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THEORETICAL EFFICIENCY ESTIMATION OF A SOLAR AIR DRYER USED FOR DRYING BITTER GOURD

¹M. Suresh, ²S.Sarathi, ³C.Prithviraj

ABSTRACT

The emerging process of utilizing the renewable energy resources is much more essential and need for human life cycle. In such a way of utilizing these energy forms we get the efficient product with the proper processing condition. Hereby the main renewable energy source used by the industries and farmers are considered as solar energy. Whereas the form of heat is utilized for drying the agro products can significantly reduce to reduce or eliminate product wastage, food poisoning and at the sometime enhance productivity of the farmers towards better revenue derived. In order to produce process heat for drying of agricultural, marine products, etc., solar energy is one of the promising heat sources for meeting energy demand without putting adverse impact of environment. Hence it plays a key role for sustainable development. Solar energy is intermittent in nature and time dependent energy source. In this project, solar power is absorbed in sheet roof plate which is used for drying of vegetable and fruits. An forced convection solar drier and tested its performance for drying chili under the metrological conditions. The system consists of a flat plate solar air collector used for air heating with a drying chamber, and a centrifugal vane blower. Drying experiments have been performed at an constant air flow rate. And the efficiency of the collector were achieved as up to 44.52%.

Keywords: Solar energy, Solar dryer, Forced convective mode, Flat plate collector.

INTRODUCTION

It is imperative that, besides employing reliable storage systems, post harvest methods such as drying can be implemented hand-in-hand to convert these perishable products into more stabilized products that can be kept under a minimal controlled environment for an extended period of time. Many food industries dealing with commercial products employ state-of-the-art drying equipment such as freeze dryers, spray dryers, drum dryers and steam dryers.

The prices of such dryers are significantly high and only commercial companies generating substantial revenues can afford them. Therefore, because of the high initial capital costs, most of the small-scale companies dealing directly with farmers are not able to afford the price of employing such high-end drying technologies that are known to produce high quality products. Instead cheaper, easy-to-use and practical drying systems become appealing to such companies or even to the rural farmers themselves. It is also useful to note that in

Author for correspondence:

¹Assistant Professor, Department of Mechanical Engineering, Adhiyaman College Of Engineering, Hosur, TN.

²PG Scholar, Thermal Engineering, Jayam College of Engineering & Technology, Dharmapuri, TN.

³Assistant Professor, Department of Mechanical Engineering, Jayam College of Engineering & Technology, Dharmapuri, TN.

many remote-farming areas in Asia, a large quantity of natural building material and bio-fuel such as wood are abundant but literacy in science and technology is limited. The proposed dryers should possess the following characteristics:

- Low initial capital costs;
- Easy to construct and fabricate with available natural materials;
- Easy-to-operate with no complicated electronic/ mechanical protocol;
- Effective in promoting better drying kinetics and product quality than the sun-drying method;
- Easy to maintain all parts and components; and
- Simple replacement of parts during breakdowns.

TYPES OF SOLAR AIR HEATER

Solar dryers can generally be classified into two broad categories: active and passive. Passive dryers use only the natural movement of heated air. They can be constructed easily with inexpensive, locally available materials which make them appropriate for small farms where raw construction material such as wood is readily available.

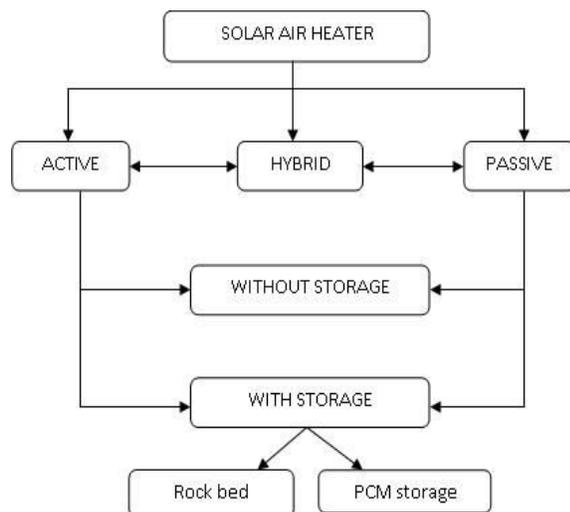


Fig: Types of Solar air heater

CLASSIFICATION OF SOLAR DRYER

Solar dryers are available in a range of size and design and are used for drying of various agricultural products. Various types of Dryers are available in the market as per requirement of farmers. Primarily all the drying systems are classified on the basis of their operating temperature ranges that is High Temperature solar dryer and Low Temperature Solar dryer. Following criteria's are required for the classification of solar dryer:-

