Performance and Quality Assessment of Solar Tunnel Drying for Peaches and Tomatoes

Badruldeen Alsayid Salim Abouryaq
Faculty of Agriculture, Zawiya University, Libya.
b.abouryaq@zu.edu.ly
https://orcid.org/0009-0005-9057-8029

Received: 18/05/2026 - Revised: 18/06/2026 - Accepted: 28/06/2026 - Published: 18/07/2026

ABSTRACT
The use of solar energy offers an environmentally friendly and cost-effective solution for drying agricultural products, particularly in regions with abundant solar radiation such as Libya. This study investigates the technical feasibility and drying performance of an off-grid solar-powered drying system designed for agricultural applications. The proposed system integrates solar photovoltaic technology with battery storage to provide a reliable energy supply for the drying process while reducing dependence on conventional energy sources. The experimental evaluation compared two solar drying techniques: open sun drying and forced-convection drying inside a solar tunnel dryer. Peaches and tomatoes were selected as representative agricultural products and were dried at three slice thicknesses (3, 5, and 7 mm). Drying performance was assessed based on drying time, moisture removal efficiency, physicochemical characteristics, rehydration capacity, antioxidant activity, total phenolic content, and sensory quality.
The results demonstrated that the 3 mm slice thickness consistently achieved the shortest drying time and the highest overall product quality for both peaches and tomatoes. Compared with traditional open sun drying, the solar tunnel dryer significantly improved drying efficiency, enhanced the retention of nutritional and bioactive compounds, increased rehydration capacity, and produced better sensory characteristics. These findings confirm that solar-powered tunnel drying is an effective and sustainable technology for preserving agricultural products while improving product quality and reducing post-harvest losses.
Keywords: Solar energy, Photovoltaic system, Solar drying, Agricultural products, Solar tunnel dryer, Sustainable agriculture.

1. Introduction

Drying is one of the most widely used post-harvest preservation methods for agricultural products. By reducing moisture content to a safe level, drying suppresses microbial growth, slows biochemical deterioration, and extends the storage life of fruits and vegetables. In addition to minimizing post-harvest losses, the drying process decreases storage and transportation costs while providing consumers with high-quality products that remain available beyond the harvesting season (Abe-Inge et al., 2018; Doymaz, 2011; Zielinska and Markowski, 2016; Amit et al., 2017). Proper drying also contributes to reducing food waste by utilizing products that may not meet fresh-market standards.

Among horticultural crops, peaches and tomatoes are highly perishable because of their high moisture content. Their quality rapidly deteriorates after harvest unless appropriate preservation techniques are applied. Drying is considered one of the most effective methods for extending the shelf life of these products while maintaining their nutritional and sensory characteristics. Previous studies have shown that appropriate drying conditions help preserve valuable compounds such as vitamin C, β-carotene, lycopene, phenolic compounds, and antioxidants, thereby improving the quality and market value of dried products (Karathanos et al., 1995; Babalis and Belessiotis, 2004; Zanoni et al., 1999).

Traditional open sun drying remains common in many developing countries because of its simplicity and low operating cost. In this method, agricultural products are directly exposed to sunlight and ambient air on trays or ground surfaces. Although this technique requires little investment, it has several disadvantages, including long drying periods, dependence on weather conditions, non-uniform drying, and considerable exposure to dust, insects, birds, and other environmental contaminants. In addition, fluctuations in solar radiation, temperature, and humidity often reduce the nutritional quality and overall safety of the dried products (Sadler et al., 2019; Energypedia, 2023).

To overcome these limitations, solar drying technologies have received increasing attention as sustainable alternatives to conventional sun drying. Solar dryers provide a more controlled drying environment by improving air circulation, increasing drying temperature, and protecting products from external contamination. These improvements enhance drying efficiency while preserving the physical, chemical, and sensory quality of agricultural products. Under properly designed solar drying systems, suitable drying temperatures and airflow conditions can be maintained, leading to shorter drying times and better product quality compared with traditional open-air drying (Kumar et al., 2016; Sharma et al., 2021).

Among different solar drying technologies, forced-convection solar tunnel dryers have demonstrated excellent performance for drying fruits and vegetables. Air heated by solar energy is circulated through the drying chamber, allowing better control of drying conditions and more uniform moisture removal. Compared with open sun drying, solar tunnel drying reduces drying time, improves energy utilization, enhances product hygiene, and better preserves nutritional compounds and sensory attributes (Vega-Gálvez et al., 2012; Mujumdar, 2006).

The performance of any drying system is strongly influenced by operating parameters such as drying temperature, air velocity, and product thickness. Appropriate control of these variables accelerates moisture removal while minimizing quality deterioration caused by excessive heating. For fruits and vegetables, drying temperatures between 55 and 65°C combined with moderate air velocities have been reported to provide efficient drying without causing significant damage to heat-sensitive components. Likewise, slice thickness plays an important role in determining drying rate, moisture diffusion, and final product quality (Doymaz, 2007; Piga et al., 2004).

The availability of abundant solar radiation throughout most regions of Libya makes solar energy an attractive and environmentally friendly source for agricultural drying applications. Solar-powered drying systems can significantly reduce dependence on fossil fuels, lower operating costs, and contribute to sustainable agricultural production, particularly in remote areas where access to conventional electricity may be limited.

Therefore, the objective of this study was to develop and evaluate a solar-powered drying system for agricultural products using photovoltaic energy as the primary power source. The study compared traditional open sun drying with forced-convection solar tunnel drying using peach and tomato slices of different thicknesses. Drying performance was evaluated in terms of drying efficiency, moisture removal, physicochemical properties, antioxidant activity, phenolic compounds, rehydration characteristics, and sensory quality to determine the most suitable drying conditions for producing high-quality dried agricultural products.

2. Materials and methods

2.1. Materials:

2.1.1. Experimental Site

The experimental work was carried out at a designated agricultural research site in the Zawiya region of Libya, between September 2025 and March 2026. The study was conducted to develop and evaluate a solar-powered tunnel drying system for agricultural products under Libyan climatic conditions, specifically those prevailing in the coastal and semi-arid zones of western Libya. The Zawiya region was selected due to its representative Mediterranean climate, with high solar irradiance, moderate humidity, and seasonal temperature variations that are typical of many agricultural areas in Libya. The developed system was designed to provide an efficient and sustainable drying technique suitable for small-scale agricultural applications while utilizing solar energy as the primary renewable energy source. This location also offered practical advantages, including proximity to local fruit and vegetable farms, accessibility for monitoring and maintenance, and relevance to the broader Libyan context where post-harvest losses remain a significant challenge.

2.1.2. Raw material:

Peach samples (*Prunus persica L.*)

Fresh fruits of the Desert Red peach cultivar were obtained from local farms and markets in the Zawiya region of Libya during the local harvesting season. Only healthy fruits having uniform maturity, size, and color, and free from mechanical damage or fungal infection, were selected for the experiments. The average initial moisture content of the fresh peaches was 90 ± 1% (wet basis).

Tomato (Solanum lycopersicum L.)

Fresh fruits of the Castle Rock tomato cultivar were purchased from the same local markets in the Zawiya area during the commercial harvesting season. Uniform fruits with similar size, ripeness, and appearance were selected. The average initial moisture content was 90 ± 1.2% (wet basis).

Immediately after purchase, all samples were transported to the designated research laboratory in the Zawiya region, where they were washed with clean water, sorted, and prepared for drying within 24 h to preserve their original quality.

2.1.3. Solar-Powered drying system

A photovoltaic-powered tunnel dryer was developed to provide a controlled drying environment using renewable solar energy. The system consisted of a photovoltaic (PV) panel connected to a charge controller, a battery storage unit, a DC circulation fan, and an electric auxiliary heater used only when the drying temperature dropped below the desired level during unfavorable weather conditions.

The photovoltaic module converted solar radiation into electrical energy, which was stored in rechargeable batteries and supplied to the control unit and airflow system. The battery ensured continuous operation of the fan and monitoring devices during periods of fluctuating solar radiation.

The drying chamber measured 150 × 60 × 50 cm and was covered with transparent polyethylene film (200 μm thickness). The tunnel was oriented in the east–west direction to maximize solar radiation throughout the day. Stainless-steel mesh trays were installed inside the drying chamber to provide uniform airflow around the samples.

The airflow inside the tunnel was maintained at approximately 2.5 m s⁻¹, while drying temperature was maintained near 40 ± 2°C under normal operating conditions
(Figures 1 and 2).

1. Steel structural framework
2. The base and tunnel floor
3. Product drying trays
4. Transparent reticular covering
5. Electronic control and monitoring unit
6. Integrated photovoltaic panel

Figure 1. Solar energy system schematic diagram

Figure 2. The solar tunnel dryer used for drying peach and tomato slices

2.1.4. Instrumentation and environmental monitoring

The drying system incorporated an Arduino Mega 2560 microcontroller to monitor and record environmental conditions during drying.

Temperature and relative humidity were continuously measured using three calibrated DHT22 sensors installed inside and outside the drying chamber. A UV sensor (VEML6070) monitored solar ultraviolet intensity, while a load-cell sensor continuously measured sample weight to determine moisture loss throughout the drying process.
Sensor readings were automatically recorded every 10 min on a micro-SD memory card. A real-time clock (DS1307) synchronized all measurements with the corresponding drying time.
To improve drying efficiency, a DC ventilation fan continuously circulated heated air inside the tunnel while periodically removing moisture-saturated air and replacing it with fresh ambient air.
.

2.1.5. Drying treatments

Two drying methods were evaluated:

- Traditional open sun drying.
- Solar tunnel drying using the developed photovoltaic-powered drying system.

For both methods, peach and tomato slices were prepared in three thickness levels:

- 3 mm
- 5 mm
- 7 mm

All samples were arranged in a single layer on stainless-steel mesh trays without overlap to ensure uniform exposure to drying air.

2.1.6. Open sun drying

For comparison purposes, identical samples were dried under direct sunlight on elevated mesh trays located adjacent to the solar tunnel dryer. Fine protective mesh was placed over the trays to minimize contamination by insects and dust while allowing unrestricted natural airflow. All samples were exposed to identical ambient weather conditions throughout the drying period

2.1.7. Drying procedure

Drying experiments were conducted during clear sunny days between 07:30 and 17:00 h**.**
Sample weight was recorded every **30 min** until constant weight was achieved. Drying continued until the moisture content reached the safe storage level recommended for dried fruits and vegetables.
After drying, the samples were cooled to room temperature, packed in low-density polyethylene bags, and stored until physicochemical, biochemical, and sensory analyses were performed.

2.1.8. Experimental design

The experiment followed a factorial arrangement involving three independent variables:

- Drying method (open sun drying and solar tunnel drying).
- Agricultural product (peach and tomato).
- Slice thickness (3, 5, and 7 mm).

Each treatment was replicated three times.

2.2. Methods

2.2.1. Sample preparation

Fresh peaches and tomatoes were carefully selected at the commercial maturity stage based on uniformity in size, color, and ripeness. Fruits showing any signs of mechanical damage, disease, or physiological defects were discarded. Selected samples were washed thoroughly under running tap water to remove dust and surface impurities, followed by gentle drying with clean absorbent cloths to eliminate excess surface moisture.
The initial moisture content of fresh samples was determined using the standard oven-drying method at 105°Cuntil constant weight was achieved. The average initial moisture contents were approximately 90 ± 1.0% (wet basis) for peaches and 90 ± 1.2% (wet basis) for tomatoes.
Each fruit was weighed individually using a digital balance with an accuracy of ±0.1 g. Peaches were peeled, cut into halves, and their stones removed before slicing, whereas tomatoes were halved and sliced after removing excess seeds to improve drying uniformity. Samples were cut into three thickness levels (3, 5, and 7 mm) using a mechanical slicer, and slice thickness was verified with a digital caliper (±0.2 mm).

Immediately before drying, all slices were weighed and arranged in a single layer on stainless-steel mesh trays to prevent overlapping and ensure uniform exposure to drying air. During drying, air velocity at the sample surface was measured using a hot-wire anemometer (Testo 405-V1, Germany) with an accuracy of ±0.1 m s^{-1}.

2.2.2. Drying procedures

Two drying methods were investigated:

Open sun drying

Solar tunnel drying

For both methods, fruit slices were distributed uniformly on perforated drying trays (60 × 40 cm) at a loading density of 2.5 kg m^{-2}. Samples were arranged in a single layer without overlap to ensure homogeneous drying conditions.

Drying experiments were conducted under similar climatic conditions. Sample weight was recorded every 30 min until the desired final moisture content suitable for safe storage was reached.

2.3. Analytical measurements

2.3.1. Moisture content and drying characteristics

Initial moisture content

The initial moisture content of fresh samples was determined according to the AOAC oven-drying method at 105°C until constant weight.

The moisture content on a wet basis was calculated as:

$$M_{iw} = \frac{Wm}{Wt} \times 100 \qquad (w_b) \rightarrow (1)$$

Where:

- $\mathbf{M_{iw}}$ is the moisture content on a w.b. (%),
- $\mathbf{W_m}$ is the moisture content in the sample (g), and
- $\mathbf{W_t}$ is the sample mass (g) at that time.

