A Novel Design Approach of Small Scale Conical Solar Dryer

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***Abstract*— Solar drier removes moisture content from the food contents and alsoit prevents them from getting decomposed. There are many additional advantages of drying the food contents by solar energy like saving of otheralternate energy, saving of time, occupying less area for drying process, improves quality of the food product, and protects food grains from environmental dust and dirt. The available solar driers in the market are having rectangle box cabinet shape, which is having certain limitations like orientation of sun rays will not be direct through-out the day.**

This study focuses on novel design approach of solar drier as conical shape, which will have better absorption of solar radiation compared to conventional cabinets. The study includes the drying process can be continued during night periods, which are developing heat energy with the LEDs. A proto type model is developed which is having conical shape and also LED heating facility for night period for experimentation purpose.The main motivation for this work is to design a two-in-one solar dryer, which is portable, easy to handle, befitting for a domestic usage and pollution free also. Such dryers are highly essential in monsoon season, when conventional open drying is not possible.

Keywords- solar dryer, photo voltaic effect, solar energy, thermal energy, Light Emitting Diode

I. Introduction

There are two main approaches currently in use to harness solar energy, namely solar energy to electricity by the photovoltaic cells and solar energy to thermal energy by solar thermal conversion. The simplest and the most efficient way to utilize solar energy are to convert it into thermal energy for heating applications. The acceptability of such an approach depends upon the overall efficiency of the system, simplicity of operation, design and cost effectiveness. For household applications quite a large amount of energy is used for various day to day activities. The most common activities are cooking, drying, water heating etc. The solar dryer is a simple solar thermal energy conversion device. Several designs of solar dryer are being manufactured and marketed in different parts of the world [1, 2]. Food losses in the developing world are thought to be 50% of the fruits and vegetables grown and 25% of harvested food grain (Burden, 1989). Food preservation can reduce wastage of a harvest surplus, allow storage for food shortages, and in some cases facilitate export to high-value markets. Drying is one of the oldest methods of food preservation. Drying makes produce lighter, smaller, and less likely to spoil [3].

The objective of this study is to envisage the drying of various tropical fruits and vegetables by using a Two-in-one solar device that is solar cooker –solar dryer. There are several advantages identified in solar dried product like better quality, storage capability, hygiene improvement, reduced wastage and drying time. It was observed that moisture reduces from its initial moisture content of 80-85% to final moisture content of about 10-15% within a short period of time when compared to conventional method of drying. The product quality is more satisfactory in terms of colour, odour, protein and sugar content in the solar dried product compared to conventional drying method. This technology of drying is economically feasible and viable. The solar dryer can dry little faster than the conventional solar dryer for more than 300 days The LEDs connected in the lower mesh gives light as well as heat to the dryer makes it 24 hours usable dryer.

Drying is one of the major food processing operations. The main objective of drying is to remove free water from fruits and vegetable to the extent, where micro-organisms do not survive, so that dried fruits and vegetables can be stored for longer period without rotting and deterioration in the quality of the product. Not only this but many agricultural, horticultural, and industrial products including chemical and pharmaceutical are dried for various purposes like safe storage, easy handling, value addition, further processing and quality improvement[5,6].

II. ANALYTICAL EQUATION

The solar dryer efficiency can be calculated by equation 1.

$$Solar\ dryer\ efficiency = \eta = \frac{\Delta\, w\, gm * h_w \quad KJ/Kg}{I * A} \tag{1}$$

Δw = weight diff. Of the sample Kg

h_w = latent heat of vaporisation KJ/Kg

I = Solar insolation W/ m^2

A = area of the absorber plate m^2.

Advantages of drying:

1. Transportation, handling and storage costs are substantially lowered including the elimination of the need of costly refrigeration during transportation and storage.
2. They provide opportunities for maximum convenience, flexibility and economics in production because they can be sized, shaped, formed etc., to fit almost any requirement.
3. Dehydration affects the main calorie providing constituents of fruits. It leaves the mineral content virtually unchanged. The process is helpful in preserving the nutritive content of the final product.

4. They provide consistent product, an important modern marketing requirement. Seasonal variation in product quality is either absent or a minimum with low-moisture fruits.

III. VARIOUS DESIGNS OF SOLAR DRYERS

Fig.1 (a) and 1(b) shows the images of conventional solar dryer which has only one transparent side from where radiations are possible. Fig 1(c) shows innovative design of conical solar drier which permits solar radiations at 360^0 or from all the directions. Fig 2(a),(b) shows the 3 D model of the designed solar dryer. Fig. 2(c) shows the plate on which 27 Light Emitting Diodes can be connected, and which can generate heat energy during night period for drying purpose.

