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Design And Development Of Solar Dryer Cabinet With Thermal Energy Storage

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Abstract : *Drying is a one of the essential process for the preservation of agricultural food products. Products, especially fruits require hot air in the temperature range of 45-60ºC for safe drying. In this, work has been made to develop the compact and portable forced convection solar dryer for drying chilies with thermal energy storage. The performance of the solar dryer has been tested experimentally. Solar dryer is having capacity of 15 kg of perishable food items and it consist of the flat plate collector based air heating system with thermal energy storage, which used Paraffin wax as phase change material (PCM). The effect of mass flow rates of air on the temperature of the collector, dryer chamber, drying rate and drying time with and without implementation of thermal energy system has also been tested. The efficiency of solar collector and solar dryer has been calculated. Result shows that drying of chilies is technically feasible as comparison with literature, also the moisture content and the reduction in drying time. Temperature in drying chamber was observed 6-9* ^{0}C *higher than the ambient temperature after sunshine hours up to 6-7 hours. Drying time for the chilies was found to be 17 hours with thermal energy storage system. In this present work, testing and experiment has been carried out in different cases: 1) Mass flow rate of air varies from 0.006, 0.008 and 0.01 kg/s. 2) With and without phase change materials*
Keywords - *Solar energy, Open drying, Thermal energy storage, Chili drying.*

I. INTRODUCTION

Solar energy is one of the greatest source of renewable energy and it is referred to as the energy that comes from the sun‘s rays. Solar energy can be utilized in many ways, like, including heating houses, providing electricity, distillation of sea water. Energy is a form of solar power that is used to do many different things. Among the various applications solar drying is one of the important application. Solar dryers are uses the air collectors to collect the solar energy. The purpose of solar drying is to minimize the moisture content of products to a level that can prevents its spoilage. Drying takes place by two processes first is heat transfer to the product using energy from the heat and mass transfer of moisture from the inner part of the product to its surface and second is from the surface to the surrounding air. Traditionally the farmers use the open drying technique, which achieves by using solar radiation intensity, ambient temperature of air, humidity of ambient air and wind speed. In this method the food and perishable items are directly placed on the ground floors, which can reach higher than the temperatures in open drying, and left there for a number of days to dry. The purpose of solar dryer is to supply more hot air to the product than that the air available naturally and reducing the relative humidly of air. There are two types of solar dryers: one is that uses the solar energy as the only source of heat i .e direct mode type and the other that use solar energy to heat the air and this air transfer to products. The airflow in the dryer can be natural convection or forced convection by a blower. In the dryer, the products can directly expose to solar radiation for drying or using the dryer or a combination both. In the dryer the product is heated by the flowing of the heated through the air to the product directly. The transfer of heat to the product is by forced convection from the flowing air on to the food products, which is at a higher temperature than that of the product by direct radiation from the open drying, and by conduction from heated surfaces of product in contact with the product. There are three types of Thermal energy storage systems are Sensible heat storage, Latent heat storage; and Thermo-chemical storage. In sensible heat storage (SHS) the amount of energy is stored by the material is by raising the temperature of a solid or liquid is called sensible heat storage. Which can use the heat capacity and change in temperature of the material during the process of charging or discharging. Latent heat storage (LHS) uses the phase change of the materials. The heat is absorbed or released when the storage material undergoes a change of one phase from solid to other liquid phase, liquid to gas at more or less constant temperature. The materials used for the latent heat storage are called phase change materials (PCM).

Dilip Jain and Pratibha Tewari dries of herbs for their color and flavor is required .In the current paper the study carried out on the solar crop dryer with thermal energy storage with natural convection mode. 50 Kg thermal energy storage materials is attached with dryer The effect of phase change material in solar dryer is to stored energy in day time and release this energy in night or evening time. Sopian.K. In this present paper they study the different solar dryers as direct, indirect and mixed mode and compare their results. They also discussed the potential of dying agricultural products. In the various regions of country. Solar energy plays important role in the active and passive mode type of solar dryers. Forson.K. In this present paper they develop solar crop dryer of the mixed mode drying method. In the experiment they used the cassava of 160 kg by mass, with the 12% of drying efficiency in the 30-36 hours drying time. The moisture content is reduced to 17% from 67% by wet basis

II. DESIGN AND DEVELOPMENT OF EXPERIMENTAL SETUP

The design and development of experiment setup consists of the different parts such as flat plate collector, thermal energy storage system as PCM consisting aluminum trays, dryer cabinet and blower. The basis of the criteria mentioned, the design of the individual parts were done and corresponding parameter like relative dimensions of solar flat plate collector, dryer cabinet and thermal energy storage were designed. The overall project is designed for drying of fruits and perishable based on the area below the collector and tilt angle of the collector on south facing.