Moisture content during drying

Moisture content at any drying time was calculated using:

$$M_t = \frac{W_t - W_o(1 - m_o)}{W_t} \qquad (2)$$

Where:

- $\mathbf{M_t}$ is the moisture content at any time,
- $\mathbf{W_t}$ is the sample mass (g) at that time,
- $\mathbf{W_o}$ is the fresh sample mass (g), and
- $\mathbf{m_o}$ is the initial moisture percentage (w.b.%).

Moisture ratio (MR)

The moisture ratio was calculated as:

$$MR = \frac{M_t - M_e}{M_i - M_e} \qquad (3)$$

Where:

-$\mathbf{M_i}$ is the initial moisture content (w.b.%),

-$\mathbf{M_t}$ is the moisture percentage at any time during drying (w.b.%), and

-$\mathbf{M_e}$ is the equilibrium moisture (w.b.%).

Drying rate

The drying rate was determined using:

$$DR = \frac{M_{t-dt} - M_t}{dt} \qquad (g/min) \ (4)$$

Where:

- $\mathbf{M_t}$ - $\mathbf{d_t}$ and M_t are the moisture contents at times t - dt and t, respectively,
- $\mathbf{d_t}$ is the drying period (in hours).

2.3.2. Physicochemical properties

pH

The pH of dried samples was measured using a calibrated digital pH meter (Jenway 3505, UK) following the AOAC (2016) standard procedure.

Titratable acidity

Titratable acidity was determined according to Araújo et al. (2020). Approximately 2 g of dried sample was mixed with 50 mL of distilled water and stirred for 20 min before titration with 0.1 M NaOH using phenolphthalein as an indicator. Results were expressed as g malic acid per 100 g dry sample.

Water activity

Water activity (aw) was measured at 25°Cusing an Aqualab CX-2 water activity meter (Decagon Devices Inc., USA) according to Lewicki and Lukaszuk (2000).

Rehydration ratio

Rehydration capacity was evaluated by immersing 5 gof dried sample in 300 mLof distilled water at room temperature. After rehydration, the samples were drained and weighed.

The rehydration ratio was calculated as:

$$RR = \frac{W_r}{W_d} \qquad (5)$$

Where:

-RR: Rehydration ratio (dimensionless),

-W_r: Weight of the sample after rehydration (g),

W_d: Weight of the dried sample before soaking (g).

2.3.3. Biochemical analysis

Reducing sugars

Reducing sugar content was determined following the method described by Anjos (2019). Absorbance was measured at 540 nmusing a UV–Visible spectrophotometer.

Total phenolic content

Total phenolic compounds were determined using the Folin–Ciocalteu method after methanolic extraction of the dried samples. Absorbance was measured after 90 min of incubation in darkness according to Yu (2018).

Antioxidant Activity

Antioxidant activity was evaluated using the DPPH free radical scavenging assay. Sample absorbance was measured at 517 nmafter one hour of incubation at room temperature.

2.3.4. Sensory evaluation

Sensory quality was assessed by a trained panel of 20 faculty members and staff from the Faculty of Agriculture, Zawiya University, Libya. The dried samples were evaluated for color, aroma, taste, texture, and overall acceptability using a 10-point hedonic scale according to the procedure described by Gallali (2000).

2.3.5. Statistical analysis

All experiments were conducted in triplicate, and the results are presented as the mean ± standard deviation. Statistical analyses were performed using SPSS software (Version 22.0, IBM Corp., USA). A two-way analysis of variance (ANOVA) was applied to evaluate the effects of drying method, slice thickness, and their interactions. Differences among treatment means were considered statistically significant at $P < 0.05$.

3. Results and discussion

3.1. Performance of the solar-powered drying system

The developed drying system was powered by a photovoltaic (PV) module coupled with a rechargeable battery to supply electrical energy for the ventilation fan and the electronic monitoring unit. During daylight hours, solar radiation was converted into electrical energy by the PV panel and stored in the battery through a charge controller to ensure continuous operation despite fluctuations in solar irradiance.

The drying chamber maintained an average drying temperature of 40 ± 2°C during the experimental period, while the DC circulation fan operated continuously to provide uniform airflow across the drying trays. Continuous ventilation enhanced heat and mass transfer inside the drying chamber, accelerated moisture removal, and improved drying uniformity compared with open sun drying.

The electrical energy required for fan operation was calculated according to:

$$E = P \times t$$

where:
E= electrical energy consumption (Wh),
P= electrical power (W),
t= operating time (h).

Since the circulation fan had a rated power of 18 W and operated continuously for 24 h, the total daily electrical energy consumption was:

$E = 18 \times 24 = 432$ Wh day^{-1}

The operating current supplied to the fan was calculated as:

$$I = P/V$$

where:
I = electric current (A),
P = electrical power (W),
V= operating voltage (12 V).
Accordingly,
$I = 18/12 = 1.5$ A

The low electrical demand of the ventilation system demonstrates that the developed solar-powered dryer can operate efficiently using a small photovoltaic power supply with battery storage, making the system suitable for agricultural applications in remote areas where grid electricity is unavailable or unreliable.

Table 1. Electrical characteristics of the solar-powered drying system

Parameter	Value
Photovoltaic panel power	40 W
Operating voltage	12 V
Fan power	18 W
Operating current	1.5 A
Fan operating time	24 h day^{-1}
Daily energy consumption	432 Wh day^{-1}

3.2 Drying kinetics

3.2.1. Moisture content

Figures 3 and 4 present the changes in moisture content of peach and tomato slices with different slice thicknesses during open sun drying and solar tunnel drying. The initial moisture content of both products was approximately 90% (wet basis), with slight variations of less than ±1.5%. All drying experiments were carried out under similar climatic conditions during the summer season, beginning at 07:00 h.

For peach slices, the solar tunnel dryer considerably accelerated moisture removal compared with conventional sun drying (Figures 7 and 8). The 3 mm slices reached the target moisture content of approximately 10% after 8 h, whereas the 5 mm slices required about 10 h. The thickest slices (7 mm) reached a final moisture content of approximately 14–15% after nearly 10 h of drying. In contrast, open sun drying required substantially longer drying periods. Peach slices of 3, 5, and 7 mm thickness required approximately 36, 48, and more than 54 h, respectively, to approach comparable final moisture contents.

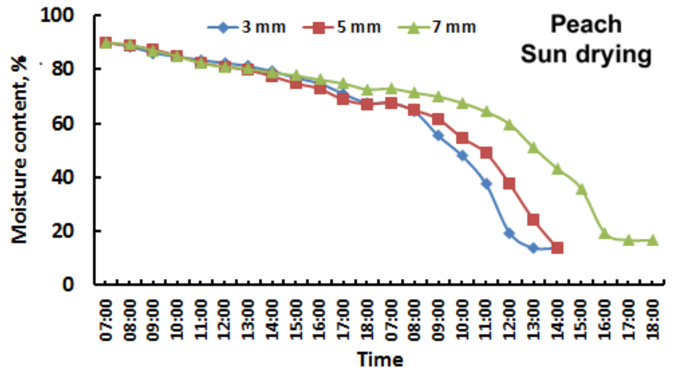


Figure 3. Effect of slice thickness on the moisture content of peach slices during open sun drying.

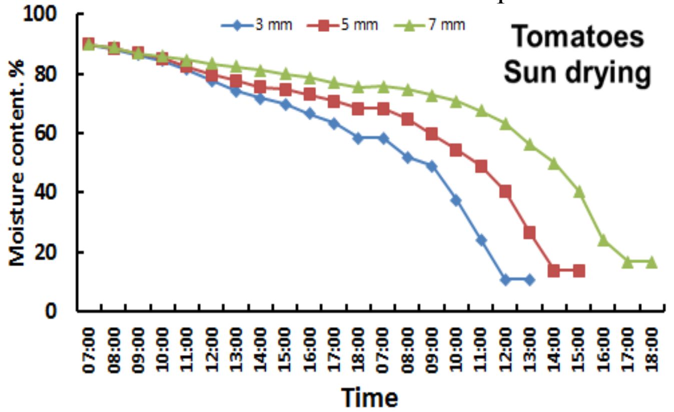


Figure 4. Effect of slice thickness on the moisture content of tomato slices during open sun drying.

A similar drying behavior was observed for tomato slices (Figures 5 and 6). Under solar tunnel drying, the 3 mm slices reached approximately 9% moisture after 7 h, while the 5 and 7 mm slices required about 9 h and 10 h, respectively. Conversely, under open sun drying, drying times increased markedly to approximately 34 h for 3 mm slices, 46 h for 5 mm slices, and more than 52 hfor 7 mm slices before reaching final moisture contents ranging from 14 to 17%.

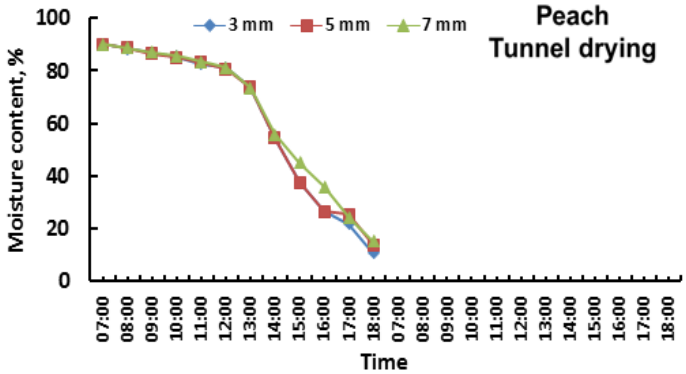


Figure 5. Effect of slice thickness on the moisture content of peach slices during solar tunnel drying.

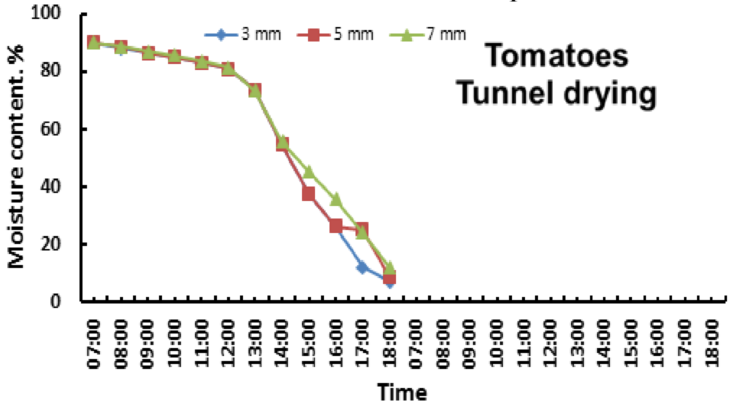


Figure 6. Effect of slice thickness on the moisture content of tomato slices during solar tunnel drying.

The faster drying observed for tomatoes during the initial stage can be attributed to the presence of higher free surface moisture and their relatively thinner epidermal layer, which facilitates moisture migration. Nevertheless, both crops exhibited similar final moisture contents under identical drying conditions.

Overall, reducing slice thickness significantly enhanced the drying process regardless of the drying method. However, the effect was considerably more pronounced in the solar tunnel dryer, which consistently produced shorter drying times and greater moisture removal efficiency than traditional open sun drying. The controlled drying environment, characterized by higher air temperature, continuous airflow, and protection from external environmental fluctuations, substantially improved heat and mass transfer, making the solar tunnel dryer a more efficient technique for drying both peaches and tomatoes.

The present findings are consistent with those reported by Doymaz (2007), who observed that reducing slice thickness significantly accelerated moisture removal during convective drying. Similar improvements in drying efficiency under solar tunnel drying were also reported by Vega-Gálvez et al. (2012), confirming that controlled drying environments enhance both drying rate and final product quality.

3.2.2. Moisture ratio

Figures 7 - 10 illustrate the variation in moisture ratio (MR) of peach and tomato slices with different slice thicknesses during open sun drying and solar tunnel drying. In all treatments, the moisture ratio decreased continuously with drying time, exhibiting the typical exponential behavior commonly observed during the drying of biological materials.

During the initial drying period (07:00–11:00 h), both drying methods showed similar moisture removal characteristics, with the moisture ratio decreasing from an initial value of 1.0 to approximately 0.92–0.94. This stage was mainly governed by the evaporation of free surface moisture, resulting in comparable drying behavior under both drying conditions.

As drying progressed, the effect of the drying method became increasingly evident. After 11:00 h, when solar radiation and the internal air temperature of the solar tunnel increased, moisture removal accelerated considerably in the tunnel dryer. By the end of the first drying day (18:00 h), the moisture ratio of the 3 mm peach slices decreased to approximately 0.073 under solar tunnel drying, whereas the corresponding value under open sun drying remained substantially higher, requiring nearly two days to reach a similar moisture ratio. A comparable trend was observed for tomato slices, where the 3 mm samples reached a moisture ratio of approximately 0.034 after only one day of tunnel drying.

Slice thickness had a pronounced influence on moisture diffusion throughout the drying process. Thinner slices consistently exhibited lower moisture ratios than thicker slices at the same drying time because of the shorter diffusion path available for moisture migration. For example, under solar tunnel drying, the moisture ratio of the 3 mm peach slices decreased to approximately 0.256 by 16:00 h, whereas the 7 mm slices remained at approximately 0.367. Under open sun drying, the influence of slice thickness was even more pronounced, with the 7 mm slices requiring more than one additional day to achieve moisture ratios comparable to those of the 3 mm slices.