Fig1(a) Conventional Solar Dryer Side View (b)Front view

IV. PROTOTYPE MODEL DEVELOPMENT

The prototype model of conical solar dryer is designed and developed. Figure3 shows the model which is developed. The model is developed in CAD software.

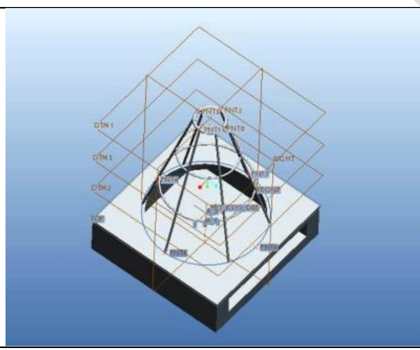

Fig. 2 Drawings of Designed Solar Dryer

The actual model is made with polycarbonate sheet material. The sheet thickness selected is of 1 mm, so the conical shape formation is easy as well as assembly is convenient. The cone section is supported with the circular base and the whole model is located on the base. The larger diameter of the cone is taken as 40 cm. This dimension is selected arbitrarily, as the objective of proto type model is to test the several parameters in drying process. The quantity of material which can be dried is depends on the size of conical shape. The present model is only proto type development.

5. They utilize the most economical and disposable form of packaging.

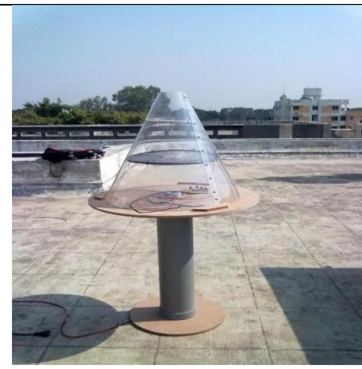

Figure 3: Model of Conical Solar Dryer

The idea for using the solar dryer 24 x 7 is use of LED for the generation of heat during night hours. The LEDs are very much cost effective for the generation of heat. The circulate plate is designed for assembly of 27 LEDs and 9 Drivers in base of the Drier which is shown figure 4(a) and (b).

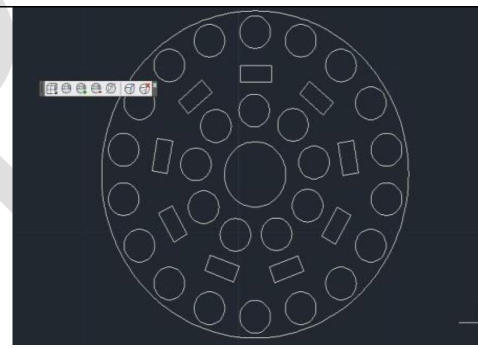

Figure 4(a): Design of LEDs on circular plate

Fig. 4(b) 1 watt High power LED

V. EXPERIMENTAL WORK

The initial experiment was carried out with empty drier for the readings of temperatures. Further tests are carried out with potato chips and certain wet grains. The experiments were conducted in the month of December (winter), which may not give optimum performance due to less ambient temperature. Ambient temperatures and intensity of solar radiations were measured with thermocouple and Pyranometer, which is connected with energy meter. The readings of temperature and radiation were measured at an interval of 20 minutes. The tests were conducted for multiple days during 11am to 4pm.

VI. RESULTS & SISCUSSIONS

The temperatures were measured at the ambient temperature, collector plate and vapour generated at inside of the drier. Fig.3 shows the plot of radiation and temperature as a function of time on 6th and 7th Dec. 2013 without any load. Fig.4 shows plot of temperatures as a function of time without load.

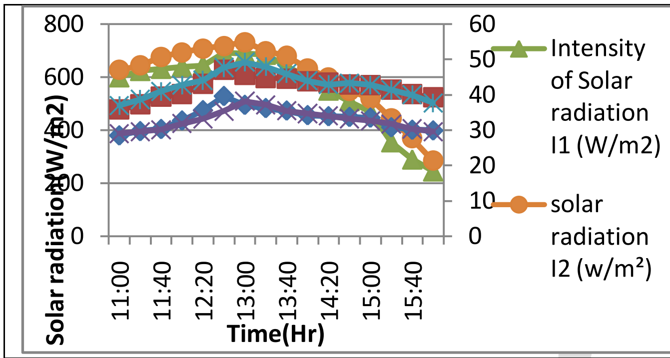

Fig.5 plot of radiation and temperature as a function of time

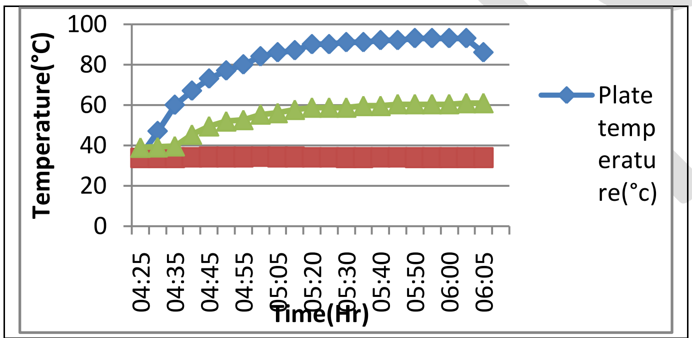

Fig.6 plot of temperatures as a function of time (Without Load)

