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Some Engineering Factors Affecting Utilization of Solar Energy in Drying Tomato Fruits

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Abstract:

Tomato fruit (TF) is considered one of the most cultivated and consumed vegetables around the world, and it is characterized by a high content of vitamins and mineral elements. But it is unfortunate that it is seasonal and contains a high percentage of moisture, which hinders the storage process. This leads researchers around the world to innovate and develop processes that will preserve TF in a safe way for safe use throughout the year and facilitate the preservation and processing. Therefore, the current study focused on studying the different engineering factors through which the use of solar energy (SE) in drying TF can be maximized. The TF were dried using a solar dryer (SD) attached to a fixed solar collector (FSC) and another SD attached to a solar collector integrated with an automatic sun tracking system (ASCT). The field experiments were done at three drying air velocities of 1, 1.5, and 2 m/s and three slice thicknesses (ST) of 4, 6, and 8 mm. The results showed that the ASCT reaches a peak air temperature of 65°C, while the FSC reaches a peak air temperature of 55°C. This 10°C difference in air temperature can have a significant impact on drying times, which led to an increase in the thermal efficiency of the SC equipped with an ASCT by about 17% compared to the traditional FSC. The maximum efficiency of the PV system was about 17% at 8.0 a.m. In addition, the ASCT samples dry more quickly than the FSC samples at all AV. On SD merged with ASCT, the TF samples dried for 5–8 hours reached EMC; whereas, on SD merged with FSC, the TF samples dried for 6–10 hours reached EMC. This indicates that the time needed to dry TF slices was reduced by 20% to 25% when the developed ASCT was used.

Keywords: air velocity, open sun drying, solar drying, solar tracker, tomato fruit.

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Nomenclature		***Abbreviation***	
μ_w	Moisture content of TF sample on wet basis, %	MC	Moisture content
		SD	Solar dryer
μ_d	Moisture content of TF sample on wet basis, %	SC	Solar collector
		OSD	Open sun drying
W_w	Initial total weight of TF sample, kg	DR	Drying rate
W_d	Final weight of tomato sample, g	MC	Moisture content
V_{oc}	Open-circuit voltage, V	SR	Solar radiation
I_{sc}	Short-circuit current, A	ASCT	Automatic solar collector tracker
Ins_{coll}	Solar intensity in W/m^2	FSC	Fixed solar collector
A_{coll}	SC surface area, m^2	PV	Photovoltaic
m_a	Air mass flow rate, kg/s	TE	Thermal efficiency
u_a	Air speed, m/s	DCh	Drying chamber
ρ_a	Air density, kg/m^3	DP	Drying process
η_{coll}	solar collector efficiency, %	AV	Air velocity
		TS	Tomato slice

1. Introduction

One of the most popular vegetables is the tomato fruit (TF) because it contains carotenoid terpenes, which are rich in vitamin A **(Boumendjel et al., 2012)**. According to the most recent statistics, developed countries experience post-harvest infection damages of 20–25% **(El Ghaouth et al., 2004).** TF are highly perishable in their mature state, which results in a constant loss during the collection period due to supply and demand imbalances. As a result, it is important to decrease the moisture content (MC) to extend their shelf life. Dried TF are used in salads, pizza, soups, willows, and other dishes. In developing countries, losses exceed 35%. Overproduction during the harvesting period and overabundance of the product on the market determine a reduction in the price of TF **(Movagharnejad and Nikzad, 2007)**. Given their significance to the global economy, TF are among the most widely utilized commercial agricultural products worldwide and the focus of extensive scientific research **(Khama et al., 2013)**. Numerous investigations have shown that lycopene levels are not considerably impacted by the thermal processing of TF, including the drying process **(Charanjeet et al., 2004)**. Additionally, drying of TF can boost their nutritional content by raising their level of lycopene and overall activity as antioxidants **(Dewanto et al., 2002)**.

One of the most widely utilized techniques for preparing agriculture products for direct consumption or use as ingredients is drying **(Giovanelli et al., 2002)**. Drying is thus recognized as a crucial method in the preparation of products from agriculture sector **(Bennamoun et al., 2015)**. Additionally, during dehydration, the dried TF's weight and ultimate volume are significantly decreased **(Celma et al., 2008)**. This can significantly lower the cost of transportation and storage **(Abouo et al., 2016; Benkhelfellah et al., 2005)**. Open sun drying (OSD) is a conventional method that uses solar radiation to preserve food by physically exposing the product to the sun **(Elkhadraoui et al., 2015).** Using this technique, the newly made product covers the ground **(Gürlek et al., 2009)**. Where it reducing the MC to 10–15% takes roughly 4–8 days **(Oberoi et al., 2005)**. This may be detrimental to the dried product's quality, particularly as it is sensitive to contamination and is directly related to the weather. However, drying TF at high temperatures causes the loss of nutrients, color, and volatile chemicals **(Sahin et al., 2011)**. **Andritsos et al., (2003)** stated that OSD requires a long time for drying, but it is very simple and requires small capital investments. **Opadotun et al., (2016)** make an experiment for drying TF by SD and OSD, where Three different varieties of TF were used in the experiments. They found that dehydrated TF retained slightly more nutrients than oven-dried TF but took longer than the oven-dried sample. On the other hand, they found that dried TF samples under an SD gave a better result compared to OSD, because of factors of control.