Tomato slices generally dried faster than peach slices throughout the drying process. This behavior is attributed to the higher proportion of free water and the relatively thinner cellular structure of tomato tissues, which facilitate moisture diffusion and evaporation. Nevertheless, both products followed similar drying trends, with rapid moisture removal during the initial drying stage followed by a gradual decrease in drying rate as internal moisture diffusion became the controlling mechanism.

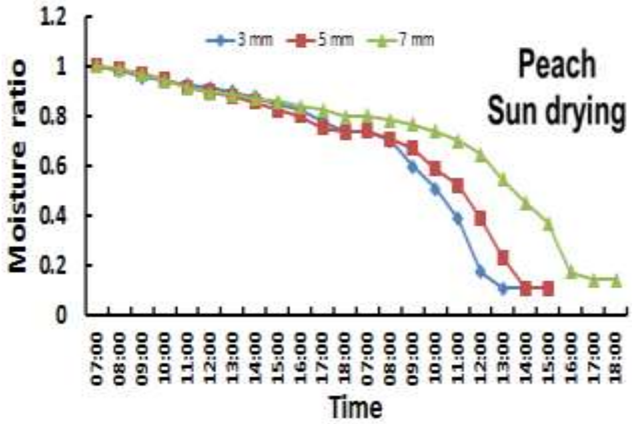


Figure 7. Effect of slice thickness on the moisture ratio of peach slices during open sun drying.

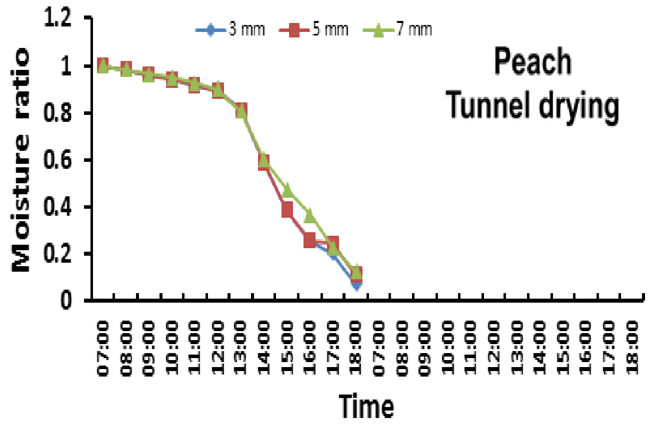


Figure 8. Effect of slice thickness on the moisture ratio of peach slices during solar tunnel drying.

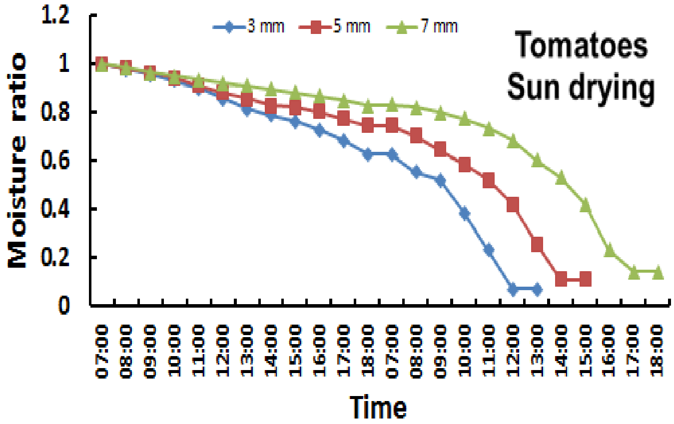


Figure 9. Effect of slice thickness on the moisture ratio of tomato slices during open sun drying.

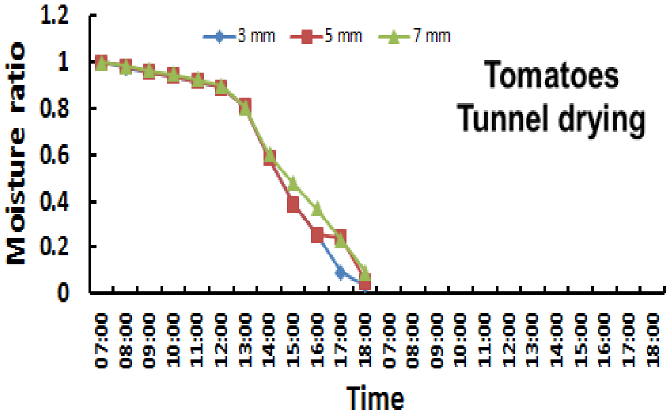


Figure 10. Effect of slice thickness on the moisture ratio of tomato slices during solar tunnel drying.

Overall, the solar tunnel dryer consistently produced lower moisture ratio values than open sun drying for all slice thicknesses, confirming its superior drying performance. The enhanced heat transfer, continuous air circulation, and more stable drying environment inside the tunnel accelerated moisture diffusion and shortened the overall drying period. These findings are in agreement with previous studies reported by Alam et al. (2020) and Ferreira and Freitas (2019), who demonstrated that controlled solar drying systems significantly improve moisture removal efficiency compared with traditional open-air drying.

3.2.3. Drying rate

Figures 11–14 illustrate the variation in drying rate of peach and tomato slices with different slice thicknesses during open sun drying and solar tunnel drying. In general, the drying rate increased rapidly during the initial stage of drying, reached its maximum during the period of highest solar intensity, and gradually declined as drying progressed. This behavior is characteristic of agricultural products, where moisture removal shifts from evaporation of free surface water to diffusion of bound moisture from the interior of the material.

During the early drying period (07:00–11:00 h), both drying methods exhibited relatively low and comparable drying rates, ranging from approximately 0.014 to 0.045 g water h^{-1}, because the drying air temperature and solar radiation were still relatively low. As solar radiation increased, the drying performance of the solar tunnel dryer improved markedly. Between 12:00 and 14:00 h, the tunnel dryer achieved the highest drying rates, reaching approximately 0.318 g water h^{-1} for the 3 mm slices, whereas the corresponding values under open sun drying remained between 0.041 and 0.045 g water h^{-1}.

Slice thickness had a significant influence on the drying rate throughout the experiments. Thinner slices consistently exhibited higher drying rates than thicker slices because of their larger surface-area-to-volume ratio and shorter internal moisture diffusion path. Under solar tunnel drying, the maximum drying rate of the 3 mm slices was approximately 1.7 times greater than that of the 7 mm slices. Under open sun drying, the influence of slice thickness was even more pronounced, with the 3 mm slices exhibiting drying rates up to 2.5 times higher than those of the thickest slices during the most active drying period.

The solar tunnel dryer maintained relatively high drying rates (greater than 0.15 g water h^{-1}) between 12:00 and 15:00 h, indicating a more stable and efficient drying environment. In contrast, open sun drying showed lower and more variable drying rates owing to fluctuations in ambient temperature, solar radiation, and air movement. Consequently, moisture removal proceeded more slowly, and the drying process required considerably longer to reach the desired final moisture content.

Tomato slices generally exhibited slightly higher drying rates than peach slices under identical drying conditions, particularly for the 3 mm treatment. This behavior can be attributed to differences in tissue structure and moisture distribution, as tomatoes contain a greater proportion of readily removable free water, which enhances moisture migration during the early stages of drying.

As the drying process continued, the drying rate gradually decreased for all treatments because the remaining moisture became increasingly bound within the plant tissues, causing internal moisture diffusion to become the rate-controlling mechanism. This behavior is consistent with the typical falling-rate drying period reported for most fruits and vegetables.

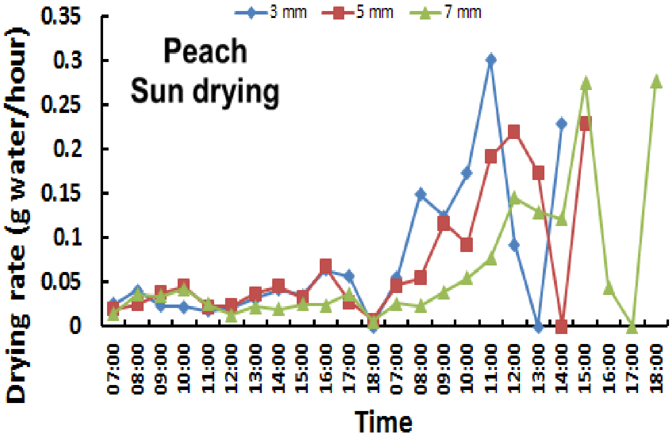


Figure 11. Effect of slice thickness on the drying rate of peach slices during open sun drying.

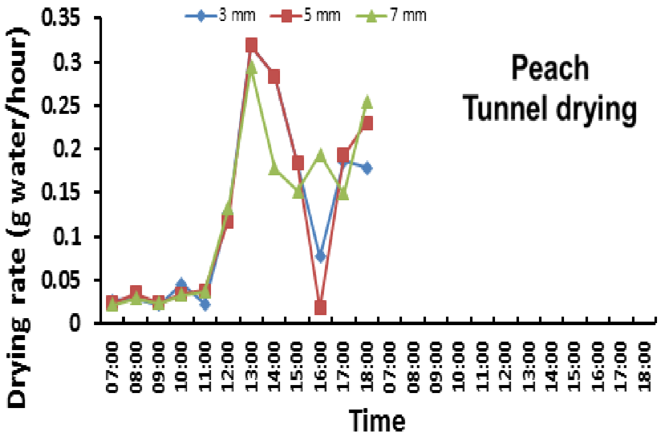


Figure 12. Effect of slice thickness on the drying rate of peach slices during solar tunnel drying.

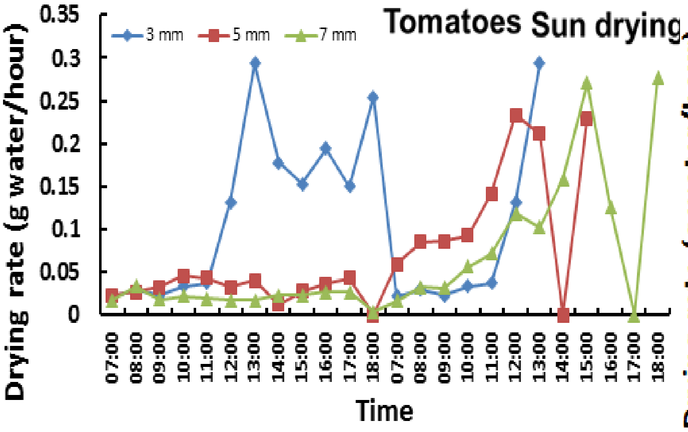


Figure **13**. Effect of slice thickness on the drying rate of tomato slices during open sun drying.

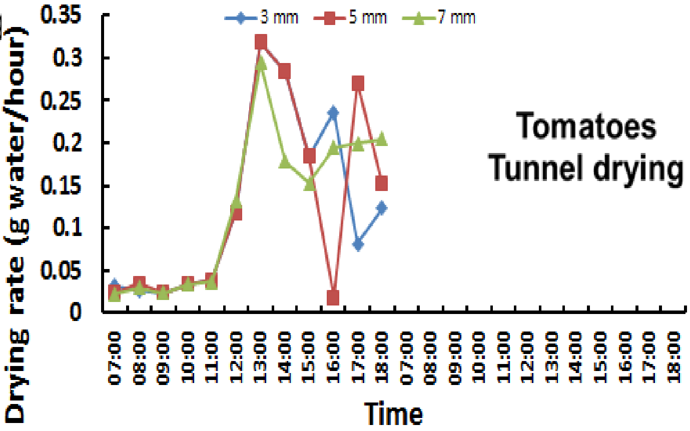


Figure 14. Effect of slice thickness on the drying rate of tomato slices during solar tunnel drying.

Overall, the solar tunnel dryer provided significantly higher drying rates than conventional open sun drying across all slice thicknesses. The combination of elevated air temperature, continuous forced airflow, and a protected drying environment enhanced heat and mass transfer, resulting in faster moisture removal and shorter drying times. These findings agree with those reported by Lahsasni et al. (2004) for prickly pear peel and Abul-Fadl et al. (2020) for grape, carrot, and okra, who also observed that controlled drying conditions substantially improve drying performance compared with traditional sun drying.

The enhanced drying performance observed in the solar tunnel dryer can be attributed to the combined effects of higher air temperature, continuous airflow, and reduced relative humidity inside the drying chamber. These conditions increase the vapor pressure gradient between the product surface and the surrounding air, thereby accelerating heat and mass transfer and promoting faster internal moisture diffusion. Consequently, the solar tunnel dryer achieved shorter drying times and higher drying efficiency than conventional open sun drying.

3.3. Physicochemical properties

3.3.1. Physicochemical properties of dried peach slices

Figures 15 and 16 present the effects of drying method and slice thickness on the physicochemical properties of peach slices. Drying significantly altered all measured quality attributes compared with fresh peaches, including pH, titratable acidity, water activity, and rehydration ratio.

