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THERMAL PERFORMANCE OF SOLAR TUNNEL DRYER BY USING VARIOUS ABSORBING MATERIALS

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Abstract: -*Sun drying of agricultural products is the traditional method employed in most of the developing countries. Sun drying is used to denote the exposure of a commodity to direct solar radiation and the convective power of the natural wind. Drying is cheapest and most common method of preservation and storing of agricultural products. It was observed that dryer efficiency continuously changing during drying process due to change in solar radiation and temperature. Performance of solar tunnel dryer is depends upon on different performing parameters. The flow rate, temperature and relative humidity of drying air plays major role in drying. Also moisture content in product, area of collector plate, thickness of polythene sheet, absorbing material and thickness of drying layer are important parameter.*

The main aim of this project is do the performance evaluation of solar tunnel dryer by varying input performing parameters such as absorber material for collector area, flow rate of drying air and thickness of polythene sheet and to determine the output performance parameters such as efficiency of solar tunnel dryer, Time required for drying agricultural product.

Keywords*: Open Sun Drying, Solar Tunnel Dryer, Absorbing materials, flow rate velocity, collecting area, polythene sheet thickness etc.*

I. INTRODUCTION

Preservation of fruits, vegetables, and food are essential for keeping them for a long time without further deterioration in the quality of the product. Several process technologies have been employed on an industrial scale to preserve food products. The major ones are canning, freezing, and dehydration. Among these, drying is especially suited for developing countries with poorly established low-temperature and thermal processing facilities. It offers a highly effective and practical means of preservation to reduce postharvest losses and offset the shortages in supply. Drying is a simple process of moisture removal from a product in order to reach the desired moisture content and is an energy intensive operation. The prime objective of drying apart from extended storage life can also be quality enhancement, ease of handling, further processing and sanitation and is probably the oldest method of food preservation practiced by humankind. 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 brings about substantial 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, in military feeding and space food formulations.

1.1Solar Tunnel Dryer

Different solar dryers have been developed and used to dry a variety of agricultural product. Solar tunnel dryer is widely used for drying various agricultural products. The solar tunnel dryer consists of different parts such as drying chamber, collector area and chimney. A solar tunnel dryer is a tunnel like framed structural covered with Ultra-violet (UV) stabilized polythene sheet, where agricultural and Industrial products could be dried under drying chamber. The product is to be dried are placed in the tunnel dryer. Thermocol is used as an insulation material to reduce heat loss from the dryer. The air at the required flow rate is provided by a DC operated fan by a battery. To prevent the entry of water inside the dryer unit when it rains, the cover is fixed like a sloping rod or semi cylindrical shape. Solar radiation (SR) passed through the transparent cover of the collector. Heat is transferred from absorber to the air in the collector and heated air from the collector passed over and absorbed moisture from the products. SR also passed through the transparent cover of the dryer and heated the products in the dryer.

Solar Tunnel Dryer is majorly depends on weather conditions to get better output the day should be clear sunny day so we can get maximum beam radiation incident on dryer. Solar tunnel dryer is very much useful for small scale farmers and household farmers for drying agricultural product which can be prevented from deterioration from rain, dust and insects by cover material .There are various performing parameters of solar tunnel dryer which affect the performance of solar dryer such as absorber material of collector, covering polythene sheet thickness, air flow velocity, drying layer thickness relative humidity of air. So it necessary to evaluate the performance of solar tunnel dryer by considering those parameters to get better output parameters such as cost of efficiency of dryer and total time required for product drying.

