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PERFORMANCE EVALUATION OF BARI SOLAR CABINET DRYER FOR RADISH

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Abstract

BARI solar cabinet dryer was tested with the moist radish (about 9 kg) at Hill Agricultural Research Station (BARI), Khagrachari, during 17-18 February 2020. Drying temperature, relative humidity, air velocity, and solar radiation were recorded. After drying, the final weight of the radish was 554 g (93.84% reduction). The inside air temperature of the drying chamber varied from 45.5 to 52.5 °C (first day) and 47.44 to 52.5 °C (second day). Air relative humidity in the drying chamber varied from 13.2 to 20.25% (first day) and 11.5 to 18.5% (second day), whereas the relative humidity in the ambient varied from 30.5 to 67.5 % (first day), and 42.3 to 65.3% (second day). Solar radiation varied from 50 to 900 W/m^2 during the testing period. Moist radish dried in the dryer attained final moisture content of 9.0% from an initial moisture content of 94% after 11 hours of drying period whereas, it took 56 hours to reduce the moisture content to 12% (wb) of a similar sample in the open sun. In the open sun drying method, 9.0 kg of moist radish was dried to 380 g (95.8% reduction). In the open sun drying method, radish losses by 30% during drying because of fungal spoilage. The color of dried slices in the dryer was more bright and the smell was good compared to sun drying of radish slices. The dryer maintained nutrition and made hygienic and safe products of radish slices. Hilly farmers and small-scale traders would be benefitted from using the BARI solar cabinet dryer.

Keywords: Ambient temperature, Fungal spoilage, Hilly Areas, Relative humidity

Introduction

Sun drying is the most commonly used method to dry agricultural products of primary processing. In sun drying, the crop is exposed directly to solar radiation, ambient temperature, wind velocity, relative humidity, etc. Many disadvantages remain in this method. Rain, insects, humans, and animals interfere with this method and as a result of the products are contaminated. In the hilly areas in Bangladesh, various vegetables are produced and the hilly people dry their vegetables by sun drying method and store these to consume in the off-season period. For this reason, a dryer is needed in a hilly area in Bangladesh to produce good-quality dried vegetables. A solar-powered cabinet dryer was developed at Farm Machinery and Post-harvest Process Engineering Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur for drying vegetables at

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farm levels. Thus, the farmers can produce quality dried vegetables and hence boost vegetable production to attain food and nutrition security. High moisture in vegetables is the major or single factor for the loss of vegetables. To minimize metabolic degradation and control mold growth, moisture content should be less than 12%, whereas to control insect infestation, it should not be over 9% (Gowda, 1997). As the storage condition at the farm level is less favorable, should be dried to 10% moisture content (Copland, 1976). During harvest, radish contains 90-94% moisture. Vegetables should be dried at a constant and optimum temperature to ensure quality. But in sun drying, it is not possible to maintain a constant temperature because of variations in solar radiation. In the sun drying method, vegetables are often dried at low or high temperatures which speeds up the deterioration of quality. Sometimes, continuous rain occurs for a few days or even for a week, spoiling the total amount of vegetables, and restricting traditional sun drying. In this circumstance, a small capacity solar dryer is needed for drying vegetables to reduce the loss of vegetables and produce good quality dried vegetables.

Materials and Methods

Description of BARI solar cabinet dryer

Farm Machinery and Post Harvest Process Engineering Division, BARI has developed BARI solar cabinet dryer. The design of the indirect solar cabinet dryer for drying vegetables was done based on the energy balance and heat and mass balance equations. The dryer comprised a concentrating type of flat plate collector, auxiliary heating unit, and drying chamber. The special feature of the dryer was that it could be operated on a sunny day using solar radiation and on a rainy or cloudy day or at night using auxiliary electric heaters. The length, width, and height of the drying chamber were 0.84 m, 0.81 m, and 1.73 m respectively and the length, width, and height of the collector were 2.30 m, 1.22 m, and 0.33 & 0.14 m respectively. Fig. 1 is a diagram of the BARI solar cabinet dryer.

