Improvement and Estimation of Diverse Approach Forced Convection Solar Dryer

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Abstract

Based on preliminary investigations under controlled condition of drying experiments, a diverse solar dryer with forced convection using smooth and rough plate solar collector was constructed. This paper describes the development of dryer considerations followed by the results of experiments to compare the performance of the smooth and the roughed plate collector. The thermal performance of solar collector was found to be poorer because of low convective heat transfer from the absorber plate to air. Artificial rib roughness on the underside of the absorber plate has been found to considerably enhance the heat transfer coefficient. The absorber plate of the dryer attained a temperature of 69.2°C when it was studied under no-load conditions. The maximum air temperature in the dryer, under this condition, was 64.1°C. The dryer was loaded with 1.5 kg of potato having an initial moisture content of 81.4%, and the final desired moisture content of 18.6% was achieved within 4 days while it was 8 days for open sun drying. This prototype dryer was designed and constructed to have a maximum collector area of 1.03 m². This solar dryer been be used in experimental drying tests under various loading conditions.
Keywords: diverse mode, Forced convection dryer, solar collector& Potato

I. Introduction

Drying may be required for several reasons. First and most often, water is removed from the fresh crop to extend its useful life. The dried product is later rehydrated prior to use in order to produce a food closely resembling the fresh crops, for example, in the use of dried vegetables. Second a crop may require drying so that it can be further processed. For example, many grains are dried so that they can be ground into flour. Third, fresh crops are sometimes dried so that a new product distinctly different from its original form can be produced.

II. Fundamentals of the Drying Process

Drying involves the removal of moisture and in thermal drying this is achieved through the application of heat to the product. The heat increases the vapour pressure of the moisture in the product above that of the surrounding air. Pressure and thermal gradient cause the moisture both liquid and vapour, to move to the surface of the product. Evaporation takes place and water vapour is transferred to the surrounding air. This air may become saturated, but the process of drying continues if this surrounding moist air is replaced by less-saturated air.

III. Traditional Sun Drying

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 products by dust, destruction by insects and micro-organism, and pecking by birds. Furthermore, some percentage will usually be lost or damaged during handling; it is labourintensive, 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 requirements for this open sun drying process is that the solar and wind energy is readily available freelyin nature; hence, the capital requirement is marginal, making it the viable method of drying agricultural produce even in commercial scale especially in developingcountry. The safer alternative to open sun drying is dryingin a solar dryer. This is a more efficient method ofdrying which produces better quality products; but in this case, initial investments are required.

IV. Solar dryers

A solar dryer is an enclosed unit to keep the food safe from damage from birds, insects, micro-organism, pilfer age, and unexpected rainfall. The produce is dried using solar thermal energy in a cleaner and healthier fashion. Basically, there are four types of solar dryers:

A. *Direct solar dryers.*

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 the 'greenhouse effect.' The drier chamber is usually painted black to absorb the maximum amount of heat.

B. *Indirect solar dryers.*

In these dryers, the sun does not act directly on the material to be dried thusmaking 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.

C. *Diverse-mode dryers.*

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.

V. The drying process

The process of dehydration consists of removal of moisture from the produce by heat usually in the presence of a controlled flow of air. Initially, the produce 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 heat energy is transferred to the produce to be dried. The heated produce 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.

VI. Methods

Solar dryer design considerations the following points were considered in the design of the natural convection solar dryer system:

1) The amount of moisture to be removed from the given quantity of potato
2) Harvesting period during which drying is needed
3) The daily sunshine hours for the selection of the total drying time
4) The quantity of air needed for drying
5) Daily solar radiation to determine energy received by the dryer per day and
6) Wind speed for the calculation of air vent dimensions.

