Study and Experimental Investigation of Solar Dryer by using Concentric Dish Collector

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***Abstract*—Drying means moisture removal from the product. Drying is helpful in preserving food product for long time; The performance of a new design of a solar dryer for drying chillis is presented. The dryer consists of drying cabinet, heat exchanger, 1.4m^2 Dish type parabolic solar collector, and water type heat storage unit. The cabinet size is 0.41 m wide × 0.51 m long × 0.61 m high with the load capacity of 1-2 kg for chillies. Three batches of chillis were dried in this dryer during April-May, 2016. For each batch, 1 kg of chillis were dried. Natural drying process is more time consumable than solar drying process. The dried products were completely protected from rains, insects and the quality of drying products is higher than that of natural sun drying. It is observed that in drying concentric collector gives better result than flat plate collector. The moisture reduction of chilies obtained with developed dryer is from 78% to 24% in 20 sunshine hours. The efficiencies of the solar collector were 40%-60%.**

***Keywords*— Concentric dish collector, Solar dryer, open drying, chilli drying.**

I. INTRODUCTION

Drying means moisture removal through product for preserving food, fruits and vegetables for long time with good quality. Agricultural products, (especially fruits and vegetables) 45–60˚C temperature range is necessary for drying. The product is found superior when it is dried under controlled condition at specific humidity as well as temperature [1]. Sun drying exposes the commodity to solar radiation and the convective power of the natural wind. It is observed that open sun drying is slow process n contamination of product found more than indirect solar drying. Sun drying is a cheap method of drying but often results in good quality of products due to its dependence of weather conditions and the product dried with this method is vulnerable to the attack of insect infestation [2].Energy must be supplied to remove and vaporise the moisture from the food products. Solar dryer is operated on heat and mass transfer process. Reproduction of micro-organism is more with the higher moisture content and this moisture content is removed by solar drying. [3].

Drying process takes place in two stages:

a) First happens at the surface of the drying material at constant drying rate and is similar to the vaporization of water into the ambient.
b) Second step is according to Properties of drying product with decreasing drying rate [4].

Previously open sun drying is common drying process in which product is spread on the floor for drying purpose which can reach higher temperature. Most important thing in open drying is it takes more than two day for drying. Direct solar drying is the most easy and basic process of drying. It is cost less process, no capital investments are required. There are some disadvantages of direct solar drying. The process, however, has some serious disadvantages. The most important ones are that the crops suffer the undesirable effects of dust, dirt, atmospheric pollution, and insect and rodent attacks. Because of these disadvantages, the quality of the resulting product can be degraded, sometimes beyond edibility. All these disadvantages can be eliminated by using a solar dryer [2].

II. LITERATURE REVIEW

Solar driers consist of three main components:

a) A drying chamber in which food is dried.
b) A solar collector that heats the air.
c) Airflow system.

Sun drying is still the most common method used to preserve agricultural products in most tropical and subtropical countries. Evaporating a water contents from solid is known as drying process. Open air and uncontrolled sun drying is still the most common method used to preserve and process agricultural product. But uncontrolled drying suffers from serious problem of wind born dust, infestation by insect, product may be seriously degraded to the extent that sometimes become market valueless

loss of and have to the food quality may have adverse economic effects on domestic and international market. Solar dryers has two types of airflow systems; one is natural convection and another is force convection. In natural convection uses the natural principle that means atmospheric air with atmospheric pressure moves through drying chamber and in forced convection forced air with some velocity is passing through the drying chamber with fans solar cabinet dryer as reported earlier in 1965 by Lawand and is ostensibly a hot box wherein fruits, vegetables and other matter can be dehydrated. It is simple type of dryer such as cabinet dryer and wind ventilation dryer design by Lawand.

In 1976 G. Roa study drying application by using simple solar collector and it is found that net effect of solar collection was to accelerate in 4 times the drying rate of product. Efficiency of drying agricultural product increases by using solar collector dryer. In 1985 moyls gives construction and performance of natural convection dryer used for fruit drying application. It is large solar dryer consist of plastic collector with 342 m^2 area directed hot air into drying chamber which have capacity of 500kg of fruit drying within 2-5 days. Peak air temperature is 63˚C with air flow rate is 73 m^3/min. In 2012 Gutti gives the comparison between open sun drying and drying with solar collector and it is found that drying is done with using solar collector gives better results than open drying. Current study gives the considerable time reduction for drying of agricultural products and fish. This paper gives the use of solar dryer leads to a considerable reduction of drying time in comparison to the sun drying, and the quality of the product dried in the solar dryer was of quality dried products as compared to sun dried products.

