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Design, Fabrication and Analysis of Indirect Type Solar Dryer for Food Preservation

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ABSTRACT

This Article presents the design, construction and performance of an indirect type solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying cabinet was up to 74% for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

Keywords: *Solar dryer; Heat transfer; Dry bulb temperature.*

1.0 Introduction

Fast increase in population and depletion of fossil fuels has summoned the requirement of alternate energy sources globally. India is a developing nation which requires both economy and energy. India has almost 300 sunny days in a year with theoretically 5,000 trillion kWh per year which exceeds than energy output from thermal power plants. Since majority of the population lives in rural areas in India, there is scope for solar energy being captured in these areas [1]. Drying is one of the methods used to preserve food products for longer periods. The heat from the sun coupled with the wind has been used to dry food for preservation for several thousand years. Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting. Solar air heaters are simple devices to heat air by utilizing solar energy and it is employed in many applications requiring low to moderate temperature below 80°C, such as crop drying and space heating [2]. Drying is the oldest preservation technique of agricultural products and it is an energy intensive process. High prices and shortages of fossil fuels have increased the emphasis on using alternative renewable energy resources. Drying of agricultural products using renewable energy such as solar energy is environmental friendly and has less environmental impact [3]. Different types of solar dryers have been designed, developed and tested in the different regions of the tropics and subtropics. The major two categories of the dryers are natural convection solar dryers and forced convection solar dryers. In the natural convection solar dryers the airflow is established by buoyancy induced airflow while in forced convection solar dryers the airflow is provided by using fan operated either by electricity/solar module or fossil fuel [4].

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The energy from the sunlight can be utilized for drying of food products. Solar drying of fruits and vegetable is an ancient food preservation technology.

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Drying is very important and essential process for preservation of agricultural products. Also, it is important for other industries, such as textile, cement, tea industry, tiles, wood processing, although the solar radiation is used for drying of food materials, it has not yet been widely commercialized because of high investment cost, time-consuming operation etc [5].

Solar drying has a number of advantages as solar energy is non-polluting, free, abundant renewable energy source. But several practical difficulties arise and it should be overcome. The intensity of incident radiation is not constant throughout the day; therefore, heat storage is needed to store the solar energy at its peak value. The auxiliary energy source is required after sunset and at the time of bad weather. Also, solar radiation has a very low energy density, which requires the large surface area to collect solar radiation (collectors). Because of these things, investment costs are notably larger [6]. An alternative solution for traditional drying method and to overcome the problem of open sun drying, indirect type solar dryer is used. The main reasons are as follows, indirect type solar drying maintains good product quality compared to open sun drying. Time for drying process can be significantly reduced as compared to open sun drying. Dried foods can be preserved for a long time period and the product becomes extremely lightweight hence easy for transportation [7].

2.0 Problem Statement

Food scientists have found that by reducing the moisture content of food to between 10 and 20%, Bacteria, yeast, mold and enzymes are prevented from spoiling it. The flavor and most of the nutritional value is preserved and concentrated. Drying and preservation of agricultural products have been one of the oldest uses of solar energy. The traditional method, still widely used throughout the world, is open sun drying where diverse crops, such as fruits, vegetables, cereals, grains, tobacco, etc. are spread on the ground and turned regularly until sufficiently dried so that they can be stored safely. However, there exist many problems associated with open sun drying. It has been seen that open sun drying has the following disadvantages. It requires both large amount of space and long drying time. The disadvantages of open sun drying need an appropriate technology that can help in improving the quality of the dried products and in reducing the wastage. This led to the application of various types of drying devices like solar dryer, electric dryers, wood fuel driers and oil-burned driers. However, the high cost of oil and electricity and their scarcity in the rural areas of most third world countries have made some of these driers very unattractive. Therefore interest has been focused mainly on the development of solar driers.

3.0 Objectives

The main objectives of this present experimental work are,

i) To design and develop an experimental setup for indirect type solar dryer,
ii) To conduct the drying experiments with the sample product of banana, tomatoes and potatoes
iii) To find the initial moisture content of banana , tomatoes and potatoes
iv) To estimate the transient moisture content distribution of banana placed at different trays of drying chamber

4.0 Design Approach and Methodology

4.1 Solar dryer components

The solar dryer consists of the solar collector (air heater), the drying cabinet and drying trays:

4.1.1 Collector (Air heater)

The heat absorber (inner box) of the solar air heater was constructed using 2 mm thick aluminum plate, painted black, is mounted in an outer box built from well-seasoned woods. The space between the inner box and outer box is filled with foam material of about 40 mm thickness. The solar collector assembly consists of air flow channel enclosed by transparent cover (glazing). An absorber back plate provides effective air heating because solar radiation that passes through the transparent cover is then absorbed by back-plate. The glazing is a single layer of 4 mm thick transparent glass sheet; it has a surface area of 800 mm by 1300 mm and of transmittance above 0.7 for wave lengths in the rage 0.2 – 2.0 μm and opaque to wave lengths greater than 4.5 μm. The effective area of the collector glazing is 1.04 m^2. One end of the solar collector has an air inlet vent of area 0.042 m^2.

