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International
Journal
Of Modern Engineering Research (IJMER)

Development and Performance Study of Solar Copra Dryer with Evacuated Tube Collector

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ABSTRACT: *The eco-friendly and non-polluting solar energy can be used to conserve vegetables, fruits, coffee and other crops has shown to be practical, economical and the responsible approach environmentally. The objective of present study is to design and fabricate the solar dryer using locally available materials and to evaluate the performance of both natural and forced convection solar dryer. The drying time and the product quality were the main deciding performance parameters of the dryer. During four hour interval from 10.00am to 2.00pm the percentage of moisture content reduced is 44.87% in forced convection and 26% in natural convection dryer. The time taken by the solar dryer with forced convection to reach desired moisture content is less than the time required in natural convection. In forced convection the maximum temperature obtained is 67.2°C and in natural convection is 51.9°C. From the performance, quality and drying rate it is evident that solar copra dryer with evacuated tube collector can be used to dry any agricultural product and product that cannot be dried under natural sun drying.*

Keywords: *Solar dryer, Drying time, Moisture content, Drying rate, Specific moisture extraction ratio.*

I. INTRODUCTION

Renewable energy-such as solar, wind, and biofuels can play a key role in creating a clean, reliable energy in future. Using renewable energy to replace conventional fossil fuels can prevent the release of pollutants into the atmosphere and help combat global warming. During traditional open sun drying, the farmer spread coconut on a mats, cement floors, rooftops or even on soil along the roadsides so as to expose to solar intensity until the completion of drying. There will be contamination by insects, birds and windborne problems like dust, dirt etc. Which ultimately degrades the quality of copra to a greater level. The solar dryer have advantages over sun dryer in faster drying rates. The faster drying reduces the risk of spoilage, improve quality of the product and gives a higher output. Drying is the simple process of removing moisture from a product in order to reach the equilibrium moisture content. The main objective of drying apart from extended storage life can also improve the quality, ease of handling and further processing.

From the literature, it is found that solar dryer with collector is one of the best type of drying techniques. Also, it is observed that most of the dryers use only flat plate collectors. But the evacuated tube collector has many advantages in compare to flat plate collectors such as high efficiency and performance even in bad weather. . An evacuated tube collector is slightly more efficient than a flat plate system due to lower heat losses.

The objective of the present work is to design and fabricate solar dryer with the locally available material and checking the performance of both natural and forced convection solar dryer method. The experiments were conducted in two days in the month of May, from 10.00am to 2.00pm.The performance of forced and natural convection solar drying characteristics are discussed in this paper. This solar dryer can be used to dry any agricultural product and product that cannot be dried under natural sun drying. And also this dryer can play a major role in improving the economic growth of a nation.

II. MATERIALS AND METHODS

2.1 Measuring Instruments and Devices

Microcontroller based RH-Cum-Temperature controller model, TRH-1012S. RHT-1000 humidity and temperature transmitter convert the humidity and temperature measured by two sensor into a 4-20Ma signal. For measuring the solar intensity we are used the pyranometer i-phone application HUKSEFLUX with diffuser placing on a camera lens. This microcontroller based instrument is basically a two channel process controller, which accepts two 4 to 20mA current inputs and display their corresponding process values of RH and Temperature. It has two individual control set points, one for each channel with a variable hysteresis. In the configuration level it has a facility for changing a variety of parameter. In the normal mode user can set the control set point for both channels and their corresponding hysteresis. The instruments have two sensors, a capacitive sensor for measuring relative humidity and a Platinum resistive sensor for measuring the temperature inside the drying chamber.

2.1 Experimental Setup

The designed solar dryer consists of a drying chamber, evacuated tube solar collector, a blower, and chimney. Blower is using in forced convection solar dryer. The cubical drying chamber with dimension of 45×45×45 cm^3 is made of galvanized iron of thickness 3.5mm and black paint is coating on all sides because it prevents heat loss and also it will absorb some amount of heat. Drying chamber consists of two perforated trays made of aluminium to place the copra. The tray shape will be like nut type, it consists of holes to transfer the rate of heat transfer from one tray to other. The solar dryer consists of four evacuated tube solar collector. The glass tube is directly exposed to the environment. The length, inner diameter and outer diameter of each tubes are found to be 1800mm, 48mm and 58mm respectively. Along north south direction the solar collector is placing, so it as to track maximum solar radiation throughout the day. Solar collector is placing 18.98^o to the ground. The inner tube of the collector is coated with magnetron sputter coating (SS-Al N/Cu). Heat loss due to convection, conduction and radiation is thus minimized and it can withstand high temperature.