There are now many modern methods, including a hot air dryer **(Lewicki, 1998)**. A heat pump **(Jeyaprakash et al., 2016)**, freeze drying **(Lin et al., 2007)**, solar drying, microwave drying, vacuum drying, infrared drying, freeze drying, oven drying, and various hybrid drying techniques **(Elwakeel et al., 2023, 2024; López-Vidaña et al., 2013; Mahmoud and Elwakeel, 2021). Lopez- Quiroga et al., (2020)** stated that the MC of TF was decreased from 91.37 % to 7.95 % after 48 h by using Freeze drying method. **Orikasa et al., (2018)** reported that the energy cost for drying TF by using Vacuum pump was 3.2 USD for drying 1 kg of TF fruits. Lopez-Quiroga demonstrated that the energy cost was 1.6 USD for drying 1 kg of TF fruits using microwave oven. Using a non-depletable free renewable energy source, solar drying is a thermodynamic technique for regulating MC **(Hamdi et al., 2023)**. There are many studies for drying TF by using solar dryers, that can be concluded as follow; **Lingayat et al. (2017)** dried TF using an indirect SD for drying TF, and MC of TF reached 0.803 kg/kg after drying, and the average TE of the SC was 59.05%. When compared to sun-drying commercially supplied dried TF available in the market, **Hossain et al. (2008)** showed that the hybrid solar dryer saves 56.25% of the time and yields a higher-quality product. **Reyes et al., (2014)** reported that using SE can save the dry TF between 6.6 and 12.5% of its energy. In June, **Jain and Tewari (2015)** provided an example of how the temperature in the drying chamber was 6 °C higher than the outside temperature after daylight hours until midnight. According to **Samimi-Akhijahani and Arabhosseini (2018)**, the solar tracking device significantly reduced the drying time, from 16.6% to 36.6%.

Based on the above, the current paper aims to study some engineering factors affecting utilization of SE in drying TF fruits.

2. Materials and methods

2.1. Experiment procedure

To achieve the proposed goal of the current study, we used two different SD have the same features and dimensions and made from the same material, the first one was integrated with FSC, and the other SD was integrated with ASCT, also, we used three VA inside the drying chamber (DCh) of 1.0, 1.5 and 2.0 m/s, in addition to we used three thicknesses of TSs of 4.0, 6.0 and 8.0 mm, as shown in Table 1, for testing of some engineering factor affecting utilization of SE in drying TF. All drying experiments related to the current study were done in Luxor city, Egypt, in summer 2023.

Table 1. Design variables of the current study.

level	1	2	3
SD type	FSC	ASCT	----
Hot AV	1.0	1.5	2.0
Thickens of TS	4.0	6.0	8.0

2.2.Sample preparation

Fresh TF (*Lycopersi conesculentum*) were purchased from a local market (Luxor city, Egypt). The TF with diameter ranged between 3.5 and 4.2 mm were used and sliced with ST of 4, 6, and 8 mm in fresh stage after purchasing immediately. The initial MC of the samples was 92 ± 2 %. For each drying experiment, about 500 g of TF samples were uniformly disrupted above the drying tray and hinged by electrical balance in the DCh, as shown in Figre1. The reading of the electrical balance was recorded each one hour. Figure 1 shows the drying tray hinged by electrical balance in the DCh, and both fresh and dried FT.

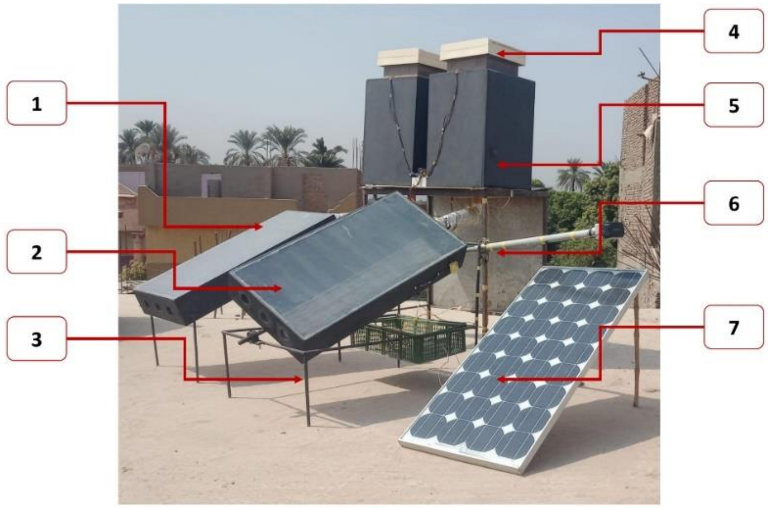
Drying tray covered with plastic mesh and hinged with electronic digital balance

Comparison between fresh and dried tomato fruits

Figure 1. The drying tray hinged by electrical balance in the DCh, and both fresh and dried FT.

2.3.Drying conditions

An SD integrated with ASCT system was designed and developed for drying TF (Figure 2) and comparing its performance with FSC and different AV and different TS of TF. Both SDs consist of many parts such as, SC, DCh, drying trays, linear DC motor, PV system, air circulation fan. Table 2 illustrates the specification of the different components of both SDs.



1. Fixed solar collector (FSC), Automatic solar collector tracker (ASCT), 3. Metallic Frame, 4. Suction fan, 5. Drying room, 6. linear DC motor, Photovoltaic (PV) system.

Figure 2. The main components of both SDs.

Table 2. The specification of the different components of both SDs.