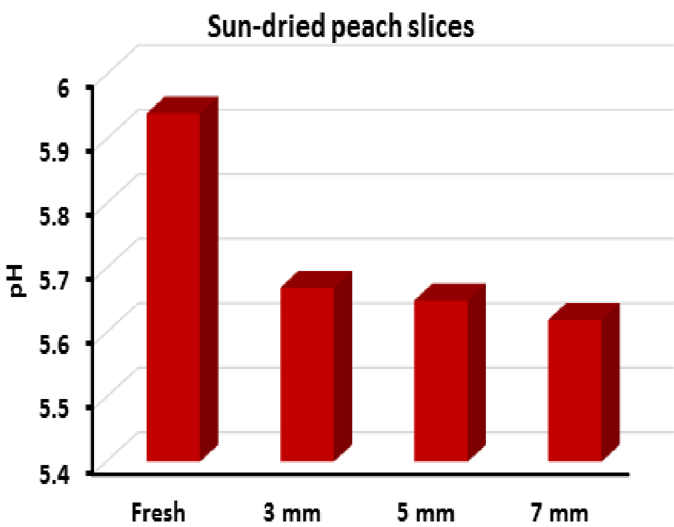
The pH of fresh peaches (5.94) decreased slightly after drying, indicating a moderate increase in acidity resulting from moisture removal and concentration of organic acids. The pH values ranged from 5.61 to 5.67 for open sun drying and from 5.59 to 5.64 for solar tunnel drying. Although the differences among slice thicknesses were relatively small, thinner slices generally exhibited slightly lower pH values, reflecting more effective moisture removal during drying. Similar observations have been reported by Ferreira and Freitas (2019) and Alam et al. (2020).

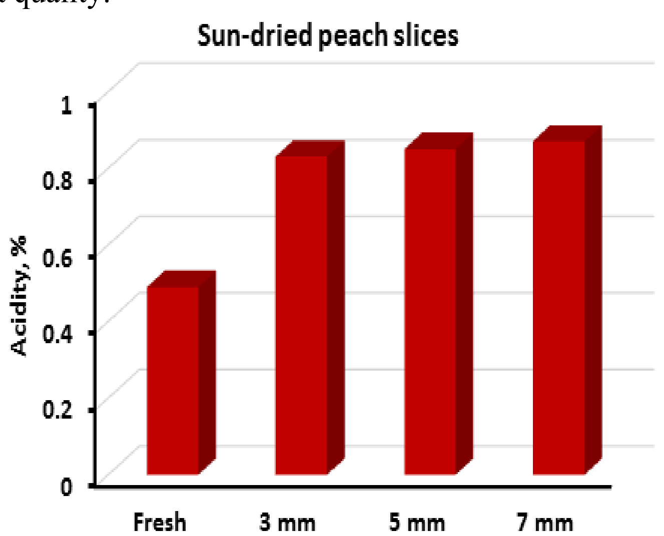
Titratable acidity increased noticeably after drying compared with the fresh fruit (0.49%). Open sun drying produced acidity values ranging from 0.82 to 0.87%, whereas solar tunnel drying resulted in slightly higher values (0.85–0.90%). The increase in acidity is mainly attributed to moisture loss, which concentrates naturally occurring organic acids within the fruit tissues. In addition, thicker slices tended to retain slightly higher acidity because of their slower moisture diffusion during drying.

Water activity was markedly reduced by both drying methods. Fresh peaches exhibited a water activity of 0.961, whereas dried samples ranged from 0.661 to 0.673 after open sun drying and from 0.631 to 0.651 after solar tunnel drying. The lower water activity achieved by the solar tunnel dryer indicates more efficient moisture removal and improved microbial stability, which contributes to extending product shelf life (Batista, 2014).

The rehydration ratio showed a clear improvement in tunnel-dried samples compared with sun-dried samples. Values ranged from 2.79 to 2.91 for open sun drying and from 3.04 to 3.15 for solar tunnel drying. Thinner slices consistently exhibited higher rehydration capacity, suggesting that rapid and uniform drying better preserved the internal cellular structure of the fruit. Similar relationships between drying conditions and rehydration capacity have been reported by Kaveh (2021).

Overall, solar tunnel drying produced superior physicochemical quality compared with conventional open sun drying. The controlled drying environment promoted lower water activity, improved rehydration capacity, and better preservation of quality attributes. Furthermore, reducing slice thickness enhanced drying efficiency and contributed to improved product quality.





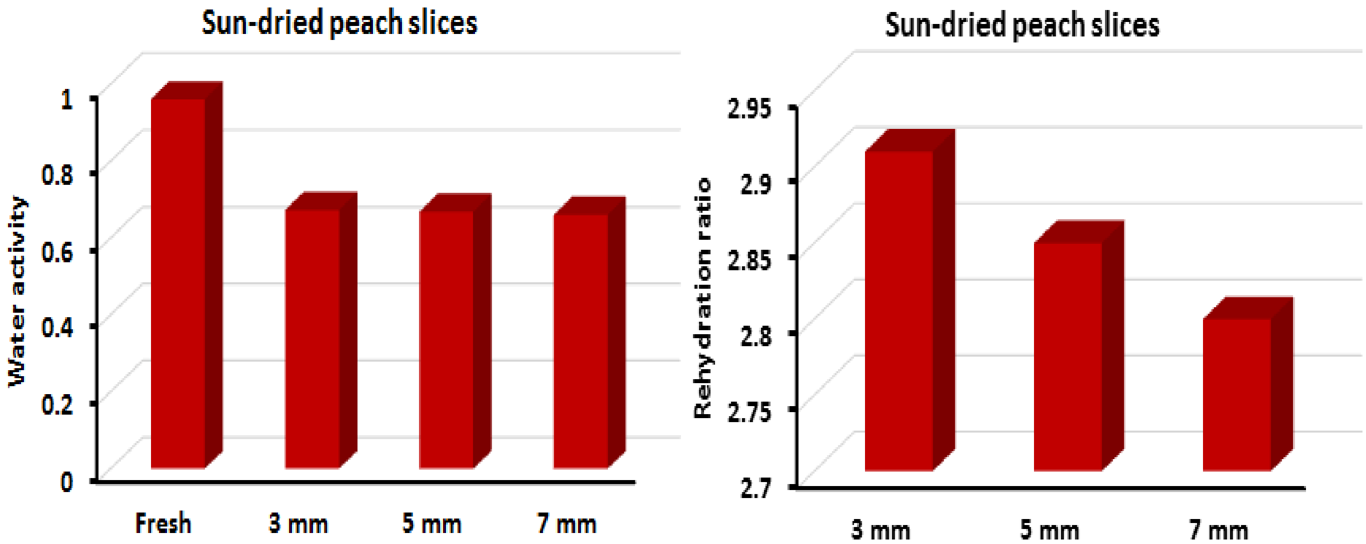


Figure 15. Effect of slice thickness on the physicochemical properties of peach slices during open sun drying.

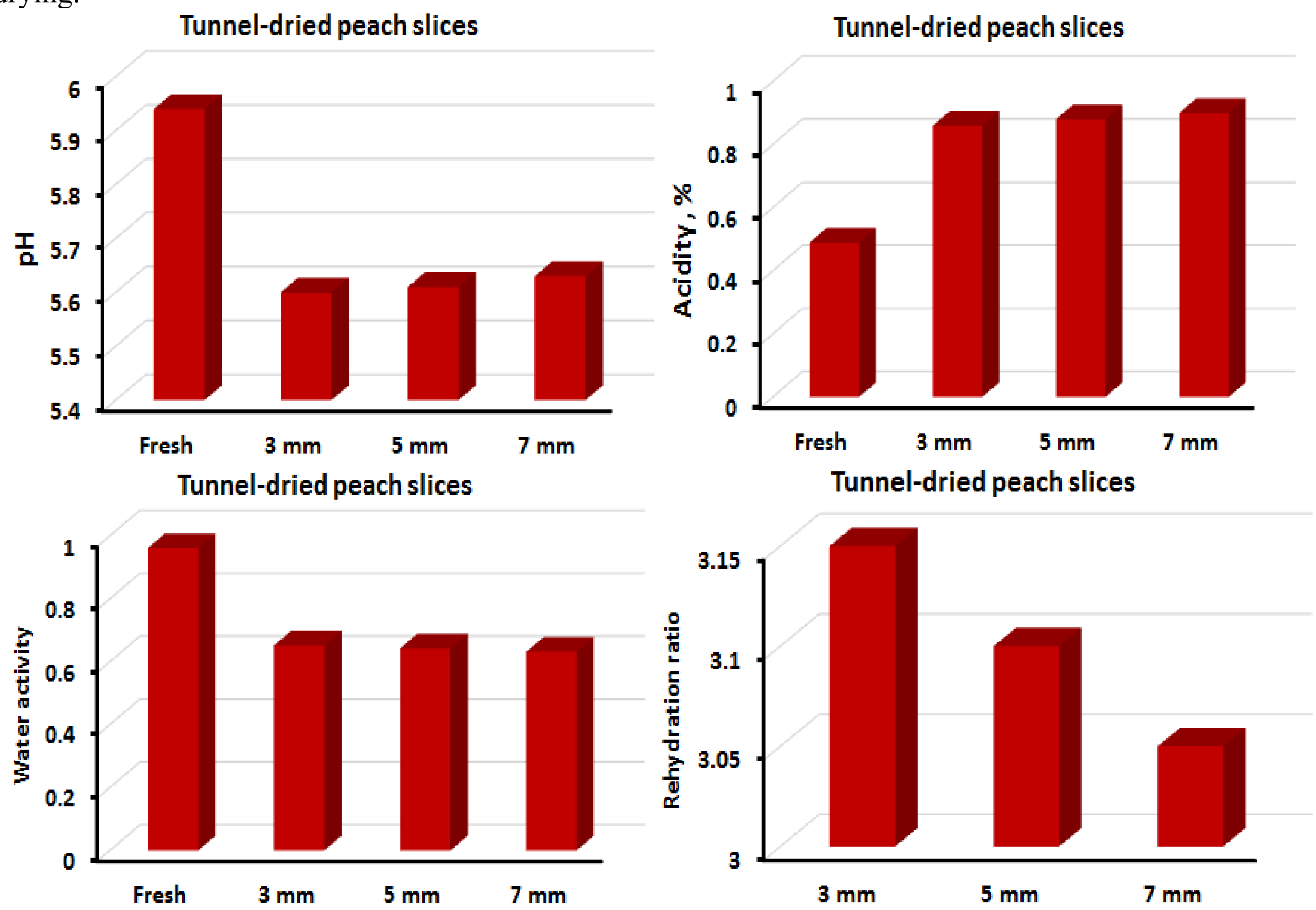


Figure 16. Effect of slice thickness on the physicochemical properties of peach slices during solar tunnel drying.

3.3.2. Physicochemical properties of dried tomato slices

Figures 17 and 18 illustrate the influence of drying method and slice thickness on the physicochemical properties of tomato slices. Similar to peaches, drying significantly affected pH, titratable acidity, water activity, and rehydration characteristics.

The pH of fresh tomatoes (4.19) decreased slightly after drying, with values ranging from 4.00 to 4.10 for open sun drying and from 4.08 to 4.14 for solar tunnel drying. The relatively small variation among treatments indicates that the drying process had only a limited influence on the acidity balance of tomato tissues. Thicker slices generally maintained pH values closer to those of the fresh fruit because of their lower drying intensity.

Titratable acidity increased from 0.35% in fresh tomatoes to 0.70–0.74% after open sun drying and 0.76–0.80% following solar tunnel drying. This increase primarily resulted from the concentration of soluble organic acids as water was removed during drying. The higher acidity observed in tunnel-dried samples reflects their greater moisture removal efficiency.

Drying also produced a substantial reduction in water activity. Fresh tomatoes exhibited a water activity of approximately 0.95, whereas the values decreased to 0.63–0.65 after open sun drying and to 0.59–0.61 following solar tunnel drying. The lower water activity achieved by the tunnel dryer indicates greater product stability and a reduced risk of microbial growth during storage.

Rehydration capacity was consistently higher for tunnel-dried samples than for open sun-dried samples. The rehydration ratio ranged from 3.05 to 3.15 under open sun drying and from 3.20 to 3.30 under solar tunnel drying. In both drying methods, thinner slices exhibited better rehydration performance than thicker slices, indicating that rapid moisture removal minimized structural damage to the plant tissues.

In general, the solar tunnel dryer produced tomatoes with lower water activity, higher rehydration capacity, and better overall physicochemical quality than conventional open sun drying. The improved drying environment provided by the tunnel dryer enhanced moisture removal while preserving the structural integrity of the product. In addition, decreasing slice thickness further improved drying efficiency and contributed to better preservation of quality attributes.

