Comparative Study on the Performance of Solar Dryer with Finned Plate Solar Chimney

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ABSTRACT

The objective of this study is to investigate the influence of geometrical parameters of a solar chimney, i.e., on the flow channel air gap, on the performance of a solar dryer in terms of thermal efficiency, drying efficiency, and dried product weight loss. Experimental outcomes showed the temperature inside the drying chamber increases as solar intensity increases, while relative humidity decreases. In the study sliced potatoes were selected to be dried. The average collector and chimney efficiency were found to be higher when a 10 cm air gap height was used instead of a 5 cm air gap height. After 8.5 h of drying, the moisture content of the 5 cm and 10 cm chimney air gap height differed by around 28%. Moreover, the temperature of the chimney absorber was found to be between 35.5-81 °C, with an average of 56.6 °C, which is roughly 13% lower than the collector absorber due to the solar chimney's orientation.

Keywords: solar dryer, natural convection, chimney, efficiency, weight loss

ABSTRAK

Tujuan dari penelitian ini adalah untuk mengetahui pengaruh parameter geometri cerobong surya, khususnya ketinggian celah udara saluran aliran, terhadap kinerja pengering surya dalam hal ini efisiensi termal, efisiensi pengeringan, dan kehilangan berat produk kering. Hasil pengujian memperlihatkan bahwa temperatur di dalam ruang pengering meningkat seiring dengan meningkatnya intensitas matahari, sementara kelembaban relatif menurun. Dalam penelitian ini, irisan kentang dipilih sebagai objek pengering. Efisiensi kolektor dan cerobong rata-rata lebih tinggi pada kondisi celah udara 10 cm dibandingkan celah udara 5 cm. Setelah 8,5 jam proses pengeringan, kadar air pada kondisi celah udara cerobong 5 cm dan 10 cm berbeda sekitar 28%. Temperatur penyerap cerobong berada diantara 35,5-81 °C, dengan rata-rata 56,6 °C, yang berarti temperaturnya lebih rendah 13% dibandingkan dengan temperatur penyerap kolektor, sebagai akibat adanya orientasi cerobong surya.

Kata kunci: *pengering surya, konveksi natural, cerobong, efisiensi, kehilangan berat*

1. INTRODUCTION

Crop solar drying systems that use solar radiation as a primary source of energy have received great attention for a long time because it is inexhaustible, abundant, and has a non-polluting nature. Drying is an essential physical unit operation used in chemical, pharmaceutical, and agricultural sectors and its importance has become apparent in all countries **(Górnicki et al., 2020; Wahidi and Rohani, 1996)**. Agricultural product drying has a vital role in the preservation and extension of the product's shelf-life after harvesting by reducing the moisture content to a safe level usually between 10 – 20% **(Benichou et al., 2018; Eltawil et al., 2018; Hatamipour et al., 2007)**. A solar dryer is a device used to dry agricultural products **(Belessiotis and Delyannis, 2011; Sözen et al., 2020)**. **Chakraverty (2003)** reported that only 20% of the world's perishable agricultural products are dried to increase their shelf-life and support food security. This is why drying research remains an important field, with development related to drying operation conditions and product quality.

Numerous designs of solar dryers have been presented in the literature and are classified according to the method of airflow and mode of heat transfer **(Matavel et al., 2021; Singh and Kumar, 2012)**. Two methods of indirect type solar dryer (ITSD) are found in the literature; natural/passive and forced/active circulation type. The natural circulation type is known as the passive solar dryer because of the natural movement of air due to the thermo-syphon effect, whereas forced circulation employs a fan or blower to force air into and out of the dryer. Natural circulation mode solar dryers are ideal for drying small batches of fruits and vegetables and are highly preferred alternatives to the traditional open sun drying methods. However, there is a risk of overheating and consequent product quality degradation **(Mohana et al., 2020)**. The drying efficiency of these dryers varies from 20 to 40% depending on airflow rate, air temperature, the dryer's location, and meteorological conditions, which is low when compared to active mode dryers **(El Hage et al., 2018; Mahapatra et al., 2019; Motahayyer et al., 2019; Udomkun et al., 2020)**.

In the drying process, air temperature and air flow rate are the two important parameters that affect the drying rate **(Mustayen et al., 2015)**. In general, food products are dried at a temperature between 45 °C and 60 °C for safe drying **(Bal et al., 2010)**. Air temperature inside the dryer can be enhanced by using a selective absorber, whereas air flow rate can be enhanced in the case of a natural convective solar dryer by integrating a chimney into the system, since the chimney plays a key role in enhancing the buoyant force **(Jairaj et al., 2009)**. **Bassey (1986)** constructed and tested five different chimney configurations of an indirect natural convective solar dryer. The chimneys were all made from 0.16 cm galvanized iron sheet. Black painted short chimneys with a transparent cover around them are recommended for cloudy and low solar radiation conditions, according to the author's findings. Therefore, a solar chimney is a device that improves natural ventilation for a given application by harnessing convection of air heated by solar energy **(Habtay et al., 2019, 2020)**. **Habtay et al. (2021b)** have developed an indirect type of solar dryer with a single-pass collector, a drying chamber, and a circular long chimney. The thermal performance of the system was investigated with and without a chimney. The collector efficiency with a chimney ranged from 29.6% to 64.8%. **Afriyie et al. (2009); Chen and Qu (2014)** developed a solar chimney-based drying system to check the heat transfer and air flow inside the system. **Tedesco et al. (2019)** performed numerical simulations to evaluate a natural convection indirect solar dryer with a chimney, and the findings were compared to experimental results from the apple drying process. **Lingayat et al. (2017)** developed an ITSD to dry banana. A solar air collector with a V-shaped absorber plate, a drying chamber and a chimney made up the dryer. They obtained that the average thermal efficiency of the collector was 31.5%, and

that the temperature of drying air was the most influential parameter during the drying process. There are fewer studies in the literature that analysed the performance of a solar dryer using the solar chimney effect.

