

COMPARISON, DESIGN AND PERFORMANCE EVALUATION OF SOLAR DRYER FOR CHILLY

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Abstract - The solar dryer uses solar heat energy to warm up the atmospheric air to dry any food substance kept in the cabinet, which is very useful in reducing wastage and conservation of agricultural food products. Open sun dryer have various limitations like discoloration, possibility to pests and rodents, uncontrolled monitoring and high cost of the mechanical dryer limits the desired need so a solar dryer is therefore developed to cope up with these limitations.

This project represents the comparison, design, construction and performance evaluation of a solar dryer for conservation of chilly. The heated atmospheric air from a separate solar collector is passed over and at the same time the drying cabinet absorbs solar energy radiation through wall and roof and all this solar energy collects into drying cabinet. The results obtained during the test period represent that the temperature inside of drying chamber or outside of solar collector were much larger than the atmospheric temperature during most hours of the day-light. The temperature increase with the help of good glazing material inside to drying cabinet was up to 173% for about three hours immediately after 12.00hr (noon). The dryer showed enough ability to dry the required food product quickly to a safe moisture level and concurrently it guarantees the higher quality of the dried food product. This natural solar dryer is compared with open air dryer and forced convection solar dryer to study and further enhance the possibility of natural solar dryer performance to optimum working condition in near future.

Key Words: solar dryer; construction of solar dryer; performance evaluation of solar dryer for chilly; comparison of solar dryer; chilly dryer

1. INTRODUCTION

Drying is the oldest procedure used to conserve food products for extended period. The solar heat energy from the sun assembled with the wind has been used to dry food for conservation from many centuries[1,3,8,11,16]. Drying is the oldest technique used to preserve the agricultural products by ancestors. It is a moisture removal process[3,8]. High price and shortage of fossil fuels have

increased the demand of using alternative renewable energy resources. Drying of agricultural products with the help of renewable energy such as solar energy is environment friendly and has no environmental loss. Solar heating technology is rapidly gaining acceptance as an energy saving measures in agricultural application because it is abundant, inexhaustible, and non-polluting[14]. Solar dryer is useful in many application requiring low to intermediate temperature below 78°C, such as crop drying and space heating et cetera[8,10,16].

Many solar dryers have been designed, developed and examined in the different regions of the tropic and sub tropic area of the earth. The major two categories of the solar dryer are natural convection solar dryer and forced convection solar dryer[2,9,10,15]. In natural convection solar dryer, the airflow is developed by buoyancy induced airflow but in forced convection solar dryer, the airflow is provided by using blower either by electricity/solar module/mechanical means or fuel.

2. COMPONENT SPECIFICATIONS AND RESEARCH METHODOLOGY

2.1 Construction and Design Specification

The purpose of drying is to get rid of moisture from the agricultural product so that it can be processed safely and stored for extended period of time. Chillies are also dried before storage. Grains and seeds are usually reaped at a moisture level between 18% - 40% depending upon the characteristic of the crops. These crops must be dried to a level of 7% - 11% moisture depending upon use and market demand[6,10,13,14] (Fig 1).

- Collector Area = 500mm × 1000mm
- Internal height of collector = 150mm
- Tilted angle = 30°
- Size of drying chamber = 680mm × 580mm
- Tray area = 620mm × 520mm