- Air movement mode
- Insulation exposure
- Air flow direction
- Dryer arrangement
- Solar contribution

DIRECT SOLAR DRYER

It is a type of dryer in which solar radiation is directly absorbed by the product to be dried. It is also called as natural convection cabinet dryer since the solar radiation is directly fall on the product; the quality of product is reduced. This dryer comprises of a drying chamber that is covered by a transparent cover made of glass or plastic. The drying chamber is usually a shallow, insulated box with air-holes in it to allow air to enter and exit the box.

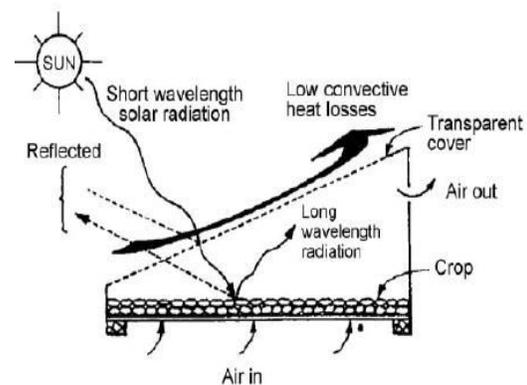


Figure 2.2 Direct Solar Dryer

INDIRECT SOLAR DRYER

The solar radiation gained by the system is utilized to heat the air which flows through the product to be dried in this dryer. In this of dryer quality of product improved though drying rate increased. Heated air is blown through the drying chamber . At the top of drying chamber vents are provide through which moisture is removed. In indirect type of solar drying systems a better control over drying is achieved. Fig. describes another principle of indirect solar drying which is generally known as conventional dryer.

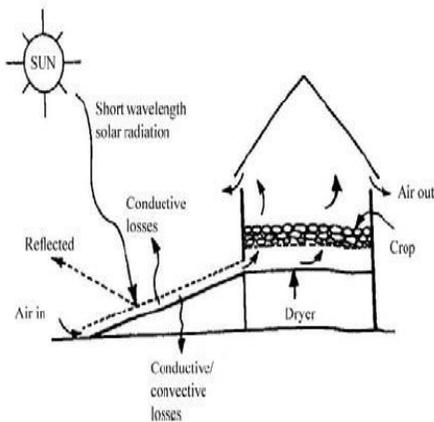


Figure 2.3 Indirect Solar Dryer

FORCED CONVECTION AND NATURAL CONVECTION SOLAR DRYER

Forced convection- In this type of dryer air is forced through a solar collector and the product bed by a fan or a blower, normally referred to as active dryer.

Natural convection – In this dryer natural movement of air takes place thus called as passive dryers. The heated air flow is induced by thermal gradient.

SOLAR COLLECTOR

A solar collector is a special kind of heat exchanger which converts solar radiation energy to

heat energy by using usually air, water or oil. There are basically two types of solar collectors. They are the flat-plate collectors and the concentrating collectors

FLAT PLATE COLLECTOR

Flat plate type is the simplest form of solar air heater. This type of solar air heater includes one or more glass covers and an absorber plate. All sides of the solar air heater except the glass cover should be well insulated to prevent heat loss. Air can flow either over or under the absorber plate. Flat plate solar air heaters can be designed as single pass, double pass, double flow or recycled. The construction of a Flat Air Channel solar air heater is simple; hence it has a low cost. Since no mechanism or method is used to enhance heat transfer in the channel, the efficiency of this kind of solar air heater is lower than other types.