Therefore, the present work has been experimentally analysed to investigate the influence of the chimney air gap height (distance between the absorber plate and cover) on the system performance. The experiment was evaluated at 5 and 10 cm air gap heights under no-load and load conditions and under various solar intensities. Testing under no-load conditions gives consistent results because product properties such as moisture content, type of product, etc., do not affect dryer performance. The thermal efficiency of the collector, solar chimney, and drying systems was determined and compared. Furthermore, sliced potatoes were employed in this study to evaluate the solar dryer's drying efficiency.

2. METHODS

The indirect natural solar dryer is made up of three main components: a solar air collector, a drying chamber, and a solar chimney, as shown in Fig. 1, and a schematic diagram of the proposed solar chimney unit is illustrated in Fig. 2. A single-pass solar collector is made of a wooden frame with a duct volume of 0.024 m^3 (1.2 x 0.5 x 0.06 m length, width, and height, respectively). To prevent heat loss from the bottom and sides, a polystyrene sheet was provided. The plexiglass was used as a transparent diathermanous material which allows short wave radiation to pass and transmit the solar radiation to the plate. A 1.2 mm thick copper plate absorber was used to increase the temperature of the collector plate. The angle of tilt of the collector was 45° from the vertical axis and facing true south. This type of collector can heat the flowing air to a temperature range of 10 to 50 °C above ambient temperature, depending on the design type **(Vengadesan and Senthil, 2020)**.

The drying chamber is made of polystyrene material of size 0.05 m thick and is usually a rectangular box with size of 0.50 m x 0.50 m x 1.00 m (0.25 m^3). The drying chamber receives hot air at higher temperature and low humidity from the solar collector through a PVC pipe connection. To upload the dried product, drying trays are provided within the drying chamber. Two trays made of plastic nets are placed at a distance of 0.20 m from one another. Each trays covers an area of 0.15 m^2. Sliding trays have been kept inside the chamber to make it easier to remove them during product loading or uploading. Using a moisture analyzer, the initial moisture content of potatoes was observed to be 82.08% in this study **(Eltawil et al., 2018)**. Two vertical solar chimneys, each with a 5 cm and 10 cm air gap height (distance between glass cover and absorber plate), were constructed. A Plexiglas (4 mm) cell casting was used for glazing purposes. The bottom and sides walls (0.05 m thickness) were constructed with EPS polystyrene material (thermal conductivity 0.038 W m^{-1}K^{-1}). Single-wall corrugated (double-faced) cardboard was used as an absorber, and copper fins were used to create the artificial roughness of the solar chimney. Corrugated cardboard is a stiff, light-weight, and strong material made up of three layers (Fig. 3) of brown kraft paper **(Semmes et al., 2014)**. Both the absorber plate and the artificial roughness were painted with black enamel paint. The detailed specifications and characteristics of each component are presented in Table 1.

Figure 1. A view of the fabricated solar dryer

p= pitch = 150 mm
e = height of baffle = 24 mm
L_{fin} = 300 mm
L_{ch} = 0.5 m
H_{ch} – chimney air gap height
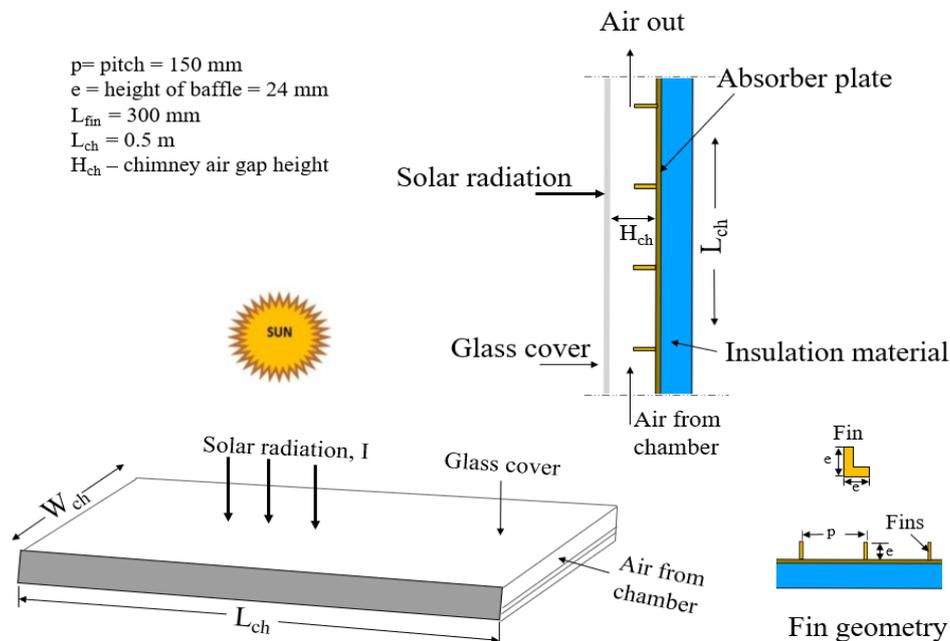
Figure 2. Schematic diagram of proposed solar chimney unit