III. METHODOLOGY

The objective of this work is to investigate the performance of solar dryer with point focus collector. Dish type concentric collector used. It is possible to adjust this concentric collector on an average level house. It is pollution free, require almost no maintenance and fuel free which makes it sustainable, reliable and affordable with less capital cost. Parabolic collector concentrates solar energy at a single focal point. It focuses all the sunlight which strikes on it to a single focal point and receiver captures this light and changes into other form.

The drying is important process in day to day life as well as in most of the industries such as food processing, food preservation, waste management, wood drying etc. It is oldest method of food preservation. Moisture content in agricultural product is found 25%-80%. It is very difficult to preserve product for long duration having this moisture content. Due to this moisture content bacterial and fungal growth is very fast in the crops. Bacteria and enzymes may spoil the foodstuff and reduces the nutrient content in it. Moisture content of crops to a certain level slows down the bacterial, enzymes, and yeasts effect. Therefore it is necessary to reduce the moisture content in foodstuff for its long preservation.

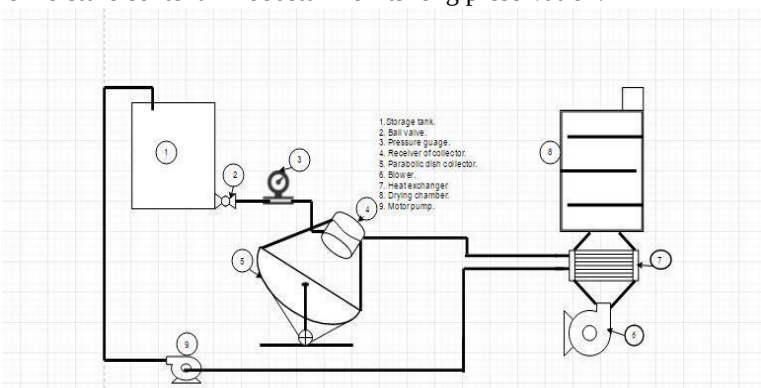

Fig 1: Schematic diagram of experimental set-up

Temperature require for drying is 60˚- 70˚C. Solar concentrating parabolic dish collector is used to get this temperature.

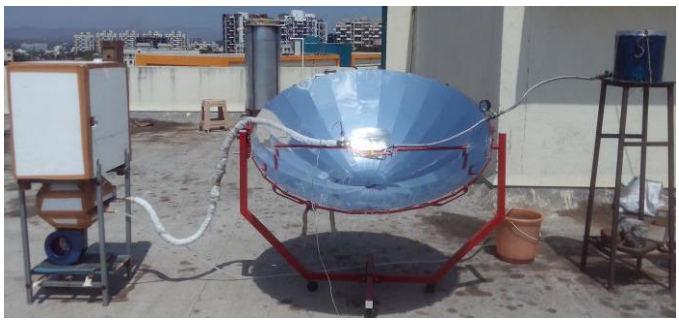

Fig 2: Front photograph of experimental set-up

The temperature at receiver is up to 95˚C, receiver is having water which is passed through heat exchanger with the help of pump. Heat from hot fluid is extracted by supplying cold air through heat exchanger. This saturated air is then passed with the help of pump in the close cabinet where chillies are placed.

1. Experimentation has been carried out for drying of chillies from initial moisture content of 74-78 % to final moisture content up to 10-20% by using concentric dish collector.
2. The mass flow rate of air kept for the individual set of Experimentation at 0.01, 0.02, 0.03 kg/Sec though the dryer cabinet with the help of anemometer.
3. Testing of dried chillies by at selected mass flow rate of air, Outlet temperature of the collector, dryer cabinet exit temperature, intensity of solar radiation is noted.
4. The effect of mass flow rate of air on moisture content, moisture loss, drying rate, drying time and dryer efficiency has to be evaluated and accordingly test has been executed.

IV. MECHANISM OF DRYING

Most effective application of solar energy is solar dryer. Various products can be dried by solar dryer like various fruits (like banana, grapes), potato chips, chillies, grains, meat, timber, fish etc. Food products are preserved by drying. In developing nations, open to the sun drying technique is used for drying agricultural products. Open to the sun drying means products are directly put on floor exposed directly to sun, allowed to absorbed solar radiation. It was reported that this method has many disadvantages like poor quality, contamination of product as well as time requirement is more than solar dryer [5]

Mechanized form of dryer means the dryer which is has a container and is powered by electricity or fuel as source of heat, design for house product like cloths or agricultural product and used air for drying the products. This is faster dryer but it needs large initial cost for various equipment's as well as for fuel. Following gives

advantages and disadvantages between Solar dryer with other means of drying [6].