To blow air into the collector, a blower motor of 0.65KW, 16000rpm, 2.8m^3/min air flow rate installed at inlet of solar collector to blow air into the collector. Regulator in the blower motor is used to vary air velocity flow rates. Chimney of 50cm height made of galvanized (GI) sheet is used at the top of chamber to remove the outgoing moist air. Chimney increases the air flow rate inside the chamber under the convective principle of rising hot air. The hot air from the drying collector outlet is connected to the inlet of drying chamber. The blower is attached at the inlet of the drying collector for conducting the experiment of forced convection.

Figure 1 pictorial view of solar dryer

2.3 Experimental Procedure

Solar drying with evacuated tube collector for both natural and forced convection were carried out for drying the copra. Fresh and good quality of broken copra's are uniformly spread in the trays and are kept inside the chamber for drying. Air is blown into the header of evacuated tube collector with the help of external device blower for forced convection solar copra dryer. The solar radiation falling on the collector, the collector gets heated up and transfers heat to the air flowing through the drying collector. This hot air enters the inlet of the drying chamber where copra is loaded in two trays. The moving hot air evaporates the water content (moisture) of the copra under the basic mechanism of removal of moisture from the surface of the product to the surrounding followed by the removal of moisture from inside the product to the surface. The velocity of the air at the tray was adjusted by using a control valve. During the experiments temperature and humidity inside the drying chamber measured at hourly intervals. The readings are taken on hourly basis from 10.00am to 3.00pm until copra attained equilibrium moisture content.

III. INDENTATIONS AND EQUATIONS

The system performance and the drying characteristics of coconuts such as moisture content, drying rate were calculated using the following equation. From the above tabulation readings we can calculate the performance of solar dryer in both natural and forced convection solar dryer method.

Determination of Moisture Content- The moisture in coconuts were determined after each hour of drying. The moisture content after each hour in drying was determined by taking initial weight and weight loss after each hour with the help of electronic balance

$M_{wb}= (m_i-m_f)/m_i$ - (1)

The initial mass (m_i) and the final mass (m_f) of the sample were recorded at an interval of 1hour till the end of drying using a reliable balance. The moisture content on wet basis

Determination of Moisture loss-Moisture loss of copra is calculated every hour using formula

$M_L = m_i-m_f$ - (2)

Determination of drying rate –The drying rate of copra is determined by using formula

$DR=dM /dt$ - (3)

Where,

dM= Change in mass of sample

dt = Change in time.

Determination of Moisture Ratio – The moisture ratio is given as follows

$MR = (M-M_e) / (M_o-Me)$ - - - - - - - - - - - - - - - - - (4)

Where,

M = Moisture content at any time

M_e = Equilibrium moisture content

M_0 = Initial moisture content of copra.

Determination of Specific Moisture Extraction Ratio –The specific moisture extraction ratio which is the energy required to remove one kg of water is given as follows.

$SMER = m_d / P_d$ -(5)

Where,

m_d = Final mass of sample

P_d = Blower power (kWh)

Pickup efficiency- It is used to evaluate actual evaporation of moisture from copra, was estimated as

$$\eta_p = \frac{(m_i-m_t)}{m_a A t (h_e-h_t)}$$ -(6)

Where,

m_a =mass flow rate of air

m_i = initial mass of sample

m_t = mass of sample at time period

A=cross section area of pipe connecting drying chamber

h_e = humidity entering at initial

h_t = humidity at a time

IV. FIGURES AND TABLES

Table 1 Hourly variation of parameters in a forced convection solar dryer

Sl.No	Time (hour)	Ambient Temp (°C)	Dryer inside Temp (°C)	Relative humidity (%)	Mass of sample in (grams)	Solar intensity (W/m²)
1	10.00	29.8	35.8	59.1	2650	1819
2	11.00	31.3	47.9	48.5	2248	2080
3	12.00	33.0	54.3	39.4	1873	2120
4	01.00	34.6	58.7	34.0	1619	998
5	02.00	36.4	67.2	30.8	1461	1081

