EXPERIMENTAL INVESTIGATION OF SOLAR FLAT PLATE COLLECTOR FOR DRYING CHILLIES

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***Abstract*—*This research includes the design and manufacture of indirect forced convection solar dryer and its performance test on Chillies under the metrological conditions of Chennai, India. Solar dryer consists of Solar Collector and Drying Chamber section with three trays. The drying test was conducted with the blower of blowing capacity 2.5m3/min. The maximum air temperature achieved in the dryer was 〖72〗^0 c.The dryer was loaded with 100grams of chillies having an initial moisture content of 75% and the final desired moisture content of 14% was achieved within 7hours.This prototype dryer was designed and constructed to have a maximum collector area of 0.07m2 .This solar dryer have been used in experimental drying tests under various loading conditions.*

***Keywords*— Solar dryer; Chillies drying;Indirect forced convection; Drying Chamber.**

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1. INTRODUCTION

The traditional method of drying known as ‘sun drying’ involves simply laying the product in the sun. Major disadvantage of this method is contamination of the product by dust, destruction by insects and microorganism, and pecking by birds. Furthermore, some percentage will usually be lost or damaged during handling. It is a labor intensive, nutrients loss occurs, such as vitamin A, and is time consuming. Lastly, the method totally depends on good weather conditions.

The major advantage in the energy requirement for this open sun drying process is that the solar and wind energy is readily available freely in nature. Hence, the capital requirement is marginal, making it the viable method of drying agriculture product even commercial scale especially in developing country.The safer alternative to open sun drying is drying in a solar dryer. This is a more efficient method of drying which produces better quality products, but in this case, initial investments are required.

A. Solar dryers

A Solar dryer is an enclosed unit to keep the food safe from damage from birds, insects, microorganism, pilferage and unexpected rainfall. The product is dried using solar thermal energy in a cleaner and healthier fashion. Basically, there are four types of solar dryer.

Direct Solar Dryer

In these dryers, the material to be dried is placed in a transparent enclosure of glass or transparent plastic. The sun heats the material to be dried, and heat also builds up within the enclosure due to ‘greenhouse effect’. The drier chamber is usually painted black to absorb the maximum amount of heat.

Indirect Solar Dryer

In these dryers, the sun does not act directly on the material to be dried thus making them useful in the preparation of those crops whose vitamin content can be destroyed by sunlight. The products are dried by hot air heated elsewhere by the sun.

Mixed Mode Dryer

In these dryers, the combined action of the solar radiation incident on the material to be dried and the air preheated in solar collector provides the heat required for the drying operation.

Hybrid Solar Dryer

In these dryers, although the sun is used to dry products, other technologies are also used to dry to cause air movement in the dryers. For example, fans powered by solar PV can be used in these types of dryers.

The Drying Process

The process of dehydration consists of removal of moisture from the product by heat usually in the presence of a controlled flow of air. Initially, the procedure to be dried is washed, peeled and prepared (if necessary), and placed on flat-bottomed trays that are placed into the dryer. The solar rays enter the cabinet through the cover material. Upon reaching the solar collector or the tray surface, they are converted into heat energy, raising the inside temperature.

The heated product gives out water vapor and dries up. Gradually the heated moist air goes up and leaves the

drying chamber through the air outlet at the high end of the drier.
The efficiency of drying of the solar dryer is influenced by relative humidity in the air, the moisture content of the materials to be dried and their amount and thickness. The solar radiation intensity on the materials varies with seasons, time of the day, and length of exposure,ambient air temperature, and wind speed, which are important factors.