Figure 1: Solar Collector Construction

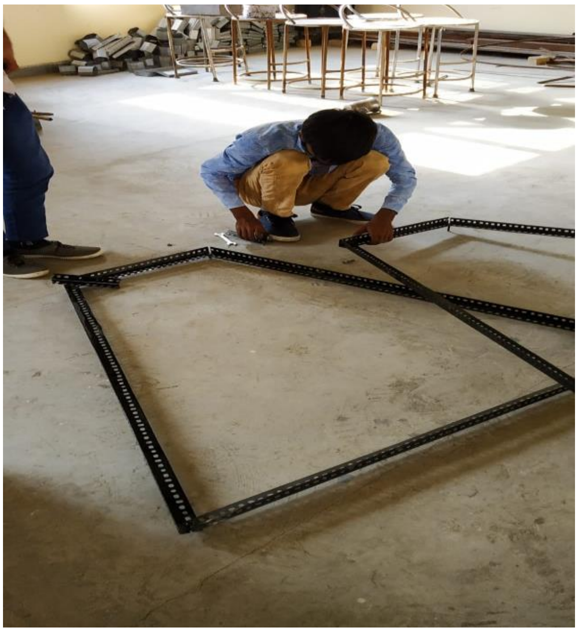


Figure 2: Wooden Planks Being Bolted with Collector Frame

4.1.2 The drying cabinet

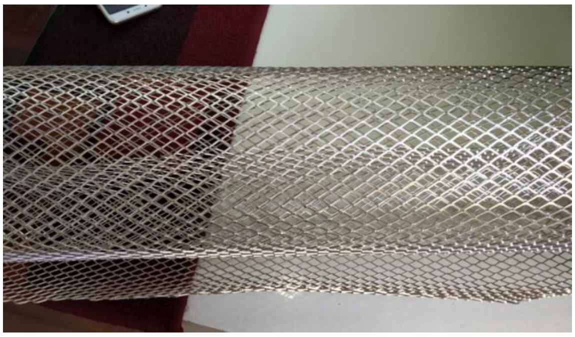
The drying cabinet together with the structural frame of the dryer was built from well-seasoned woods which could withstand termite and atmospheric attacks as shown in Figure 5. An exhaust fan was provided toward the upper end of the cabinet to facilitate and control the convection flow of air through the dryer. Access door to the drying chamber was also provided at the back of the cabinet. The roof and the two opposite side walls of the cabinet are painted black, which provided additional heating.

Figure 3: Drying Cabinents

4.1.3 Drying trays

The drying trays are contained inside the drying chamber and were constructed from a double layer of fine chicken wiremesh with a fairly open structure to allow drying air to pass through the food items as shown in figure 4.

Figure 4: Wire Mesh for Tray



4.1.4 Complete Solar Dryer Setup

Figure 5: Complete Setup of Solar Dryer

5.0 Experimental Results

5.1 Final products macrographs

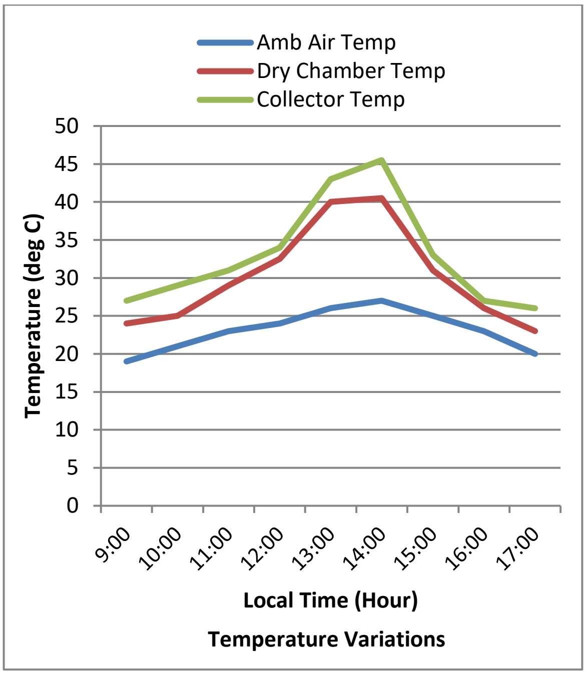
Figure 6: Slices of Bananas After Drying