Table 2 Hourly variation of parameters in natural convection solar dryer

Sl.No	Time (hour)	Ambient Temp (°C)	Dryer inside Temp (°C)	Relative humidity (%)	Mass of sample in grams	Solar intensity (W/m2)
1	10.00	29.4	34.3	60.5	2200	776
2	11.00	30.2	48.3	53.7	2062	885
3	12.00	34.7	51.5	46.3	1921	1215
4	01.00	31.20	48.4	55.7	1803	880
5	02.00	32.5	51.9	48.2	1628	912

From Table 1 it is observed that average ambient temperature varies from 29.8°C to 36.4°C, whereas the temperature of the chamber varies from 35.8°C to 67.2°C in forced convection solar dryer experiments. And in natural convection from Table 2 we can observed that temperature inside the drying chamber gradually increased up to 51.9°C. The readings were taken by hourly basis from 10.00am to the 2.00pm.

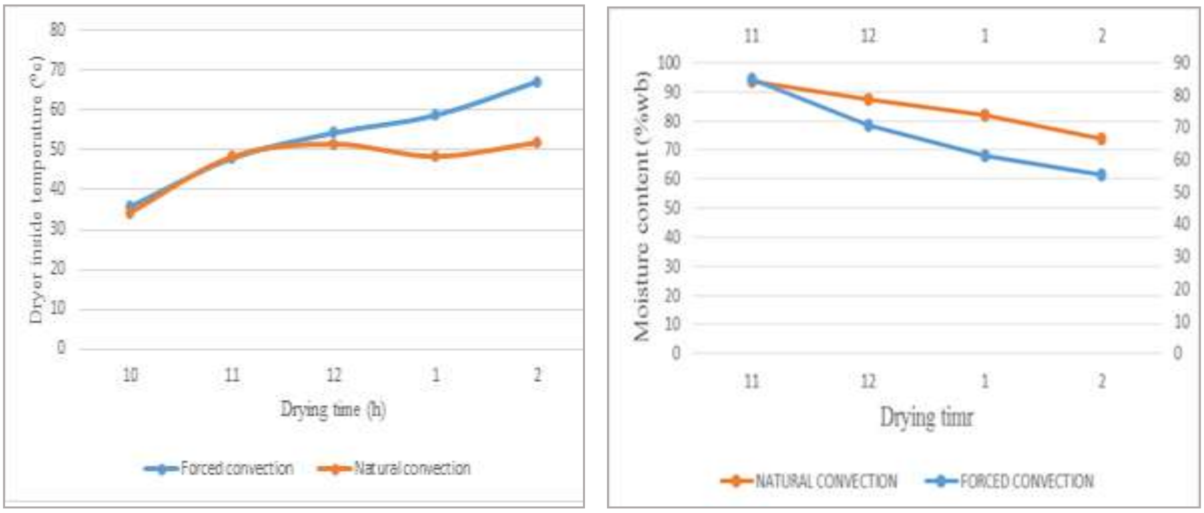

Figure 2 Dryer temperature, moisture content vs drying time

The variation of parameters in an experiment were represented by using a graphs for natural and forced convection combined. Temperature variation of the designed solar dryer forced circulation for 10.00am to 2.00pm during the experiments, temperature of the chamber varies from 35.8°C to 67.2°C. And in natural convection is temperature of the chamber varies from 34.3°C to 51.9°C. The average moisture content of the copra was reduced from 84.83% to 55.13% during 4 hour intervals in forced convection, where as in natural convection is, moisture content of the copra was reduced from 93.72% to 74%.