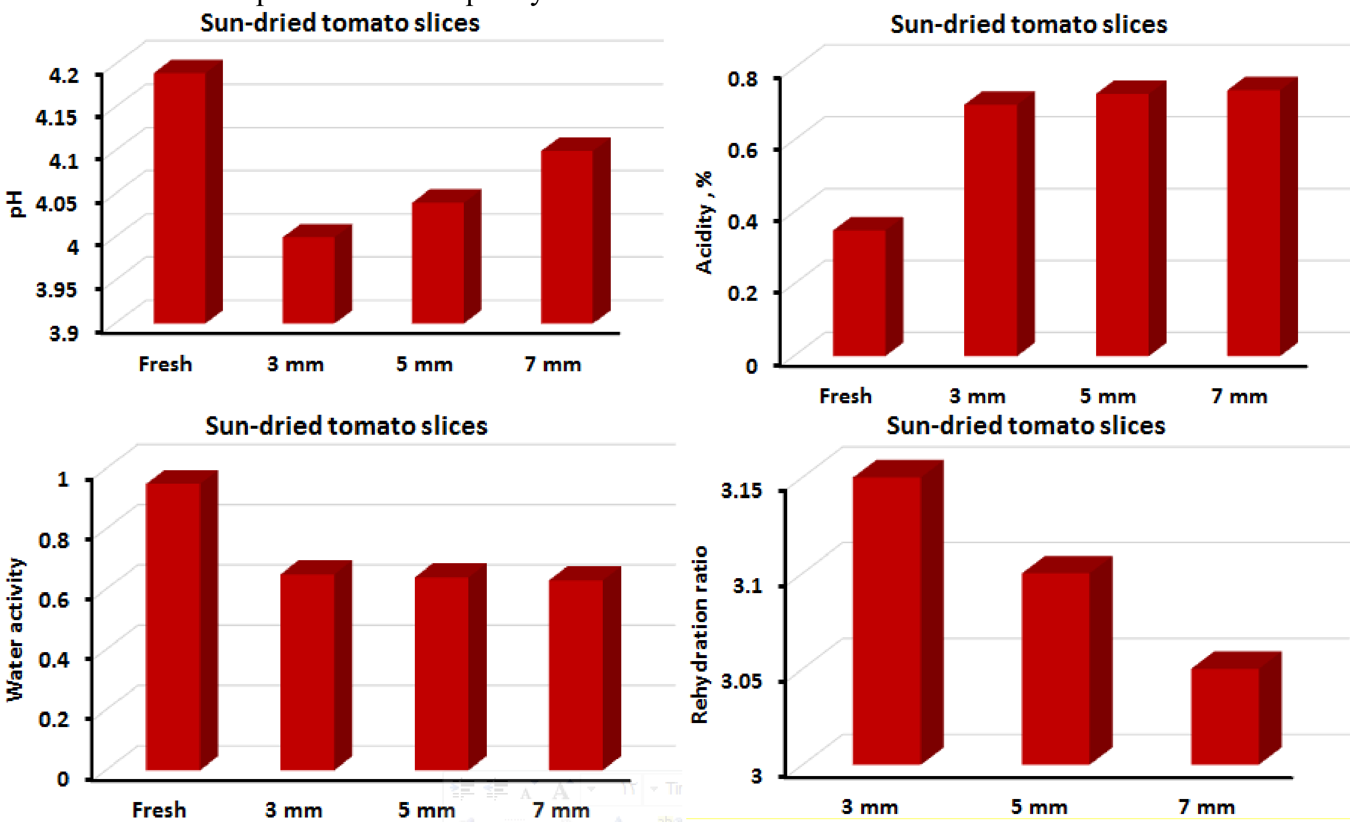


Figure 17. Effect of slice thickness on the physicochemical properties of tomato slices during open sun drying.

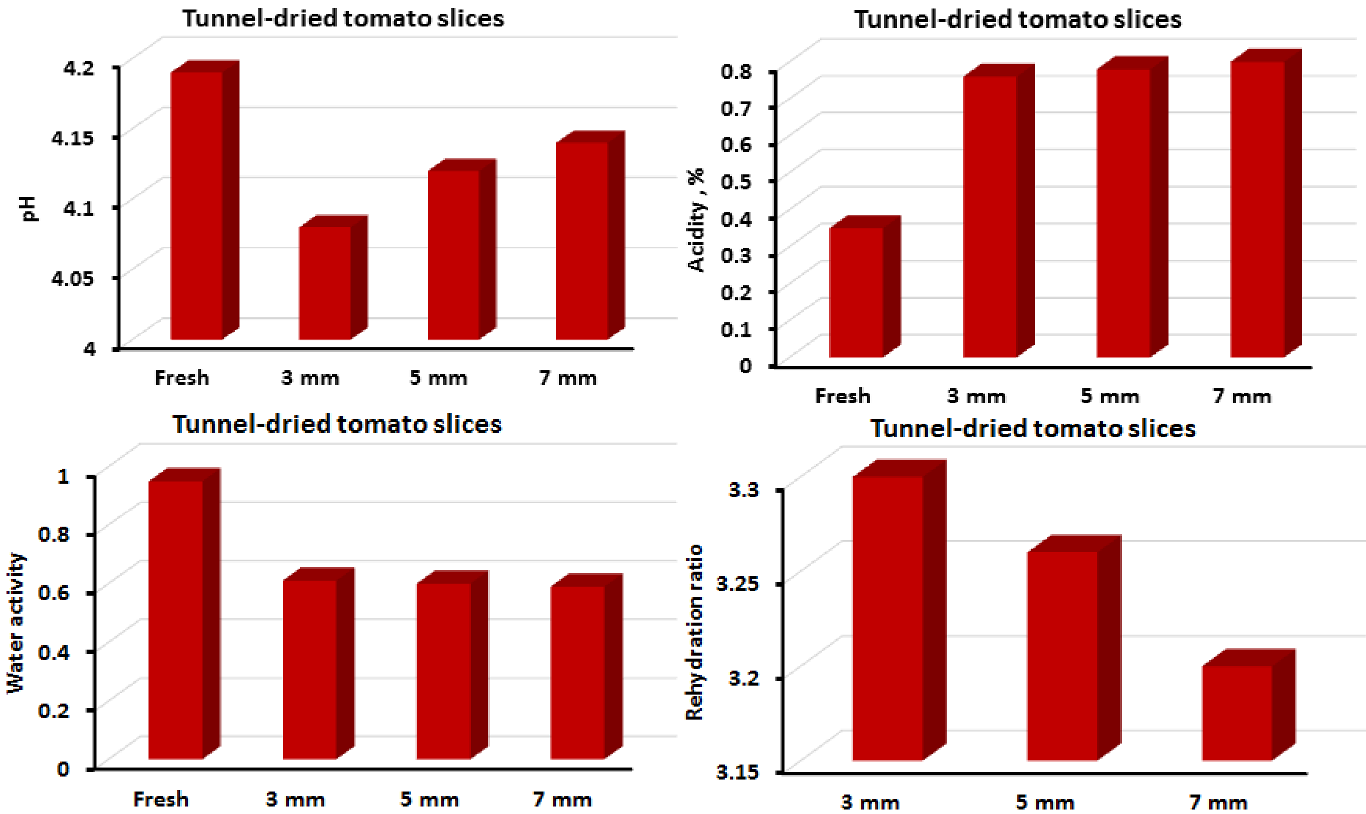


Figure 18. Effect of slice thickness on the physicochemical properties of tomato slices during solar tunnel drying.

3.4. Nutritional properties

3.4.1. Nutritional properties of dried peach slices

Figures 19 and 20 illustrate the influence of drying method and slice thickness on the nutritional characteristics of dried peach slices, including reducing sugar, total phenolic content, ascorbic acid, and antioxidant activity. Drying significantly affected all measured nutritional parameters compared with fresh peaches.

Reducing sugar content increased after drying relative to the fresh fruit (16.08), reflecting the concentration of soluble solids following moisture removal. Solar tunnel drying resulted in slightly higher reducing sugar values (19.3–19.8) than open sun drying (18.8–19.4). A gradual increase in reducing sugar content was observed with increasing slice thickness, and the highest values were recorded in the 7 mm slices. Similar changes in sugar concentration during fruit drying have been reported by Takougnadi et al. (2020).

The total phenolic content increased from 96.91 mg kg^{-1} in fresh peaches to 109–120 mg kg^{-1} after open sun drying and 119–136 mg kg^{-1} after solar tunnel drying. The higher phenolic retention observed in tunnel-dried samples is likely associated with the shorter drying period and reduced exposure to oxidation. In addition, thicker slices retained greater amounts of phenolic compounds than thinner slices, with the 7 mm treatment exhibiting the highest values. These observations are consistent with previous reports indicating that phenolic retention is influenced by cultivar, processing conditions, and drying duration (Bennett et al., 2011; Abdelraouf et al., 2020).

Ascorbic acid retention was also strongly influenced by the drying method. Although drying inevitably reduced vitamin C, the solar tunnel dryer preserved substantially higher levels (88.59–88.66%) than open sun drying (80.54–80.61%). Thinner slices consistently retained more ascorbic acid than thicker slices, most likely because the shorter drying time reduced thermal and oxidative degradation. Similar findings were reported by Dufera et al. (2021) and Alam et al. (2020).

Antioxidant activity (DPPH) increased after drying, reaching 83.00–83.80% for open sun drying and 85.00–85.80% for solar tunnel drying. The highest antioxidant activity was observed in the 5 mm slices, suggesting that this thickness provided an appropriate balance between moisture removal and preservation of bioactive compounds. The enhancement in antioxidant activity can be attributed to the concentration of phenolic compounds and other antioxidant constituents during dehydration, as previously reported by Kapasakalidis et al. (2006) and Oszmiański and Wojdył (2009).

Overall, the solar tunnel dryer preserved the nutritional quality of peach slices more effectively than conventional open sun drying. The controlled drying environment reduced nutrient degradation while improving the retention of phenolic compounds, vitamin C, and antioxidant activity. Among the evaluated treatments, slice thicknesses of 5–7 mm provided the best overall nutritional quality.

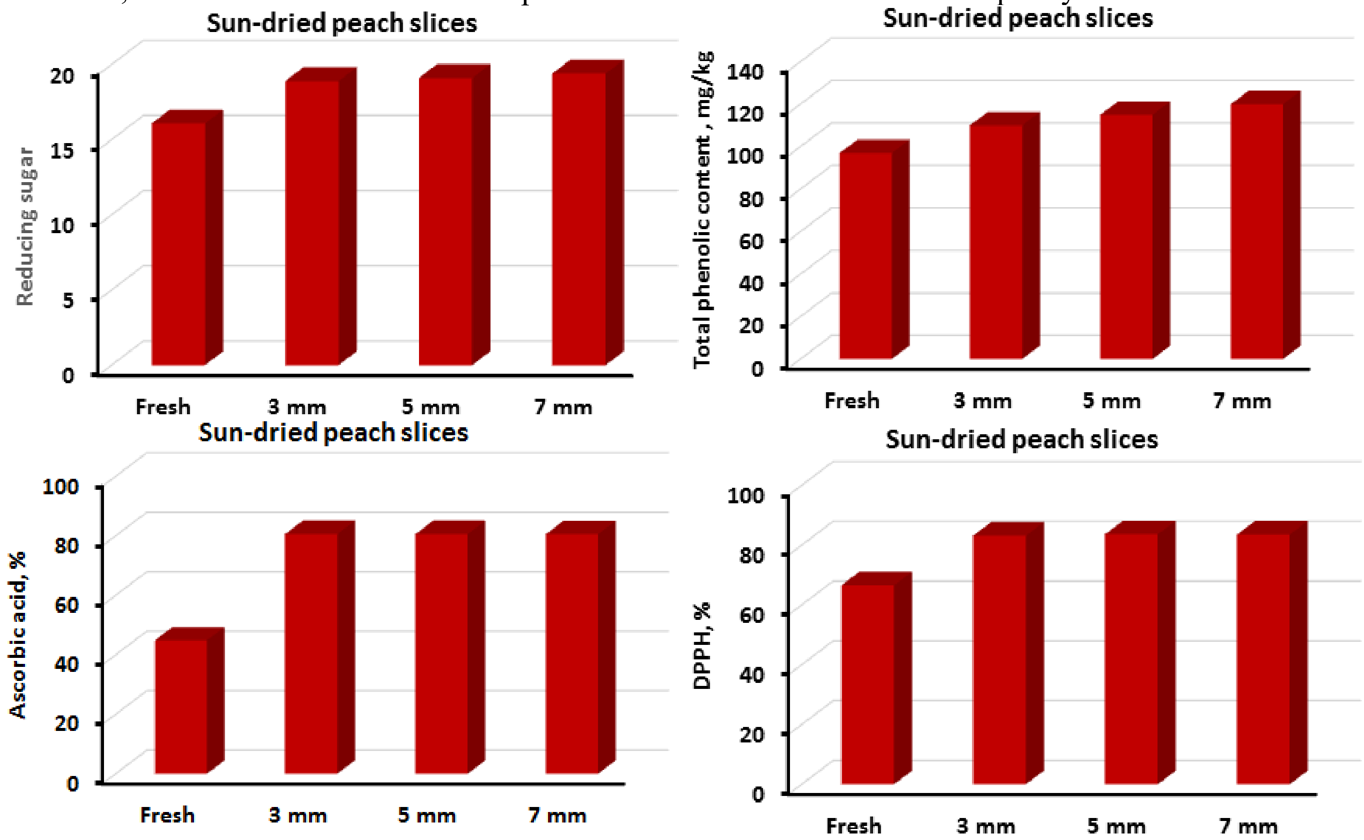


Figure 19. Effect of drying method and slice thickness on reducing sugar, total phenolic content, ascorbic acid, and antioxidant activity of open sun-dried peach slices.