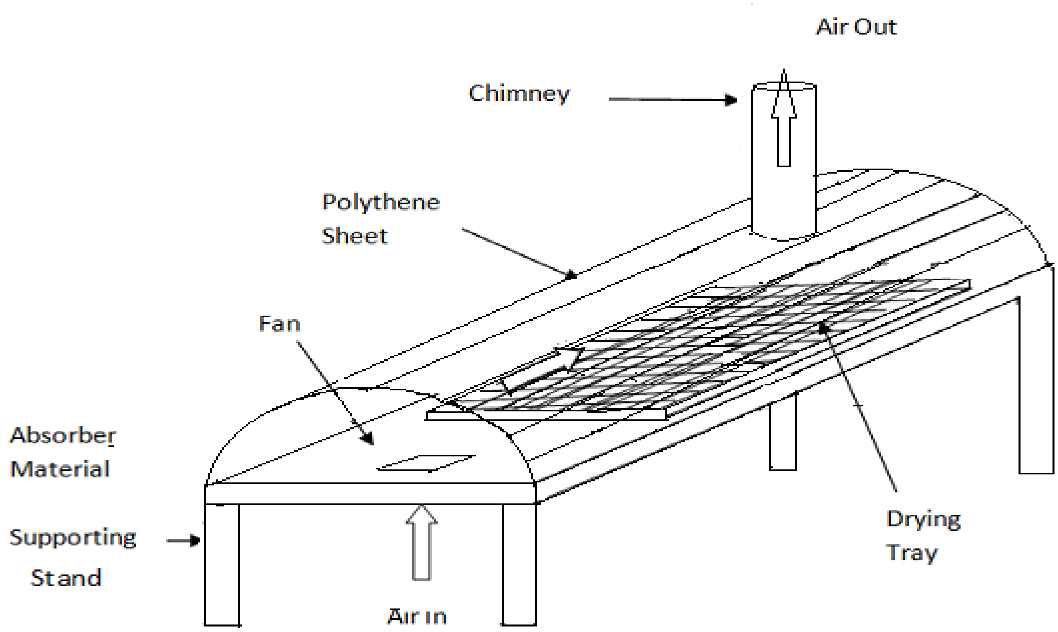


Figure 1:
Schematic of Solar Tunnel Dryer

1.2 Drying Product (Red Chilli)–

India is not only the largest producer but also the largest consumer of chilli in the world. Chilies are the most common spice cultivated in India. Chilli is a universal spice of India. It is cultivated in all the States and Union Territories of the country. India contributes about 36% to the total world production of chillies.

II DESIGN OF EXPERIMENT

2.1 Design of Solar Tunnel Dryer

Conditions for design of solar tunnel dryer

Mass of Agricultural Product = 3 kg (**Red Chilli**)
Latent heat of vaporization of water = 2257 kJ/Kg
Efficiency of dryer is assumed to be 0.20 or 20%.
Atmospheric pressure is 1.01325 bar
Ambient Temperature of air is 35˚C
Exit temperature of air is 60˚C
Initial moisture content is 80%
Final moisture content is 5%
Drying Process is carried out on clear sunny day.
Sunshine hours = 8 hrs/day & Total Drying Hours Required = 16 hrs
Solar radiation = 600 W/m^2

2.1.1. Quantity of water to be removed

The mass of water to be removed during drying is calculated using following equation

$$M_w = \frac{(m_1 - m_2) \times W}{100}$$
$$= \frac{[(80\text{-}5)\times 3]}{100}$$
$$= 2.25 \text{ kg of water}$$

Where

M_w = Mass of water to be removed (Kg)
m_1 = Initial moisture content of drying product in %
m_2 = Final moisture content of drying product in %
W = Mass of Drying product taken for drying (Kg)

2.1.2 Total energy required for drying

Total energy for drying is calculated by following equation

$$Q = M_w \times h_{fg}$$
$$= 2.25 \times 2257$$
$$= 5078.25 \text{ KJ}$$

Energy required per hour for drying is calculated using following equation

$$Q_t = \frac{Q}{t}$$
$$= \frac{5078.25}{16}$$
$$= 317.4 \text{ KJ/hr}$$
$$= 5.29 \text{ KJ/min}$$

2.1.3. Drying Rate

Drying rate is calculated by (k)

$$= \frac{M_w}{t}$$
$$= \frac{2.25}{16}$$
$$= 0.1406 \text{ Kg/hr}$$
$$= 0.00234 \text{ Kg/min}$$

2.1.4. Collector area of solar tunnel dryer required for drying

Collector area of solar tunnel dryer required for drying is calculated using following relation

$$A_c = \frac{Q_t}{I \times \eta}$$
$$= \frac{317.4 \times 1000}{600 \times 0.20 \times 3600}$$
$$= 0.735 \text{ m}^2 = 0.75 \text{ m}^2 \text{ (approx.)}$$

Where I = Avg. solar radiation (W/m^2)

2.1.5. Dimensions of solar tunnel dryer

Area of solar collector equals area of solar tunnel dryer. ($a = A_c$)
Area of solar tunnel dryer is calculated as

$$a = l \times b$$

Consider, width of solar tunnel dryer as 2 ft or 0.6096 m
As we have diameter of semi-cylindrical shape equals to width of tunnel dryer.

