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DESIGN AND PERFORMANCE ANALYSIS OF VEGETABLE DRYER USING SOLAR ENERGY

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Abstract - *The solar drying system utilizes solar energy to heat up air and to dry any food substance loaded, which helps in preservation of agricultural product. This research presents the design, construction and performance of a mixed-mode 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 12.00hr (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. In this dryer heat will be stored in an absorber made of granite which will be covered with aluminium sheet. The required angle of tilt will be provided for the collector section depending on solar incident ray for the effective heating on absorber. A blower will be employed at the inlet of the collector for air flow meant for forced convection of heat to the drying chamber. Finally solar dryer will be compared with open sun drying.*

Key Words: Solar Energy, Alternative Energy, Efficiencies, Performance, Natural convection

1.INTRODUCTION

Sun drying is still the most common method used to preserve agricultural products in most tropical and subtropical countries. However, being unprotected from rain, wind-borne dirt and dust, infestation by insects, rodents and other animal, products may be seriously degraded to the extent that sometimes become inedible and the resulted loss of food quality in the dried products may have adverse economic effects on domestics and international markets. Some of the problems associated with open-air sun drying can be solved through the use of a solar dryer which comprises of collector and a drying chamber.

Solar dryer is simply a device to heat air by utilizing solar energy and it is employed in application requiring low to moderate temperature below 80 degree Celsius, such as crop drying and space heating. They are defined as a process of moisture removal due to simultaneous heat and mass transfer. The most important reason for the popularity of dried products are longer shelf life, product diversity as well as substantial volume reduction, this could be expanded further with improvements in product quality and process application. Solar dryers are usually classified according to the mode of air flow into natural convection and forced convection dryers. Natural convection dryers do not require a fan or blower to pump the air through the dryer. Therefore research efforts will be focused on designing and constructing a simple forced convection dryer.

The use of solar technology has often been suggested for the dried fruit industry both to reduce energy costs and economically speed up drying which would be beneficial to final quality. It is believed that as compared to oil or gas heated dryers, solar drying facilities are economical for small holders, especially under favorable meteorological conditions. Traditional drying which is frequently done on the ground in the open air is most widespread method used in developing countries because it is the simplest and cheapest method of conserving food stuffs. Some disadvantage of open air drying are exposure of food stuff to rain and dust, uncontrolled drying, exposure to direct sunlight which is undesirable for some food stuffs, infestation by insects, effect by animals etc.

2.EXPERIMENTAL WORK

The mixed-mode solar dryer with box-type absorber collector was constructed using the materials that are easily obtainable from the local market. A section of the solar dryer. The dryer has four main features namely: the box-type absorber solar air collector, the drying chamber, the drying rack and inlet and outlet ducts. The experimental setup consist of a solar collector consisting of an aluminium sheet as absorber plate, granite as thermal storage medium. A drying chamber consisting of 2 perforated trays held in two on each side of partition wall pattern is used to accommodate the vegetables for drying.

Based on design calculation length, width and height of the solar collector is given as 70cm, 40cm and 25cm respectively. The absorber is placed below the solar collector; here aluminium sheet painted black is used as absorber. Below absorber plate granite slab is placed for storing sensible heat. At the top of the absorber glass sheet is placed which transmit maximum solar radiation falling on it. A blower is used for continues blowing of air from outside to the solar collector, the air is heated and heated air is taken to drying chamber. Calibrated thermocouple is fixed on granite plate, aluminium sheet, drying chamber and collector for measuring the temperature. Inlet and ducts for transfer of heated air is provided by means of PVC pipe between both the chambers and between the blower and collecting chamber.

2.1.COLLECTING CHAMBER

The heat absorber of the solar air heater was constructed using 1.3 mm thick galvanized plate, painted black, the surfaces were painted with black paint along with red oxide metal primer to increase its absorbing capability. The solar collector assembly consists of air flow channel enclosed by transparent cover (glass). The covering is a single layer of 4 mm thick transparent glass sheet. It has a surface high transmittance. The collector was oriented facing solar radiation coming from the sun on the collector surface.

2.2.ABSORBER

The absorber which is 35cm X 25cm black painted aluminium sheet, fixed in the middle of solar collector. The absorber was implicit to be a perfect black body and greatest heat capacity. The aluminium sheet was used for fabrication of the absorber because it has a high value of adsorption (88%) and high heat capacity. It is low cost, high melting point, inflammable and easily available in the local market.

2.3.DRYING CHAMBER

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 quantity of the dried product and the relative humidity of the air passing over the food material.

2.4.DRYING TRAYS

The drying chamber houses two drying racks, between a tray and another tray is 20 cm. Two trays of dimension (50cm x 50cm) were fabricated and stacked uniformly/evenly at distances (20cm) apart, for placing of material to be dried. The tray was made from an aluminum wire mesh (0.003 x 0.003 m in size) attached to it.

2.5.INLET AND OUTLET DUCT

The inlet duct to the collecting chamber is 2.54cm diameter made up of PVC fixed at the bottom of the collector due to the fact that the air enters from lower side at lower temperature whereas the other end is connected to the blower. The outlet duct from the collecting chamber is 3.175 diameter made up of PVC fixed at the top of the side face of the collecting chamber to take away the heated air to the inlet of the drying chamber which is also a duct of 3.175 diameter such that the heated air from the collecting chamber is transferred to the drying chamber.

