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Design Analysis of Moisture Content for Potato Slices in Solar Dryer

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Abstract

Based on preliminary investigations under controlled conditions of drying experiments, a mixed-mode natural convection solar dryer with three trays was designed and constructed to dry potato slices in the rural area. This paper describes the design considerations followed and presents the results of the design parameters. A minimum of 1.43 m^2 solar collector area is required to dry 5 kg potato slices in 16 hours (two days drying period). The average ambient conditions are 32 ºC air temperatures and 76 % relative humidity with daily global solar radiation incident on horizontal surface of 17.7 $MJ/m^2/day$. The weather conditions considered are of Hlaing Thar Yar (latitude 16° 51′ 0″ N, longitude 96° 4′ 0″ E), Myanmar. Evaluation of the solar dryer was carried out in April, May and June. The result shows that the reducing of moisture content of the three trays from 65% (wb) to 13% (wb) is done between 8 hr and 13 hr and of open sun drying is done between 9 hr and 18 hr for the all three months. The collector efficiencies were 66.44%, 62.79% and 58.28% for April, May and June respectively. These results indicated sufficient drying and preservation of potato slices within two full days of sunlight.

Keywords: Solar radiation, collector, solar dryer, moisture content, potato slices

1. Introduction

Open sun drying is still the most common method used to preserve fruits, grains and vegetables 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 solar dryer which comprises of collector, a drying chamber and sometimes a chimney. The conditions in tropical countries make the use of solar energy for drying food practically attractive and environmentally sound.

Dryers have been developed and used to dry agricultural products in order to improve shelf life. Most of these either use an expensive source of energy such as electricity. Most projects of these natures have not been adopted by the small farmers, either because the final design and the data collection procedures are frequently inappropriate or the cost has remained inaccessible and the subsequent transfer of technology from researcher to the end user has been anything but effective.

In Myanmar, potatoes are grown twice a year in Shan state, Rakhine state, Magway Division, and Ayeyarwaddy division**.** There are many dried-potato and potato confectioneries in Hlaing Thar Yar Industrial zone, Yangon region. By using solar dryers instead of using conventional sun drying method, they would be produced more fresh and hygienic products in short time.

Solar dryers may be classified according to the mode of air flow as natural convection and forced convection dryers. Natural convection dryers do not require a fan to blow the air through the dryer. Solar drying may also be classified into direct, indirect and mixed-modes. In direct solar dryers, the air heater contains the materials and solar energy passes through a transparent cover and is absorbed by the materials. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the material bed. In indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the material bed, while in the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a material bed and at the same time, the drying cabinet or chamber absorbs solar energy directly through the transparent walls or roof.

Therefore research efforts will be focused on designing and constructing a simple natural convection dryer. Since the rural or remote areas of Myanmar are not connected to the national grid and remote areas of Myanmar facing energy crisis. 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 of dried fruits using solar energy. Drying time is reduced significantly resulting in a higher product quality in terms of colour and reconstitution properties. There is also believe that as compared to oil or gas heated dryers, solar drying facilities are economical for small holders, especially under favourable meteorological conditions.

The objective of this research is to construct the solar dryer using locally available materials to assess their efficiency in drying potato slices.

2. Dryer Design

The mixed-mode dryer was constructed using the materials that are easily available from the local market. Fig. 1 shows a section of the solar dryer. The main parts of the dryer are solar collector, drying chamber and drying trays.