$$0.75 = l \times 0.6096$$
$$l = 1.23 \text{ m} = 4.035 \text{ ft}$$

Therefore, width of solar tunnel dryer as 2ft or 0.6096 m
Length of solar tunnel dryer as 4.035 ft or 1.23 m

2.1.6. Final Design

Width (b) of solar tunnel dryer as 2 ft or 0.6096 m

Length (l) of solar tunnel dryer as 4.053 ft or 1.23 m
Radius or height of semicircular ring of solar tunnel dryer = 0.3048m

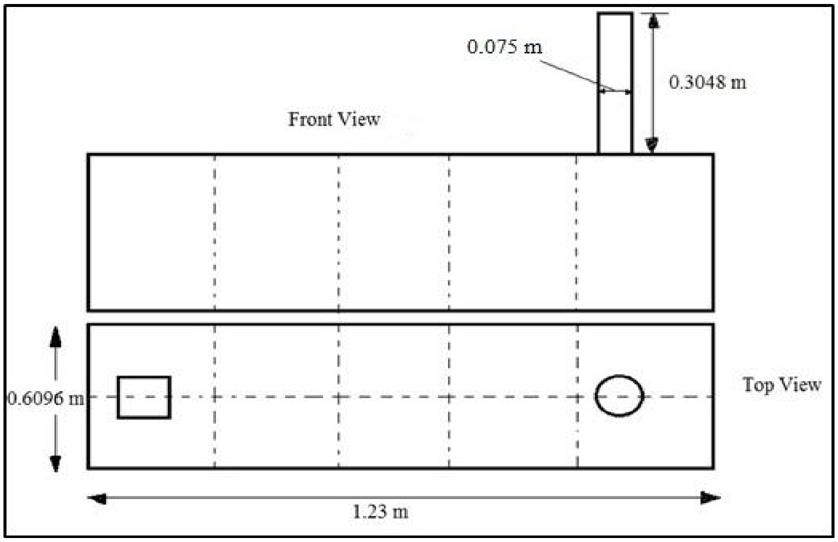


Figure 2: Front View and Top View of Dryer

2.2 Parameter of Solar Tunnel Dryer

As per identified performance parameter of solar tunnel dryer four input parameter are consider for design of experiment such as absorber material for dryer with different coating materials, thickness of drying layer, thickness of covering sheet and flow velocity of air. These input parameters are taken to determine the effect of that parameter on efficiency and drying time of dryer. Aluminium sheet is taken as a base absorber material, on which the coating material (Black paint, Beryllium powder, Copper powder) were used to increase absorptivity of aluminum. 80 micron semi transparent polythene sheet is used for covering. 20 mm drying layer was used for chilli drying. The size of single chilli is 20 mm. flowing air velocity 0.7 m/s was used for drying.

1. Parameter of Solar Tunnel Dryer

Sr. No	Absorber Material (Coating)	Covering Sheet thickness (micron)	Flow velocity (m/s)	Drying layer thickness (mm)
Set – 1	**Aluminium**	80	0.7	20
Set – 2	**Black Paint** as Coating Material	80	0.7	20
Set – 3	**Black Paint + Beryllium Powder** as coating material	80	0.7	20
Set – 4	**Black Paint + Copper Powder** as coating material	80	0.7	20
Set – 5	Open Sun Drying **(OSD)**	80	_	20

2. Properties of Absorber (Coating) Material

Absorber Material	Absorptivity	Availability
Aluminium	0.15	Easy
Black paint	0.98	Easy
Beryllium Powder	0.5-0.7	Easy
Copper Powder	0.5	Easy

III EXPERIMENTAL SETUP

3.1 Fabrication of Absorber/Collector

Four sets dryer collector are made, aluminium used as base absorber material over which selective absorbing coating materials use which were easily available in local market. Black paint, Beryllium powder, copper powders, were used as coating to increase absorptivity of dryer. The collector and drying chamber made up of metal sheet and plywood sheet. Collector was made (2×4 feet) in dimension. 12 mm plywood sheet over which aluminium sheet of 4 mm is stamped. The dryer was covered with semitransparent UV stabilized polythene sheet (80 micron).