Components	Solar dryer type	
	ASCT	FSC
Absorber plate	Galvanized steel sheet, with dimension of 100 cm in length × 50 cm in width and thickness of 2 mm, painted in black, insulated by wood dust 3 mm in thickness.	
Glass cover	A glass cover with 3 mm in thickness was used, where the depth of the solar collector was 15 cm.	
Rotation axes	Only one axes rotating system by using relay, Arduino Uno, light sensor, and linear DC motor	None (Fixed solar collector)
Power supply (Solar panel)	PV model (320 W), battery charger, converter, battery	
Air circulation fan	Using two suctions fans (model VF5025G, 40 W, 220 - 240 V AC, 50 HZ, 30×30 cm)	
Drying chamber	Wooden drying chamber with dimensions 44 cm in length * 44 cm in width * 63 cm in height	
Drying trays	Made from wooden frame covered with plastic mesh with dimensions 44 cm in length * 44 cm in width	

2.4.Theoretical principles

2.4.1. Moisture content (MC)

The MC was estimated by heating a TF sample at 105 ± 1 °C in a hot-air electrical oven for 10 hours, based on the described method by **(AOAC, 2005)**. The initial and final MC of the TF samples on a wet basis was estimated using Eq. 1, as mentioned by **(Eke and Simonyan, 2014)**.

$$\mu_w = \left[\frac{W_w - W_d}{W_w}\right] \times 100 \qquad ..(1)$$

where: μ_w is the MC on wet basis in %, W_w is the wet weight, W_d is dry weight.

The MC on a dry basis (μ_d) of dried TF, was calculated based on Eq. 2. As reported by **(Tesfaye and Habtu, 2022)**.

$$\mu_d = \left[\frac{W_w - W_d}{W_d}\right] \times 100 \qquad ..(2)$$

2.4.2. Thermal balance for photovoltaic (PV) system

The energy consumed by the AC suction fan is used as an output source of energy in the calculation of the efficiency of a photovoltaic (PV) system, according to **(Shen et al., 2020)**, as shown in Eq. 3,

$$P_{output} = V_{oc} \times I_{sc} \qquad ..(3)$$

where: V_{oc} is the open-circuit voltage, and I_{sc} is the short-circuit current.

According to **Qi and Wang, (2013)**, fill factor may be defined as the ratio of the maximum output power of the PV panel (P_{max}) to the output power mentioned in Eq. 4.

$$FF = \frac{P_{max}}{V_{oc} \times I_{sc}} \qquad ..(4)$$

2.4.3. Solar collector efficiency

The efficiency is the ratio of input power and output power of the solar collector. It was estimated according to Eqs from 5 to 8 according to (**Bala and Janjai, 2005; Eltawil et al., 2018; Usub et al., 2008)**.

$$E_{input.coll} = A_{coll} \int_0^t Ins_{coll}(t)dt \qquad ..(5)$$

Energy output from the SC ($E_{input.coll}$, J) is given as:

$$E_{output.coll} = \int_0^t m_a(t) \times C_{p,a} \times \left(T_{a,in} - T_{a,out}\right) dt \qquad ..(6)$$

$$m_a = \rho_a \times V_a = \rho_a \times u_a \times A_{coll} \qquad ..(7)$$

where: Ins_{coll} is the solar intensity in W/m^2, A_{coll} is the solar collector surface area in m^2, m_a is the air mass flow rate in kg/s, u_a is the air speed in m/s, and ρ_a is the air density in kg/m^3.

As above mentioned, the solar collector efficiency (η_{coll}) was calculated based on Eq. (8):

$$\eta_{coll} = \frac{E_{output.coll}}{E_{input.coll}} \times 100 \qquad ..(8)$$

2.5.Instrumentation and Measurement used in the current study

- ✓ The incident solar radiation on Luxor city, Egypt, was given using **(Tutiempo, 2023)**.
- ✓ The TF sample was weighted on the SD using a portable digital electronic scale of measurement range 0.0 - 50 kg with an accuracy of ± 0.005 kg. While the TF sample was weighed on the laboratory using a digital electronic scale of measurement range 0.0 – 1.0 kg with an accuracy of ± 0.0001 kg.
- ✓ A digital temperature and humidity meter (model: UT333s) was used to calibrate the temperature and humidity sensor (model: DHT-22). This equipment is manufactured by UNI-T Instruments, which is based in China, with an accuracy of 0 – 100 % RH ± 5 % & -10 – 80 °C ± 1 °C.
- ✓ A temperature and humidity sensor (model: DHT-22) was used to measure the dry air temperature and humidity at five points on the solar dryer (outside (ambient air), inlet of drying chamber, and outlet of drying chamber). This equipment is manufactured by UNI-T Instruments, which is based in China, with an accuracy of 0 – 100 % RH ± 5 % & -10 – 80 °C ± 1 °C.
- ✓ A digital light intensity meter (model: UT383s) was used to calibrate the LDR sensor. This equipment is manufactured by UNI-T Instruments, which is based in China, functions range resolution accuracy luminance 0 ~ 9999 Lux, 1.0 Lux ± 4 % rdg + 5 dgts ≥ 10000 Lux, 10 Lux ± 5 % rdg + 8 dgts.
- ✓ A LDR sensor (model: DHT-22) was used to measure the ambient light intensity around the SC for controlling and ASCT.
- ✓ A digital anemometer (model: UT363) was used to measure the air speed inside the DCh. This equipment is manufactured by UNI-T Instruments, which is based in China. Wind speed 0.0 – 30 m/s, accuracy ± 5 % rdg + 0.5.
- ✓ A digital multimeter (model: 9205) was used to measure the open circuit voltage and short circuit current for the PV model. This equipment is manufactured by SUOER Instruments, AC/DC voltage measurement up to 700/1000 V, DC current measurement up to 20 A.