Table 1. Specifications of the indirect solar dryer

Components	Specification and characteristic
Gross dimensions	2.5 m x 1.35 m x 0.5 m
Mode of air flow	Natural air flow
Collector type	Single pass flat plate solar air collector
Collector absorber plate	1.2 mm thick copper plate black coated (0.6 m^2)
Glazing	4 mm thick Plexiglas, τ=0.92 (for collector and chimney cover)
Insulation	Polystyrene 50 mm thickness
Collector tilt angle	45°, facing south (Azimuth angle = 180°)
Drying chamber	Polystyrene, thickness 50 mm, size 0.5 m (L) x 0.5 m (W) x 1 m (H)
Tray number and size	2 trays with wire meshed, size 0.46 m x 0.46 m
Chimney absorber plate	6 mm thick double-face corrugated cardboard with blackened copper fin
Chimney tilt angle	90°, facing south (Azimuth angle = 180°)

At a given geographical location, the cloud cover, the frequency of clear sky days, and the solar radiation that can be measured on the earth's surface are all determined by meteorological data gathered over many years. Hungary is between 45.8° and 48.6° north latitude in the northern temperate zone. According to data, annual average sunshine hours range between 1.900 and 2,200 hours per year. The yearly amount of heat reaching the horizontal surface is 1280 kWh/m^2/year (3.38 kWh/m^2/day) **(Kafui et al., 2019)** and the annual amount of heat reaching the south-facing surface at 45° is 1370 kWh/m^2 **(Naplopo, 2014)**. For optimal annual energy production, the solar collectors have to be tilted to face south with a tilt angle equal to the geographical latitude **(El-Sebaii et al., 2010; Gevorkian, 2008)**. In terms of solar radiation, there are no notable differences between regions of Hungary. The highest difference between regions of the country is around 8%.
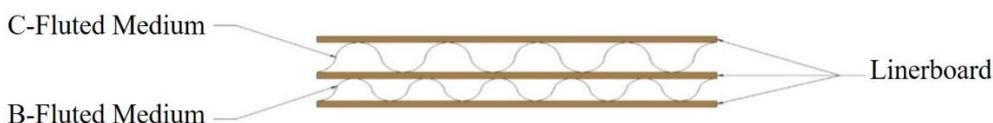
Figure 3. Schematic of double-faced corrugated cardboard as an absorber plate

The experimental measurements were performed in the forecourt of the solar laboratory of the Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary. The geographical latitude and longitude of the site location are 47° 35'39" N, 19° 21'59" E respectively (Fig. 4). The experimental measurements were carried out in July and August because these are the months with the most solar radiation **(Kafui et al., 2019)**. Each experiment starts at 09:00 and continues to 17:30. Many parameters are measured during each experiment, which include temperature, inlet air velocity, solar intensity, and weight loss of the product across the dryer.
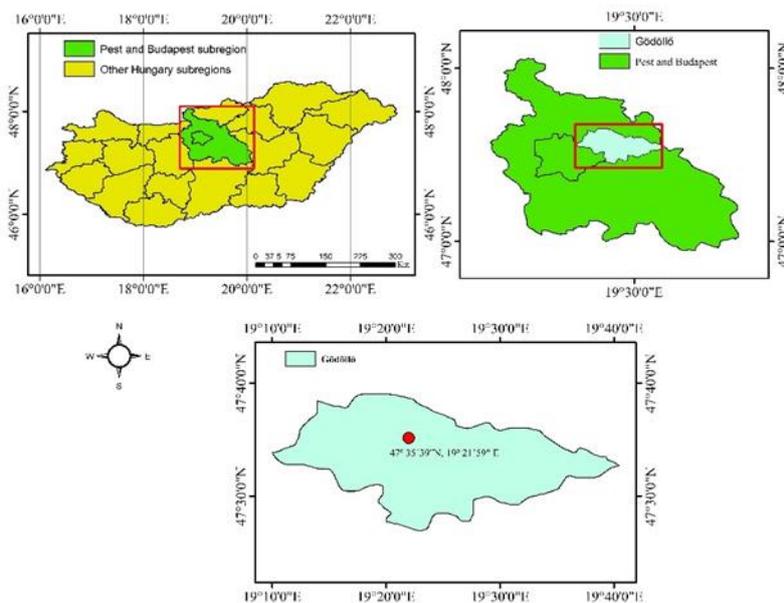
Figure 4. Map and geographical location of the study area of Gödöllő in Hungary

