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Performance evaluation of solar tunnel dryer for potato chips

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Abstract
A solar tunnel dryer with a polycarbonate cover was kept under sunlight condition for four days. The dryer consists of two parts, namely a solar collector and a drying chamber with eight trays. Both parts are connected in series on the same structure. A polycarbonate cover is used to reduce heat losses inside of dryer, while allowing the incident solar radiation to transmit into the dryer. Loading and unloading of products to be dried are undertaken through windows at a side wall of the dryer. A ac-fan driven by a mean of electricity having 42 watt electricity consumption is employed to ventilate the dryer. To investigate its performance, the dryer was used to dry four batches of Potato chips. For most cases, the temperature of the drying air in the dryer varied between 32 to 42 °C from 9 A.M. to 5 P.M. This dryer can be used to dry 16 to 24 kg of potato from an initial moisture content of 60-75% weight basis (wb) to final moisture content of 0.02-0.04% (wb) within 4 days. High quality products in terms of flavor, color and texture were obtained. The quality of potato chips was fine almost.

Keywords: Solar tunnel dryer, potato chips, moisture content

Introduction
Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis. The United Nations Development Programme in its 2000 World Energy Assessment found that the annual potential of solar energy was 1,575–49,837 exajoules (EJ). This is several times larger than the total world energy consumption, which was 559.8 EJ in 2012. Most of the food crops are lost because of fungal and micro bacterial attacks. Drying is one of the classical and oldest agricultural methods of food preservation. Drying process is a basic operation of reducing the moisture content of the product. Proper drying of foodstuff by removing enough moisture can prevent decay, spoilage and makes it safer for long storage. The temperature inside the dryer rises due to trapping the long wave solar radiation, resulting in evaporation of moisture from the food product. A chimney is normally located at the top end of the dryer to remove moist air from cabinet. At the base of the dryer, four holes are made to allow air entry in cabinet. The partition walls between compartments also have similar type of air holes to allow air flow.
The unloading the tray is done through a door, which is made at one of the vertical sides of the dryer chamber. To create the required draft, through of air in the dryer chamber usually, a chimney provided at the top of the chamber (Pangavhane, 2002) [4].

Material and Method
The tunnel solar dryer was installed at Vaughn Institute of Agriculture Engineering and Technology. The dryer consists of a parabolic roof structure made form polycarbonate sheets

on a concrete floor. The dryer has a width of 3.0 m, length of 10 m and height 1.5 m. 8 trays were installed inside of it and operated in sun light. Solar radiation passing through the polycarbonate roof heats the air, the products inside the dryer, as well as the metallic floor. Moist air is sucked from the dryer by the one fan at the surface of the rear of the dryer. The following material and measuring device were used to carry out the experiment. The experiment was carried out for 4 respective days. The solar collector unit was a flat-plate type with air flow above the absorber plate while the cover was a transparent 200 µm polythene sheet. The reason for using this type of collector unit is because of its low thermal losses. The absorber plate was made from a flat Galvanized Iron (GI) sheet and in order to increase the solar absorptivity of the plate, it was painted matte black. To minimize heat losses to the surrounding, the base and sides of the collector unit were insulated with 20 mm Poly sheets. The drying unit and the collector unit were made in one subassembly and from the same materials and configured in series. The base and sides of the drying unit were also clad with 20 mm Styrofoam sheets to minimize heat losses to the ambient air. To provide for the drying of the product, the drying unit was mounted with a removable wire mesh tray to hold the product during the drying. The chimney was a bare flat-plate type collector constructed from a 0.3 mm thick flat GI sheet with a channel depth of 0.1 m and served the purpose of reheating the air exiting the drying unit. The solar radiation receiving surface of the chimney was painted matte black to absorb as much of the incident solar radiation as possible. The whole dryer assembly was supported by four legs 0.6 m above the ground, and the collector-drying unit subassembly, the chimney, and the legs were all detachable to allow for easier transportation.

Dryer efficiency: This is given as:

$$\text{Efficiency\%} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times \frac{100}{1}$$

The average efficiency of tunnel Dryer:

$$\text{Average efficiency } \eta_{avg} = \frac{d1+d2+d3+d4}{dn}$$

Moisture Content (M.C.): The moisture content is given as: Where M1 = mass of sample before drying and M2 = mass of sample after drying.

Moisture loss ML: The moisture Loss is given as-

ML= (M1-M2) gm

Where M1 is the mass of the sample before drying and M2 is the mass of the sample after drying

Average Drying Rate: Average drying rate, MDR, is determined from the mass of moisture removed by dryer and drying time as given by equation below:

Where, = Average drying rate, kg/h

TD = Overall drying time

= mass of evaporated water

Results and discussion

The experiment was conducted for four days in the sun light at various atmospheric conditions like temperature, sunlight intensity, heat generation and air flow etc. Analysis of the different condition potato chips, we make 9 sample of product. For that 400 gm weight of potato chips was taken for the experiment and each sample was 50 gm. The sample was put in 8 tray of tunnel dryer and four replications had been done for an experiment on each day with difference of half an hour of day.