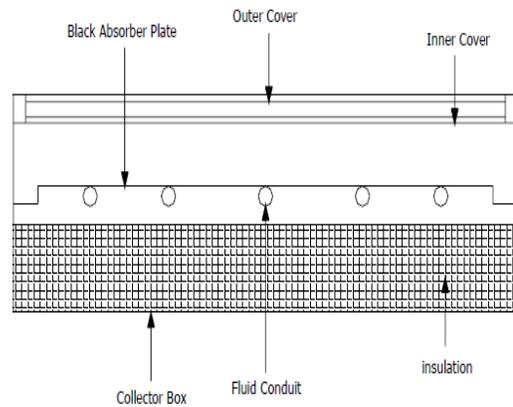


Fig: Cross Section of a Basic Flat-Plate Solar Collector

CONCENTRATING COLLECTORS

For many applications higher temperatures that obtained from flat-plate collectors are desirable to deliver energy. Energy delivery temperatures can be increased by decreasing the area from which heat losses occur. This is done by interposing an optical device between the source of

radiation and the energy absorbing surface. The small absorber has smaller heat losses compared to a flat-plate collector at the same absorber temperature. Because of this reason, concentrating collectors which generally collect the sun's rays from a relatively large area and focus them on a point by using parabolic mirrors are used.

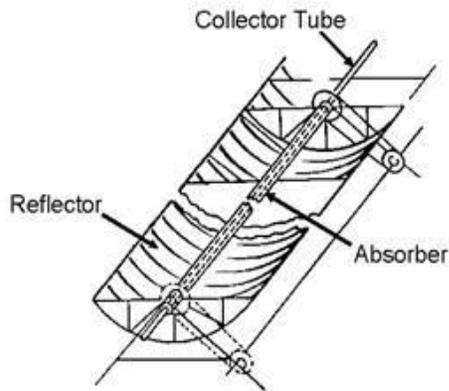


Fig: Basic concentrating type solar collector

EXPERIMENTAL SETUP

The experimental setup is assembled and kept facing towards south pole to north pole due to the solar radiation will be from east pole to west pole. An air blower is connected externally to flow the air in to the solar collector plate. The inlet temperature is measured in the solar collector plate and the outlet temperature is measured by the outlet of the collector plate

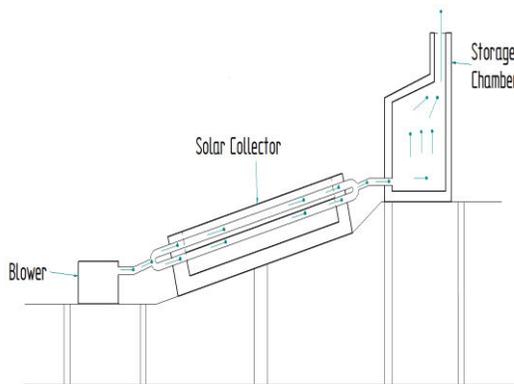


Fig: 2D view of the solar air dryer setup



Fig : Experimental setup

SPECIFICATIONS

COLLECTOR AREA AND DIMENSION

Length of the sheet metal	=	2m.
Width of the sheet metal	=	1m.
Area the collector surface	=	$1 \times b$
	=	$2m^2$

PIPE AREA AND DIMENSION

Pipe inner dia	d_i	=	0.016m
Pipe outer dia	d_o	=	0.020m
Dia of the pipe	d	=	$d_1 + d_2 / 2$
		=	$(0.016 + 0.020) / 2$
	d	=	0.018m

THEORETICAL CALCULATION

COLLECTOR EFFICIENCIES

$$\eta = Q_u / A_c I_0 = F_R [\tau_g \alpha_p - U_L (T_{f,i} - T_a) / I_0]$$

$$F_R = (\dot{m} C_p / A_c U_L) \{ 1 - \exp[-(U_L F' A_c / \dot{m} C_p)] \}$$

$$A_c = n W l = \text{constant (i.e., } n = A_c / W l \text{ or } l = A_c / n W)$$

$$F' = (1 / U_L) / [W \{ (1 / (U_L [D + (W - D) F])) + (1 / C_b) + (1 / \pi D h_{f,i}) \}]$$