2.1 Dryer Chamber The dryer chamber of the main part of solar dryer it was designed for the forced convection mode method. Material used was plywood and polystyrene (Thermocol). The dimensions of dryer chamber are: Length = 1.0 m, Width = 0.6 m, Height=0.8 m 2.2 Thermal Energy Storage Thermal energy storage is to store the solar energy during day time and utilize in evening time .TES was done by using the Phase change material as latent heat storage. PCM was used is paraffin wax.

III. INDENTATIONS AND EQUATIONS

The energy balance equation for absorber is heat gained to the total heat loosed by the heat absorber of the solar collector

IV. $$I_t.A_c = q_u + q_l$$

Useful heat gain by absorber plate is given as

V. $$q_u = A_p.S - q_l$$

Heat loss from the collector is as

VI. $$q_l = U_l.A_p(T_{pm} - T_a)$$

Heat loss from collector is sum of the heat loss from top, bottom and the sides.

VII. $$q_l = q_t + q_{b+}q_s$$

Instantaneous efficiency of collector is

$$\eta = \frac{\text{Useful heat gain}}{\text{Radiation incident on the collector}}$$

$$\eta_i = \frac{q_u}{I_T \times A_c}$$

Moisture content of substance is given as percentage by weight on wet basis and dry basis. The moisture content based on dry basis.[9]

$$m = \frac{m_w - m_d}{m_d}$$

System drying efficiency is defined as the ratio of energy supplied to evaporate the moisture to the heat supplied to the drier. Heat supplied to drier is solar radiation.

$$\dot{\eta} = \frac{L_v \times M_e}{3600 \times A_c \times I_t + P_b}$$

Fig.2.1:- Actual Experimental setup of Solar Dryer

To ensure a high-quality product, diagrams and lettering MUST be either computer-drafted or drawn using India ink.

Figure captions appear below the figure, are flush left, and are in lower case letters. When referring to a figure in the body of the text, the abbreviation "Fig." is used. Figures should be numbered in the order they appear in the text.

Table captions appear centered above the table in upper and lower case

IV. METHODOLOGY

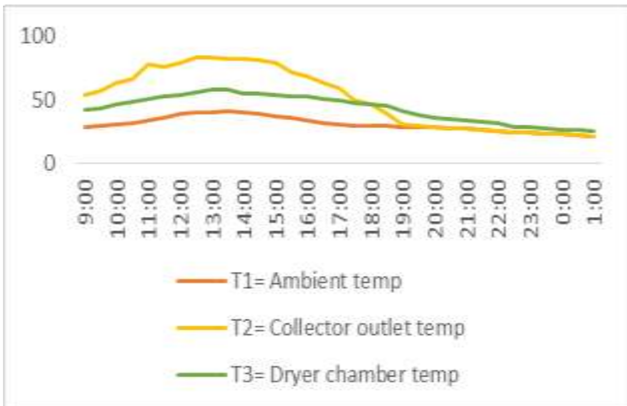
Testing methodology carried out in such way that to find the drying time, moisture content, Efficiency of the dryer and collector with and without implementation of thermal energy storage in developed solar dryer.

1. The effect of various mass flow rates of air on moisture content, drying rate, solar collector temperatures and dryer efficiency has to be tested.
2. Testing has been carried out for drying of chili from initial moisture content of 74-78 % to final moisture content up to 10-20% with and without implementation of a thermal energy storage system.
3. The mass flow rate of air kept for the individual set of testing at 0.006, 0.008, 0.01 kg/Sec though the dryer cabinet with the help of anemometer
4. With the selected mass flow rate of air, reduction in weight of the sample chilies, Outlet temperature of the collector, dryer cabinet exit temperature, is noted.
5. The inlet and outlet temperatures of the collectors, dryer chamber temperature, and dryer chamber exit temperature, relative humidity in dryer chamber is recorded.

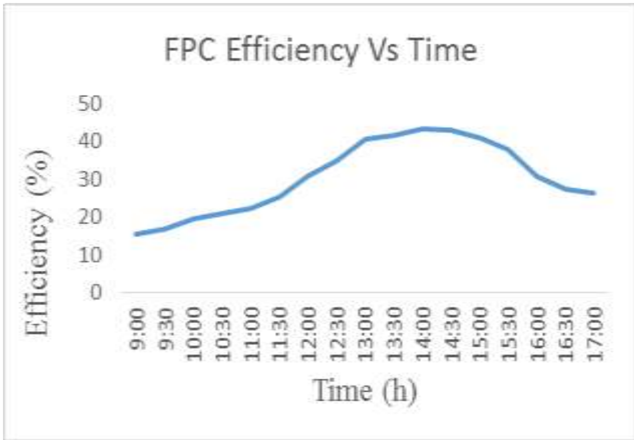
V. RESULTS AND DISCUSSIONS

The results obtained from the experiment carried out on the solar dryer by the testing methodology are presented in this section. Various groups are plotted for the study of variation of solar radiation to time, study of the effect of various mass flow rates, drying time, the variation in the efficiency of flat plate collector etc.