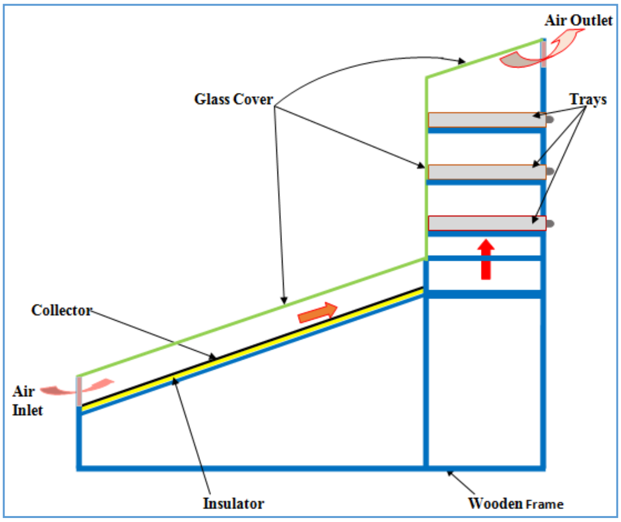

Fig. 1 Section of the mixed-mode solar dryer

2.1. Solar Collector

The heat absorber of the solar air heater was constructed using 18 gate plain sheet, painted black; the surface facing sunlight was painted with black paint. The collector area for 5 kg of potato slices is 1.43 m^2 and it is tiled at an angle of 17° for optimal year round. The solar collector was insulated with cork board of about 2.5 cm thickness and thermal conductivity of 0.04 $Wm^{-1} K^{-1}$ on all sides. The solar collector assembly consists of air flow channel enclosed by transparent cover (glazing). The glazing is a single layer of 4 mm thick transparent glass sheet. It has a surface area of 1.65 by 0.91 m and of transmittance above 0.86 (Fig. 2). The two sides and bottom of the collector are covered by plywood. The air inlet of solar collector is covered with wire mesh to protect the insects and rodents.

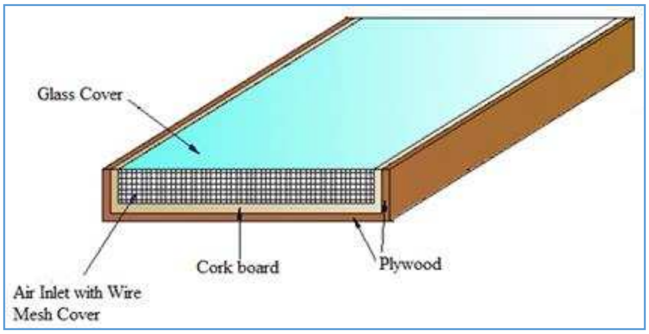

Fig. 2 Solar collector

2.2. Drying Chamber

The design 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. The drying chamber houses three drying trays, between a tray and another tray is 15 cm. The drying chamber is lined with cork board 2.54 cm thick to prevent loss of heat. At the top of the trays behind the chamber, there is the air outlet covered by the wire mesh as shown in Fig. 1.

2.3. Drying Trays

Three trays of dimension (81 cm x 38 cm x 5 cm) were fabricated and stacked evenly at distances (15 cm) apart, for placing of material to be dried. The trays are made with (5 cm x 2.54 cm) hard wood frames and a GI wire mesh attached to it as shown in Fig. 3. Metal handles were attached on each tray for ease of handling and sliding the trays inside the chamber through the produce to be dried.

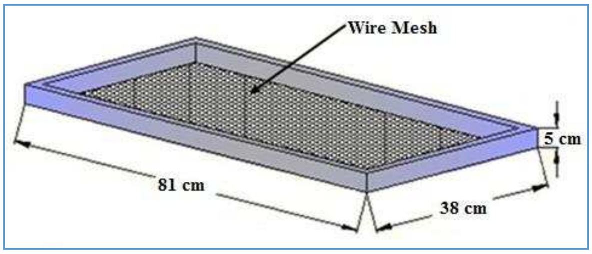

Fig. 3 Dimensions of trays

2.4. Drying Specification of the Dryer

The specification of the mixed-mode solar dryer is shown in Table 1.

Table 1. Specifications of the Dryer

Overall length	**1.98 m**
Overall height	1.8 m
Absorber plate dimension	1.65 m × 0.91 m
Glass cover thickness	4 mm
Insulation thickness	2.5 cm
Gap between absorber plate and glass cover	7.5 cm
Number of trays	3
Tray dimension	81 cm × 38 cm
Distance between trays	15 cm
Tilt angle of the collector	17° due south

3. Experimental Procedure

The dryer was constructed and tested during the months of April, May and June 2018, at department of Mechanical Engineering, West Yangon Technological University, Yangon. In the drying experiment, fresh potato slices are used as the test sample in the dryer.