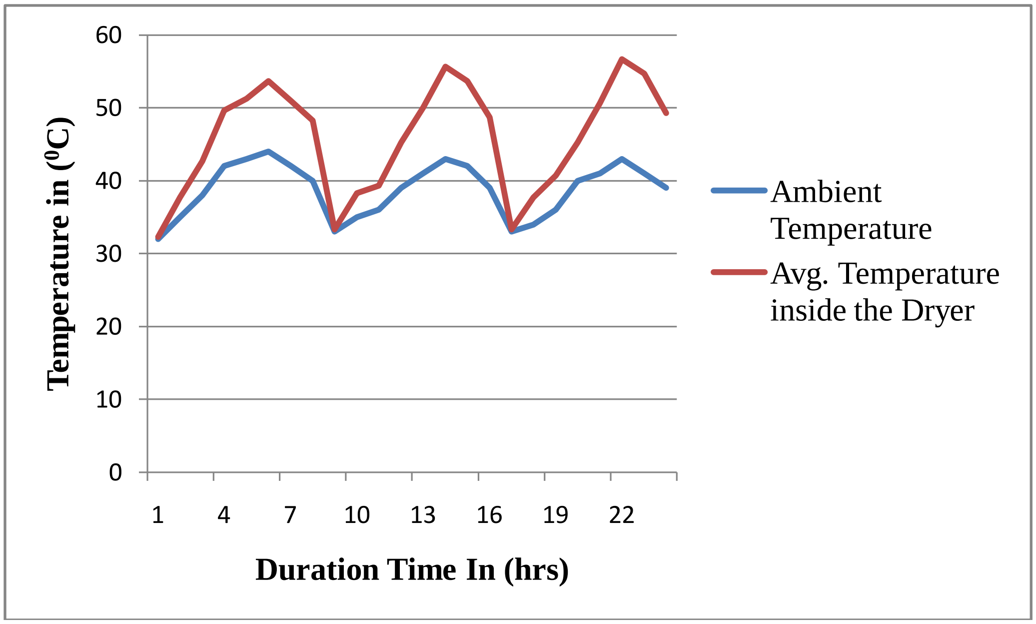
The dryer area made rough for increase surface area for absorption of radiation. Semicircular rings were weld to dryer frame to support the polythene sheet.

Four semicircular rings were weld to bottom frame. Polythene covering sheet covered on semicircular ring. Semicircular ring support the covering sheet help to keep it tide. The height of semicircular ring is the height of tunnel. It is half of width of dryer (2 feet). Absorber provided with 4 inch square hole for fan fitting, to maintain air flow in the tunnel. The tray is used to dry chilli. The tray has 1.5× 2.5 feet area. The tray has painted black color to facilitate absorption of solar radiation. The tray place 2 inches above the floor of the collector for proper ventilation of air through tray and better quality of drying.

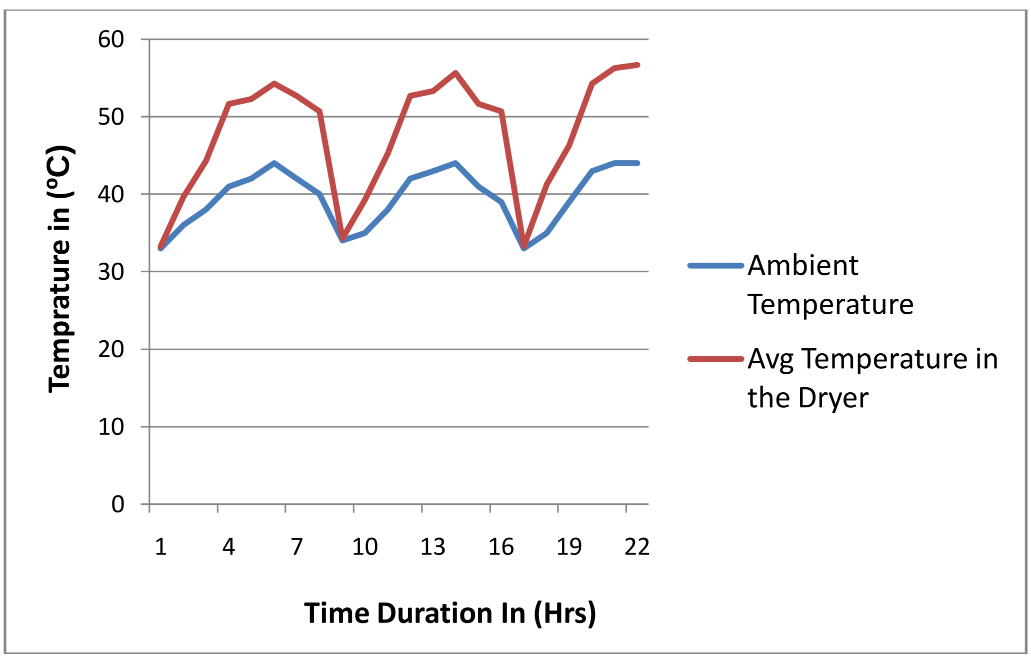
Figure.3 Actual Experimental Set Up Of Solar Tunnel Dryer