2. LITERATURE REVIEW

The performance of the solar drying system is highly influenced by the performance of the collector. Therefore, several studies have been conducted in order to improve the performance of the solar dryer. Belhamri [1] studied a simple efficient and inexpensive solar batch dryer for agriculture products. During periods of low sunshine a heater is used. Onion was chosen as the dried product because of its swift deterioration characteristics. The result showed that drying is affected by the surface of the collector, the air temperature, and the product characteristics.
Muller et al[2] designed and constructed a solar dryer with a collector area of 16.8m2 which is expected to dry 195.2kg of fresh mango(100 kg of sliced mango) from 81.4% moisture level to 10% wet basis in 2 days under ambient conditions during harvesting period from April to June.
Ismail et al. [3] designed and constructed a solar dryer based on preliminary investigation from mango slices drying under controlled conditions. Mujumdar et al. [4] studied briefly the emerging drying methods and selected recent developments applicable to postharvest processing. In their study, they included the heat pump assisted drying with multimode and varying heat inputs, low and atmospheric pressure superheated steam drying, modified atmospheric drying, intermittent batch drying, osmotic pretreatments, microwave-vacuum drying etc. Bolaji et al. [5] developed a simple and inexpensive mixed-mode dryer from locally sourced materials.
Bukola et al. [6] experimentally found out the performance evaluation of a mixed-mode solar dryer for food preservation. The temperature increase inside the drying cabinet was up to 74% for about 3 hours immediately after 12noon.The drying rate and system efficiency were 0.62 kg/h and 57.5% respectively. Sarsavadia [7]developed a solar-assisted forcedconvection dryer to study the effect of airflow rate (2.43, 5.25, 8.09kg/min),air temperature(55oc, 65oc, 75oc),and fraction of air recycled (up to 90%) on the total energy requirement in drying of onion slices. Kumar et al. [8] used a natural convection mixed-mode solar dryer in performing the experiments on potato slices of the same thickness of 0.01m with respective length and diameterof 0.05m to investigate the convective heat transfer coefficient.
Sreekumar et al. [9] developed a new type of efficient solar radiation by the absorber plate. Abene et al. [10]studied experimentally to improve the efficiency-temperature rise couple of the flat collector. Ramana Murthy [11] studied various aspects of solar drier applied to during of food products at a small scale. Karim et al.[12] studied experimentally the effect of different operating variables on drying potential and drying time. Smitabhindu et al.[13]used a simulation and optimization model to minimize the drying cost per unit of dried banana.

3. DESIGN CALCULATIONS

A. *Moisture Content (M.C)*

The moisture content is given as:
MC(%)=(M_i-M_f│M_i)×100%
Where
M_i =mass of sample before drying and M_f= mass of sample after drying.
B. Moisture Loss (M.L)
The moisture loss is given as:
ML=(M_i-M_f)(g)
Here, M_i is the mass of the sample before dying and M_fis the mass of the sample after drying.

4. THE EXPERIMENTAL SET-UP

The solar dryer with box-type absorber collector was constructed using the materials that are easily obtainable from the local market. Solar dryer was shown in the fig1. The dryer has four main features namely: the box-type absorber solar air collector, thedrying chamber and the drying rack.

Fig.1.The Experimental setup.

A. *Collector (Solar Air Heater)*

The heat absorber (inner box) of the solar air heater was constructed using 2mm thick copper plate. The solar collector was insulated with plywood of about 2cm thickness and thermal conductivity of 0.04Wm-1k-1 on all sides. The solar collector assembly consists of air flow channel enclosed by transparent cover (glazing). The glazing is a single layer of 5mm thick transparent glass sheet. It has a surface area of 23cm by 30cm and of transmittance above 0.86.

B. The drying cabinet and drying racks

The designing of the drying chamber depends on many factors such as the product to be dried, the required temperature and velocity of the air to dry food material, the quality of the dried product and relative humidity of the air passing over the food material. The drying chamber houses three drying racks, between a tray and another tray is

10cm. Three trays of dimensions (29cm × 29cm ×5cm) were fabricated for placing the material to be dried. The tray was made with a plastic wire mesh. The drying chamber was also lined with thermocol insulation material 2cm thick to prevent loss of heat.

5. DRYING MECHANISM

In the process of drying, heat is necessary to evaporate moisture from the material and a flow of air helps in carrying away the evaporated moisture. There are two basic mechanisms involved in the drying process; 1) the migration of moisture from the interior of an individual material to the surface and 2) the evaporation of moisture from the surface to the surrounding air. The drying of a product is a complex heat and mass transfer process which depends on external variables such as temperature, humidity and velocity of the air stream and internal variables which depend on parameters like surface characteristics (rough or smooth surface), (chemical composition (sugar, starches,etc.), physical structure (porosity, density, etc.), and shape of product.