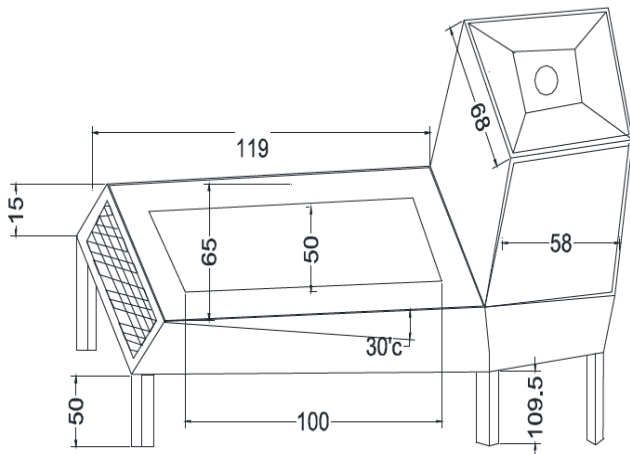


Fig.1 Constructive view of the solar dryer

2.1.1 Solar Collector (Air Heater)

The heat absorber (inner box) of solar collector is constructed using 2 mm thick aluminium plate, painted black, situated in an outer box build from well-seasoned wood. The volume joining the inner box and outer box is full of foam material of about 40 mm thickness[13]. The solar air heater assembly comprises of air flow channel enclosed by transparent cover of glazing material made from single layer of glass sheet[6]. An absorber plate furnishes effective air heating because of solar radiation, that passes through the transparent cover, is absorbed and trapped. Glazing material transmittance τ is above 0.7 for wave lengths within the range of $0.2 \mu\text{m} - 2.0 \mu\text{m}$ and opaque to wave lengths greater than $4.5 \mu\text{m}$. The effective area of the collector glazing material is 0.8 m^2 . One end of the solar collector has an air inlet vent of area 0.0888 m^2 , which is covered by a galvanized wire mesh to prevent entrance of rodents, the opposite end opens to the plenum chamber[6,12,13].



Fig.2 Sectional view of the solar dryer

2.1.2 Glazing material

Transparent single layer of glass sheet is used for experiment purpose, which have following specifications

- Absorptivity, $\alpha = 0.1 - 0.15$
- Transmittivity, $\tau = 0.7 - 0.8$
- Reflexivity, $\rho = 0.1 - 0.15$
- Solar radiation, $I = 1120 \text{ W/m}^2$
- Thermal conductivity, $k = 0.043 \text{ Wm}^{-1}\text{K}^{-1}$
- Thickness, $l = 4 \text{ mm}$

2.1.3 The drying cabinet

An outlet vent was provided toward the upper end at the rear of the cabinet to facilitate and control the convection flow of air through the dryer [4,19,23]. Entrance to the drying chamber was also provided at the front of the cupboard. The roof and therefore the three other side walls of the cupboard are covered with metallic aluminium sheets of 4 mm thick, painted black which provided additional heating[5].

2.1.4 Drying trays

The drying trays are contained inside the drying chamber and were constructed from a double layer of fine net mesh with a fairly open structure to allow drying air to undergo food item[12](Fig 3).

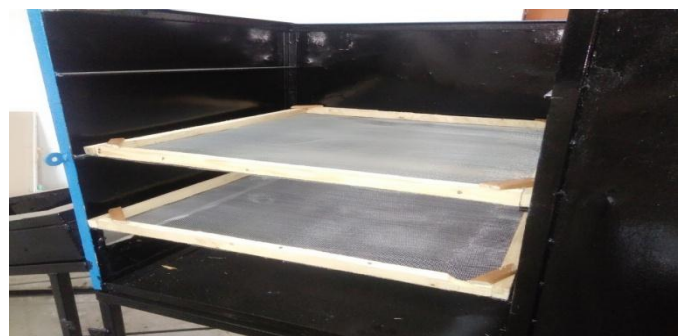


Fig 3 Drying trays

2.2. Mathematical Model

The energy balance on the absorber is obtained by equating the entire heat gained to the entire heat loosed by the warmth absorber of the solar dish .

$$\text{Therefore, } IA_c = Q_u + Q_{\text{cond}} + Q_{\text{conv}} + Q_r + Q_p, \quad (1)$$

Where:

I = rate of total radiation incident on the absorber's surface (W/m^2);

A_c = collector area (m^2);

Q_u = rate of useful energy collected by the air (W);

Q_{cond} = rate of conduction losses from the absorber (W);

Q_{conv} = rate of convective losses from the absorber (W);

Q_r = rate of radio wave re-radiation from the

absorber(W);

Q_p = rate of reflection losses from the absorber (W);

The three heat loss terms Q_{cond} , Q_{conv} and Q_r are usually combined into one-term Q_L

i.e., $Q_L = Q_{cond} + Q_{conv} + Q_r$. (2)

If τ is the transmittance of the top glazing and I is the total solar radiation incident on the top surface, therefore,

$$IA_c = \tau IA_c \quad (3)$$

The reflected energy from the absorber is given by the expression:

$$Q_p = \rho \tau IA_c \quad (4)$$

Where ρ is that the reflection coefficient of the absorber.