Drying chamber

The drying chamber comprised a tray, heater, and inlet and outlet fans. Six drying trays were placed in the drying unit. The dimension of the drying tray was 0.08 m × 0.745 m × 0.0488 m. The stainless steel mesh was used and the mesh number was 20. The drying air was passed through the products. Each tray was of metallic frame and a stainless steel net with dimensions of 1040 mm × 780 mm. The drying air was heated in the collector and passed to the drying chamber through a curved pass at the end of the drying unit. and flew over and under all the drying trays and was exhausted from the outlet. For auxiliary heating, two electric heaters each of 2.5 kW capacities were installed at the bottom of the drying chamber. A temperature controller would have to maintain a constant temperature in the dryer. Two small DC fans (each of 5W) were used for air flowing in the dryer operated by a small solar panel (25W) and in the absence of solar energy, it is operated by alternative current (electricity). A 5 W axial flow fan was connected outside the collector to draw the atmospheric air into the collector and to push out the heated air to the drying chamber with the desired air velocity. Another 5 W axial flow fan was at the top of the drying chamber. A temperature controller was used to maintain the temperature in the dryer.

Collector

The collector was fabricated with a transparent polyethene sheet, corrugated iron sheet, MS flat bar, wood, and MS angle bar, overall dimensions of the flat plant plate concentrating solar collector are 2.30 m long and 1.22 m wide. The transparent cover of the collector was a 2 mm thick clear plastic sheet. About 1 mm black painted corrugated iron sheet is used as an absorber plate. The collector was placed on 4 legs with 140 mm diameter wheels to turn the solar collector horizontally and change its direction according to the change of the sun's angle.