The temperature measurements at various locations on the dryer are measured using T-type thermocouples (nickel-copper), which sends its signals to a data logger. A pyranometer **(Kipp & Zonen CM11)** of ±0.1 W m^{-2} accuracy was attached parallel to the solar collector to measure the solar radiation. All the thermocouples and a pyranometer were connected to a

data logger **(Advantech ADAM-4018 16-bit, 8-channel analog input data acquisition module)**, which converted the physical signal into digital data. A solarimeter model KIMO Sl-200 was attached in parallel to the vertically mounted solar chimney to measure the amount of solar radiation on the surface. The velocity of the airflow was computed by a hot wire anemometer model Testo 405i with ±0.1 m s^{-1} accuracy, which is located at the entrance of the collector. A digital weight scale model APT457 with a 0 – 5 kg measuring range and an accuracy of ±0.1 g was used to quantify weight loss at 2-hour intervals during drying. Experiments were carried out using a sliced potato (4±1 mm thickness) weighing about 458 g in each tray and placed on a single layer basis. The initial moisture content of the potato was measured using an electronic Sartorius moisture analyser model MA 30. Fig. 5 shows the experimental set-up of the dryer with measuring instruments, and Table 2 provides the detailed information about the measured instruments.
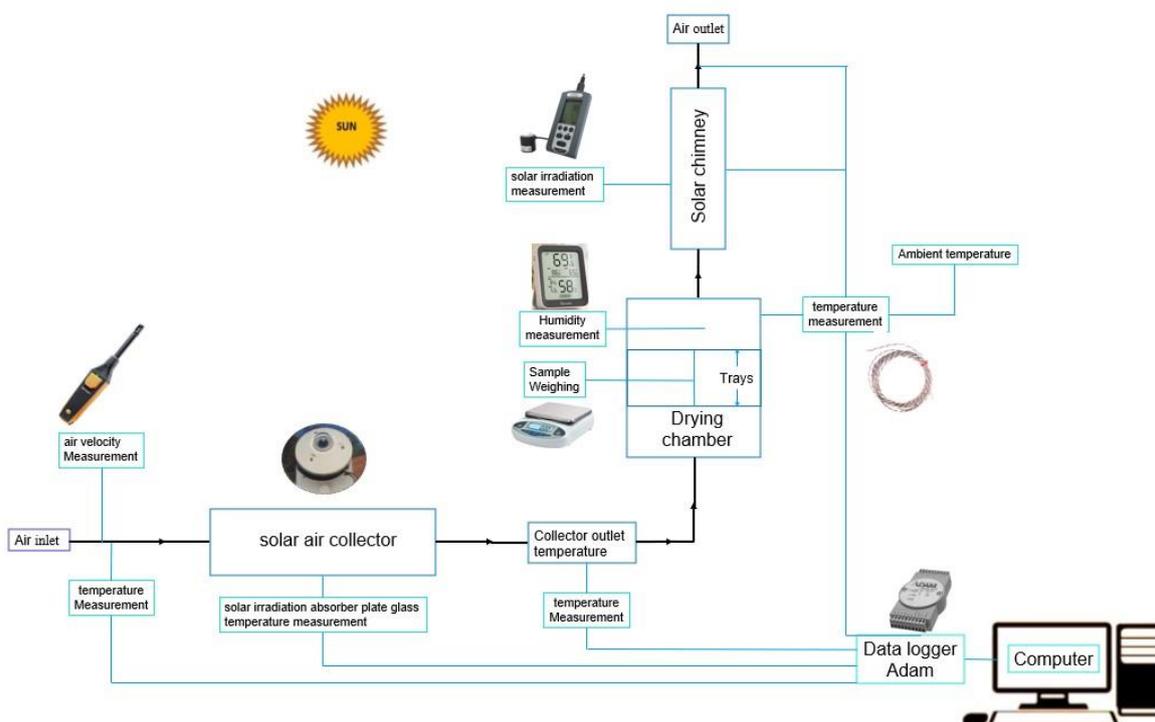
Figure 5. Experimental set-up of the system with measuring instruments

Table 2. Equipment used for the data measurement

Instrument	Name and type	Range/ Specification	Accuracy
Pyranometer	CM-11*	max: 4000 Wm^{-2}	±3%
Solarimeter	KIMO SL 200	1–1300 Wm^{-2}	±5%
Data logger	ADAM-4018**	±6 μV/ °C	–
Thermocouple	T-Type*	-270 to 370	±1 °C
Anemometer	Testo 405i hot wire	0–30 m s^{-1}	±0.1 m s^{-1}
Thermo-hygrometer	Govee H5075	0 – 99% RH 0 –70 °C	±3% ±0.3 °C
Moisture analyser	Sartorius MA 30	0 – 100% M	±0.05%MC
Digital balance	APTP457**	0 – 5000 g	±0.1 g

*(Habtay et al., 2020)

**(Habtay et al., 2021a)

The performance of the indirect passive type solar dryer (ITSD) was evaluated using the parameters product weight loss, energy efficiency, exergy and drying efficiency. Equation (1) can be used to determine the instantaneous moisture content, MC_t of the products on a dry basis **(Fudholi et al., 2014)**.

$$MC_t = \frac{m_t - m_{dry}}{m_{dry}}, \tag{1}$$

where, m_t is the mass of the potato slice at instant t (kg), and m_{dry} is the dry mass (kg).

The mass of water evaporated from a wet product (m_w) can be computed using the following formula:

$$m_w = m_o \frac{(MC_i - MC_f)}{100 - MC_f}, \tag{2}$$

where m_o is the initial total product mass (kg); MC_i and MC_f are the initial and final moisture content on a wet basis.