It was observed that radiation varies in-between 200 w/m^2 to 700w/m^2 during 11 a.m. to 4 p.m. and the ambient temperatures were between 30 to 40°C. The plate temperatures were higher to ambient by 10°C. The empty dryer test with LEDs was conducted inside the laboratory to avoid the wind effect. It was observed that, initially the plate temperature was 30°C which increased to 90°C and it remained constant onwards. The vapour temperature was initially 30 °C which increased to 60°C gradually and was maintained then after. In further testing of solar dryer, potato chips, rice and banana slice were used during day time. Table 1 shows reading of drying of potato chips, table 2 shows drying of wet rice and table 3 shows drying of banana slice. These experiments were conducted with only three LEDs of the dryer and ambient temperature, hot air temperature and plate temperatures were measured at an interval of 5 minutes with platinum 100 thermocouple sensors and temperature indicators. The accuracy of temperature measurement was ±0.1 °C. Potatoes and banana slices were dried effectively and satisfactorily with the dryer for the testing of the dryers.

Table 1: Drying of Potato slices

Time (Hr)	Inside Temperature (^{0}C)	Moisture Reduction Initial = 60%	% Moisture Reduction
11.00 – 11.55	37.8 – 43.6	40	20.0
12.00 – 12.55	44.1 – 49.7	31	9.0
13.00 – 13.55	48 – 46.6	29	2.0
14.00 – 14.55	45.9 – 43.2	24.1	4.9
15.00 – 16.55	43.1 – 39.00	18.3	5.8

Table 2: Drying of Rice

Time (Hr)	Inside Temperature (^{0}C)	Moisture Reduction Initial = 45%	% Moisture Reduction
11.00 – 11.55	33.2 – 41.4	39	6.0
12.00 – 12.55	43 – 48.3	33	6.0
13.00 – 13.55	48 – 43.2	29.6	3.4
14.00 – 14.55	43.3 – 39.5	21.2	8.4
15.00 – 16.55	39.6 – 29.90	17.9	3.3

Table 3: Drying of banana slices

Time (Hr)	Inside Temperature (^{0}C)	Moisture Reduction Initial = 55%	% Moisture Reduction
11.00 – 11.55	33.2 – 41.4	49	6.0
12.00 – 12.55	43 – 48.3	41	8.0
13.00 – 13.55	48 – 43.2	33.8	7.2
14.00 – 14.55	43.3 – 39.5	29.2	4.6
15.00 – 16.55	39.6 – 29.90	26.9	2.3

The percentage reduction in moisture has been calculated for all three materials. The readings are mentioned in table 1, 2, and 3 for potato slice, rice and banana slice respectively. These percentage reduction are plotted in the graph as shown in figure 5.

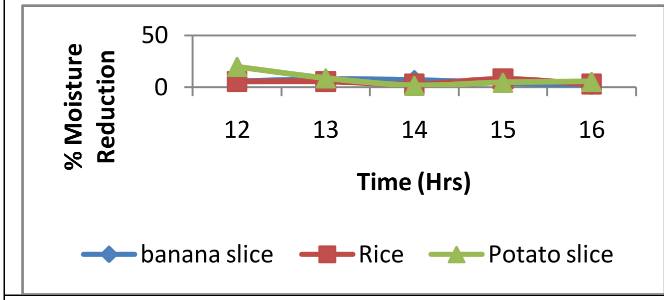

Figure 7: Comparative % Moisture reduction versus time scale

The above graph shows that the highest initial moisture is in the potato slices. Hence, maximum reduction is occurring in the potato slices. The moisture reduction rate is maximum during 12 noon to 2 pm, further the rate of reduction may decrease due to reduction in solar radiations.

VII. CONCLUSIONS

1. Conical shape solar drier works efficiently throughout the day for drying process.
2. The LEDs used in solar dryer can maintain the temperature during night and can also provide heat energy for drying process. The number of LEDs can be increased as per the load to be dried and the moisture contain of the load.
3. Switches and regulator can be connected to control the temperature within the dryer.
4. Seasonal foods can be dried and can be stored for the whole year.
5. During the seasonal production of potatoes, the rate is reducing drastically, and farmers are forced to use cold storage for the preservation. The potatoes can be converted to slices and they can be used for making other products like chips.

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