Fig. 4 Solar dryer set-up

The experiment was carried out to determine the performance of the dryer. To conduct the experiment, the following procedure has been adopted:

- The temperature of the collector, the air temperature passing through the trays, the ambient temperature was measured by the use of digital thermometer connected to the data acquisition system.
- The potatoes are sliced into 3 mm thickness and pretreated with salt water about 10 hours and placed on trays. All trays were weighted and recorded and put in the dryer.
- At an interval of 1 hour, samples were taken out of the dryer, weighed and returned to the dryer. The weight losses of potato slices in trays were recorded with respect to time. This process was continued until the weight approached desired final moisture content.
- From the experimental data, the three graphs for each month were plotted for potato slices. They are:
  - Variation of temperatures as a function of time.
  - Variation of mass against drying time.
  - Variation of moisture content against drying time.
- The experiment was carrying out one time per one month on April, May and June.

4. Results and Discussion

4.1. Variations of Temperature

From the experimental results, it is found that solar radiation affects the dryer temperature. When the level of solar radiation is high, the inlet air temperature to the dryer becomes high, as the collector absorbs more solar radiation. Similarly, when the solar radiation is low, dryer inlet temperature is low.

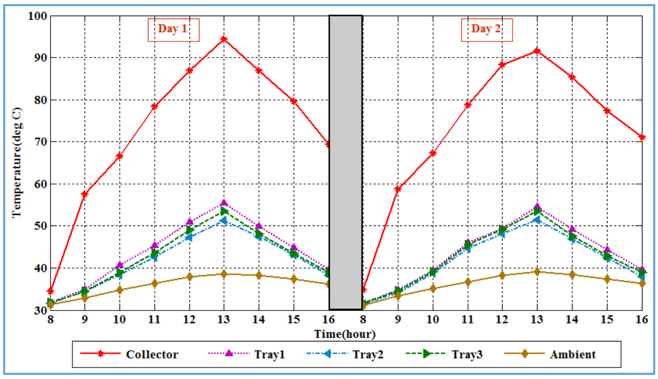

Fig. 5 Temperatures within the solar dryer at various locations (April)

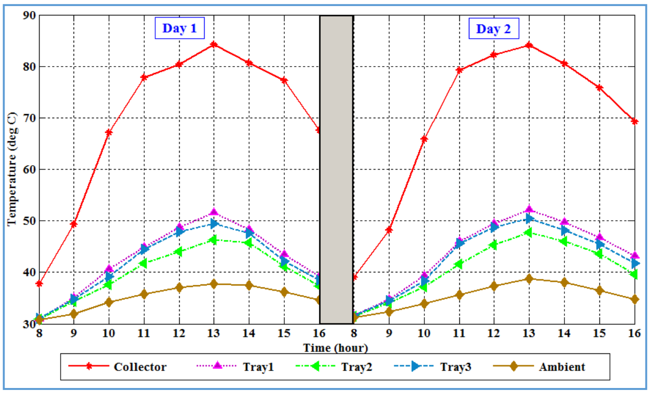

Fig. 6 Temperatures within the solar dryer at various locations (May)

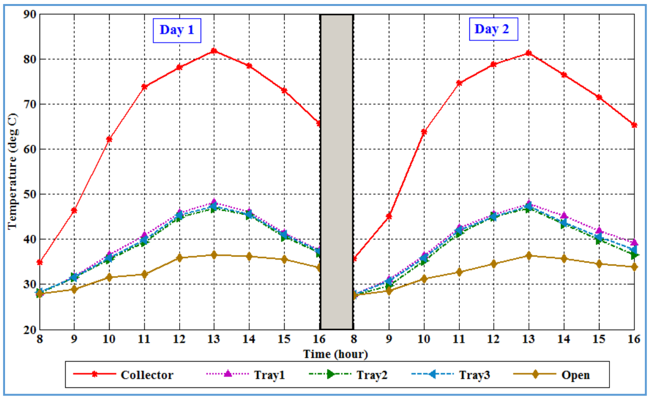

Fig. 7 Temperatures within the solar dryer at various locations (June)

From Fig. 5 to Fig. 7 show the graphs of the temperature of each tray, the collector temperature and the ambient temperature with drying time for April, May and June respectively. The maximum drying temperature at tray 1 is 55.4°C when the maximum collector temperature is 94.4°C in April.