IV RESULT AND DISCUSSION

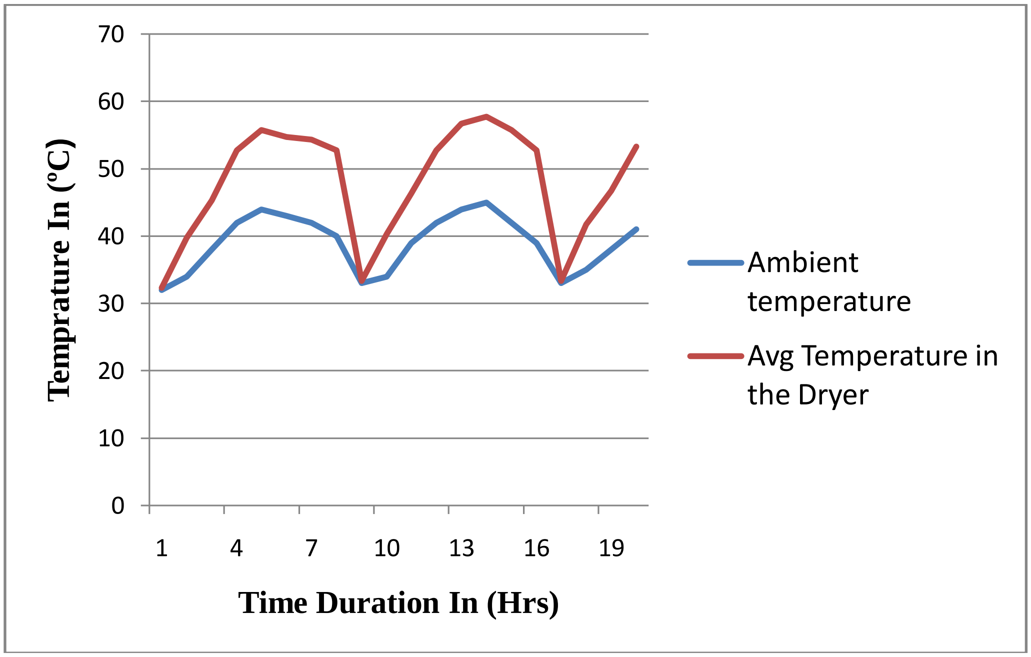
4.1.1 Temperature Variation in Dryer for Set-1



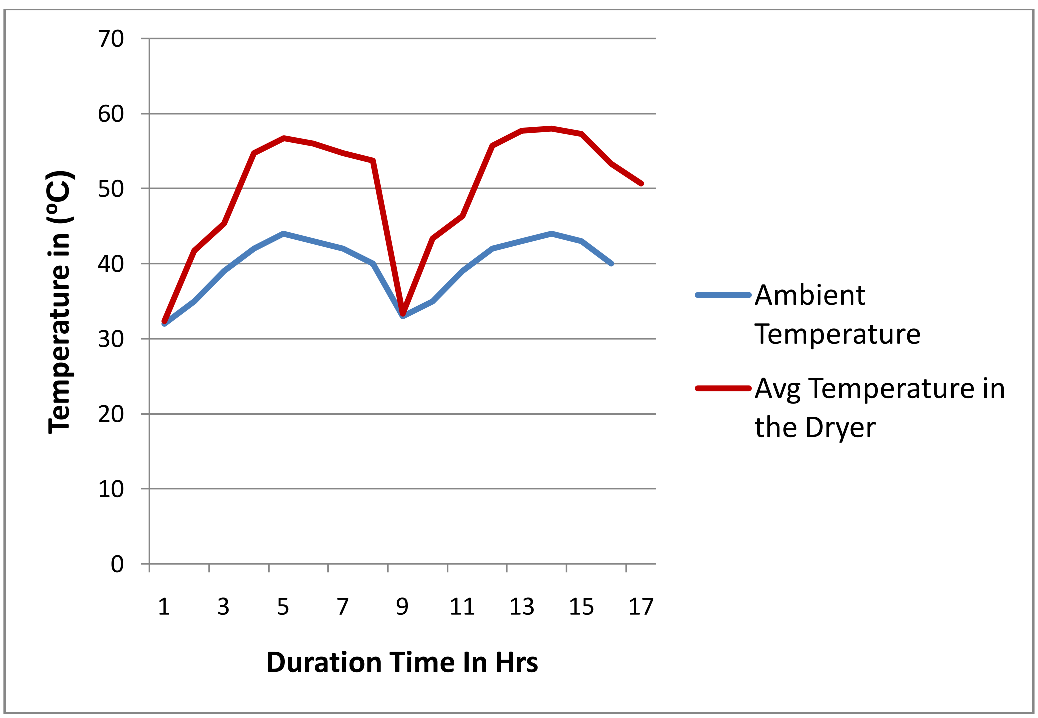
4.1.2 Temperature Variation in Dryer for Set-2