VII. METHODOLOGY

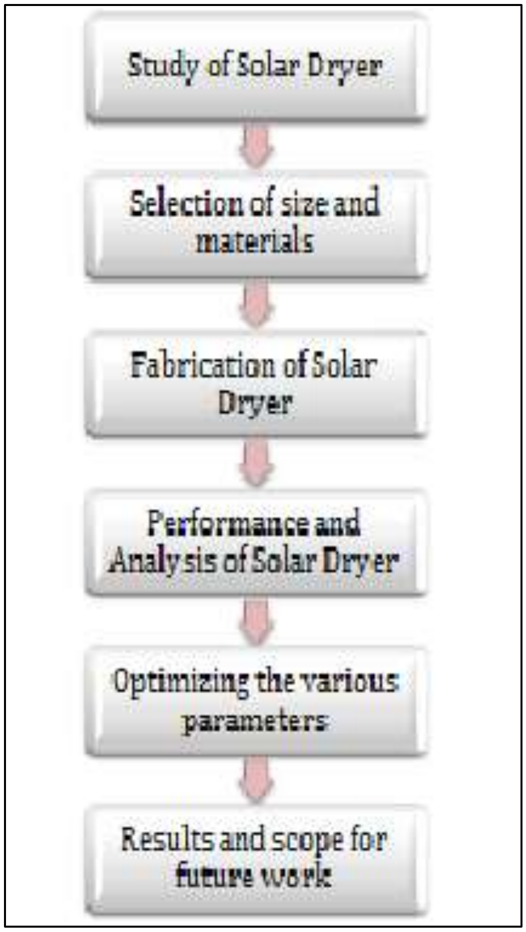

Fig. 1: Methodology

VIII. CONSTRUCTION OF MIXED-MODE SOLAR DRYER

The materials used for the construction of diverse-mode solar dryer were inexpensive and easily obtainable in the local market. It shows the essential features of the dryer consisting of the solar collector (air heater), drying cabinets, and drying trays.

A. Solar Collector Setup

The experimental setup is an open-flow loop that consists of a test duct with entrance and exit sections, a blower unit, control valve, orifice plate, various devices for measurement of temperature, and fluid head. The flow system consists of an entry section, a test section,exit section, a flow meter, and a centrifugal blower. The setup consists of two identical wooden ducts: one is rough absorber duct and other one is smooth absorber duct. Each duct size is 2,030 mm × 200 mm × 25 mm (dimensions of inner cross section) and is constructed from wooden panels with 32 mm thickness. The section length is 1,500 mm (33.75 D). The entry and exit lengths were 177 mm ($2.3\sqrt{WH}$) and 353 mm ($5\sqrt{WH}$), respectively, as shown in Figure 2. The absorber plate material which is an aluminium sheet with 1,500 mm × 200 mm in size has a thickness of 3 mm which is painted black to increase the absorbing capacity of the plate. Another absorber plate is roughed with strips to provide obstacle to the path of air to obtain the maximum temperature. The solar collectorassembly consisted of airflow channels enclosed by transparent cover (glazing). The glazing is a single layer of 4-mm thick transparent glass sheet. It has a surface area of 200 mm by 1,500 mm. The outlet of duct is connected to the orifice meter with an inclined manometer to measure the mass flow rate of air. The outlet of the orifice meter is connected to the inlet of the blower. The outlet of blower is connected to the inlet of the cabinet dryer.

B. The Drying Cabinet

The drying cabinet, together with the structural frame of the dryer, was built from well-seasoned wood which could withstand termite and atmospheric attacks. Anoutlet vent was provided toward the upper end at the back of the cabinet to facilitate and control the convective flow of air through the dryer. The roof and the two opposite side walls of the cabinet are covered with transparent glass sheets of 4-mm thick, which provided for measurement of temperature and fluid head.

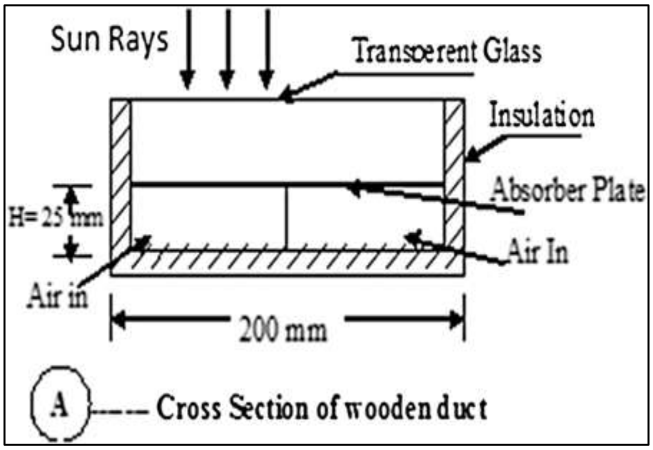

Fig. 2: The drying cabinet

C. Construction details

In the constructed solar drying cabinet, the materialsused in the construction include 3/4 plywood, Perspex glass, wooden bars, (for construction of the body) nails,wire mess, black paint, and hardwood Perspexglass was used as glazing surface to cover the topand the sides. The top glazing measures 550 mm × 500mm, and the each two side measures 640 × 520 mm.The plywood with 550 mm × 600 mm size was used incovering the base. The door of the dryer was made ofthe wood 520 mm × 500 mm, while the opposite side ofthe door was covered by 540 × 500 mm of the Perspex glass.