Substitution of Equation (2), (3) and (4) in Equation (1) yields:

$$\tau IA_c = Q_u + Q_L + \rho \tau IA_c$$

$$\text{or } Q_u = \tau IA_c (1 - \rho) - Q_L \quad (5)$$

It is presented in the following form (Bansalet al. 1990):

$$Q_L = UA_c (T_c - T_o), \quad (6)$$

Where

U = overall heat transfer coefficient of absorber(W/m²/K);

T_c = temperature of solar collector/absorber (K);

T_o = ambient air temperature outside of dryer (K);

From equation (5) and (6) the useful energy gained by the collector;

$$Q_u = (1 - \rho) \tau IA_c - UA_c(T_c - T_o) \quad (7)$$

The efficiency of the air collector may be calculated as

$$\eta_c = Q_u / IA_c \quad (8)$$

During drying, water moisture at the surface of the food substance evaporates and moisture within the inner part migrates to the surface for urge to evaporation. The ease of this migration depends upon porosity of the food items and the surface area available. Other factors which will enhance quick drying of food items are: heat, wind speed, absolute and relative humidity.

3. EXPERIMENT AND RESULT

3.1 Experimental data

The experimental data of temperature reading was performed by me (Mayank Srivastava) on 12/04/2018, school of engineering, Babu Banarasi Das University, Lucknow. To compare this result data we have also dried the same product in forced convective solar dryer located in HMT lab, Babu Banarasi Das University, Lucknow and the data obtained from both test are given below.

3.1.1 Natural solar dryer

Table 1 Temperature reading at various location in natural solar dryer

Time	T ₁ °C	T ₂ °C	T ₃ °C	T ₄ °C	T ₅ °C	T _a °C
10:00am	38	48	27	33	37	31
11:00am	42	56	27	32	39	32
12:00pm	44	62	25	36	43	33
01:00pm	45	62	22	38	46	35
02:00pm	48	59	26	40	44	38
03:00pm	46	58	25	39	41	36
04:00pm	47	55	24	37	39	35

3.1.2 Forced convective solar dryer

Table 2 Temperature reading at various location in forced convection solar dryer

Time	T ₁ °C	T ₂ °C	T ₃ °C	T ₄ °C	T ₅ °C	T _a °C
10:00am	20	73.5	50	57	44	29
11:00am	24	71.5	51	57	45	30
12:00pm	29	72.9	53	56	44	32
01:00pm	23	71	52	57	44	34
02:00pm	27	71.9	53	61	45	34
03:00pm	26	71.9	52	62	45	35
04:00pm	24	71.6	52	58	44	33

Where,

T_1 = collector plate inlet temperature,

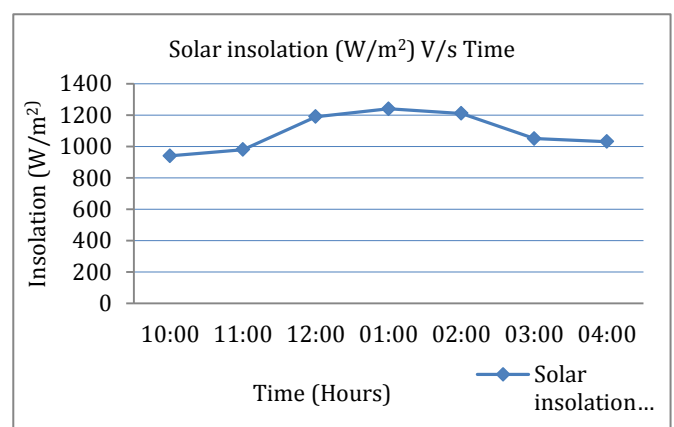
T_2 = collector plate outlet temperature,