4.1 Advantages and disadvantages of Solar dryer over Mechanized form of dryer:

Advantages:

a. It is less expensive.
b. It reduces environmental impact.
c. It is not dependent on fuel.
d. It can be manageable.

Disadvantages:

a. It takes more time than mechanized form of dryer.
b. Requires adequate solar radiation.
c. Requires hot and dry climate (relative humidity requires below 60%).

4.2 Advantages and disadvantages of Solar dryer over open air drying:

Advantages:

a. It gives better quality of drying product(Product contamination is 0%).
b. It reduces losses and bacterial contamination.
c. It requires less area for drying.
d. It reduces labour requirement.
e. Drying time requires less.

Disadvantages:

a. More expensive.
b. It may require some parts material to be import.

V. DESIGN OF STUDIED SYSTEM

A. Objective

Researchers have done lots of research on solar dryer by using flat plate collector. Objective of this study is to analyse the performance of solar dryer by using concentric dish collector.

B. Concentric dish collector

Solar concentric dish collector is the collector which concentrates solar radiation which is falling on the collector surface and concentrates at one point, hence it is called as point focus concentric collector. Thermal and optical efficiency of parabolic dish concentrator is highest than all other current concentrator option [7].

Figure (3) shows when rays of light travels parallel from the sun to the principal axis and incident on a curved parabolic shape, they come together after reflection to a point F on the principal axis called the principal focus. Where, F is principle focus, P is pole, C is Centre curvature, AB is aperture (width of the mirror).

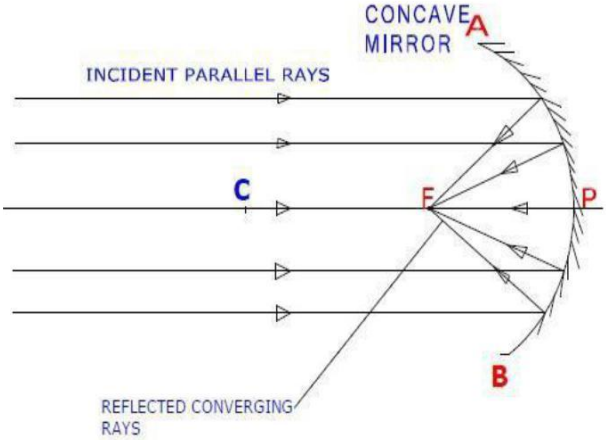

Fig 3: Parabolic dish collector [8]

Collector efficiency is given by,

$$\eta = \frac{Q}{I_t A_c}$$

Where,
Q = The rate of useful gain. Ac= Area of collector.
It = The amount of solar radiation falling on the collector.

$Q = mC_p \Delta T$.

Concentration ratio (CR) for concentric dish collector is given by,

$$CR = \frac{A_a}{A_r}$$

Where,
Aa = aperture area.
Ar = receiver area.

Specification of concentric dish collector:

Area of dish collector	1.4 m^2.
Diameter of collector	1.33 m.
Area of receiver	0.14 m
Concentration ratio	10.
Depth of dish collector	0.24m.
Focal length	0.46 m.

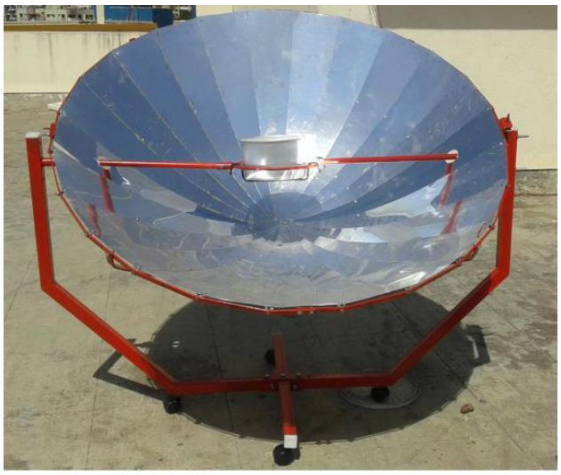

Fig 4: Concentric Dish collector

C. Drying chamber

Solar drying used in this set up is Force convection or Hybrid Solar dryer. Optimum air flow can be provided in the dryer throughout the drying process to control temperature and moisture in wide ranges independent of the weather condition. Hence the capacity and the reliability of the dryers are increased considerably compared to natural convection dryer. The use of forced convection can reduce drying time by three times.