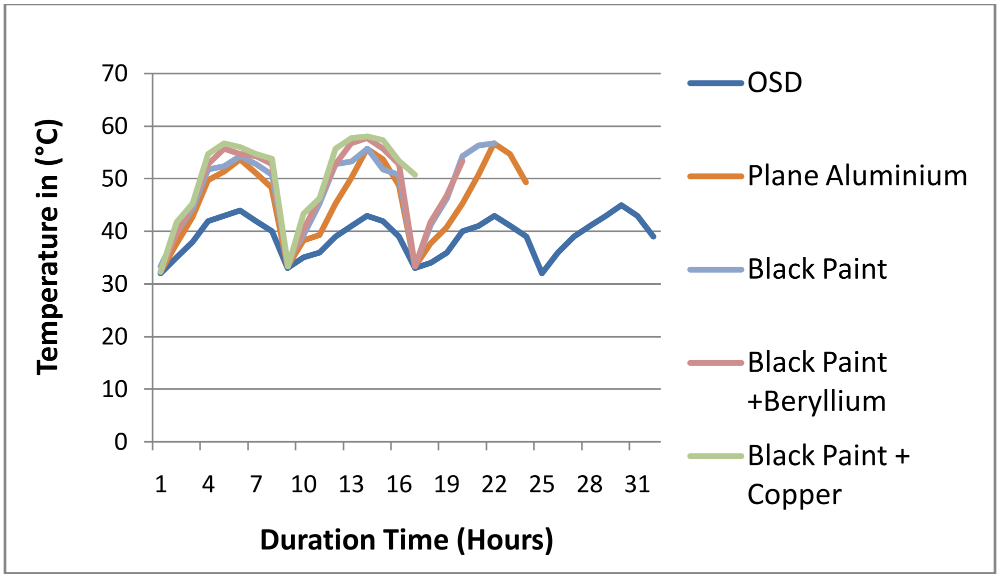
4.1.3 Temperature Variation in Dryer for Set-3