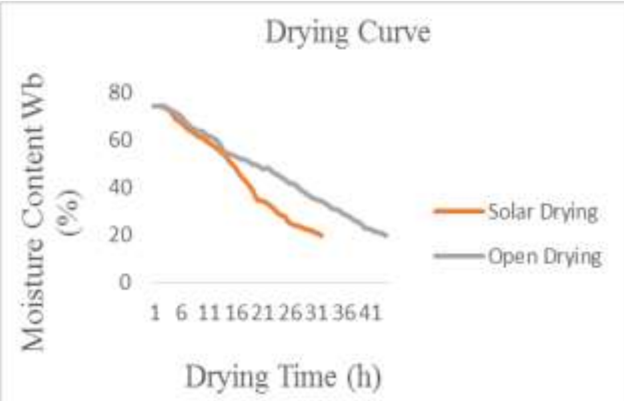
4.1 Outlet temperature of collector and dryer chamber temperature with TES



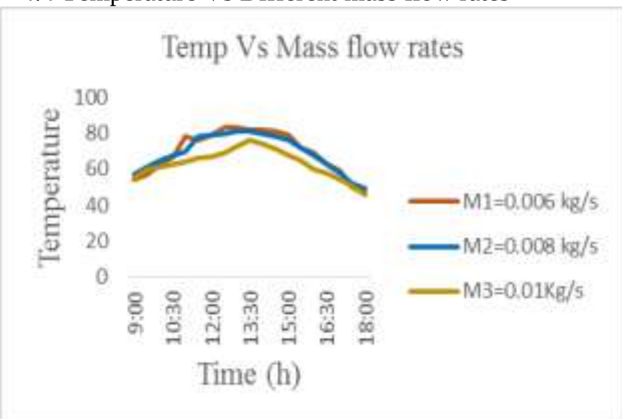
4.2 Efficiency of Flat plate collector Vs Time.



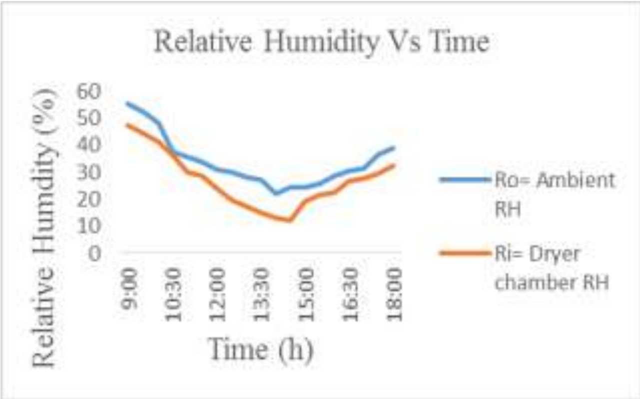
4.3Moisture content Vs Time of air.



4.4 Temperature Vs Different mass flow rates



4.6 Relative Humidity of air Vs Time



From the above graphs we can conclude the maximum solar radiation intensity is at 716 W/m^2 at 1:30 PM and the maximum flat plate collector exit temperature is 83°C at 2:00 PM for mass flow rate 0.006 kg/s. Efficiency of flat plate collector for forced convection is maximum at 1 to 2 PM which is 43 %. Weight of chilies was reduced to 0.295 kg from 1 kg of chillies in 31 hours. Relative Humidity in dryer chamber is lower than ambient which improves the drying process and as sell as it has tendency to remove moisture from food products.

VI. Conclusion

In this work forced mode convection solar dryer with thermal energy storage has been developed and tested. The designed solar dryer with a phase change material is used for drying food items in the evening and till midnight hours also. The variations of the mass flow rate of air on temperatures, drying time is studied and the dryer efficiency of solar dryer has been calculated for chilies is 22 % at the same time effect of thermal energy storage on drying time on chilies also tested with and without implementation of thermal energy storage. The drying experiment tested with chilies and the complete drying process could be complete with 31 hours, for open drying it takes place around 43 hours which is very 33 % less compared with open sun drying. Incorporation of thermal energy storage system reduces drying time .Utilization of thermal energy storage the drying time for a particular day can be extended from sunshine hours to non-sunshine hours. The temperature in drying chamber was observed 6-9 ^{0}C higher than the ambient temperature for at least 6-7 hours hence,

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