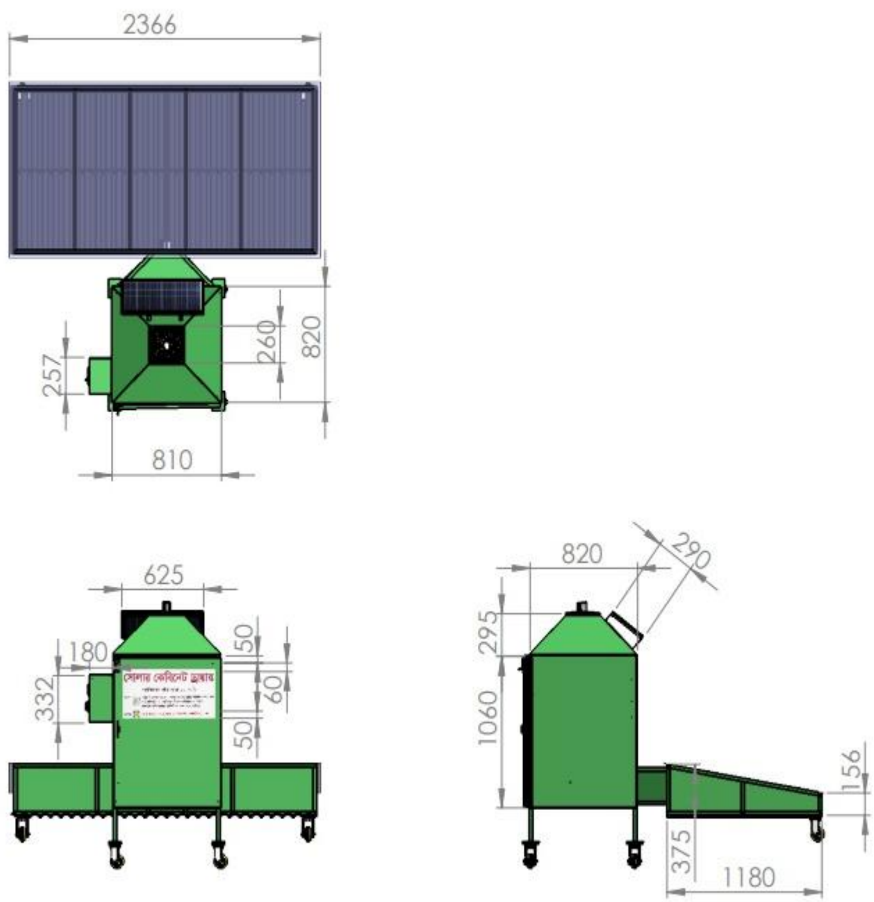

Fig. 1. Diagram of BARI Solar Cabinet Dryer

Testing procedure

The dryer was placed in a sunny place so that it was not affected by shadows. The dryer was tested for drying of radish (Fig. 2) during 17-18 February 2020. Drying in the open sun drying method is shown in Fig. 3. Freshly harvested radish (White Star) was purchased from a farmer in Khagrachari and sliced in 1.8 cm thickness manually. Nine kilograms of sliced radish spread on three trays of the dryer. A similar sample of sliced radish was placed in the open sun for comparison with the solar dryer. Ambient temperature, ambient relative humidity, solar radiation, the temperature at different points in the collector and drying chamber, air velocity at the outlet of the drying chamber, and moisture contents of radish slices were recorded at 1-hour interval. Temperatures were measured at 1-hour interval by a digital temperature meter (model: k 102, accuracy ± 0.3%, Conrad Electronic, Germany). Relative humidity was measured using a digital hygrometer (Model: MY-91HT, accuracy ±0.5%, Conrad Electronic, Germany). A digital solar meter (Model: 776E, accuracy ±3%, Digital Engineering. the USA) was used to measure the solar radiation during daytime drying period. The velocity of drying air was measured by an anemometer (Model TA430, accuracy ± 3% Airflow Ltd., England). The moisture content of radish slices was measured by oven-dry methods. Three layers (i.e., top, middle, and bottom layers) in the drying rack were used in the dryer. The data were recorded at 1-hour intervals from 9.00 am to 5:00 pm. The weights of the samples were measured with an electronic balance. Brand: Shimadzu, model: ELB-3000, made: Japan, capacity and sensitivity 3000g and 0.1g, respectively.

Fig. 2. Photographs showing drying of radish in BARI solar cabinet dryer

Fig. 3. Photographs showing drying of radish in the open sun

Results and Discussion

Dryer performance test with radish

Variations of ambient air temperature and dryer air temperature with solar radiation at different times of a typical day are shown in Fig. 4 during 17-18 February 2020. It was observed that ambient air temperature and solar radiation varied with the time of the day and these were found to reach a peak between 1:00 pm and 12:00 pm. The collector outlet air temperature or inlet air temperature of the drying chamber was found higher than the ambient air temperature.

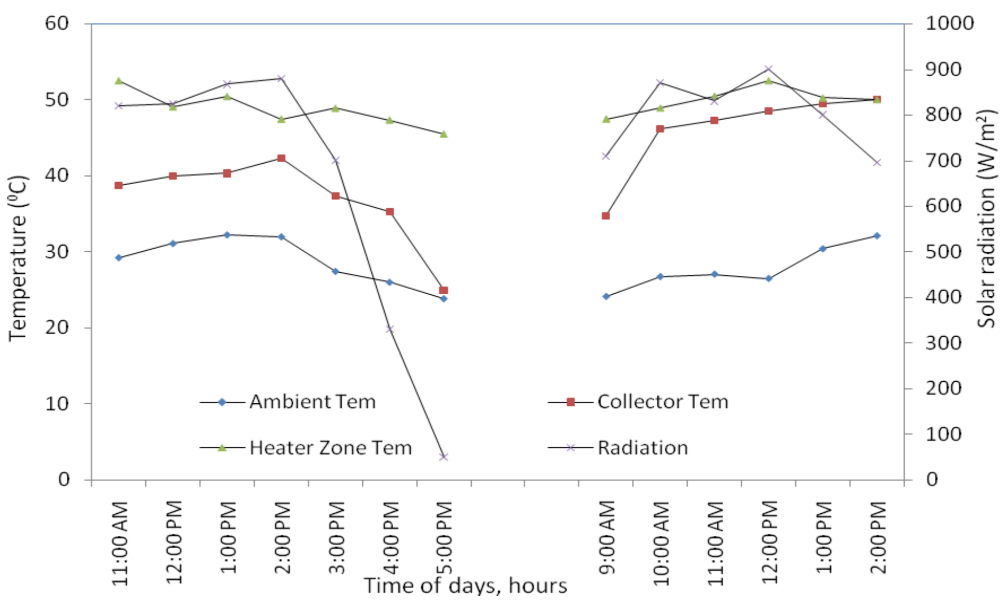

Fig. 4. Variation of an air temperature of ambient, collector, and dryer chamber with solar radiation

The temperature in the collector varied with the ambient temperature and solar radiation. The outlet temperature of the drying chamber was lower than that of the inside temperature of the drying chamber. The inside temperature of the drying chamber varied from 45.5 to 52.5^{0}C (1st day) and 47.4 to 52.5 ^{0}C (2nd day). This temperature was maintained at almost 45-50 ^{0}C using a temperature controller and adjusting air velocity.

