sheet coated with black paint were fixed. As the time passes the moisture from the POP sheets vaporises (which is inside the dryer) and it accumulates on the inner surface of polyvinyl sheet. As there is a vent hole at the top, this moisture goes out through this vent hole and thus POP sheets gets dried.

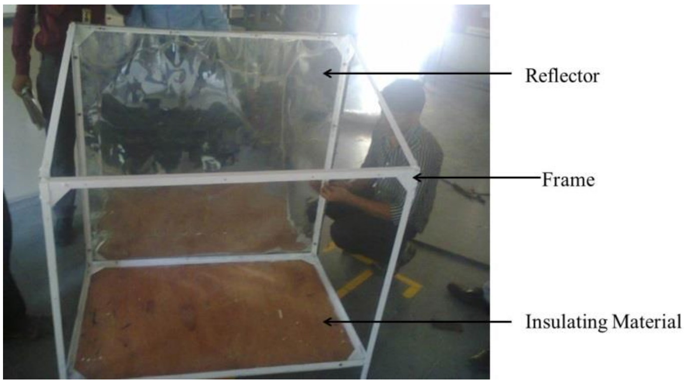


Figure 1 Design of Solar Dryer Equipment

The bottom of the frame is covered by absorber plate made of GI sheet coated with black paint below which an insulating material (plywood) is placed. At the backside of the dryer, there is a steel sheet used as reflector.In front it is covered by clear polyvinyl sheet which can be opened to place the POP sheets. Other three sides of the dryer are covered with clear polyvinyl sheet.Vent holes are provided at the top for moisture to escape. Top surface is made inclined.

Materials Used

Iron Angles

Solar drier is fabricated by using L-angles of mild steel. These were fitted by using nuts and bolts.

Dimensions of L-angles used

4ft. L-angles - 6no.
3ft. L-angles - 4no.
2½ ft. L-angles - 2no.

L-angles are shown in fig.

Clear Poly Vinyl Sheet

Clear polyvinyl sheet is used for the dryer. It transmits solar rays falling on it.

Absorber Plate

GI sheet with black paint coating is used as absorber plate.

Figure 2 Iron angles, Poly Vinyl sheet and Absorber Plate

Insulating Material

Insulating material can minimise the heat losses from the drier. It is placed under the absorber plate. The insulator must be able to withstand stagnation temperature, should be fire resistant and not subjected to out- going gassing and should not be damageable by moisture or insect. Insulating materials are usually fibreglass, mineral wool, plywood, Styrofoam and urethanes.

IV. Fabrication Of Solar Dryer

Different steps involved in fabrication process are:

1. Fabrication of L-angles and with plywood as base.
2. Assembly of Iron frame with steel sheet.
3. Iron frame covered with poly vinyl sheet.

Fabrication of L-Angles and With Plywood As Base

Iron rods of L angular shape are used in the fabrication of main frame. Holes of diameter 6mm are drilled on the iron frame to accommodate nuts and bolts. Plywood is incorporated at the bottom of the frame it acts as both base and insulating material to prevent the heat losses from base. Plywood of size 4x2 ½ is used.

Iron Frame with Poly Vinyl Sheet

As the poly vinyl sheet is good absorber of heat and it has the ability to store more heat, the other three sides of the iron frame are covered with poly vinyl sheet. Vent holes are made on the top side of the poly vinyl sheet for the moisture to escape.Absorber plate is a metal plate placed above the plywood base to absorb the incident solar radiation transmitted by the polyvinyl sheet.

Figure 3 Fabricated Solar Dryer

V. Testing of Solar Dryer

Testing consists of comparing the psychometric properties of POP sheet which is inside the dryer and the POP sheet placed outside in open air. For the purpose of testing, hygrometer and moisture meter were used to measure dew point temperature and moisture content. The amount of water vapour contained in air or gas is called humidity. It plays a vital role in many industrial processes such as chemical, textile, paper, food, leather, pharmaceutical industries as well as precision equipment manufacturing. Before going into the details of measuring of humidity it is important to know some terms related to humidity measurement.