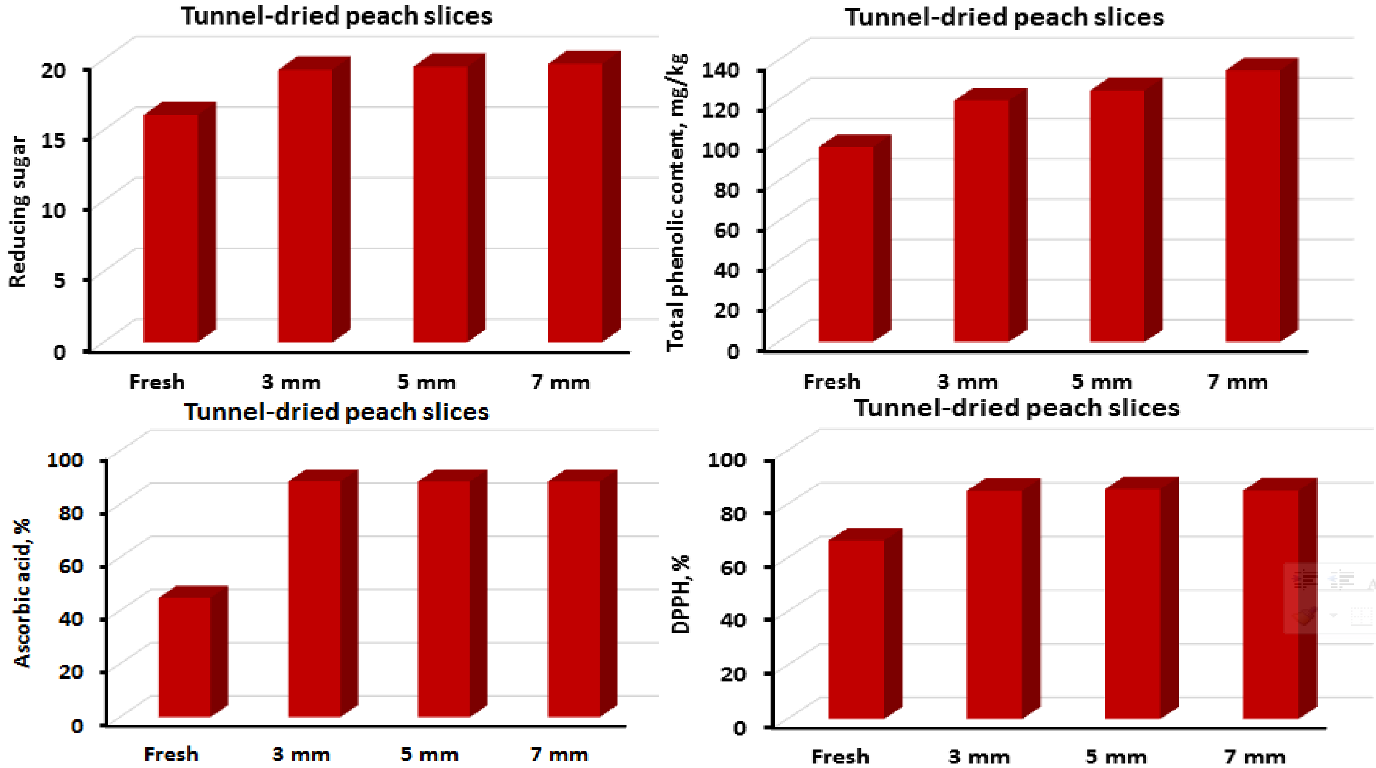


Figure 20. Effect of drying method and slice thickness on reducing sugar, total phenolic content, ascorbic acid, and antioxidant activity of solar tunnel-dried peach slices.

3.4.2. Nutritional Properties of Dried Tomato Slices

Figures 21 and 22 show the effects of drying method and slice thickness on the nutritional characteristics of tomato slices. Similar to peaches, drying significantly influenced reducing sugar, total phenolic content, ascorbic acid, and antioxidant activity.

Reducing sugar content increased from 3.5 in fresh tomatoes to 4.0–4.6 after open sun drying and 4.4–4.8 following solar tunnel drying. The increase reflects the concentration of soluble carbohydrates as moisture was removed during drying. In both drying methods, thicker slices exhibited slightly higher reducing sugar contents than thinner slices.

Unlike peaches, the total phenolic content of tomatoes decreased after drying. Fresh tomatoes contained approximately 100 mg kg^{-1}, whereas values declined to 79–91 mg kg^{-1} after open sun drying and 87–96 mg kg^{-1} following solar tunnel drying. Nevertheless, the solar tunnel dryer consistently preserved a greater proportion of phenolic compounds than open sun drying. Thicker slices also retained higher phenolic contents than thinner slices, indicating reduced oxidation during the drying process.

Ascorbic acid was the most heat-sensitive nutritional component. Its concentration decreased substantially from the fresh value (20%) under both drying methods, reaching 8.0–10.5% after open sun drying and 9.0–10.5% after solar tunnel drying. Although the influence of slice thickness was less pronounced than for the other quality attributes, the tunnel dryer consistently maintained slightly higher vitamin C levels owing to the shorter drying time and more stable drying conditions.

Antioxidant activity also declined after drying, decreasing from 60% in fresh tomatoes to 21–26% following open sun drying and 22.5–27% after solar tunnel drying. In contrast to the behavior observed for phenolic compounds, thinner slices exhibited slightly greater antioxidant activity than thicker slices, probably because rapid drying reduced the oxidation of antioxidant constituents.

Overall, solar tunnel drying provided better preservation of the nutritional quality of tomato slices than conventional open sun drying. Although drying inevitably reduced vitamin C and antioxidant activity, the controlled drying conditions minimized nutrient losses and improved the retention of phenolic compounds and reducing sugars. These findings indicate that tomatoes are more susceptible to nutritional degradation during drying than peaches, emphasizing the importance of controlled solar drying conditions for maintaining product quality.

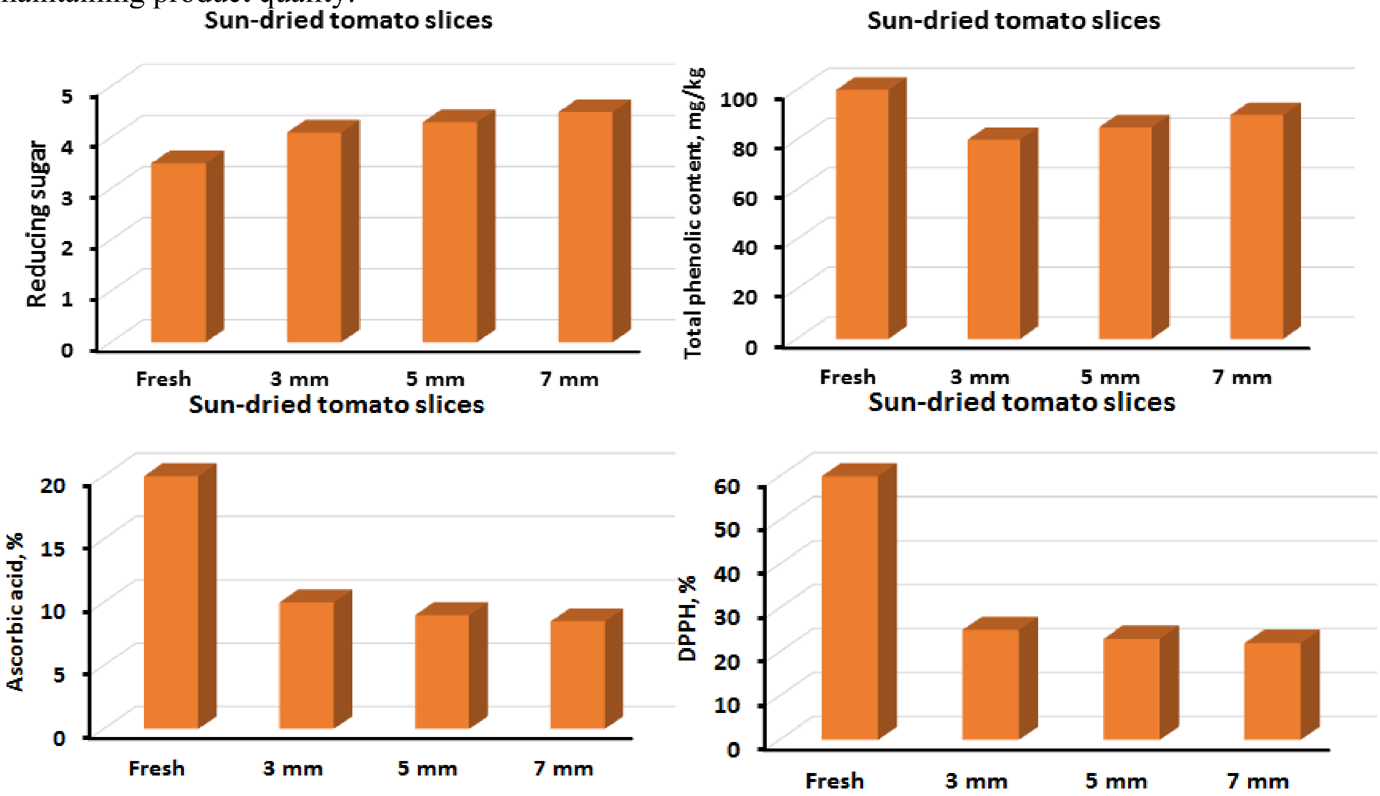


Figure 21. Effect of drying method and slice thickness on reducing sugar, total phenolic content, ascorbic acid, and antioxidant activity of open sun-dried tomato slices.

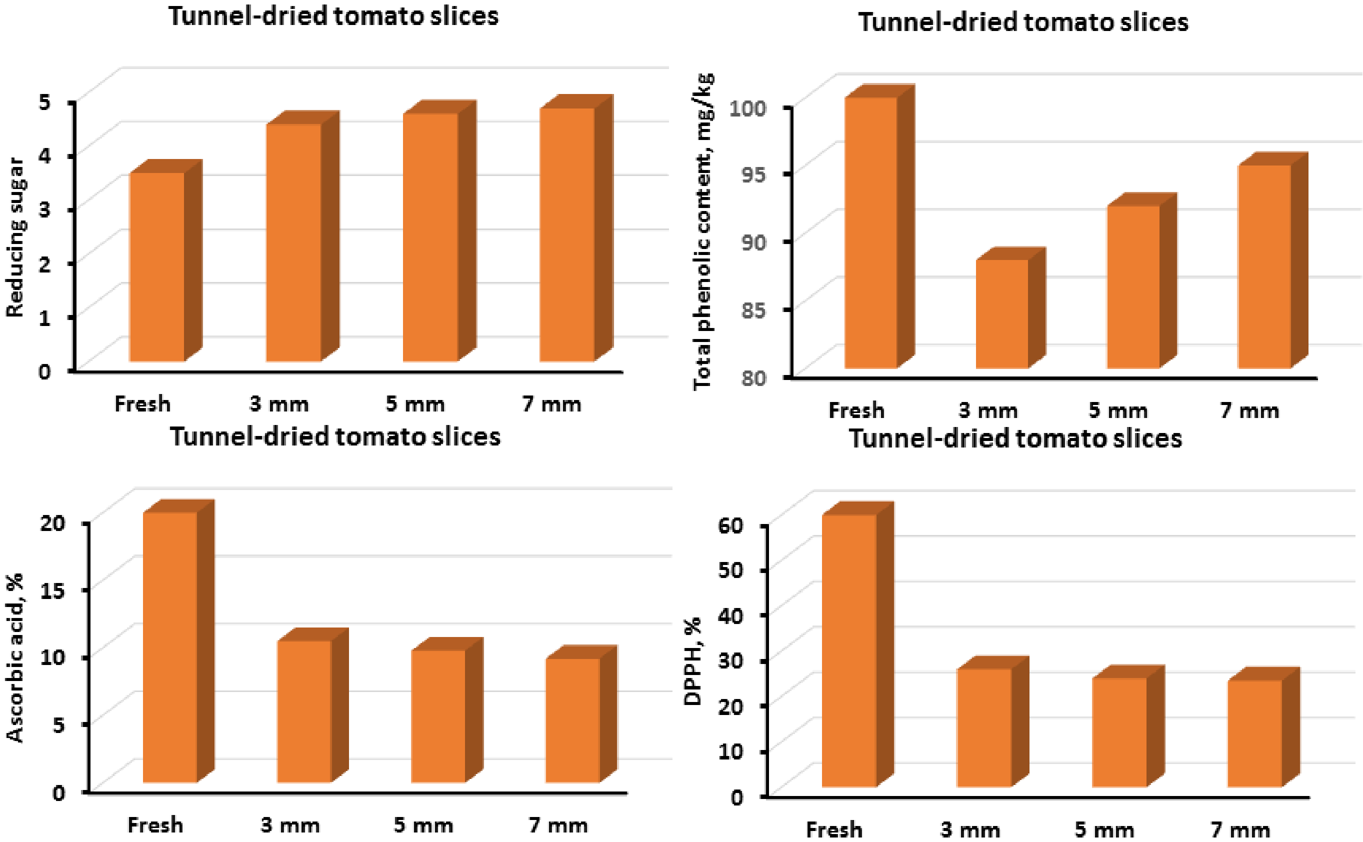


Figure 22. Effect of drying method and slice thickness on reducing sugar, total phenolic content, ascorbic acid, and antioxidant activity of solar tunnel-dried tomato slices.

3.5. Organoleptic properties

3.5.1. Organoleptic properties of dried peach slices

Figures 23 and 24 illustrate the effects of drying method and slice thickness on the sensory characteristics of dried peach slices, including color, taste, odor, texture, and overall acceptability. The sensory evaluation demonstrated that both drying method and slice thickness significantly influenced product quality.