Table 1: The variation among the properties of potato chips during 4 days of experiment

No. of Day	Atmospheric Temperature (°C)		Tunnel Inside Temperature (°C)		Average Solar Radiation (kWh//day)	Input Weight (gm)	Output Weight (gm)	Efficiency
	Initial	Peak	Initial	Peak				
Day 1	35.5	41.0	40.5	65.0	3.37	400	79.66	80.07
Day 2	35.5	40.5	43.5	68.0	4.43	400	85.47	78.63
Day 3	34.3	31.5	41.9	66.9	3.56	400	88.57	77.85
Day 4	35.0	41.0	50.0	65.0	4.36	400	87.09	78.22

The table No. 1 showing the different kind of variation of Potato chips, hence the typical graph has been generated for proper variation of potato chips properties. Hence the dryer efficiency has been calculated by given all properties and all are show in next table with brief graph.

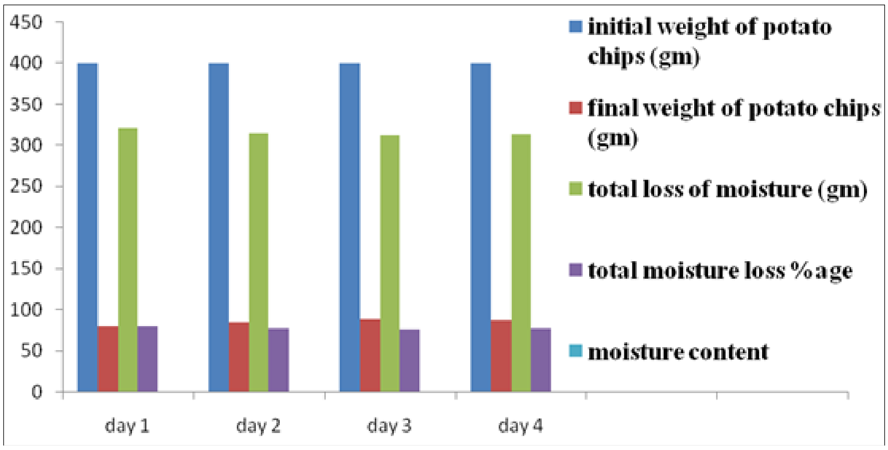

Fig 1: The typical variation among the drying results during 4 days of experiment

a) Dryer Efficiency-efficiency% $= \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times \frac{100}{1}$

b) The average efficiency of tunnel Dryer-

Average efficiency $\eta_{avg} = \frac{d1+d2+d3+d4}{dn}$

Average efficiency $\eta_{avg} = \frac{80.07+78.63+77.85+78.22}{4}$

Average efficiency $\eta_{avg} = 78.69\%$

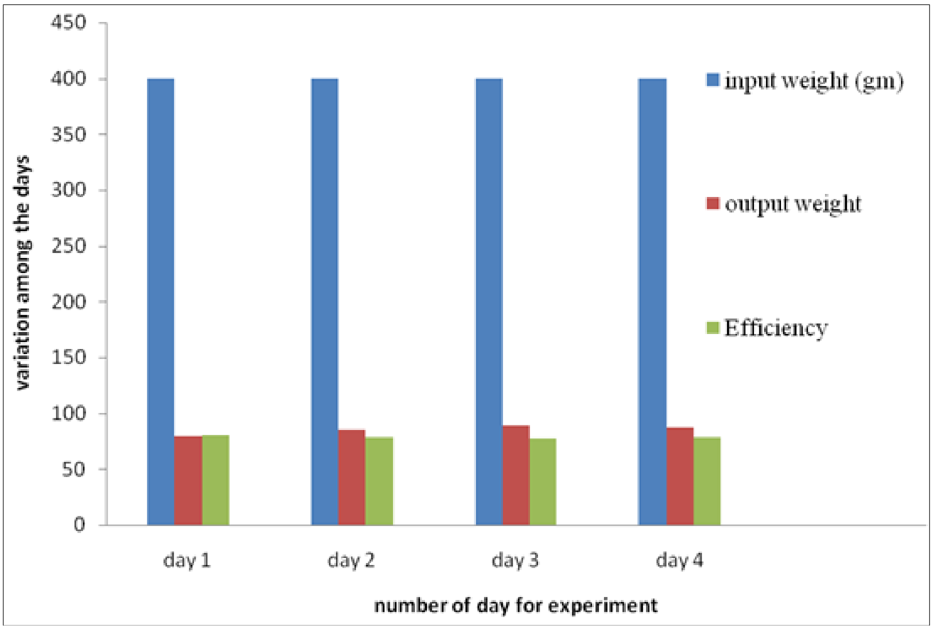

Fig 2: Variation of efficiency of solar dryer on basis of weight of potato chips

The maximum temperature inside the tunnel dryer was 70 °C while the minimum was 28 °C in the typical day of the may against the ambient temperature of 30 °C and 36 °C respectively. Average thermal efficiency was found 78.69%. So, solar tunnel dryer can be utilized for drying highly perishable vegetables and fruits which could increase the income of farmers with little maintenance. From the research result of drying technology of solar agricultural products and the practical experience of promotion, we can know that in technology, the drying of solar agricultural products is feasible; in economy, the reduction of consumption of primary energy sources can save cost and raise benefits; in environment, no pollution is caused due to the clean energy technology. Therefore, the drying of solar agricultural products is the energy-conserving project worthy of promotion, and has wide application value. In the meantime, the current results and technologies can fully ensure the smooth development of the drying industry of solar agricultural products, and play an important role in sustainable development of the drying industry of solar agricultural products in our country.

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