Variations of relative humidity of ambient and drying chamber with solar radiation on typical days are given in Fig. 5. Ambient relative humidity on the first and second day varied from 30.5 to 67.5% and 42.3 to 65.3 % respectively, whereas the relative humidity in the drying chamber varied from 13.2 to 20.3% and 11.5 to 18.5%, respectively. Relative humidity in the dryer was reduced due to the increased temperature in the drying chamber. The lower relative humidity is important in drying for higher moisture-carrying capacity of the air (Hossain and Gottschalk, 2009). Collector outlet air relative humidity was found lower than that of the ambient. Air relative humidity in the collector varied with the ambient temperature and solar radiation. The outlet air relative humidity of the drying chamber was higher than that of the inlet of the drying chamber.

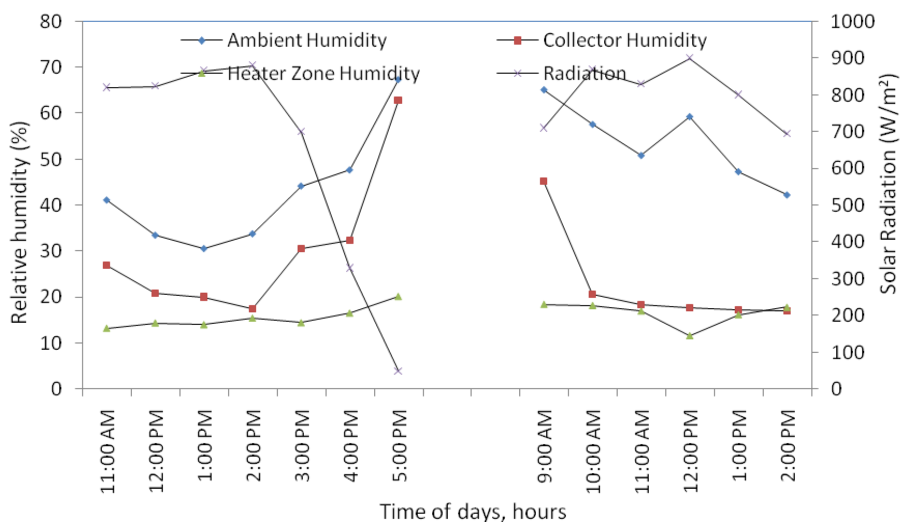

Fig. 5. Variation of ambient and dryer relative humidity with radiation

Air velocity in the drying chamber varied with the time of the days (Fig. 6). Air velocity varied from 2.4 to 3.5 m/s. This variation was because of the variation of voltage in electricity. Two DC fans were operated by a solar panel. Voltage depends on the intensity of global solar radiation. The drying rate increases with the air velocity, but the drying rate becomes independent of a certain air velocity. For drying most of the crops, air velocity should be within the range of 0.50 to 0.75 m/s. The air velocity was higher than the desired range. The temperature in the drying chamber was almost constant although air velocity varied. This was because the air temperature in the dryer was maintained constant by the temperature controller.

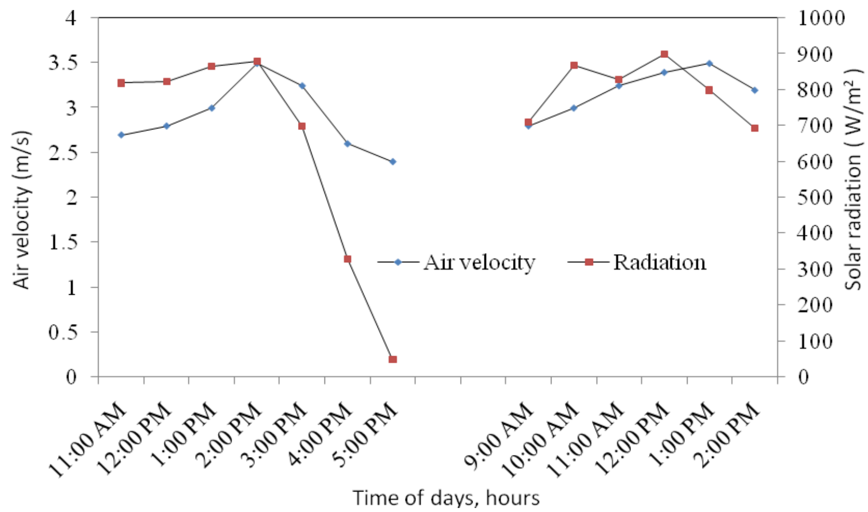

Fig. 6. Variation of air velocity in the dryer with the solar radiation during different times of a day