Psychometric Properties

1. **Humidity**: The amount of water vapour contained in air or gas is called humidity.
2. **Dry air**: When there is no water vapour contained in the atmosphere, is called dry air.
3. **Moist air:** When there is water vapour contained in the atmosphere, then the air is called moist air.
4. **Saturated air**: Saturated air is the moist air where the partial pressure of water vapour equals the saturation pressure of steam corresponding to the temperature of air.
5. **Relative humidity:** It is defined as the ratio of the mass of the water vapour in a certain volume of moist air at a given temperature to the mass of water vapour in the same volume of saturated air at the same temperature and is denoted by RH.

RH = water vapour actually present/water vapour required for saturation.

6. **Dry bulb temperature (DBT):** The temperature of the air measured by the ordinary thermometer is called as the dry bulb temperature of air, commonly referred as DBT. When ordinary thermometer is exposed to the atmosphere, it indicates the dry bulb temperature, which is nothing but the atmospheric temperature.
7. **Wet bulb temperature (WBT):**Temperature of the ordinary air measured by the thermometer when it is covered by wet cloth or wick is called as the wet bulb temperature, commonly referred to as WBT. When the air comes in contact with the wet cloth it absorbs some moisture and gives up some heat, due to which the temperature of the air reduces. This reduced temperature measured by the thermometer is called as the wet bulb temperature.
8. **Dew Point Temperature (DPT):** The temperature at which the water vapor within the air at some temperature starts condensing is called as the dew point temperature of the air or DPT. When the dew is formed the air is said to be in saturated condition.

VI. Hygrometer

A hygrometer is an instrument used to measure relative humidity. Relative humidity is a measure of how much water the air is holding, relative to the maximum amount of water the air could possibly hold at a given temperature.Because of delicate design of hygrometers, it is for them to become inaccurate (e.g. with shipping or over time). A simple method of calibrating the hygrometer will help measuring the relative humidity as accurately as possible.

Features

a) Dew point temperature (-30^0 C – 100ºC/-22^0F-199^0F)

b) Wet bulb temperature (0^0C-80^0C/32^0F-176^0F)

Humidity/Temperature Measurement Range

a) Humidity: 0% - 100% RH

b) Temperature: -30^0 C – 100ºC, -30^0F-199^0F

Moisture Meter

It is small in size, light in weight, easy to carry. Although complex and advanced, it is convenient to use and operate. It will allow many years of use if proper operating techniques are followed.Can be applicable to fibre materials, wooden articles, tobacco, cotton etc.,

Specifications

Moisture content: 0-50%

Temperature:-10-65^0C

Operation humidity :<85%

Figure 4 Hygrometer and Moisture meter

VII. RESULTS AND OBSERVATIONS

During the daytime the dryer is placed outside with POP sheets in it and another POP sheet is placed outside the dryer so that properties of both the sheets are compared and the observations are tabulated. As the time passes the moisture from the POP sheets vaporises (which is inside the dryer) and it accumulates on the inner surface of polyvinyl sheet as shown in figure below. As there is a vent hole at the top, this moisture goes out through this vent hole and thus POP sheets gets dried.

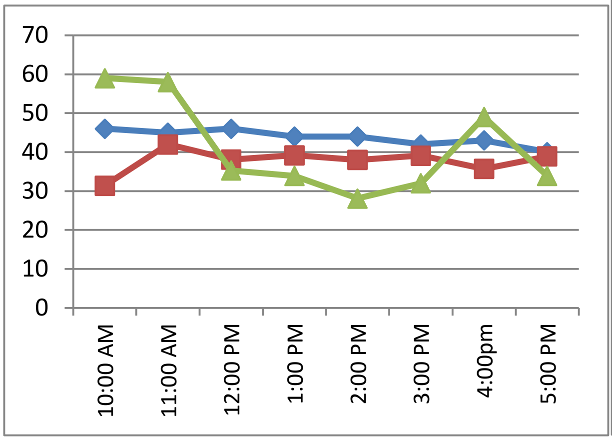
Figure 5 Testing of Solar Dryer Using POP sheets

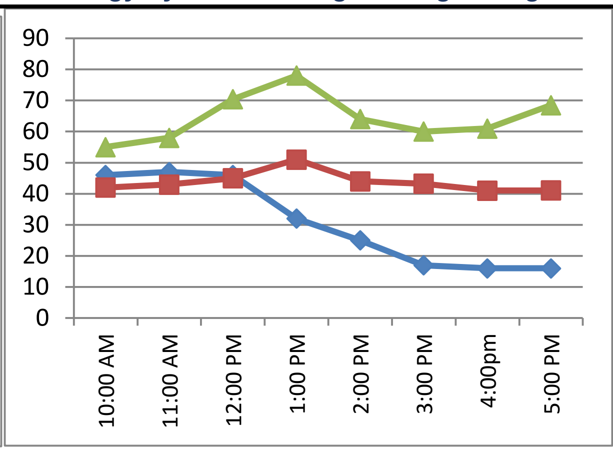
We have made one vent hole for the escaping of moisture and the following observations are tabulated on first day.