The performance of a solar collector and solar chimney is evaluated by their instantaneous thermal efficiency, η_{th}, which is defined as the ratio of the useful thermal energy collected to the total amount of radiation hitting the surface of the collector and chimney, I_T, over a specific period. Mathematically, the efficiency is expressed as **(Chabane et al., 2013; Duffie and Beckman, 2013)**:

$$\eta_{th} = \frac{useful\ energy\ gain}{Total\ solar\ energy\ available}. \tag{3}$$

The useful energy gain (Q_u) in a collector operating under steady state conditions is defined as the rate of energy being added to a heat transfer fluid passing through the absorber. Mathematically **(Ekechukwu and Norton, 1998)**:

$$Q_u = \dot{m} C_p (T_{out} - T_{in}). \tag{4}$$

The denominator of the thermal efficiency is the total solar energy input (Q_{in}) falling on the collector, it is usually known from practical measurements (a pyranometer), can be obtained using equation (5):

$$Q_{in} = A_c I_T, \tag{5}$$

where, $\dot{m}$ is mass flow rate of air (kg s^{-1}), C_p is the specific heat of air at constant pressure (J kg^{-1}K^{-1}), A_c is the collector area (m^2), T_{in} and T_{out} are collector inlet and outlet air temperature (K), I_T is total solar radiation (W m^{-2}).

The system drying efficiency of a solar dryer, η_d, was defined as the ratio of the energy required to evaporate moisture to the energy supplied to the drier, can be calculated as **(Mujumdar, 2014)**:

$$\eta_d = \frac{m_w L}{A_c I_T}, \tag{6}$$

where, L is the latent heat of vaporization of water (kJ kg^{-1}). It is 2,383.33 kJ kg^{-1} at atmospheric pressure at an average temperature of 50 °C in the drying chamber **(Erick César et al., 2020)**.

3. RESULTS AND DISCUSSION

An indirect type natural solar dryer (ITSD) was investigated with two different dimensional parameters (airgap height) of a solar chimney. The collector and chimney efficiencies were calculated directly from the data obtained from each system. In this study, the experimental results are presented in the form of graphs that describe incident radiation, ambient air temperature, absorber temperature across the collector and chimney, and collector and chimney efficiencies as a function of drying time.

Figs 6a and 6b show the weather conditions (variations of solar radiation and ambient air temperature) during the experimental days. As shown in the graphs, the amount of solar radiation increased over the time and reached its maximum level at around 12:30 pm and then declined. This is due to the angle of the sun's rays, which is not perpendicular to the collector in the morning and evening. The average solar radiation on the collector surface for cases 1, 2, 3, and 4 was observed as 735.4 W m^{-2}, 748 W m^{-2}, 718.7 W m^{-2}, 742.5 W m$^{-2,}$ respectively, while the average solar radiation on chimney surface was 462 W m^{-2}, 421.4 W m^{-2}, 463.5 W m^{-2}, and 417.7 W m^{-2}. The solar radiation curves for case 1 and 3 are not smooth curve, as a result of cloudy days. Throughout the drying experiments, the ambient air temperature variation ranged from 19 to 35 °C with an average value of 27.6 °C. In the drying process, the amount of solar radiation and the ambient temperature are both crucial components.

(a)   (b)
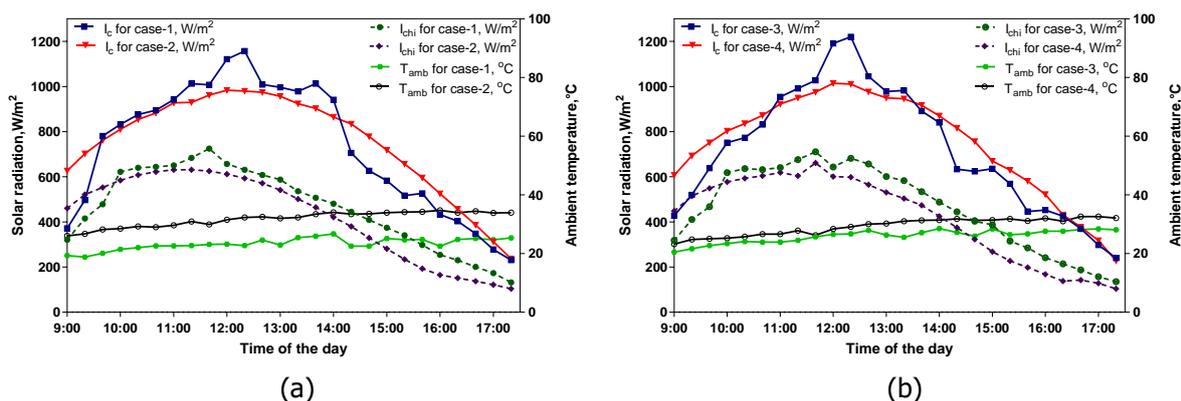
Figure 6. Variation of solar radiation and ambient temperature: (a) under no-load and (b) under load conditions