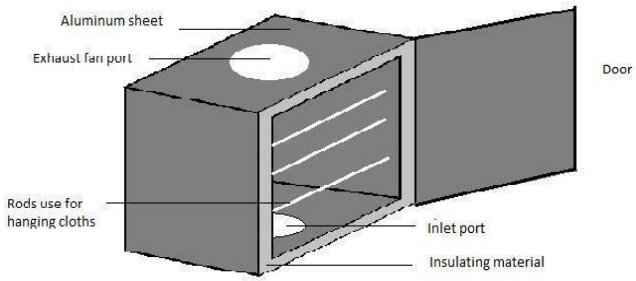

Fig 5: Schematic diagram of drying chamber.

The drying cabinet is 0.41m wide × 0.51 m long equipped with 3 drying trays and these trays mounted inside the drying cabinet, as shown in fig 5. Fresh air enters via the air inlet into the heat exchanger and the heated air leaves the heat exchanger. Then the heated air from the heat exchanger is passed over the drying material spread in the thin layers on 3 horizontally stacked trays arranged in drying chamber. Each tray is made of aluminium net with the dimension of 0.31 m × 0.41 m. The trays are of sieve-type to allow air circulation through the drying material. This drying cabinet is specially designed in such a way that hot air is guided to flow vertically over the product placed in the trays (Fig. 5). This design has the advantage of allowing uniform distribution of air temperature in the cabinet.

Type of Anemometer	AVM 06
Air velocity	0.80-30 m/s

VI. RESULTS AND DISCUSSION

This part of paper shows observations and result obtained during the experimentation with relevant discussion. The results include drying effect of Potato chips with respect of time and mass basis.

Fig 6: Drying chamber

The general equation of mass conservation of drying air can be expressed as,

$$\Sigma m_{dai} = \Sigma m_{dao}$$

Where, m_{dai} = inlet mass flow of drying air.
m_{dao} = outlet mass flow of drying air.

The useful energy gain by the drying air, Q_{uda}, was determined from,

$$Q_{uda} = m_{da} C_{pda} (T_{ho} - T_{hi})$$

Where,
T_{ho}= drying air temperature at inlet.
T_{hi}= Drying air temperature at outlet.

Specification of drying chamber:

Area of drying chamber	0.20m^2.
No of trays	3.

Specification of blower:

Type of blower	Centrifugal blower
Frequency	50Hz
RPM	2800
Motor	90W

VII. RESULTS AND DISCUSSION

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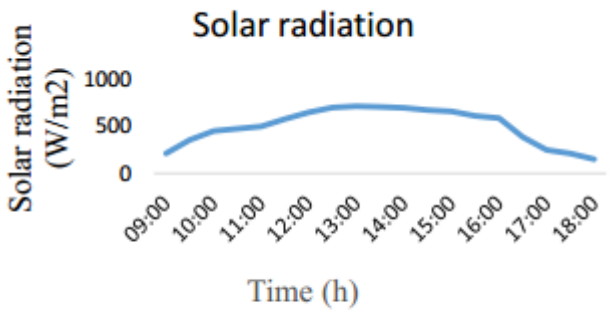
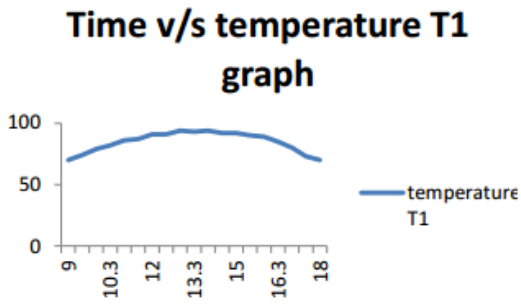
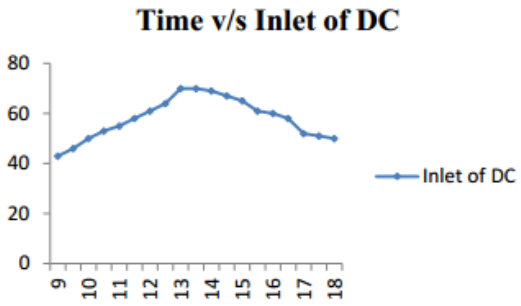