DAY 1:

OUTSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00 am	46	31.4	59
11:00 am	45	42	58
12:00 pm	46	38.10	35.30
1:00 pm	44	39.2	33.89
2:00 pm	44	38	28.11
3:00 pm	42	39.12	32
4:00pm	43	35.7	49
5:00 pm	40	38.9	33.89

INSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00 am	46	42	55
11:00 am	47	43	58
12:00 pm	46	45	70.4
1:00 pm	32	51	78
2:00 pm	25	44	64
3:00 pm	17	43.26	60
4:00pm	16	41	61
5:00 pm	16	41.07	68.5

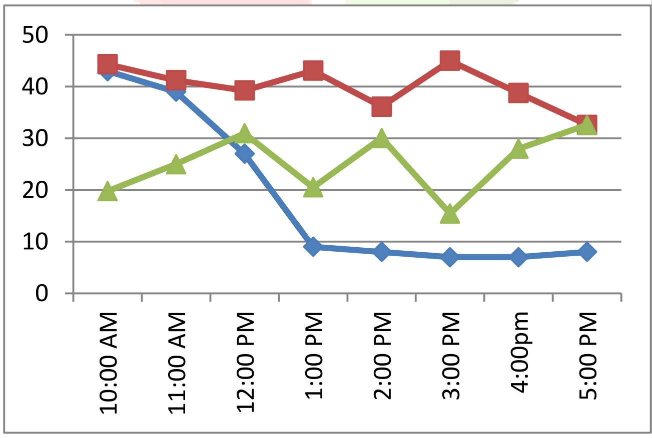


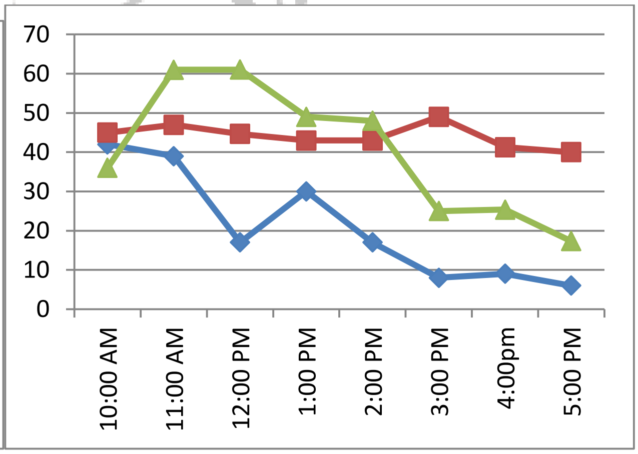


DAY2:
On the 2nd day, the number of vent holes and their size has increased. And the following observations are tabulated

OUTSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00 am	43	44.32	19.78
11:00 am	39	41.24	25
12:00 pm	27	39.24	30.96
1:00 pm	9	43.1	20.5
2:00 pm	8	36.14	30.08
3:00 pm	7	45	15.43
4:00pm	7	38.77	28
5:00 pm	8	32.6	32.6

INSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00 am	42	45	36
11:00 am	39	46.96	61
12:00 pm	17	44.65	61.04
1:00 pm	30	43	49
2:00 pm	17	43	48
3:00 pm	8	49	25
4:00pm	9	41.26	25.38
5:00 pm	6	40	17.32





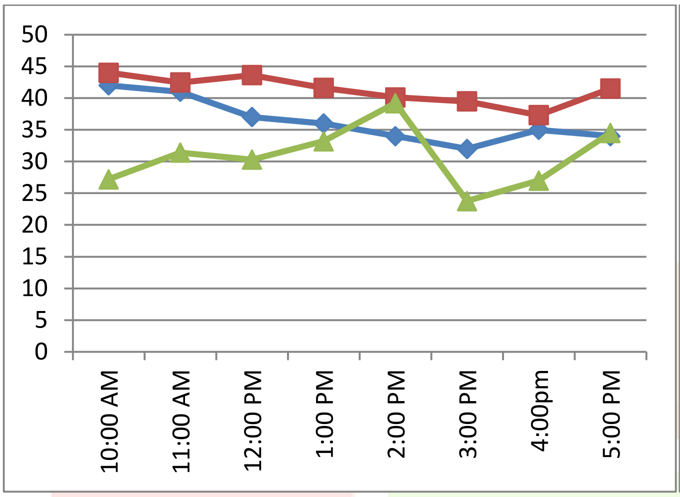
We have observed that more heat is losing from the back side of the drier i.e., from steel sheet.