3.WORKING

Interested product to be dried may be washed and or preheated as per requirements. The product is then loaded in the trays. The trays must be filled with the vegetable and at no place should the bottom of tray be visible. Otherwise, the hot air will flow through that area and bypass the product, resulting in the reduction of the thermal efficiency. It may be noted that if the product to be dried is less than the capacity of the dryer, the loading of the product should be done only in the top trays and the lower trays may be left empty. The drying of the product is done on batch mode. In the batch mode, the fresh product is loaded only after removing the dried product of the previous batch. Heat absorbed by the absorber will be transferred to the storage medium and this heat will be dissipated and sent to the drying chamber via duct by blowing ambient air sucked by blower through an intermediate duct. Air runs inside the solar collector in a Z flow path above the storage medium. This heated air will be passed through the trays inside the drying chamber and finally escapes out to the atmosphere. Air can take up moisture, but up to a limit, this limit is the absolute (max) humidity and it is temperature dependent. When air passes over a moist food it will take moisture until it is virtually fully saturated, i.e. until absolute humidity has been reached. But capacity of air for taking up this moisture is dependent on its temperature.

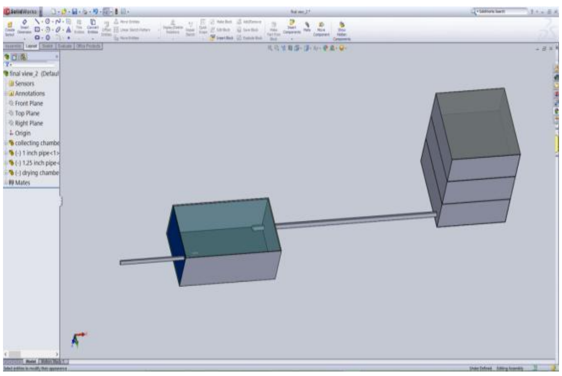

Fig -1: Dryer setup

4.OBSERVATIONS

This project presents the design, construction and performance of a mixed-mode solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a 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 12.00p.m. (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.

Table -1: Design Considerations

Location – Coimbatore	10deg 38min N & 76deg 51min E
Product to be dried	Potato
Drying Period	April 2016
Drying Material Quantity	0.5kg
No Of Trays	2
Load rating	250g/tray
Initial Moisture Content	71.4% wet basis
Final Moisture Content	18.6% wet basis
Ambient air temperature	34OC(Average for April)
Maximum allowable temperature	64 OC
Drying Time	5hrs
Flate plate medium	Aluminiumflate plate
Heat storage medium	Granite Sheet
Test collector size	70cm long and 40cm wide

5.OPEN DRYING VS DRYING IN SOLAR DRYER

The initial weights of the potatoes were measured and dryer was loaded with equal mass in each trays. Weights of the product in each tray were measured at regular interval of 1hr between 09:00 to 14:00 local time. Also the temperatures at solar absorber, heat storage medium (granite), covering and drying chamber were measured using thermometers. After measuring the weight and temperature position of each tray were changed as to achieve uniform heating rate. Contemporarily, open sun drying was done and weight of the potatoes were measured at regular interval of 1 hr. this procedure was continued up to a stage when the moisture content in the potatoes reduced to 18.6%.

Chart -1: Comparison of solar drying V/S open sun drying

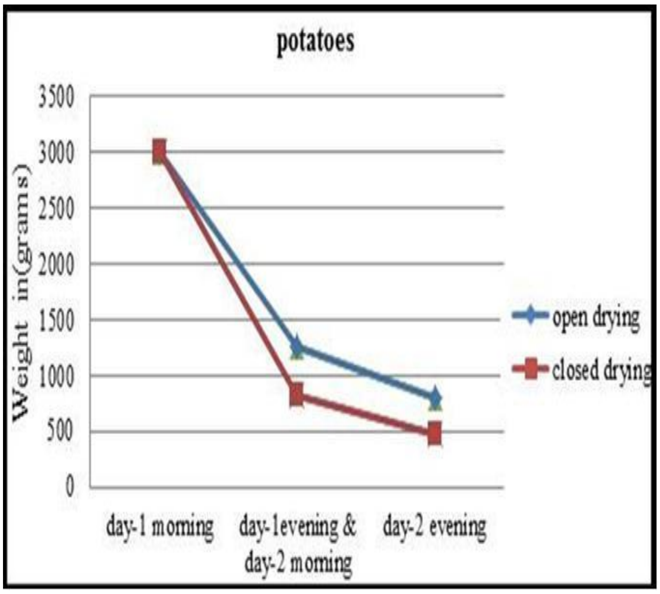

Table -2: Variation of temperatures in the solar dryer

Time Hrs	Ambient Temperature (degree)	Drying Chamber Temperature (degree)	Collector Temperature (degree)
09:00	32	34	37
10:00	33	37	42
11:00	35	40	50
12:00	38	46	58
13:00	35	50	62
14:00	34	45	58
15:00	32	42	50
16:00	31	39	47
17:00	30	36	44
18:00	30	34	39

Table -3: Variation of relative humidity in the dryer

Time	Ambient Air Humidity	Drying Chamber Humidity
09:00	40	81
10:00	33	79
11:00	29	77
12:00	32	73
13:00	36	70
14:00	38	74
15:00	39	78
16:00	46	79
17:00	48	81
18:00	50	83

6.CONCLUSIONS

In this work, the practical way of cheaply and sanitarily preserving food items by the use of solar dryer has been demonstrated. The fabrication of the dryer does not require high technology. At once installed the maintenance cost is minimal the dryer was tested and the following conclusion can be drawn based on result obtained, Drying rate was more in solar dryer than open sun drying process.

While performing experiment without changing the position of trays it was concluded that the tray which was first to be in contact with the incoming hot air had the highest drying rates than other trays. 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.

Also from the test carried out, the simple and inexpensive mixed-mode solar dryer was designed and constructed using locally sourced materials. 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 the drying cabinet was up to 24oC (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

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