Figs 7a and 7b show the comparison of collector outlet and absorber temperature as a function of drying time under no-load and load conditions. For all cases the outlet and absorber temperatures rise from morning to 12:30 and then decreases due to the variations of solar radiations during the experimental days. However, case 2 has a higher outlet and absorber temperature than the others. The values of collector outlet temperature under no-load and load conditions varied from 28.3 °C to 54.4 °C and 27.8 °C to 57.2 °C, respectively. The average collector outlet temperature in cases 1, 2, 3 and 4 were 40 °C, 50 °C, 43 °C and 49 °C, respectively, whereas the absorber temperature was 58.5 °C, 74 °C, 60 °C, and 70 °C, respectively. Case 2 and 4 had a higher value than the others, according to the result. This is due to the fact that the solar radiation and ambient temperature are higher in those cases (see Fig. 6). The solar chimney employed in this study differs from traditional chimneys (circular type) in that it has rectangular cross section and a front face covered by glazing. It's similar to a solar air collector and mounted vertically. The temperature change, the temperature of the absorber, and the chimney's efficiency have all been presented. Figs 8a and 8b indicates the absorber temperature and the temperature change of the solar chimney during the experimental days. As seen in Fig. 8, the maximum absorber temperature was

around 86 °C in case 2, with 76 °C, 69 °C, and 78 °C in case 1, 3 and 4, respectively. The temperature change is also shown in the figure, with average temperature of 3.1 °C, 1.5 °C, 5 °C, and 2.3 °C in cases 1, 2, 3, and 4, respectively, which is very low due to the low thermal conductivity of the chimney absorber even its absorber temperature higher than 68 °C. Compared to the temperature of the chimney absorber was found to be between 35.5 and 81 °C, with an average of 56.6 °C, which is roughly 13% lower than the collector absorber due to the solar chimney's orientation.

| (a) | (b) |
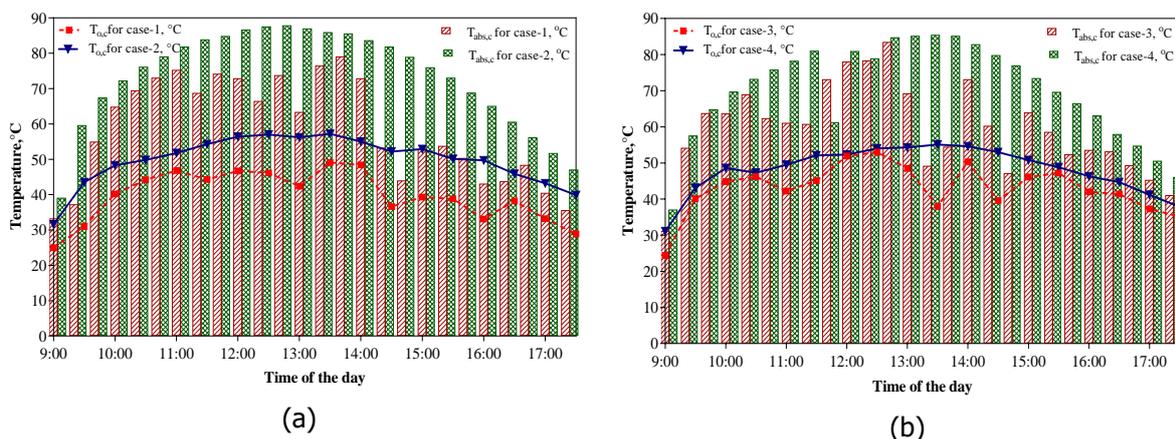
Figure 7. Comparison of collector outlet and absorber temperature values during experimental days: (a) under no-load and (b) under load

| (a) | (b) |
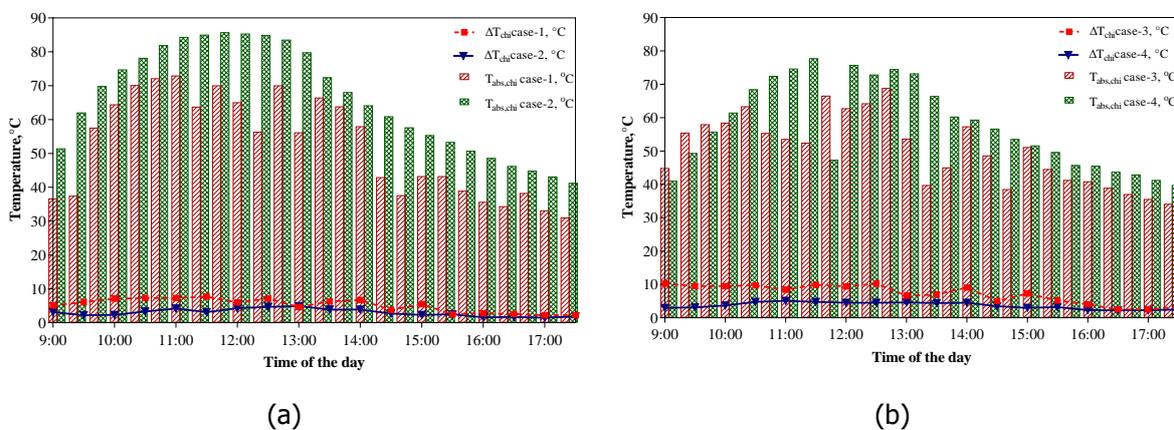
Figure 8. Comparison of chimney absorber temperature and temperature change values during experimental days: (a) under no-load and (b) under load

Table 3a, b and Table 4a, b presents the useful heat gain and the instantaneous thermal efficiency of the solar air collector and solar chimney during drying time under no-load and load conditions. The average collector efficiency in cases 1, 2, 3 and 4 is 35.5%, 54%, 29%, and 47.8%, respectively. The maximum solar collector efficiency was obtained at 40%, 73.4%, 33.2% and 57.2%, respectively (Table 3a and Table 4a). It could be indicated that case 3 had higher efficiency in comparison with others. This study outperforms compared to previous studies such as **(Lingayat et al., 2017)**, which found an average efficiency of 31.5% and **(Hegde et al., 2015; Mahapatra et al., 2019)** which both found that the average collector efficiency was 27.5%.