2.6.Statistical Analysis

The obtained results of the current study were statistically analyzed using SPSS 18.0 statistical software (SPSS Inc.).

3. Results and discussion

The current study was conducted in Luxor city, Egypt, during the period from 7/29/2023 to 8/6/2023, form 8.0 a.m. to 6.0 p.m. to study some of the engineering factors that lead to utilize the use of SE for drying TF fruits. The TF fruits were dried using a SD attached to ASCT in order to collect a larger amount of solar radiation, and the performance was compared with a SD attached to FSC by using three levels of hot AVs (1, 1.5 and 2 m/s), as well as cutting the TF into slices with three different thicknesses (4, 6 and 8 mm).

3.1.Relative humidity and temperature of ambient air

The temperature and relative humidity of the air were measured during the period of the field experiments (7/29/2023 to 8/6/2023) from 8.0 a.m. to 6.0 p.m. and explained in Figure 3.

There was a fluctuation in temperature and humidity during the entire period of the experiments, which was neglecting.

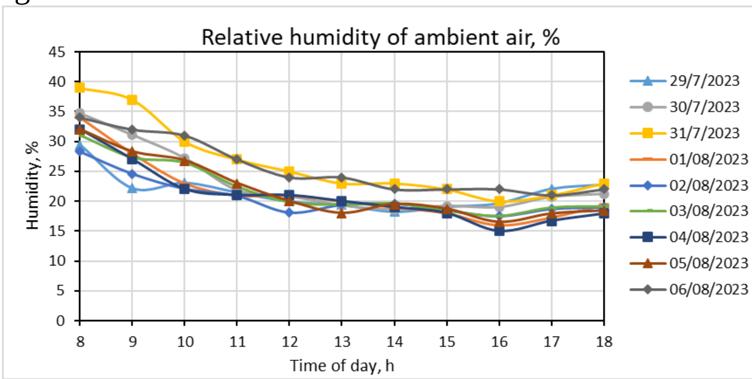


Figure 3a. Relative humidity and temperature of ambient air.

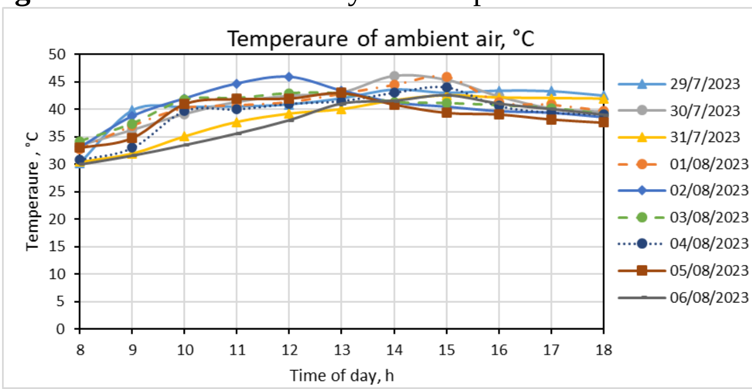


Figure 3b. Relative humidity and temperature of ambient air.

3.2.Relative humidity and temperature of hot air inside the SC.

Figure 4 shows the air temperature inside two types of SDs during the period of field tests, an SD with an ASCT and a solar dryer with an FSC. The resented data shows that the air temperature inside the ASCT is higher than the air temperature inside the FSC. The collector causes the ASCT uses a tracking system to rotate the solar collector towards the sun, which ensures that the SC is always receiving the maximum amount of sunlight. This results in faster drying times and higher efficiency. In addition, the air temperature inside both types of SDs increases over time. This is because the SC is absorbing the sun's energy and heating the air. This is because the ASCT can achieve higher air temperatures, which results in faster drying times. Here is a more detailed explanation of the same figure:

- ✓ The ASCT reaches a peak air temperature of 65°C, while the FSC reaches a peak air temperature of 55°C. This 10°C difference in air temperature can have a significant impact on drying times.
- ✓ The ASCT reaches its peak air temperature more quickly than the FSC. This is because the ASCT is always receiving the maximum amount of sunlight, while the FSC is only receiving maximum sunlight when the sun is directly overhead.
- ✓ The ASCT maintains a higher air temperature for longer than the FSC. This is because the ASCT can track the sun and continue to absorb sunlight throughout the day, while the FSC is only able to absorb sunlight when the sun is directly overhead.

Overall, the graphs show that the ASCT is more efficient than the FSC. This is because the ASCT can achieve higher air temperatures and maintain those temperatures for longer.