4.2. Drying Time

Comparison of drying time of each tray and open sun drying are shown in Fig. 8 for April, May and June respectively. The figure shows that the fastest dry time is 8 hours at tray 1 of the dryer in April. In this figure tray 1 has the fasted drying time, tray 3 is second and tray 2 is third. The drying times of open sun drying in all three months has the longest drying time. It is faster 2.5 hours than open sun drying time in April. The most the time difference between the tray 1 and open sun drying is in June about 7.5 hours. The experiment results show that drying in the solar dryer is more efficient than the open sun drying.

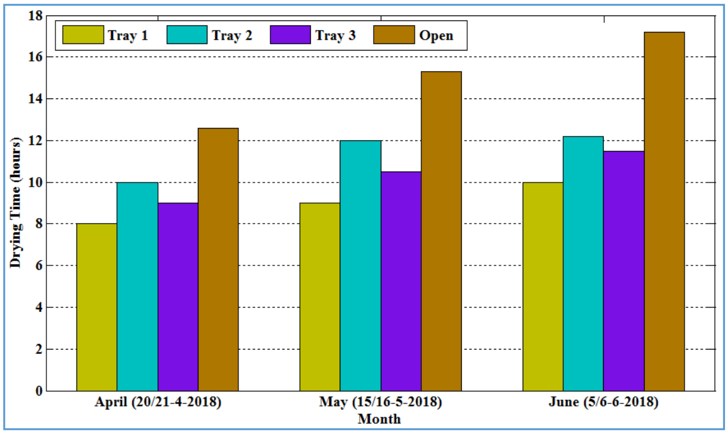

Table 2. Practical Measurement in Operation Time

4.3. Variation of Mass and Moisture Content

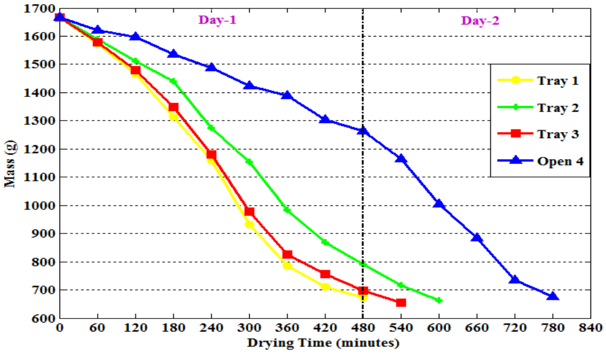

Fig. 9 Comparison of mass versus drying time for each tray and open sun drying in April

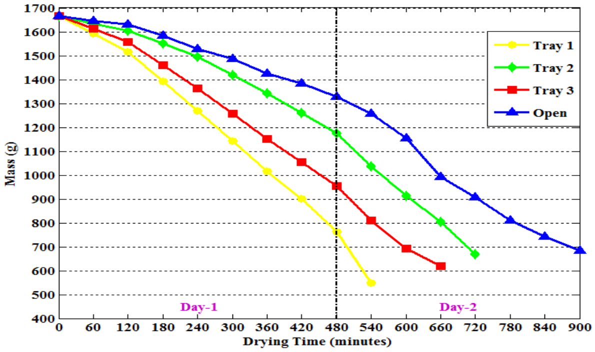

Fig. 10 Comparison of mass versus drying time for each tray and open sun drying in May

The mass lost in grams with respect to drying time for each tray and open sun drying in April, May and June are shown in Fig. 9 to Fig. 11. Each tray has a loading rate of 1.667 kg to be total potato slices 5 kg and each tray's end weight must be reduce to 0.671 kg.