Table 3a. Collector efficiencies under no-load condition

Time of drying	Useful heat gain, W		Collector efficiency, η, %	
	Case-1	Case-2	Case-1	Case-2
09:00	42.95	54.60	21.63	16.32
11:30	226.57	375.95	39.97	73.59
13:30	187.23	334.91	35.13	68.66
15:30	93.69	169.13	33.03	50.27
17:30	36.73	25.73	33.87	23.41

Table 3b. Chimney efficiencies under no-load condition

Time of drying	Useful heat gain, W		Chimney efficiency, η, %	
	Case-1	Case-2	Case-1	Case-2
09:00	28.07	17.04	43.73	18.52
11:30	71.66	20.91	48.95	16.65
13:30	61.40	27.88	58.47	28.51
15:30	22.99	20.33	36.49	47.28
17:30	6.20	8.71	26.25	44.45

Table 4a. Collector efficiencies under load condition

Time of drying	Useful heat gain, W		Collector efficiency, η, %	
	Case-3	Case-4	Case-3	Case-4
09:00	28.76	49.02	13.13	15.14
11:30	156.29	297.83	30.16	57.22
13:30	154.57	239.97	32.06	48.53
15:30	85.41	146.75	33.20	49.43
17:30	26.59	42.19	20.28	35.88

Table 4b. Chimney efficiencies under load condition

Time of drying	Useful heat gain, W		Chimney efficiency, η, %	
	Case-3	Case-4	Case-3	Case-4
09:00	26.43	22.51	41.55	25.12
11:30	59.27	62.29	40.82	48.14
13:30	41.14	46.32	36.73	47.07
15:30	24.78	23.86	40.49	59.65
17:30	9.44	14.23	39.00	54.73

The efficiency of chimney varies from 26.3% to 58.5% (case 1), 17% to 47.3% (case 2), 36.7% to 41.6% (case 3), and 25.1% to 59.7% (case 4), and the average efficiency of the chimney was about 43%, 31%, 39.7%, and 47% in cases 1, 2, 3, and 4, respectively (Table 3b and Table 4b). The system drying efficiency was calculated using eqn. (6) as 14.45 for case 3 and 13.82% for case 4 after 8.5 h of drying.

In the course of the experimental days, the variations of the drying chamber air temperature (T_{cha}) and the average relative humidity of a drying chamber (RH) are shown in Figs 9a and 9b. From these figures it can be realised that the daily average of the drying air temperature and relative humidity range from about 25.8 – 60.4 °C, 8.2 – 46% and 21.5 – 52 °C, 18.6 – 75.2%, under no load and load conditions respectively. Whereas the average drying air temperature was recorded to be 42.5 °C, 55.3 °C, 37.6 °C, 45 °C in the case 1, 2, 3, and 4 respectively.

The obtained results suggest that the average value of air temperature in all the cases was 10 – 28 °C higher than the ambient temperature. Average drying air temperature of 40.3 °C has been reported in natural modified indirect mode solar dryer **(Mohammed et al., 2020**).

The daily averages of relative humidity at the drying chamber under load in cases 3 and 4 were about 36 and 30%, respectively, which is roughly 50% higher than the dryer without load. This is due to the fact that the flowing air absorbs moisture from the food product. The air velocity was measured at the collector inlet. The average maximum and minimum air velocity in all cases noticed is 1 and 0.5 m s^{-1}. At maximum solar radiation, the maximum air velocity in cases 1, 2, 3, and 4 was found to be around 0.96 m s^{-1}, 1.45 m s^{-1}, 0.65 m s^{-1}, and 1.12 m s^{-1}, respectively.

(a)   (b)
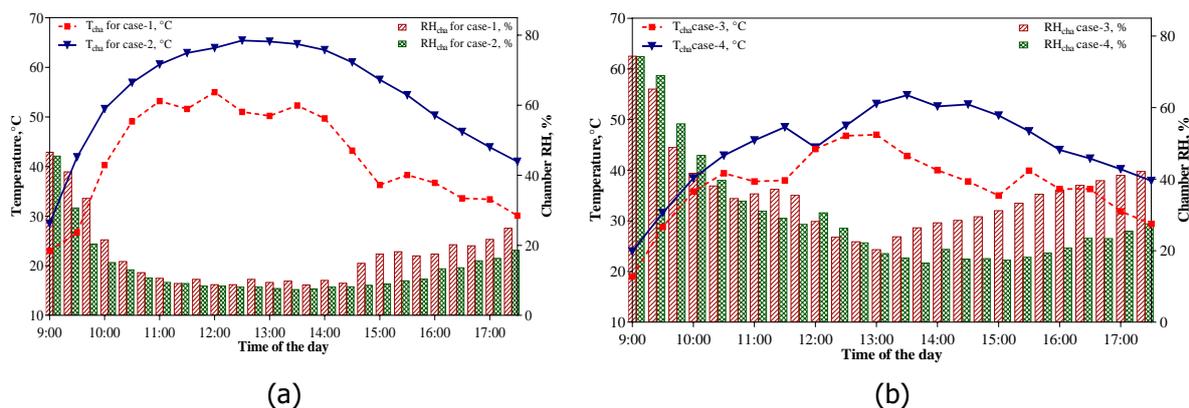
Figure 9. Variation of average chamber dry air temperature and relative humidity during experimental days: (a) under no-load and (b) under load

Fig. 10 shows the values of weight reduction with respect to time for cases 3 and 4. The weight reduction data were used to calculate the transient moisture content of the product. After eight and a half hours of drying, the values of weight reduction in case 3 were observed to reduce from 458 g to 101 g and 112 g in the bottom and top trays, respectively, while the values of weight reduction for potato slices dried in case 4 were 94 g and 103 g in the bottom and top trays, respectively.