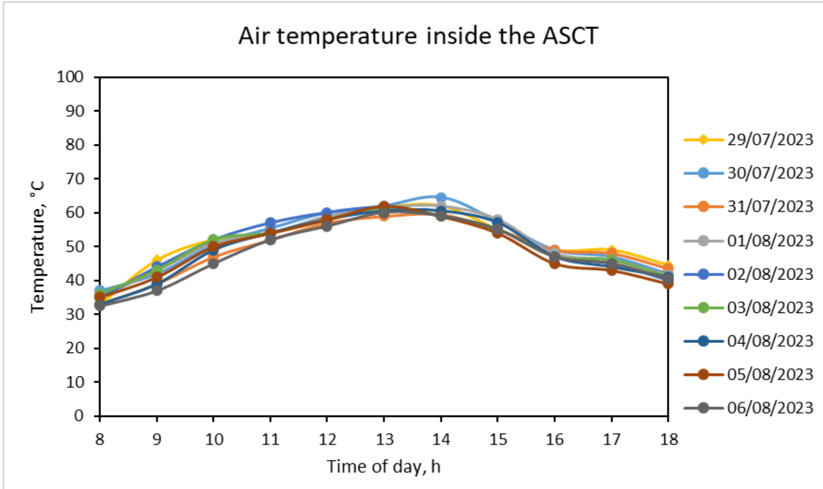


Figure 4a. Relative humidity and temperature of hot air inside the SC.

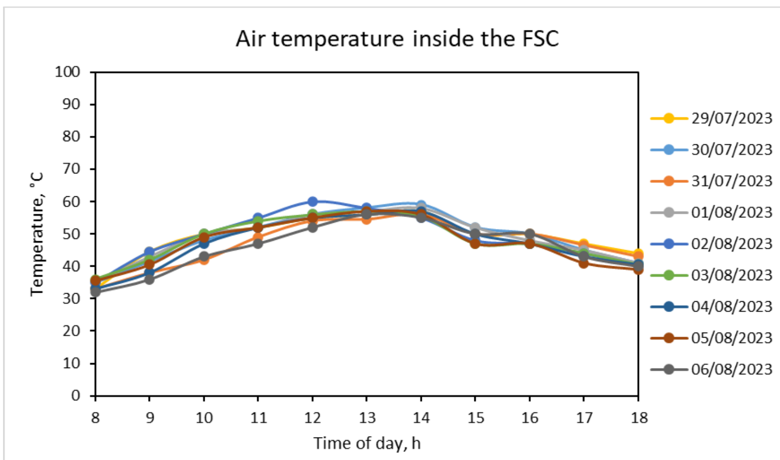


Figure 4b. Relative humidity and temperature of hot air inside the SC.

3.3.Effect of hot air velocity on the reduction on the total weight of the dried TF samples

Figure 5 shows the reduction on the total weight of the dried TF samples using two different types of SDs, (FSC and ASCT), at different AV. The x-axis represents the time of drying in hours, and the y-axis represents the AV in m/s. The data points on the graphs represent the air velocity required to dry the samples to a certain MC. The presented results show that AV did not have significant effect on the drying time under the same conditions. In addition, the ASCT samples dry more quickly than the FSC samples at all AV. On SD merged with ASCT, the TF samples dried for 5–8 hours reached EMC; whereas, on SD merged with FSC, the TF samples dried for 6–10 hours reached EMC. This indicates that the time needed to dry TF slices was reduced by 20% to 25% when the developed ASCT was used.

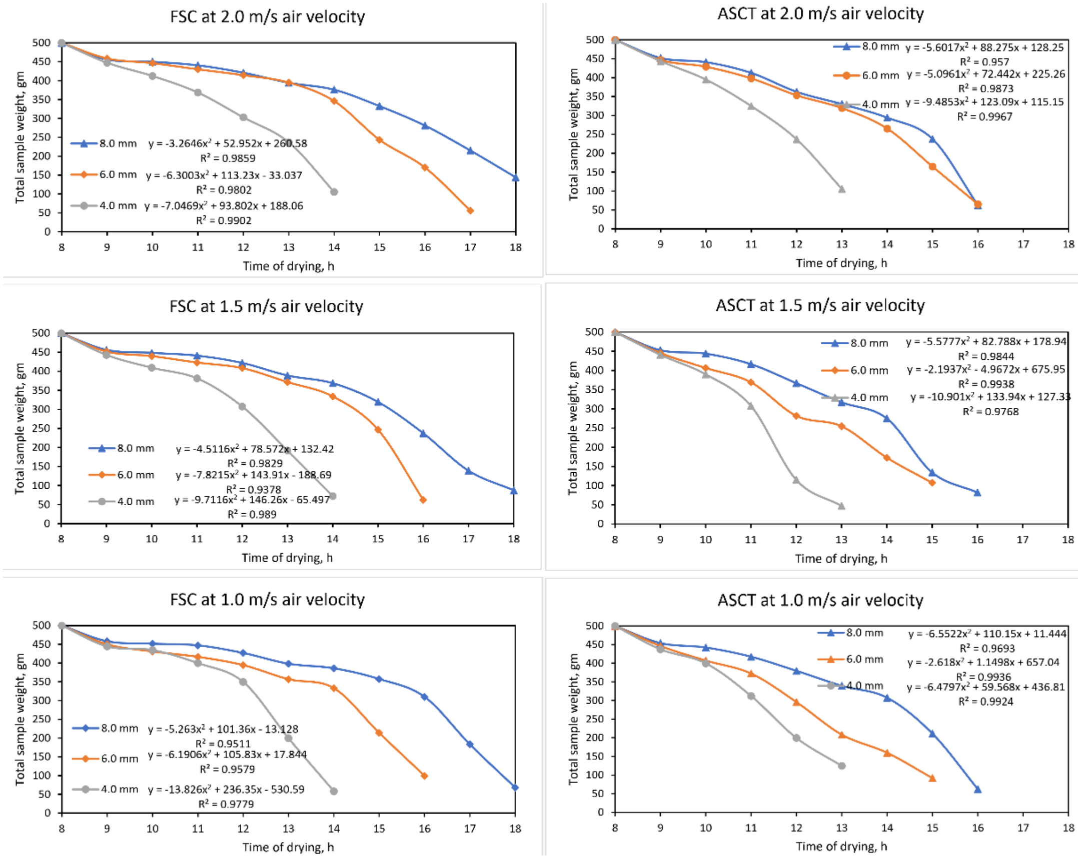


Figure 5. The reduction on total sample weight versus time of drying for the SD with ASCT and SD with FSC at different AV.