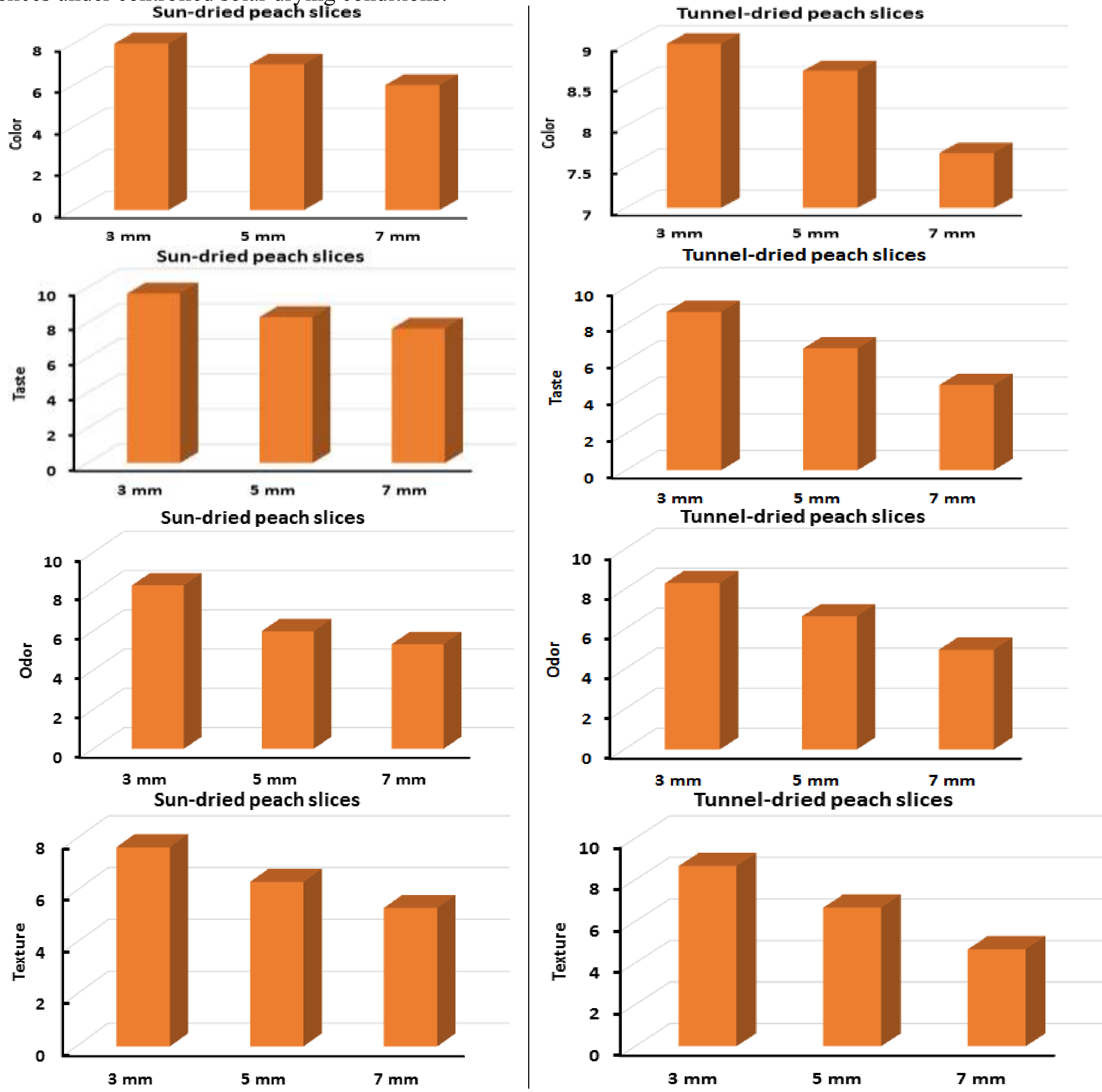
Color scores were consistently higher for samples dried in the solar tunnel than for those dried under open sun conditions. The highest color score was obtained for the 3 mm slices (score = 9), while color quality gradually declined as slice thickness increased. The superior color retention achieved by the solar tunnel dryer can be attributed to the shorter drying period and the more stable drying environment, which limited enzymatic and non-enzymatic browning reactions. Similar observations were reported by Elicin and Sacilik (2005).

Taste scores also varied with slice thickness. Thin slices (3 mm) received the highest scores in both drying methods, whereas thicker slices showed progressively lower acceptability. The reduced taste scores observed in the 7 mm slices may be associated with their longer drying time, which can promote undesirable flavor changes resulting from prolonged thermal exposure. Comparable findings have been reported by Soomro et al. (2020).

Odor followed a similar trend, with the highest scores recorded for the 3 mm slices and a gradual decline as thickness increased. The decrease in odor quality in thicker slices is likely related to the loss or modification of volatile aromatic compounds during the extended drying process.

Texture was significantly improved by solar tunnel drying, particularly for the thinner slices. The 3 mm slices achieved the highest texture scores, reflecting a desirable balance between firmness and crispness, whereas the 7 mm slices exhibited lower texture ratings because of their less uniform moisture removal.

Overall acceptability reflected the combined influence of all sensory attributes. The 3 mm slices received the highest overall scores under both drying methods, whereas acceptability decreased progressively with increasing slice thickness. Although both methods produced acceptable dried peaches, the solar tunnel dryer generally provided superior color and texture while maintaining high overall sensory quality. These findings indicate that a 3 mm slice thickness is the most suitable for producing high-quality dried peach slices under controlled solar drying conditions.



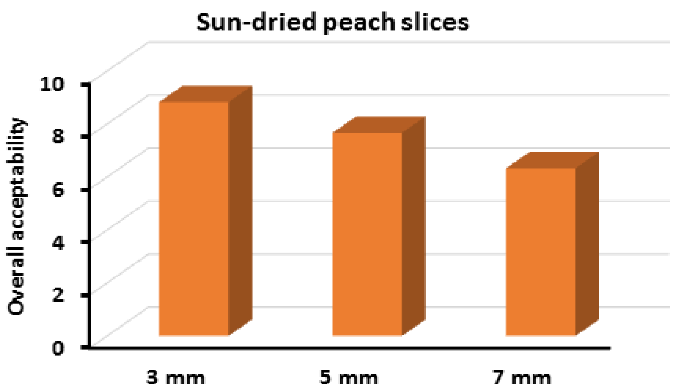


Figure 23. Effect of drying method and slice thickness on the organoleptic properties of open sun-dried peach slices.

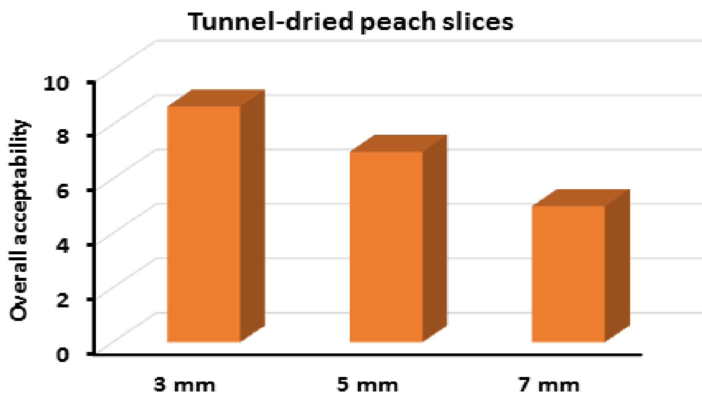


Figure 24. Effect of drying method and slice thickness on the organoleptic properties of solar tunnel-dried peach slices.

3.5.2. Organoleptic properties of dried tomato slices

Figures 25 and 26 present the sensory evaluation of dried tomato slices produced by open sun drying and solar tunnel drying. Similar to peaches, both the drying method and slice thickness significantly affected the organoleptic properties of the dried products.

The highest color scores were obtained for the 3 mm slices, particularly under solar tunnel drying, indicating that the controlled drying conditions effectively preserved the natural red color of tomato slices. Increasing slice thickness resulted in lower color scores under both drying methods, most likely because the longer drying time promoted pigment degradation and browning reactions.

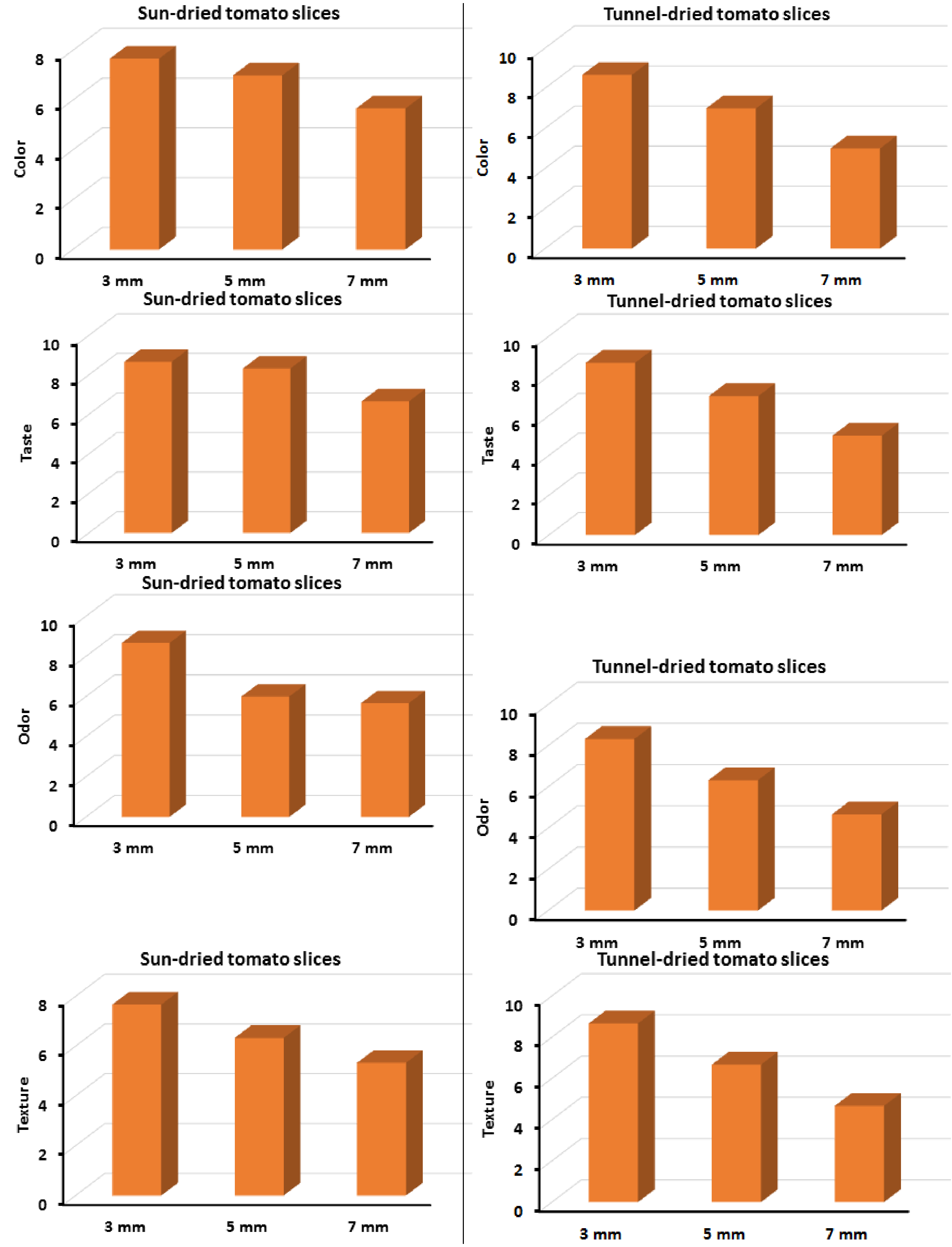
Taste scores followed the same general trend, with the 3 mm slices receiving the highest panel ratings. As slice thickness increased, taste acceptability gradually declined, especially in the tunnel-dried samples. The prolonged drying period required for thicker slices may have contributed to slight changes in flavor intensity and the development of undesirable taste characteristics.

Odor scores decreased with increasing slice thickness regardless of the drying method. The lower aroma scores observed for the thicker slices can be explained by the greater loss of volatile compounds during the extended drying process. Nevertheless, both drying methods produced acceptable aroma characteristics in the thinner slices.

Texture evaluation showed that the 3 mm slices dried in the solar tunnel achieved the highest scores, indicating more uniform dehydration and better structural preservation. In contrast, thicker slices received lower texture scores because incomplete moisture removal produced a less desirable product consistency.

Overall acceptability closely reflected the combined sensory attributes. The 3 mm slices achieved the highest overall acceptance under both drying methods, whereas acceptability declined steadily as slice thickness increased. Although the differences between drying methods were relatively small, solar tunnel drying generally provided better color and texture preservation while maintaining satisfactory flavor and aroma.

Overall, the sensory evaluation demonstrated that reducing slice thickness substantially improved consumer acceptance of dried tomato slices. Among the evaluated treatments, the 3 mm slices produced by the solar tunnel dryer exhibited the most desirable overall sensory quality, confirming that controlled solar drying is an effective technique for producing high-quality dried tomato products.