D. Drying trays

The drying trays are contained inside the drying chamberand are constructed from a double layer of fine chicken wire mesh with a fairly open structure to allow drying air to pass through the food items. The three trays were separated with a gap of 100 mm. The traysare arranged in a zigzag manner. The trays were made of wire mess and hardwood measuring 30 mm in depth and with dimension of 300 mm × 540 mm.

E. Operation of the dryer

The dryer was a passive system in the sense that it hadno moving parts. The sun rays entering through the collector glazing energizes it. The absorption of the rays is enhance by the inside surface of the collector that were painted black and the absorbed energy heats the air drying cabinet.

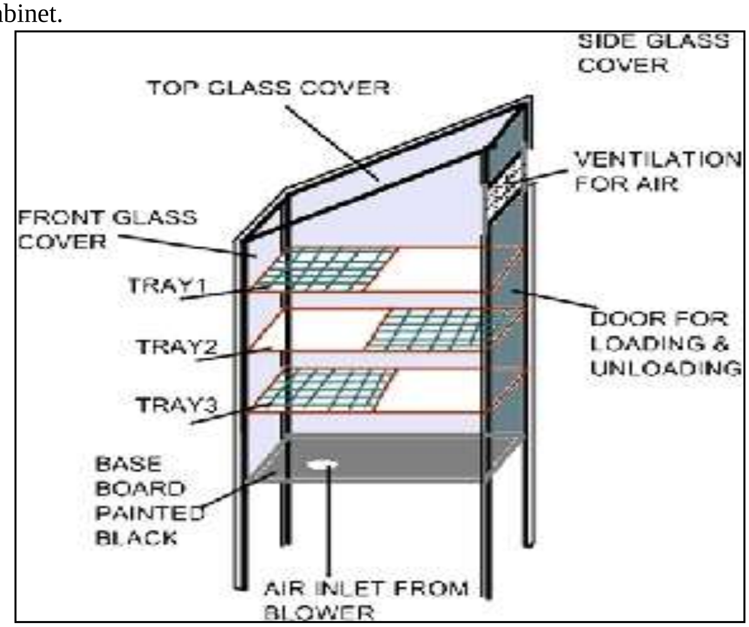

Fig. 3: 3D view of drying cabinet

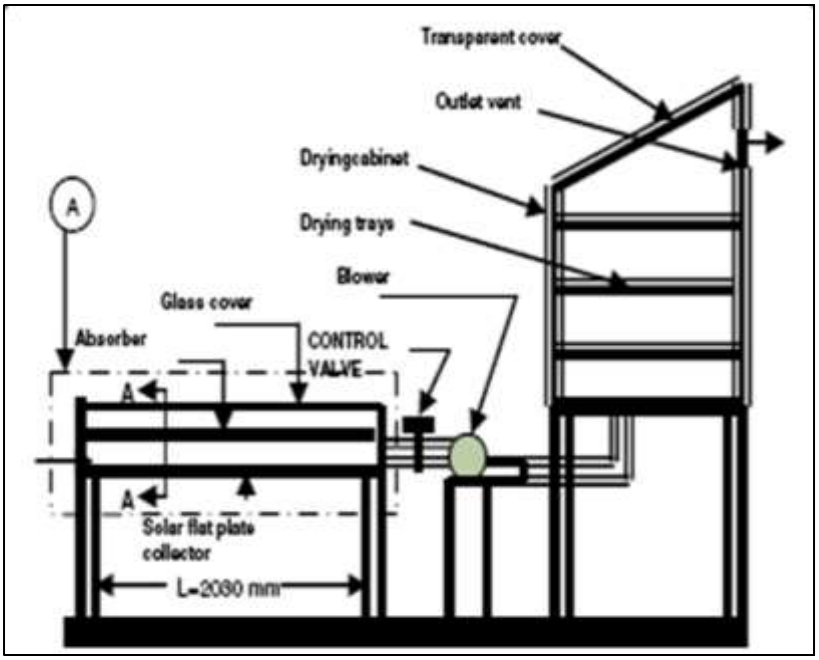

Fig. 4: Schematic Diagram of Experimental Setup

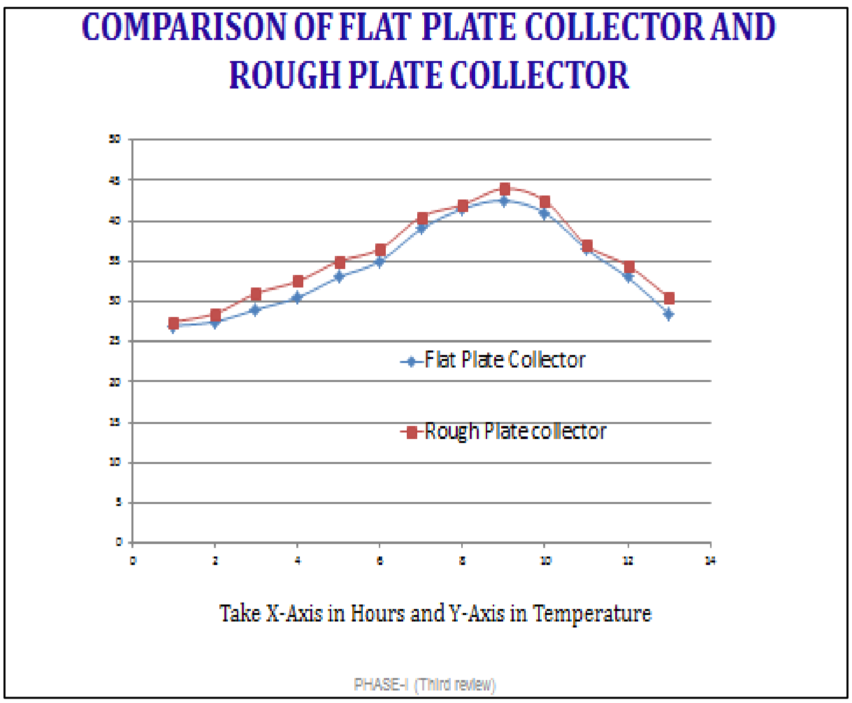

Fig. 5: Graph showing comparison of FP and RP

- FP- FLAT PLATE COLLECTOR
- RP- ROUGH PLATE COLLECTOR

Table – 1
comparison of FP and RP

COMPARISON OF FLAT PLATE COLLECTOR AND ROUGH PLATE COLLECTOR

S NO	INDIAN TIME	TOTAL Hrs	FLAT PLATE COLLECTOR TEMP IN C	ROUGH PLATE COLLECTOR IN C
1	6 A M	1	27.5	28
2	7 A M	2	28	29.5
3	8 A M	3	29.5	31
4	9 A M	4	30	33.5
5	10 A M	5	33	36.5
6	11 A M	6	36	38
7	12 P M	7	38	41
8	1 P M	8	41	43.5
9	2 P M	9	43	45
10	3 P M	10	41.5	43.5
11	4 P M	11	36	37.5
12	5 P M	12	33.5	34
13	6 P M	13	28	29.5

IX. Conclusions

- A simple and inexpensive mixed-mode solar dryer was designed and constructed using locally sourcedmaterials.
- The hourly variation of the temperatures inside thecabinet and air heater is much higher than theambient temperature during the most hours of theday.
- The temperature increase inside the drying cabinetwas up to 22°C (64.5%) for most the hours in thenoon time. The drying rate, collector efficiency.
- The dryer exhibited sufficient ability to dry foodlevel and simultaneously ensured a superior qualityof the dried productThe drying of potato in the open sun takes 7 to 8days during clear sunny weather conditions.
- However, it only takes 4 to 5 days in the solarcabinet dryer under similar weather conditions.
- Also, the quality of dried potato is remarkably betterin cabinet dryer compared to open sun drying as theproduct is protected from dust and insects.
- The drying rate of the dryer for potato is 0.24 kg/day while that of open air is 0.1 g/day. This showsthat the dryer performance is much better thanopen sun drying. The moisture to be removed fromthe potato is 0.7 kg. The dryer efficiency is 31.0%per day.
- The dryer is easy to build and required only semiskilled laborer and limited facilities to fabricate.Thus, the dryer is suitable for use in urban as well asrural areas of the country.

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