This is because the SD attached to ASCT collects larger amounts of SR and thus raises the temperature of the drying air higher than a FSC, which allows the air to remove moisture more quickly. A regression analysis of the SD integrated with ASCT, and the SD integrated with FSC is conducted to elucidate the impact of the AV on their respective performance metrics.

According to a preliminary analysis of the test results, the field evaluation results for both SD merged with ASCT and FSC are comparatively stable over AV values of 1.5 m/s to 2.0 m/s. The test findings steadily fluctuate after each SD's previously stated range. The drying curve's prior pattern was consistent **(Samimi-Akhijahani and Arabhosseini, 2018**; **Kocabiyik et al., 2015)**. In addition, Figure 5 shows that the two examination variables of the two SDs are comparable in the law of change of AV: the provided findings fluctuate reasonably steadily between 1.5 and 2.0 m/s, and they fluctuate significantly at 1.0 m/s.

3.4. Effect of thicknesses of TS on the reduction on the total weight of the dried TF samples

Regression analysis of the ST is carried out to elucidate the impact of the TS on the outcomes of the SD merged with ASCT and the SD merged with FSC that are presented. According to a first investigation into the test results, similarly, the test results are relatively stable in the ST of 8.0 mm, and the TS has a small effect on the SD's result accuracy. In the range of 4 – 6 mm, the test results vary greatly, and the ST has a greater impact on the SD's result accuracy at all levels of AV.

Figure 6 shows the regression analysis of two types of SDs on two evaluation parameters. It can be seen from Figure 6 that the two evaluation parameters of the two SDs are not similar in the law of change of the ST: in the range of 4 – 6 mm ST, the presented results fluctuate greatly, but at 8 mm ST, the change in the presented results is relatively stable. In addition, from the presented results in Figure 6, we found that there is a significant difference between the drying curves for SD merged with ASCT and SD merged with FSC at the tested ST, as well as a significant difference for both curves and under the same conditions of operation, the TF samples dried on SD merged with FSC reached EMC after 6, 9, and 10 hours for 4.0, 6.0, and 8.0 mm ST, respectively, whereas the TF samples dried on SD merged with ASCT reached EMC after 5, 7, and 8 hours. This indicates that the time needed to dry TF slices was reduced by 20% to 25% when the developed ASCT was used. Furthermore, as Figure 6 illustrates, drying TF at 4 mm ST reduced the DT by 50% and attained the EMC more quickly than 6 mm and 8 mm ST. The findings observed are consistent with **(Samimi-Akhijahani and Arabhosseini, 2018; Shahi et al., 2011)**.

3.5.Thermal efficiency (TE) of the SC.

Figure 7 demonstrates the TE of the ASCT and FSC during the period of field tests. TE is the percentage of the sun's energy that is converted into useful heat. The presented data on Figure 7 shows that the TE of both the ASCT and FSC increases with increasing the intensity of the SR. However, the ASCT has a higher thermal efficiency than the FSC all the time. For example, at day of time of 2.0 p.m., the ASCT has a TE of 82%, while the FSC has a TE of 70%. This means that the ASCT is converting 82% of the sun's energy into useful heat, while the FSC is only converting 70% of the sun's energy into useful heat. This indicated that, using of ASCT led to increase the TE of the SC by about 17 %.

The higher TE of the ASCT solar dryer is due to the fact that it uses a tracking system to rotate the SC towards the sun. This ensures that the SC is always receiving the maximum amount of sunlight, which results in higher temperatures and higher TE.

3.6.Thermal efficiency of the PV system.

Figure 8 illustrates the TE of a photovoltaic (PV) panel at different times of day (different SR levels). The x-axis of the graph represents the time of day in hours, and the y-axis represents the TE in percentage. Where presented data showed that the TE of the PV panel decreases as the solar irradiance decreases. The maximum TE of the PV system was about 17% at 8.0 a.m. then the TE decreased with increasing the surface temperature of the PV system where the lowest TE was 10% at 3.0 p.m. then increased again where it reached 12 % at 6.0 p.m.

This is because the PV panel is less efficient at converting SR into electricity at low solar irradiance levels. The TE of a solar panel is an important factor that determines how much sunlight can be converted into electricity. A solar panel with a high transmission efficiency will generate more electricity from a given amount of sunlight than a solar panel with a low transmission efficiency. There are a number of factors that affect the transmission efficiency of a solar panel, including the type of semiconductor material used, the purity of the semiconductor material, the thickness of the semiconductor material, the design of the solar cell, and the operating temperature of the solar cell. The transmission efficiency of a solar panel can be improved by using a semiconductor material with a high band gap and a low defect density, using a thin semiconductor material, using a design that minimizes the amount of light that is reflected by the solar panel, and using a cooling system to keep the solar panel cool.