The drying curves of the radish are shown in Fig. 7. It was observed that the moisture content decreased gradually with drying time. The initial moisture content of radish slices was 94% (wb) and after drying the moisture content was 9.0% (wb) in 11 hours of drying time in the solar cabinet dryer. At the same time, the moisture content of a similar sample of radish slices in the open sun drying method was reduced from 94% to 73% (wb). A total of 11 hours is needed to dry a radish in the solar cabinet dryer to reduce moisture from about 94.0% to 9.0% and 56 hours are needed in open sundry methods to reduce moisture contents from about 94% to 12%. During night, when radish slices were not dried, then the slices absorbed moisture from the air, and as a result, the moisture content of the slices on the second day was higher than at the end of the first day. The moisture content of the radish of the bottom tray was the lowest compared to middle and top trays and the radish of the middle tray was the second lowest. Due to two electric heaters being installed at the bottom of the drying chamber, the drying rate of the bottom tray was the highest, followed by the middle and top trays. After drying 9 kg, raw radish becomes 554 g in the cabinet dryer. During drying in the open sun dry method, some radishes were infected by fungus and needed to sort out after drying 9 kg of raw radish became 390 g. The color was white and the smell was good in the solar cabinet dried radish slices whereas the color was white-dark and the smell was not good in the open sun drying methods (Fig. 8 and 9) respectively.

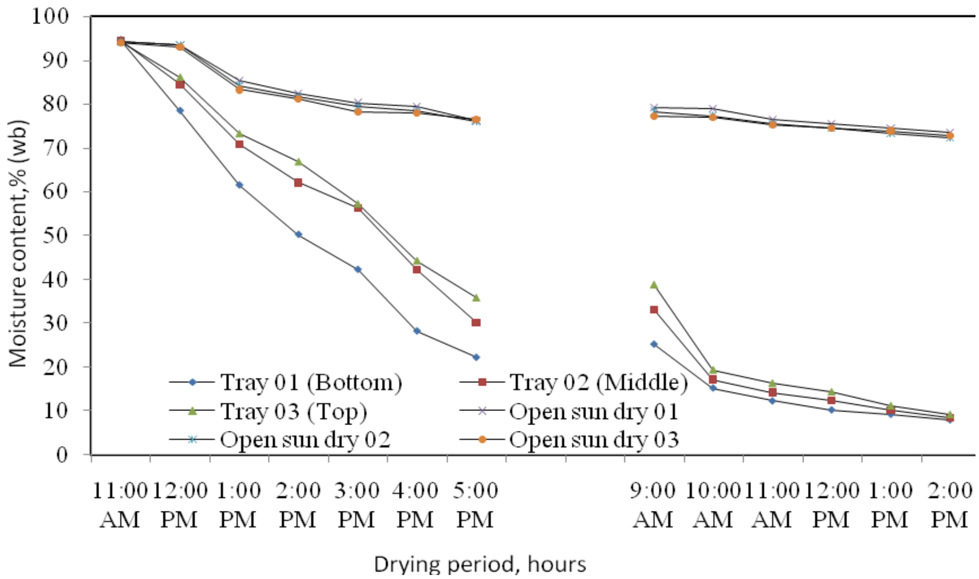

Fig. 7. Variations of moisture content of sliced radish in the dryer and open sun drying methods

Fig. 8. Dried radish slices in the solar cabinet dryer

Fig. 9. Dried radish slices in the open sun

Conclusion

Nine kilograms of moist radish was dried, and it was reduced to 554 g. The drying temperature in the drying chamber was maintained to be 45.5 to 52.5 ^{0}C during the drying period. Relative humidity in the drying chamber varied from 11.53 to 20.5%. The solar radiation varied from 50 to 900 W/m^2 during the testing period. The moisture content of the radish reduced from 94% to 9.0% (wb) in 11 hours of drying whereas, it took fifty-six hours to reduce the moisture content to 12% (wb) of a similar sample in the open sun. In the open sun drying method, 9.0 kg of moist radish was reduced to 380 g after drying. The dryer should be used for drying hygienic, safe, and nutritious radish slices. Hilly farmers and small-scale traders would be benefitted from using the BARI solar cabinet dryer.

Acknowledgement

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Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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