6. THE EXPERIMENTAL MEASUREMENTS

Two thermometers have been positioned to measure the air temperature at the inlet and outlet portion of the air heater. Another three thermometers have placed at trays 1, 2 and 3 in order to measure the temperature of trays. Ambient temperature was also recorded during the course of experiments with the help of mercury thermometer. Air velocity or flow rate of air at the inlet position of the drying chamber was measured by anemometer. Mass of the chillies before and after drying was also measured using weighing machine.

7. RESULTS AND DISCUSSIONS

The variations of temperature of air at solar collector outlet and ambient temperature for a typical day are shown in figure 2.The average drying air temperature recorded at inlet of the drier inlet were measured to be about 〖62.8〗 ^0 c. The maximum and minimum temperature of air achieved at the collector outlet were 〖72〗 ^0 c and 〖52〗 ^0 c respectively.

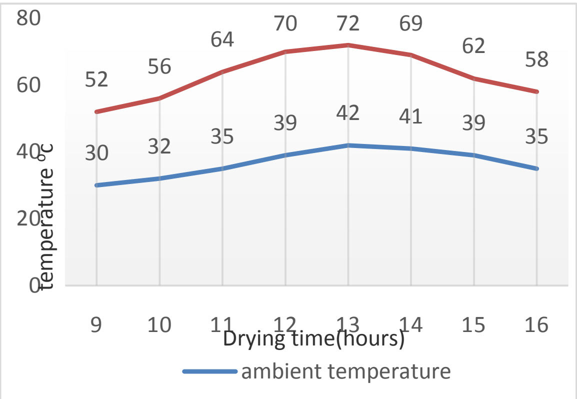

Fig.2. Drying Time vs. Temperature

The variation of moisture content with drying time illustrated in figure 3. The moisture content was reduced from 75% to 14% in 7 hours. The higher reduction during initial stages of drying was observed due to evaporation of free moisture from the outer surface layers and then reduced due to internal moisture migration from thinner layers to surface, which results in a process of dehydration. The reduction in moisture content at bottom tray was higher than that of top tray. Temperature inside drier was higher than ambient temperature and corresponding relative humidity in the drier was lower than ambient relative humidity.

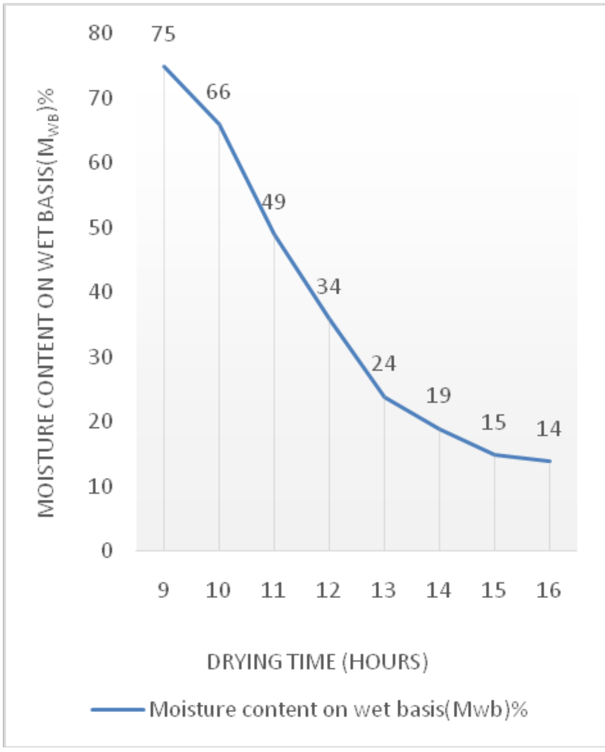

Fig.3. Drying Time vs Moisture content

As a result, drying rate of chillies in a forced convection drier was found to be higher than that of open sun drying chillies

8. CONCLUSION

The performance of an indirect forced convection solar drier was investigated for chillies drying. The drier with copper absorber plate enables to maintain consistent air temperature inside the drier. The chillies were dried from initial moisture content 75% to the final moisture content about 14%(wet basis). The maximum drying temperature through the drying time was 〖72〗 ^0 c.

The moisture content reduction mainly depends on drying temperature and the time of exposure to sun radiation. The main factor in controlling the drying rate was found to be the drying air temperature and air velocity. It could be concluded that forced convection solar drier is more suitable for producing high quality dried chillies for small holders.

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