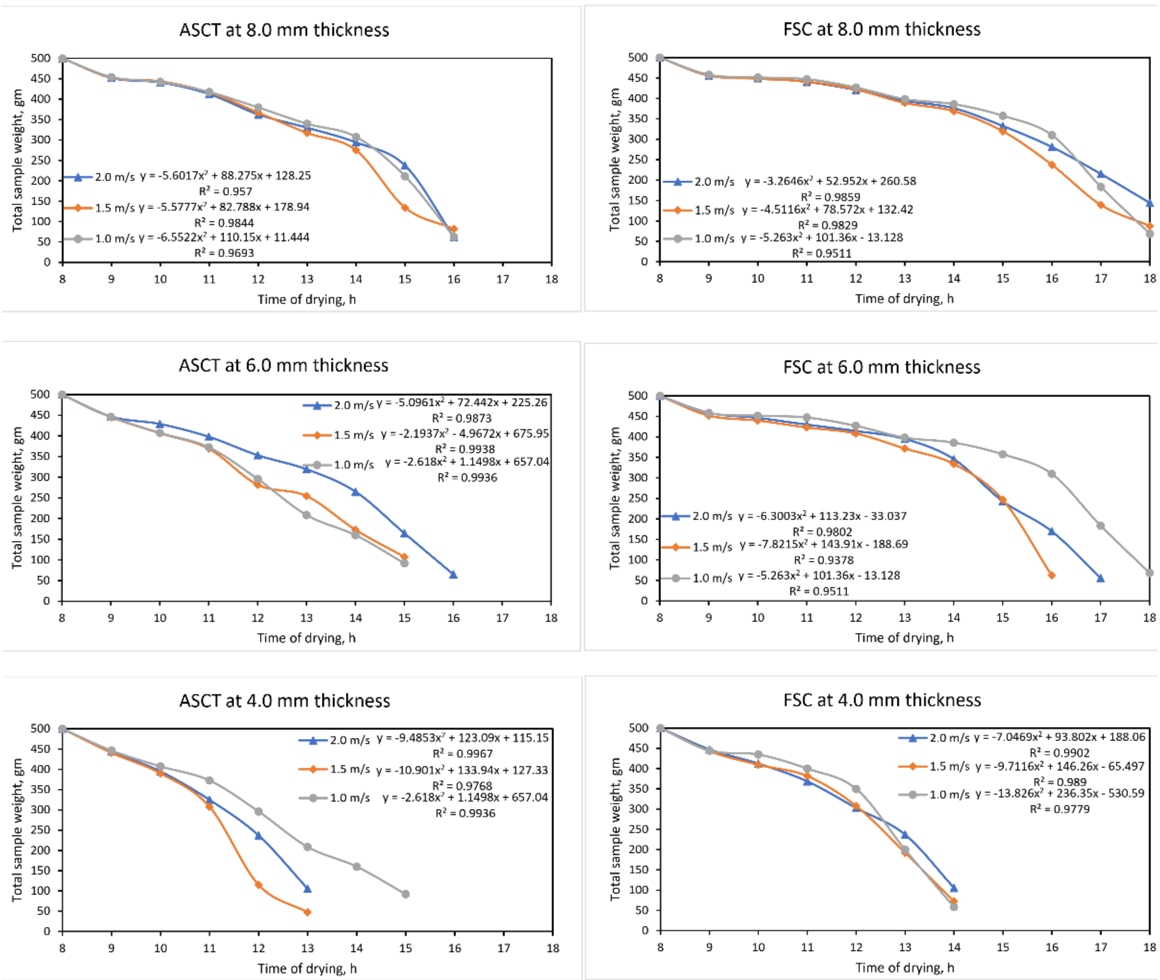


Figure 6. The reduction on total sample weight versus time of drying for the SD with ASCT and SD with FSC at different thicknesses of TS.

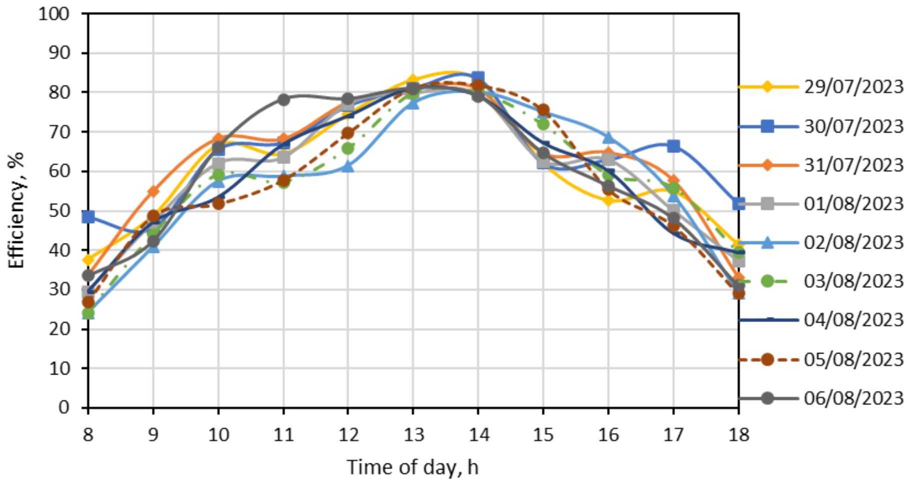


Figure 7a. Thermal efficiency of the SC, a. ASCT, and b. FSC.