In which the collector overall loss efficient U_L is sum of the top (U_T) and bottom (U_B) and edge (U_E) loss coefficients, i.e.,

$$U_L = U_B + U_T + U_E$$

HEAT TRANSFER COEFFICIENTS

The resistance to energy loss through the edges can be neglected, i.e.,

$$U_L = U_B + U_T + U_E \equiv U_T + U_B \equiv U_T + K_i / d$$

$$U_T = \{ 1 / N_g / \{ (C / T_{p,m}) [(T_p - T_a) / (N_g + f)]^{0.33} \} + (1 / h_w) \}$$

$$+ [\sigma (T_p^2 + T_a^2) (T_p + T_a) / \{ 1 / [\epsilon_p + 0.005 N_g (1 - \epsilon_p)] + [(2 N_g + f - 1) / \epsilon_g] N_g \}]$$

MODEL CALCULATION

$$U_T = \{ 1 / N_g / \{ (C / T_p) [(T_p - T_a) / (N_g + f)]^{0.33} \} + (1 / h_w) \} + [\sigma (T_p^2 + T_a^2) (T_p + T_a) / \{ 1 / [\epsilon_p + 0.005 N_g (1 - \epsilon_p)] + [(2 N_g + f - 1) / \epsilon_g] - N_g \}]$$

$$= \{ 1 / [(320.27 / 333) (27 / 1 + 0.0115) \text{power of } 0.33 (1 / 11.2)] \} + 1.35562$$

$$U_T = 2.1574 \text{ w/m}^2\text{k}$$

$$f = 1.2865$$

$$c = 320.279$$

$$h_w = 11.2 \text{ w/m}^2\text{k}$$

$$F_R = (\dot{m} C_p / A_c U_L) \{ 1 - \exp[-(U_L F' A_c / \dot{m} C_p)] \}$$

$$= (26.360 * 1.006 / 2 * 2.1574) * \{ 1 - e - [(2.1574 * 2.258 * 2) / (26.360 * 1.006)] \}$$

$$\eta = Q_u / A_c I_0 = F_R [\tau_g \alpha_p - U_L (T_{f,i} - T_a) / I_0]$$

$$= 0.2218 [0.77 * 3.4 - 2.1574 (309 - 302) / 881.00]$$

$$= 0.45306$$

$$\eta = 45.306\%$$

TABULATION

Time	T ₁	T ₂	T _s	T _{amp}	I ₀	$\bar{\eta}$	Eff
10.00	309	317	329	302	881.00	1.855045	45.30601
10.30	312	322	335	303	708.63	1.891465	44.46283
11.00	313	326	337	305	942.33	1.920796	44.05933
11.30	314	329	345	306	1043.67	1.973579	43.14649
12.00	315	331	341	307	1049.33	1.962469	43.34232
12.30	318	336	349	308.7	1109.67	2.02377	42.26561
13.00	321	339	355	308	1151.00	2.054469	41.66151
13.30	321	339	349	308.2	1183.33	2.018612	42.2721
14.00	322	337	350	307	1223.67	2.013403	42.31257
14.30	321	336	344	306	1161.67	1.968099	43.07063
15.00	321	336	344	305.5	1046.33	1.962433	43.10801
15.30	322	335	345	306.5	1075.33	0.663594	44.3217
16.00	320	332	333	305	957.67	1.902185	44.16762
16.30	318	329	329	306.5	870.33	1.906892	44.16028
17.00	314	327	323	306	741.67	1.888788	44.57485
17.30	313	320	321	305	209.00	1.873306	43.97657
			339.3125				43.51303

Results, Fabrication and Discussion

A solar dryer was designed and fabricated a prototype based on preliminary investigations of bitter gourd drying under controlled conditions (laboratory dryer). The fabricated dryer will be used to dry bitter gourd under controlled and protected conditions. The designed dryer with a collector area of 2 m² is expected to dry 1000g of bitter gourd from 79 % to 10 % wet basis in two days under ambient conditions all year round. The design computation was done using MS excel spreadsheet to facilitate lesser computational time and flexible design. A prototype of the dryer with 1.08 m² solar collector area was fabricated to be used in experimental drying tests.

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