It is observed that the highest weight reduction was noticed in case 4 compared to that of case 3. Therefore, case 4 is more efficient as it saves time and energy during drying. This is due to the higher drying temperature in the drying chamber. According to equation (1), in case 3, the moisture content decreased from 82.08% of initial moisture content to 18.83% in tray 1 and 26.8% in tray 2; in case 4, it decreased from 82.08% to 12.79% in tray 1 and 20.41% in tray 2 at the end of 8.5 h of drying. It is observed that potato slices from tray 1 lose its moisture content faster compared to tray 2, because tray 1 gets a chance to absorb more heat energy than tray 2.

Fig. 11 illustrates the quality and texture of dried potato slices after eight and a half hours of drying in both load cases.
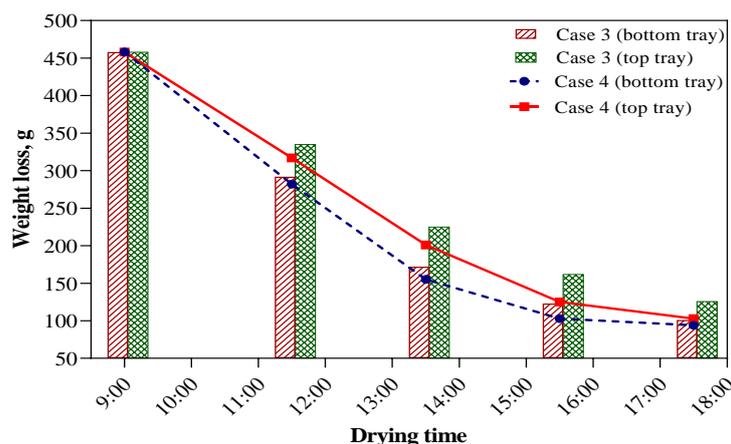
Figure 10. Graph of reduced weight versus time for potato slices

| (a) | (b) |
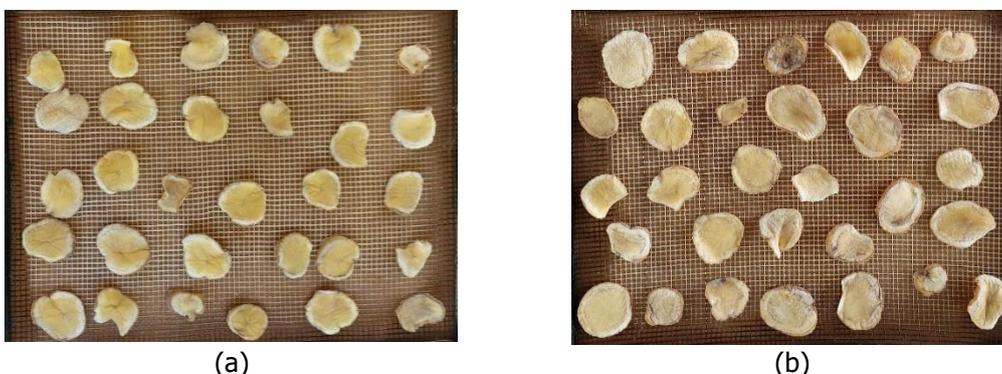
Figure 11. Visual quality appearance of the dried potato samples: (a) case 3 and (b) case 4

4. CONCLUSIONS

A novel concept for a low-cost solar chimney is described, which is made up of a glazing, polystyrene box, and a cardboard absorber plate and has a 40% average efficiency. The heat transfer from the cardboard plate to the flowing fluid and the temperature difference between the inlet and outlet of the solar chimney observed low (average less than 5.5 °C) due to low thermal properties of the material. The absorber temperature, however, was higher more than 68 °C. In this study, it is found that the average collector efficiency can be improved by improving the solar chimney's efficiency. Therefore, the solar collector's performance is influenced by the chimney's performance. The system drying efficiency obtained for 5 cm air gap height (case 3) was 14.45%, whereas it was 13.82% for 5 cm air gap height (case 4). The collector outlet temperature and absorber plate temperature are significantly dependent on the intensity of the solar radiation and ambient temperature.

In terms of weight loss, a solar dryer with a 10 cm air gap height chimney (case 4) loses more weight than a dryer with a 5 cm air gap height chimney (case 3). After 8.5 h of drying, moisture content in case 3 decreased from 82.08% to 18.83% in tray 1 and 26.8% in tray 2; in case 4, it decreased from 82.08% to 12.79% in tray 1 and 20.41% in tray 2. The quality in terms of colour and shape of the dried potato remains the same in both configurations.

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