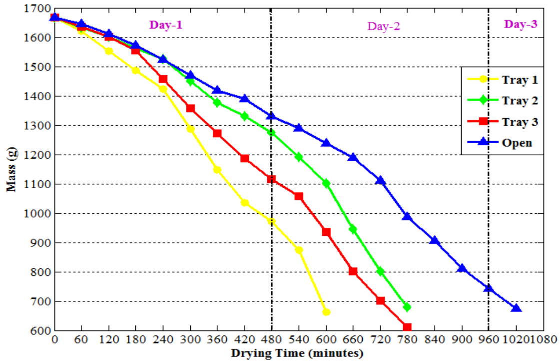

Fig. 11 Comparison of mass versus drying time for each tray and open sun drying in June

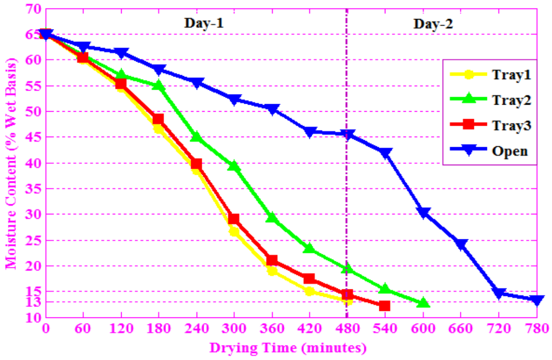

Fig. 12 Decreasing of moisture content for each tray and open sun drying in April

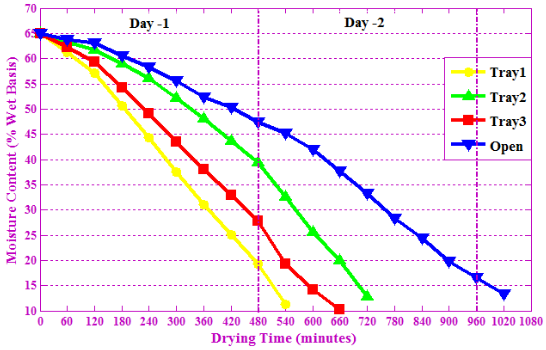

Fig. 13 Decreasing of moisture content for each tray and open sun drying in May

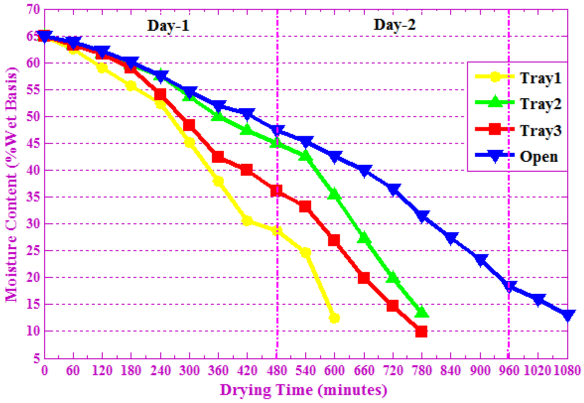

Fig. 14 Decreasing of moisture content for each tray and open sun drying in June

Fig. 12 to Fig. 14 are shown the results of moisture content verses drying time for each tray and open sun drying for April, May and June. The moisture contents of potato slices in each tray are reduced from 65% to 13% in 8 to 13 hr but 13 to 18 last long in the open sun drying.

5. Conclusions

In summary, the mixed-mode solar dryer was constructed to convert solar energy into heat energy for domestic purposes. The maximum collector temperature is 94.4°C in April. Tray 1 has the highest temperature and tray 2 has the lowest temperature for all three months. Maximum tray temperature is 55.4°C at tray 1 in April. Average drying temperature is 14.8°C higher than the ambient temperature. The drying time is fastest in April as 8 hr, 9 hr and 8.4 hr long for tray 1, tray 2 and tray 3 respectively and 12.5 hr for open sun drying. The decreasing in moisture content of the three trays from 65% to 13% is done between 8 hr and 13 hr for the all three months. The decreasing in moisture content of the open sun drying from 65% to 13% is done between 9 hr and 18 hr for the all three months. The desire moisture content 13% is firstly reached in April as the solar radiation is highest in April.

Acknowledgements

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