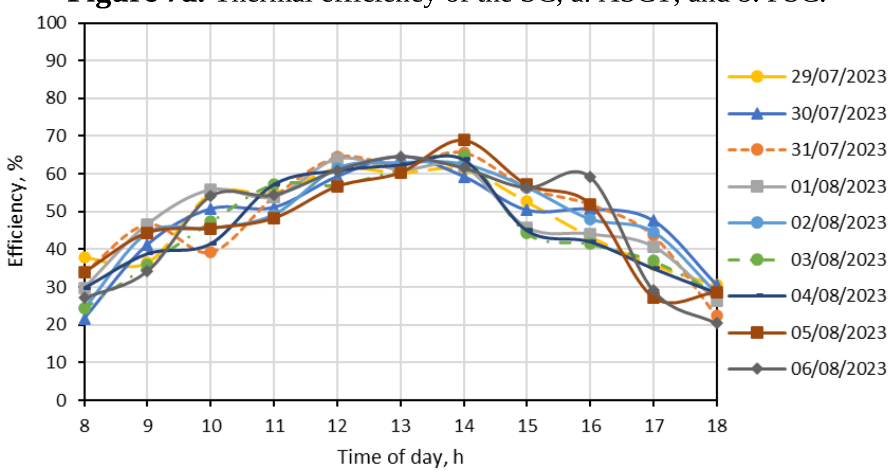


Figure 7b. Thermal efficiency of the SC, a. ASCT, and b. FSC.

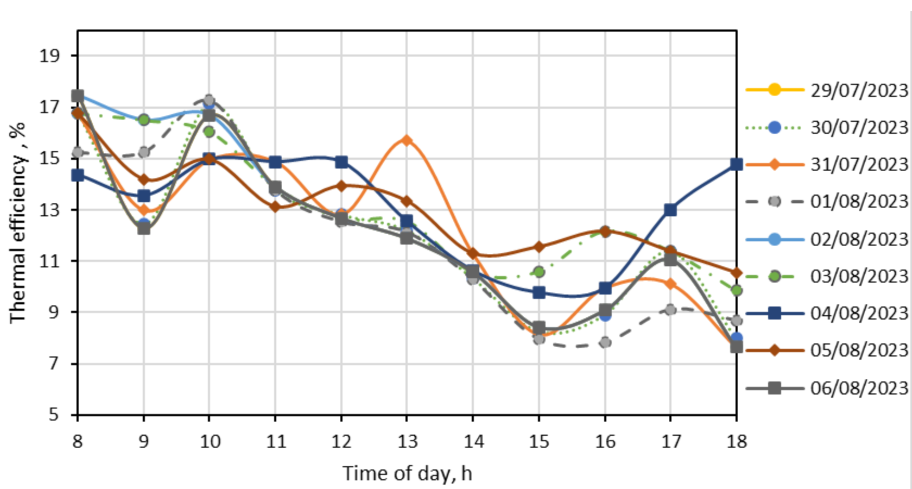


Figure 8. Thermal efficiency of the PV system.

Table 3. Some studies in the literature examining the TE of the SC.

Reference	DC type	TE of traditional SC	TE of tracking SC	Increasing ratio of TE
ElGamal et al., (2021)	Solar air heater	--	45%	--
Bhowmik and Amin, (2017)	Flat plate SC	--	--	10%
Zheng et al., (2016)	Parabolic concentrator SC	--	60.5%	--
Zou et al., (2016)	Small-sized parabolic trough SC	--	67%	--
Chamsa-ard et al., (2014)	Heat pipe evacuated tube with a SC	--	78%.	--
Rittidech et al., (2009)	Circular glass tube SC	--	76%	--
Wei et al., (2013)	Flat plate heat SC	--	66%	--
Verma et al., (2020)	Single spiral shaped SC tube	--	--	21.94%
Ramachandran et al., (2022)	Flat plate SC integrated scheffler solar concentrator	--	--	6%
Das and Akpinar, (2020)	SD integrated with ASCT	--	75.7 %	--
Elwakeel et al., (2023)	Flat plate solar dryer	75 %	--	--
Current study	Flat plate SC integrated with ASCT	61.6 %	83.2 %	21.6 %

4. Conclusion and future work

In the current study, the effect of different engineering factors in utilizing the use of SE in drying TF fruits was studied. The performance of an SD equipped with an FSC was compared to another equipped with a solar collector that automatically tracks the movement of the sun (ASCT). The effect of hot air speed and its effect on Drying time for TF fruits, as three AVs were used, namely 1, 1.5, and 2 m/s. The effect of the thickness of TSs on the drying time for TF fruits was also studied, as three thicknesses of TS were used, namely 4, 6, and 8 mm.

The results showed the following: The ASCT reaches a peak air temperature of 65°C, while the FSC reaches a peak air temperature of 55°C. This 10°C difference in air temperature can have a significant impact on drying times; the field evaluation results for both SD merged with ASCT and FSC are comparatively stable over AV values of 1.5 m/s to 2 m/s; the time needed to dry TS was reduced by 20% to 25% when the developed ASCT was used; using of ASCT led to increase the TE of the SC by about 17 %; Maximum TE of the PV system was about 17% at 8.0 a.m. then the TE decreased with increasing the surface temperature of the PV system where the lowest TE was 10% at 3.0 p.m. then increased again where it reached 12 % at 6.0 p.m.

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