4.1.4 Temperature Variation in Dryer for Set-4

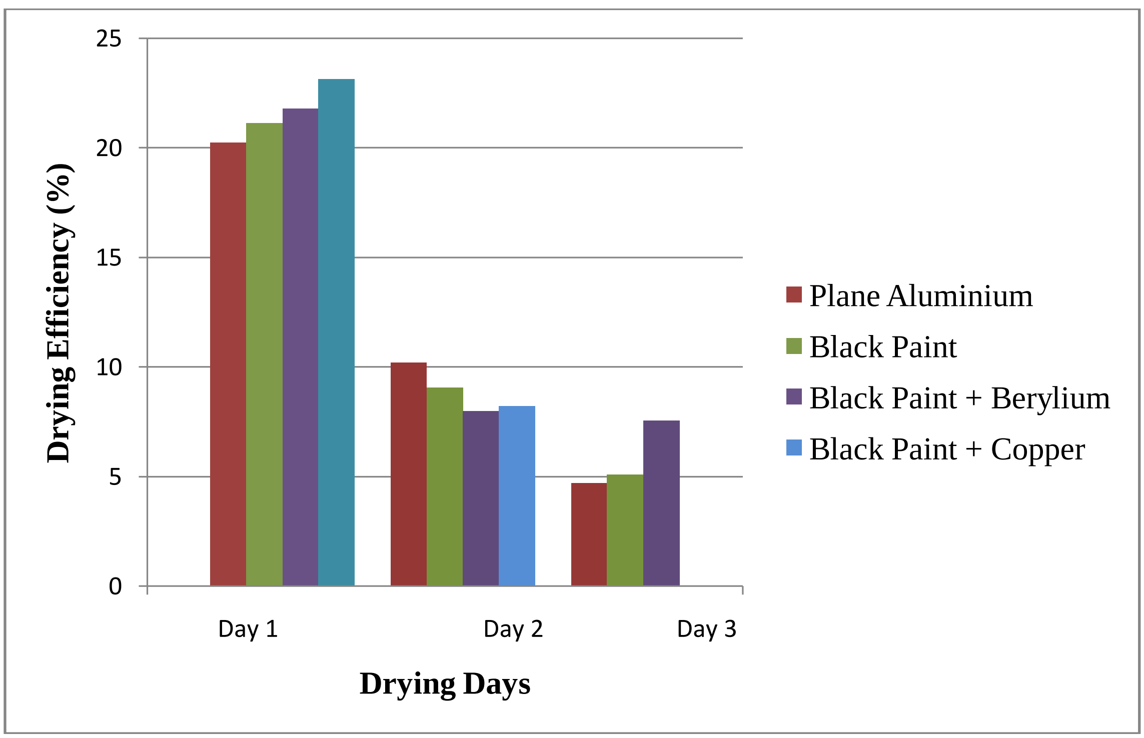


4.1.5 Temperature Variation in Dryers with OSD

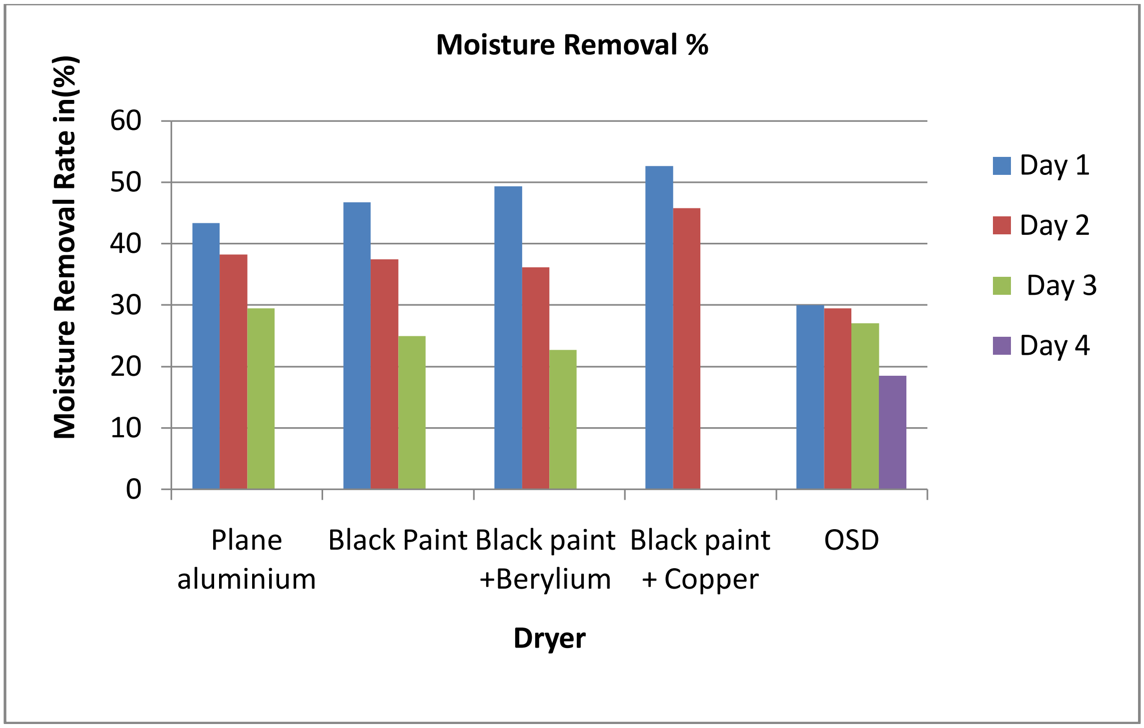


From above data it was observed that the temperature difference (ΔT) inside and outside of dryer was low in the morning as compare to evening and afternoon period, higher in the afternoon period. In the afternoon the temperature difference is high due high solar radiation intensity. 10 to 16^0C higher temperatures obtain inside the dryer as compared to ambient.