Graph 6.1: Solar radiation intensity Vs Time

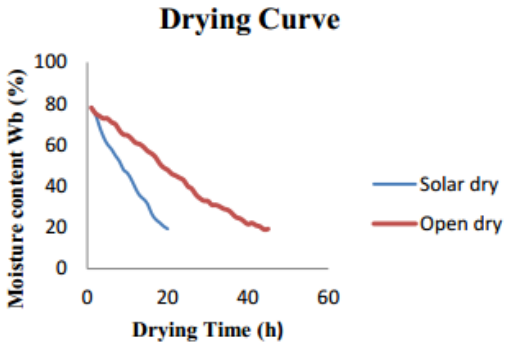
Figure 4.2 shows the temperature to time graphs for the mass flow rate of water 0.044 kg/m. The water temperature at the output of the receiver of the solar concentric dish collector reached up to maximum of 95ºC at mass flow rate of 0.044 kg/m. This temperature is reached at 1 Hrs. After 6 hrs sunshine effect will minimized and the temperature of the concentric dish collector is minimized and the equalized with the ambient temperature. The small energy loss may occur between the collector and the drying chamber. The energy from the air mass flow with this temperature is absorbed by the potato chips placed on the trays. The temperature in the drying chamber is constant up to 60ºC-70ºC to 6-7 hours. Difference between the temperatures of inside of drying chamber to the out let of the drying chamber shows the energy utilized for the drying of the potato chips.



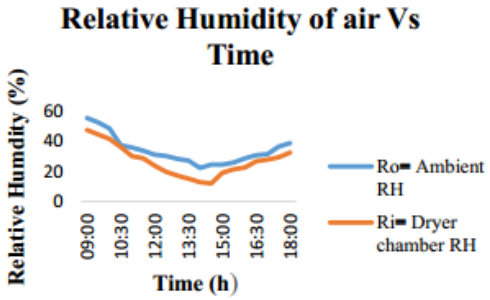
Graph 6.2: time v/s temperature T1 graph (at receiver outlet)



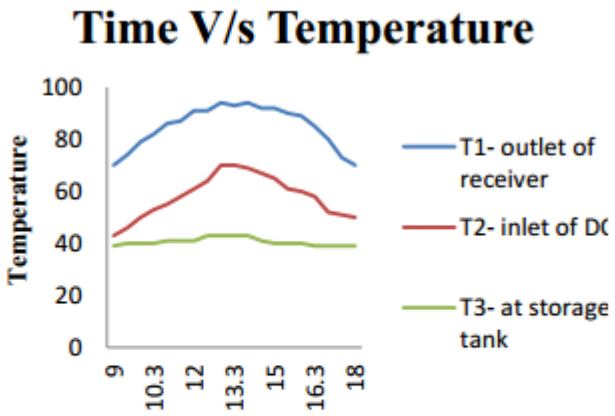
Graph 6.3: Time v/s Temperature Graph (at inlet of drying chamber)



Graph 6.5: Moisture content Vs Time of air.



Graph 6.6: Relative Humidity of air Vs Time



Graph 6.4: Temperature to time graph for mass flow rate of water 0.044kg/m

From the above graphs we can conclude the maximum solar radiation intensity is at 716 W/m2 at 1:30 PM and the maximum collector outlet temperature is 96°C at 2:00 PM for mass flow rate of water 0.044 kg/s. Weight of chillies was reduced to 0.295 kg from 1 kg of chillies in 20 hours. Relative Humidity in dryer chamber is lower than ambient relative humidity, lower humidity improves the drying process as it has tendency to remove moisture from food products.

VII. CONCLUSION

As the temperature obtained through this collector is more than the flat plate collector so time required for drying is less as compared to other collector. Flat plate collector used in application where temperature required is below 100° C and the temperature obtained receiver point is 120° C. In this work forced mode convection solar dryer with concentric dish collector has been developed and tested. The drying experiment conducted with chillies and the complete drying process could be complete with 20 hours, for open drying it takes place around 45 hours which is very 67% less compared with open sun drying. Implementation of concentric dish collector reduces drying time. The temperature in drying chamber inlet was observed 70^0 C at least 6-7 hours hence, we can increase the quantity of products dried. By increase the mass flow rate of water the collector outlet temp of air gets reduced. Hence drying time also reduces and when decreases in mass flow rate of water at the outlet of collector temperature increases and hence inlet temperature of drying chamber increases. Hence it is found that concentric dish collector gives better results than flat plate collector

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