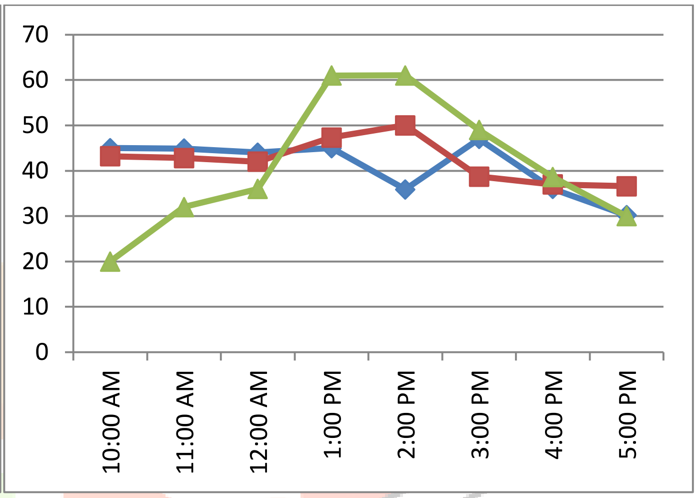
DAY 3:
On 3rd day we have replaced the steel sheet with poly vinyl sheet to minimise the heat loss. The following observations are tabulated.

OUTSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00 am	42	44	27.2
11:00 am	41	42.46	31.4

12:00 pm	37	43.62	30.3
1:00 pm	36	41.6	33.2
2:00 pm	34	40.1	39.2
3:00 pm	32	39.49	23.78
4:00pm	35	37.32	27
5:00 pm	34	41.5	34.5

INSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00 am	45	43.2	20
11:00 am	44.9	42.8	32
12:00 am	44	42	36
1:00 pm	45	47.32	61
2:00 pm	35.9	50	61.04
3:00 pm	47	38.73	49
4:00pm	36	37	38.6
5:00pm	30.2	36.6	30

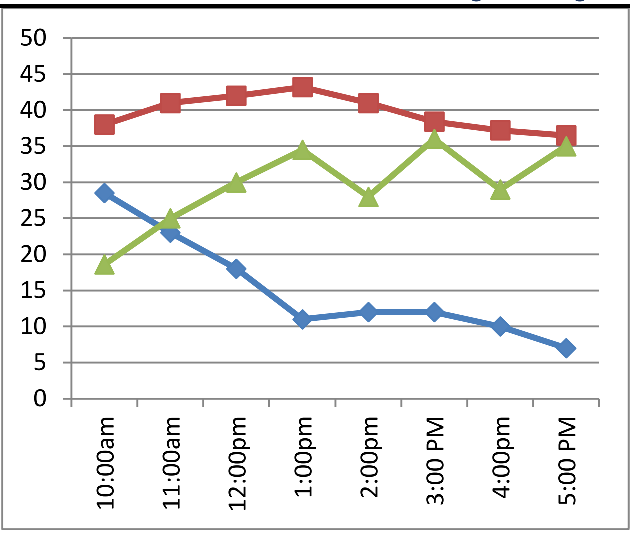


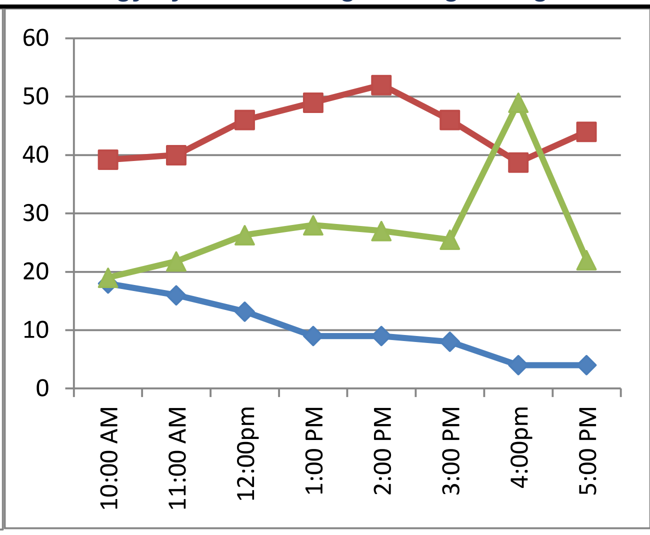


DAY 4:

OUTSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00am	28.5	38	18.6
11:00am	23	41	25
12:00pm	18	42	30
1:00pm	11	43.2	34.5
2:00pm	12	41	28
3:00 pm	12	38.4	36
4:00pm	10	37.2	29
5:00 pm	7	36.5	35

INSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00 am	18	39.2	19
11:00 am	16	40	21.8
12:00pm	13.2	46	26.3
1:00 pm	9	49	28
2:00pm	9	52	27
3:00 pm	8	46	25.5
4:00pm	4	38.73	49
5:00 pm	4	44	22

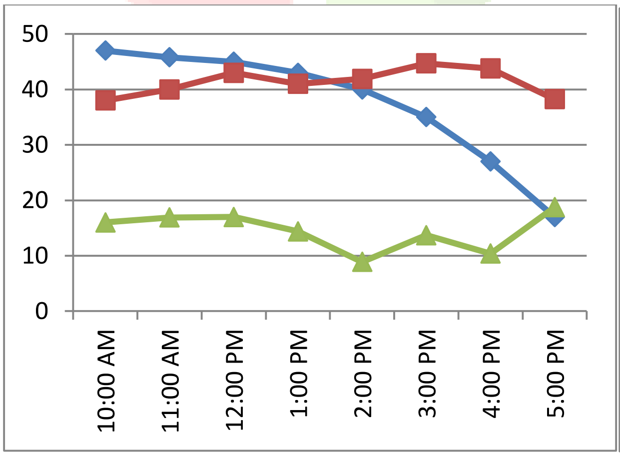


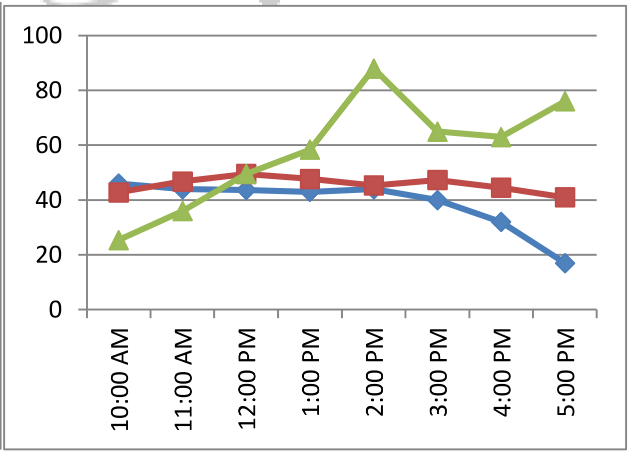


DAY 5

OUTSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00 am	47	38	16
11:00 am	45.8	40	16.9
12:00 pm	45	43	17
1:00 pm	43	41	14.4
2:00 pm	40	41.9	8.9
3:00 pm	35	44.7	13.7
4:00 pm	27	43.79	10.4
5:00 pm	17	38.25	18.75

INSIDE			
Time	**Moisture**	**Dry Bulb Temperature(^{0}C)**	**Relative Humidity %**
10:00 am	46	42.8	25.4
11:00 am	44	46.8	36
12:00 pm	43.7	49.5	49.5
1:00 pm	43	47.7	58.4
2:00 pm	44	45.3	88
3:00 pm	40	47.3	65
4:00 pm	32	44.5	63
5:00 pm	17	41	76





Moisture
Dry Bulb Temperature(0C)
Relative Humidity %

VIII. CONCLUSION

From the observations and results, it is clear that solar dryer with steel reflector is more suitable than the other type of dryer where reflector is not used. Though the cost of dryer with reflector is more than without reflector but the drying time to remove moisture from POP sheets is much faster. The time taken by dryer to dry POP sheets is half than that of without reflector. Therefore it is advised to use the dryer with steel reflector.

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