Sun-dried tomato slices
Color
0
2
4
6
8
3 mm
5 mm
7 mm
Tunnel-dried tomato slices
Color
0
2
4
6
8
10
3 mm
5 mm
7 mm
Sun-dried tomato slices
Taste
0
2
4
6
8
10
3 mm
5 mm
7 mm
Tunnel-dried tomato slices
Taste
0
2
4
6
8
10
3 mm
5 mm
7 mm
Sun-dried tomato slices
Odor
0
2
4
6
8
10
3 mm
5 mm
7 mm
Tunnel-dried tomato slices
Odor
0
2
4
6
8
10
3 mm
5 mm
7 mm
Sun-dried tomato slices
Texture
0
2
4
6
8
3 mm
5 mm
7 mm
Tunnel-dried tomato slices
Texture
0
2
4
6
8
10
3 mm
5 mm
7 mm

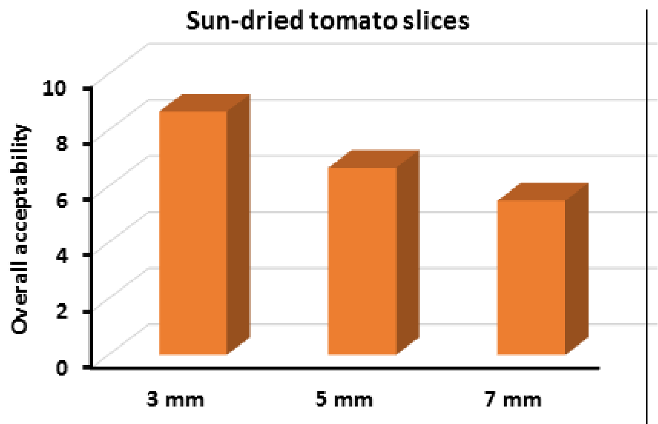


Figure 25. Effect of drying method and slice thickness on the organoleptic properties of open sun-dried tomato slices.

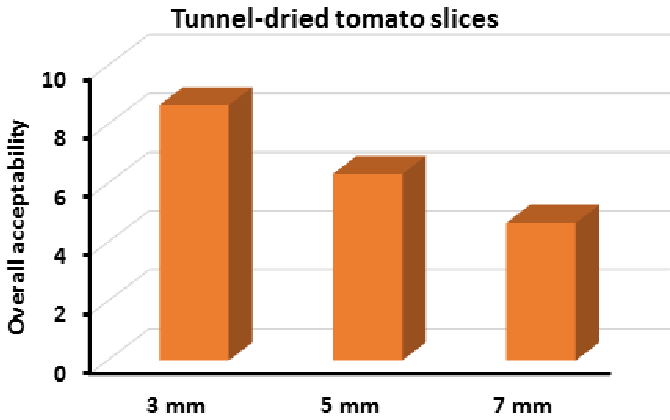


Figure 26. Effect of drying method and slice thickness on the organoleptic properties of solar tunnel-dried tomato slices.

4. Conclusion and Recommendations

This study demonstrated that both the drying method and slice thickness had significant effects on the drying performance and quality characteristics of dried peaches and tomatoes. Among the evaluated treatments, 3 mm slice thickness consistently provided the shortest drying time, the highest drying rate, and the most efficient moisture removal for both crops. Thinner slices also exhibited superior physicochemical, nutritional, and sensory characteristics compared with thicker slices.

The solar tunnel dryer markedly outperformed conventional open sun drying by providing a controlled drying environment that accelerated moisture removal while preserving product quality. Compared with open sun drying, solar tunnel drying produced lower final moisture content and water activity, higher rehydration capacity, better retention of phenolic compounds and ascorbic acid, and improved antioxidant activity. In addition, the tunnel dryer generally achieved higher sensory scores for color, texture, and overall acceptability.

The drying process was most effective during periods of high solar radiation, when the drying chamber maintained favorable thermal conditions and continuous airflow. These conditions enhanced heat and mass transfer, shortened drying time, and reduced exposure of the products to environmental contamination compared with traditional open-air drying.

Based on the obtained results, the following recommendations can be made:

- A 3 mm slice thickness is recommended for drying both peaches and tomatoes because it provides the best balance between drying efficiency and final product quality.
- Solar tunnel drying should be preferred over conventional open sun drying, particularly for moisture-sensitive agricultural products requiring high nutritional and sensory quality.
- Continuous airflow and proper temperature control should be maintained throughout the drying process to improve moisture removal and ensure uniform drying.
- Regular monitoring of moisture content, water activity, pH, nutritional quality, and sensory characteristics is recommended to maintain consistent product quality during processing.
- The developed solar drying system has strong potential for application to other fruits and vegetables with high initial moisture content, supporting sustainable post-harvest processing in rural and remote areas.

Future research should focus on improving the thermal performance of solar tunnel dryers through enhanced airflow management, thermal energy storage, and automatic environmental control systems. Additional studies on different agricultural products and optimized operating conditions would further improve drying efficiency, product quality, and the practical application of solar drying technology.

References

Abdelraouf, R.E.; Abdou, S.M.M.; Abbas, M.M.; Hafez, M.; Popov, A.I.; Hamed, L.M.M.(2020). Influence of N-Fertigation Stress and Agro-Organic Wastes (Biochar) io

Improve Yield and Water Productivity of Sweet Pepper Under Sandy Soils Conditions. Plant Arch. 2020, 20, 3165–3172.

Abe-Inge, V., Agbenorhevi, J.K., Kpodo, F.M. and Adzinyo, O.A. (2018). Effect of different drying techniques on quality characteristics of African palmyra palm (*Borassus aethiopum*) fruit flour.

Abul-Fadl, M.M., Ghanem, T.H., El-Badry, N. and Nasr, A. (2020). Effect of puff drying on seedless grape fruits quality criteria compared to convective air drying. Al-Azhar Journal of Agricultural Research, 45(1), pp.75-91.

Alam, M., Hossain, M.A. and Sarkar, A. (2020). Effect of edible coating on functional properties and nutritional compounds retention of air dried green banana (Musa sapientum L.). IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), 14(2), pp.51-58.

AOAC, (2016). Official Methods of Analysis of the Association of Official Analytical Chemists International, 20th ed.; AOAC International: Rockville, MD, USA, 2016.

Amit, S.K., Uddin, M.M., Rahman, R., Islam, S.R. and Khan, M.S. (2017). A review on mechanisms and commercial aspects of food preservation and processing. Agriculture & Food Security, 6, pp.1-22.

Anjos, O., Paula, V., Delgado, T. and Estevinho, L., (2019). Influence of the storage conditions onthe quality of bee pollen, Zemdirbyste-Agriculture 106 (1), 87-94.

Araújo, C.D.S., Macedo, L.L., Vimercati, W.C., Ferreira, A., Prezotti, L.C. and Saraiva, S.H. (2020). Determination of pH and acidity in green coffee using near-infrared spectroscopy and multivariate regression. Journal of the Science of Food and Agriculture, 100(6), pp.2488-2493.

Babalis, S. J., & Belessiotis, V. G. (2004). Influence of the drying conditions on the drying constants and moisture diffusivity during the thin-layer drying of figs. Journal of Food Engineering, 65(3), 449-458.

Batista, D.D.V.S.; Cardoso, R.L.; de Godoy, R.C.B. (2014). Evangelista-Barreto, N.S. Stability physical-chemical and microbiological of organic dehydrated banana/Estabilidade fisico-quimica e microbiologica de banana passa organica. Cienc. Rural. 2014, 44, 1886–1893.

Bennett, L.E.; Jegasothy, H.; Konczak, I.; Frank, D.; Sudharmarajan, S.; Clingeleffer, P.R. (2011). Total polyphenolics and antioxidant properties of selected dried fruits and relationships to drying conditions. J. Funct. Foods 2011, 3, 115–124. https://doi.org/10.1016/J.JFF.2011.03.005.

Doymaz, İ. (2007). Air-drying characteristics of tomatoes. *Journal of Food Engineering, 78*(4), 1291–1297.

Doymaz, İ. (2011). Drying of green bean and okra under solar energy. Chemical Industry and Chemical Engineering Quarterly, 17(2), pp.199-205.

Dufera, L.T.; Hofacker, W.; Esper, A.; Hensel, O. (2021). Physicochemical quality of twin layer solar tunnel dried tomato slices. Heliyon 2021, 7, e07127. https://doi.org/10.1016/J.HELIYON.2021.E07127.

Elicin, A.K.; Sacilik, K. (2005). An experimental study for solar tunnel drying of apple. Tarim Bilim. Derg. 2005, 11, 207–211.

Elwalwa, H. M., Zarig, F. H. A., Murad, M. K. H., & Nashnush, A. N. E. (2026). The role of innovation technology in developing solar energy technologies: challenges and future trends towards sustainable development (literature review). *Al-Farooq Journal of Sciences*, *2*(3), 585-594. https://doi.org/10.65405/x5jyz108

Energypedia. (2023). Solar drying. Retrieved from https://energypedia.info/wiki/Solar _Drying

Ferreira, T.H.B. and Freitas, M.L.F. (2019). Production, physical, chemical and sensory evaluation of dried banana (Musa Cavendish). Emirates Journal of Food and Agriculture, 31(2), pp.102-108.

Gallali, Y.M., Abujnah, Y.S. and Bannani, F.K., (2000). Preservation of fruits and vegetables using solar drier: a comparative study of natural and solar drying, III; chemical analysis and sensory evaluation data of the dried samples (grapes, figs, tomatoes and onions). Renewable Energy, 19(1-2), pp.203-212.

Kapasakalidis, P.G.; Rastall, R.A.; Gordon, M.H. (2006). Extraction of polyphenols from processed black currant (Ribes nigrum L.) residues. J. Agric. Food Chem. 2006, 54, 4016–4021. https://doi.org/10.1021/JF052999L.

Karathanos, V. T., Villalobos, G., & Saravacos, G. D. (1995). Comparison of two methods of estimation of the effective moisture diffusivity from drying data. Journal of Food Science, 60(2), 218-223.

Kaveh, M.; Abbaspour-Gilandeh, Y.; Fatemi, H.; Chen, G. (2021). Impact of different drying methods on the drying time, energy, and quality of green peas. J. Food Process. Preserv. 2021, 45, e15503. https://doi.org/10.1111/JFPP.15503.

Kumar, M., Sansaniwal, S. K., & Khatak, P. (2016). Progress in solar dryers for drying various commodities. Renewable and Sustainable Energy Reviews, 55, 346-360.

Lahsasni, S., Kouhila, M., Mahrouz, M., Idlimam, A. and Jamali, A. (2004). Thin layer convective solar drying and mathematical modeling of prickly pear peel (Opuntia ficus indica). Energy, 29(2), pp.211-224.

Lewicki, P.P.; Lukaszuk, A. (2000). Changes of rheological properties of apple tissue undergoing convective drying. Drying Technology, 18(3), pp.707-722.

Mujumdar, A. S. (2006). Handbook of industrial drying. CRC Press.

Oszmiański, J.; Wojdyło, A. (2009). Effects of blackcurrant and apple mash blending on the phenolics contents, antioxidant capacity, and colour of juices. Czech J. Food Sci. 2009, 27, 338–351. https://doi.org/10.17221/20/2008-CJFS.

Piga, A., Del Caro, A., & Corda, G. (2004). From fresh traditional products to functional foods: Drying behavior of prunes (*Prunus domestica L.*). *Food Chemistry, 86*(4), 601–606.

Sadler, M.J., Gibson, S., Whelan, K., Ha, M.A., Lovegrove, J. and Higgs, J. (2019). Dried fruit and public health–what does the evidence tell us?. International journal of food sciences and nutrition, 70(6), pp.675-687.

Sharma, A., Chen, C. R., & Lan, N. V. (2021). Solar-energy drying systems: A review. Renewable and Sustainable Energy Reviews, 13(6-7), 1185-1210.

Soomro, A.H.; Miano, T.F.; Marri, A.; Kumar, D.; Khaskheli, G.S.; Arain, U.F.; Baloch, A.B. (2020). Application of pretreatments on banana slices for improving drying characteristics. Food Sci. Qual. Manag. 2020, 103, 35–41.

Takougnadi, E.; Boroze, T.E.T.; Azouma, O.Y. (2020). Effects of drying conditions on energy consumption and the nutritional and organoleptic quality of dried bananas. J. Food Eng. 2020, 268, 109747. https://doi.org/10.1016/J.JFOODENG.2019.109747.

Vega-Gálvez, A., Ah-Hen, K., Chacana, M., Vergara, J., Martínez-Monzó, J., García-Segovia, P., ... & Di Scala, K. (2012). Effect of temperature and air velocity on drying kinetics, antioxidant capacity, total phenolic content, colour, texture and microstructure of apple (var. Granny Smith) slices. Food Chemistry, 132(1), 51-59.

Yu, G., Bei, J., Zhao, J., Li, Q. and Cheng, C. (2018). Modification of carrot (Daucus carota Linn. var. Sativa Hoffm.) pomace insoluble dietary fiber with complex enzyme method, ultrafine comminution, and high hydrostatic pressure. Food Chemistry, 257, pp.333-340.

Zanoni, B., Peri, C., Nani, R., & Lavelli, V. (1999). Oxidative heat damage of tomato halves as affected by drying. Food Research International, 31(5), 395-401.

Zielinska, M. and Markowski, M. (2016). The influence of microwave-assisted drying techniques on the rehydration behavior of blueberries (*Vaccinium corymbosum L.*). Food chemistry, 196, pp.1188-1196.