Figure 7: Slices of Bananas, Potatoes in Drying Cabinets

5.2 Variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature

Fig 8 shows a typical day results of the hourly variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature. The Solar Collector and Dryer were hottest about mid-day when the sun is usually overhead. The temperatures inside the dryer and the solar collector were much higher than the ambient temperature during most hours of the daylight. The temperature rise inside drying cabinet was above 35 ^{0}c for about three hours immediately after 12.00h (noon). This indicates prospect for better performance than open-air sun drying.

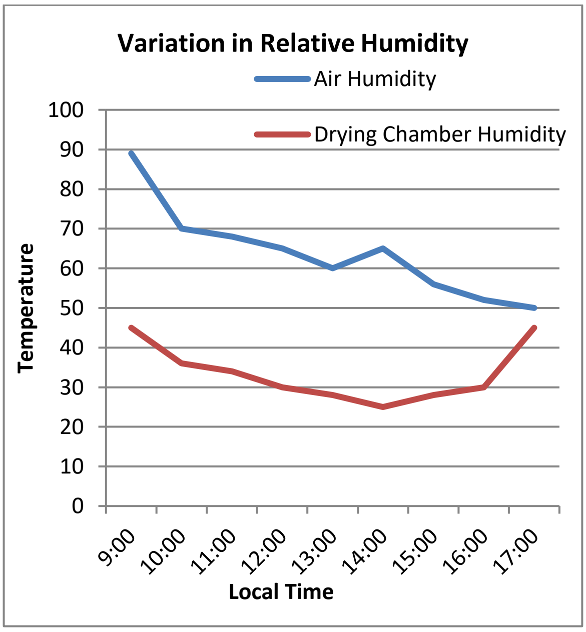
Figure 8: Variation of the Temperatures in the Solar Collector and the Drying Cabinet



5.3 Variation of the relative humidity of the ambient air and drying chamber

Figure 9 shows a variation of the relative humidity of the ambient air and drying chamber. It is clear that as the temperature increases, relative humidity significantly decreases, and thereby dehumidifying the fruits in drying cabinets.

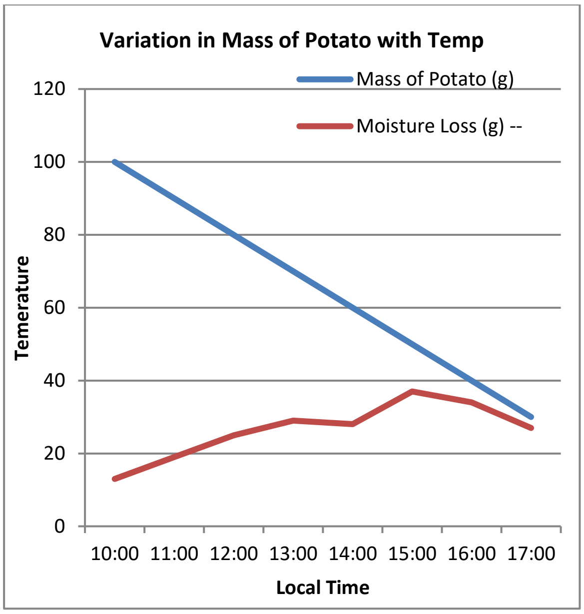
Figure 9: Variation of the Relative Humidity of the Ambient Air and Drying Chamber



5.4 The drying curve for Potato chips in the mixed-mode solar dryer

Fig. 10 shows the drying curve for potato chips in the mixed-mode solar dryer. It was observed that the drying rate increased and continuous due to increase in temperature which shows the continuous removal of moisture from the dried item.

Figure 10: The Drying Curve for Potato Chips in the Mixed-mode Solar Dryer



6.0 Conclusions

From the test carried out, the following conclusions were made. The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of agricultural crops. The product inside the dryer requires less attentions, like attack of the product by rain or pest (both human and animals), compared with those in the open sun drying. Although the dryer was used to dry Potato, it can be used to dry other crops like yams, cassava, maize and plantain etc. There is ease in monitoring when compared to the natural sun drying technique. The capital cost involved in the construction of a solar dryer is much lower to that of a mechanical dryer. The hourly variation of the temperatures inside the cabinet and air-heater are much higher than the ambient temperature during the most hours of the day-light. The temperature rise inside of the drying cabinet was above 35^0 C (74%) for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product

7.0 Acknowledgment

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