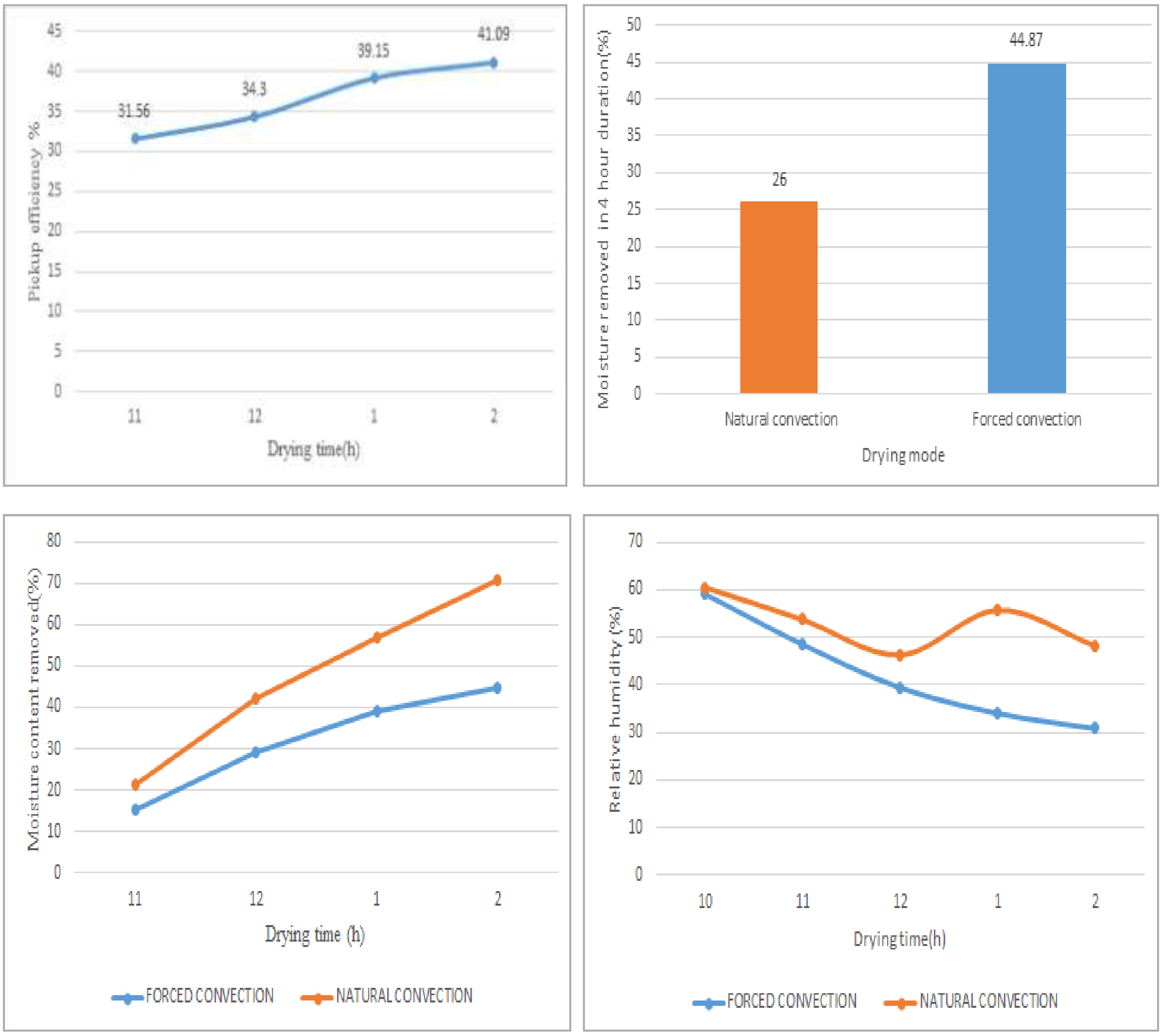

Figure 3 Pickup efficiency, Moisture removed, Relative humidity vs drying time

From the fig.3 it can be observed that Pickup efficiency varies 31.56% to 41.09% for forced convection solar dryer. Increase in pickup efficiency observed during initial stages of drying due to faster evaporation of free moisture in outer surface. Pickup efficiency gets decreased due to internal moisture migration. In this dryer energy is obtained from blower work. During four hour interval the percentage of moisture content reduced is 44.87% in forced convection and 26% in natural convection solar copra dryer. The time taken by the solar dryer with forced convection to reach desired moisture content is less than the time required in natural convection. Moisture content removed in forced convection is from 15.16% to 44.87%. And in natural convection is 6.27% to 26%.

V. CONCLUSION

In this experimental study, the drying of copra was investigated under the two different modes as natural and forced convection. The newly designed solar dryer with four evacuated tube collector considerably reduces the moisture content in the product. The following conclusions are drawn from the experimental study,

- The hourly variation of drying chamber temperature is much higher than the ambient temperature during the most part of the experimental period.
- The temperature of the drying chamber was almost uniform 60-70°C across the trays with time duration of 4 hours.
- The moisture content reduced in forced convection is more 44.87% but in natural convection is 26% during 4 hour intervals.
- The dryer reduces the cost of energy usage and can be used for other agricultural products.

The quality of the copra obtained after our experiment was good compared to the open sun drying. As solar drying is free from dust, contamination and is protected against rain, birds and insects. This dryer can be used to dry any agricultural product that cannot be dried under natural sun drying.

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