T_3 = drying chamber lower tray temperature,

T_4 = drying chamber upper tray temperature,

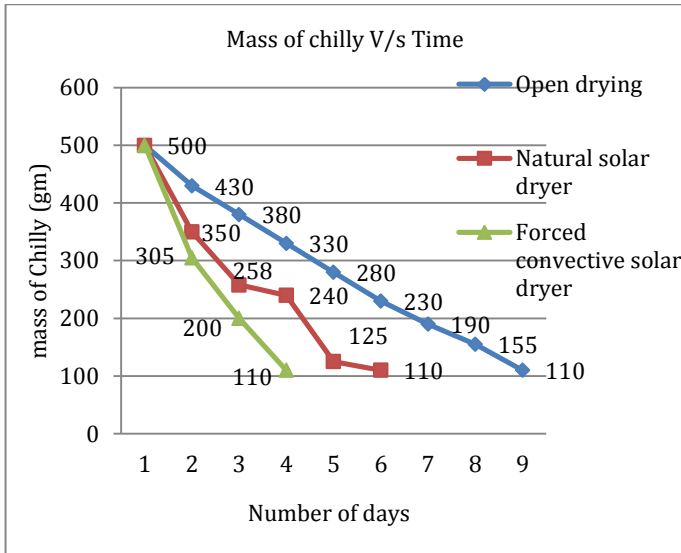
T_5 = exhaust air temperature,

T_a = ambient temperature



Graph 1 Variation of solar insolation with time

The mass of chilly reduced in 9 days with different method of drying is given below. Initially the mass of chilly was 500 gm and its reduction of mass and moisture is given in chart.



Graph 2 Variation of chilly mass with days

3.2 Instrument used

The above solar insolation is measured with the help of solarimeter. Solarimeter is a pyranometer device used to measure combined direct and diffused solar radiation. Average wind speed measured by anemometer is 1.8 m/s. Temperature is measured at different location of solar dryer with the help of thermocouple.

3.3 Calculation

Efficiency of natural solar dryer

$$\eta_c = Q_u / IA_c$$

$$\eta_c = [(1-\rho) \tau IA_c - UA_c(T_c - T_o)] / IA_c$$

$$T_c = (T_2)_{avg} = (48+56+62+62+59+58+55)/7 = 57.14^\circ C$$

$$T_o = (T_a)_{avg} = (31+32+33+35+38+36+35)/7 = 32.42^\circ C$$

$$U = k/l = 0.043/0.004 = 11 \text{ W/m}^2/\text{K}$$

$$\text{So, } Q_u = [(1-0.13) \times 0.75 \times 1120 - 11 \times (57.14 - 32.42)]$$

$$Q_u = 458.97 \text{ A}_c$$

$$\eta_c = 458.97 A_c / 1120 A_c$$

$$\eta_c = 0.4097$$

$$\eta_{\text{natural solar dryer}} = 40.97 \%$$

forced convective solar dryer efficiency is calculated earlier

$$\eta_{\text{forced convective solar dryer}} = 42 \%$$

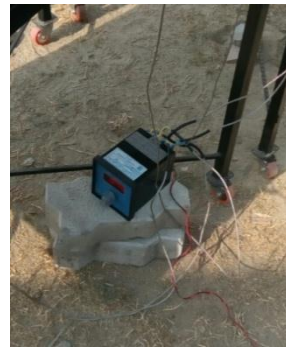


Fig 4 six point thermocouple Fig 5 solar absorber(collector) plate



Fig 6 Chilly drying in the cabinet Fig 7 Forced convective solar dryer



Fig 8 Natural solar dryer in the presence of sun

4. CONCLUSION

The paper presents the redesigned solar dryer with glazing material and its study with chilly. Paper shows comparative study of forced convection solar dryer and open solar dryer with efficiency. The experiment is done on open solar dryer, natural solar dryer, forced convective solar dryer with average temperature was 34.34°C, 57.14°C and 65°C respectively. 400 gram of moisture was removed from 500 gram chilly in redesigned natural solar dryer. The drying rate of natural solar dryer upper tray chilly was higher than that of the lower tray chilly. Drying rate was maximum in forced convective solar dryer than natural solar dryer and minimum in open solar dryer. Inside relative humidity of cabinet chamber was significantly lower than that of outside relative humidity. Efficiency obtained from natural solar dryer experiment was satisfactory high and it can be further increased with invention of good glazing material in near future.

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