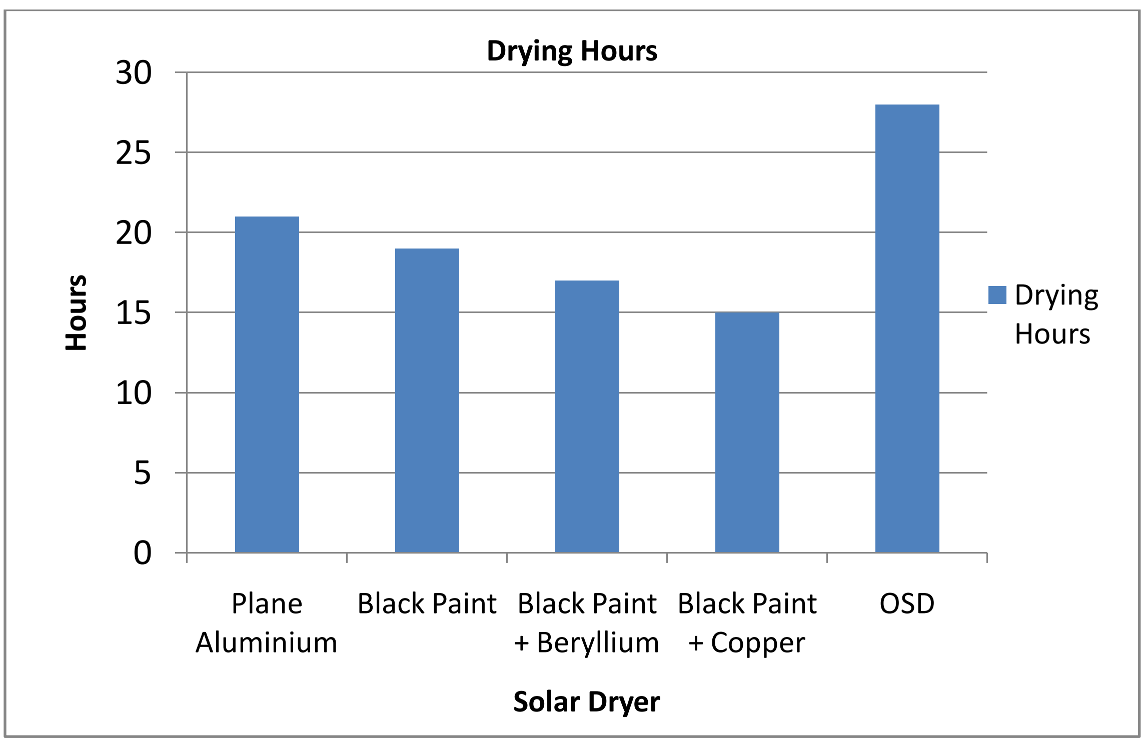
4.2 Efficiency of Dryers (Drying Days vs Efficiency)



4.3 % Moisture Removal for Dryer



4.4 Drying hours of Dryer



V CONCLUSION

In the Present study, the thermal performance of solar tunnel dryer based was studied.
The solar tunnel dryer was used to dry the chilli as a drying product for experimentation. The experimentation has been carried out on three different types of coating materials viz. Black paint, Beryllium powder, and Copper powder. Following conclusions can be drawn from the experimentations:

1. The drying time considerably reduced by using solar tunnel dryer and quality of final product is good. The temperature difference between inside and outside of dryer was low in the morning and evening periods as compared to afternoon.
2. In can be observed that the use of copper powder as a coating material on the absorber the dryer efficiency is maximum, which is higher than Black paint and Beryllium powder as tested in the present system.
3. Maximum efficiency of collector is achieved by 23.15 % with copper powder as coating material to the absorber.
4. The percentage change in drying time is reduces considerably by 46.42% with copper powder as a coating material as compare to the Open Sun drying.
5. The percentage change in moisture removal rate increase is 75.53% as compared to the open sun drying.
6. In second day, the removal of the moisture content in chilli is less hence, efficiency of the dryer is less.

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