

Article

Effects of Different Natural Drying Methods on Drying Characteristics and Quality of *Diaogan apricots*

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Abstract: Drying is one of the best methods to preserve the quality of fresh fruits and prolong their shelf life. This study focuses on *Prunus armeniaca* L. cv. ‘Diaogan’ (commonly known as *Diaogan apricot*) sourced from Xinjiang, China to explore the impact of two natural drying methods (shade drying and open-air drying in the rocky desert) on the drying kinetics, color, textural characteristics, microstructure, chemical properties, and antioxidant capacity of *Diaogan apricots*. The experimental results indicate that throughout the natural drying process, the time required for open-air drying in the rocky desert was reduced by 26.47% compared to shade drying. The L^* , a^* , and b^* values of the shade- and ventilation-dried *Diaogan apricots* were higher than those sun-dried in the rocky desert, exhibiting a lower color difference (ΔE) than apricots dried through rocky desert sun drying. Specifically, the ΔE for shade-dried *Diaogan apricots* was 19.66 ± 0.24 . The *Diaogan apricots* dried in the rocky desert exhibited greater hardness, lower elasticity, stronger adhesiveness, and higher chewiness compared to those dried in the shade, with the hardness, adhesiveness, and chewiness being, respectively, 14.71%, 18.89%, and 35.79% higher. Scanning electron microscopy (SEM) observations revealed that the high temperatures experienced during open-air drying in the rocky desert caused rapid dehydration of the *Diaogan apricot*’s skin, leading to clogging and crust formation in the flesh pores, along with deformation or tearing of the tissue structure, ultimately resulting in poor rehydration ability. After drying, there was a significant increase in the soluble solids in the *Diaogan apricots*, whereas titratable acidity, total phenols, ascorbic acid, and antioxidant capacity were significantly decreased ($p < 0.05$). In summary, the quality of dried *Diaogan apricots* post-drying is dependent on the natural drying method employed, with shade drying resulting in superior quality of *Diaogan apricots* compared to open-air drying in the rocky desert. This study offers fundamental data and serves as a theoretical reference for the industrialized production of apricots.

Keywords: apricot; natural drying; drying kinetics; microstructure



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1. Introduction

Prunus armeniaca L. cv. ‘Diaogan’ (abbreviated as *Diaogan apricot*) is a deciduous tree plant of the genus *Prunus* in the Rosaceae family. Its fruit is rich in nutrients, boasting a tempting taste and flavor, and it is deeply loved by consumers [1]. Apricots are rich in polyphenols, vitamins, and minerals. Once absorbed by the human body, these compounds

enhance antioxidant capabilities, immunity, and anti-aging and promote intestinal motility, offering considerable medicinal and nutritional value [2]. Fresh apricots have high water content and strong respiration metabolism; post-harvest, they dehydrate quickly, leading to softening, wrinkling, and rotting [3,4]. The global apricot planting area in 2021 [5] reached 572,900 hectares with a production of 3.6492 million tons. Moreover, in 2020, the apricot planting area in Xinjiang was 116,300 hectares, yielding a production of 937,600 tons, which accounts for one-fifth of the global planting area [6,7]. However, Xinjiang is situated in a remote and arid region where long-distance transport logistics are unreliable, which is not conducive to long-term storage and transport of fresh apricots, thereby seriously affecting their quality and shelf life [8,9]. To enhance the preservation of apricots, researchers have explored various methods, such as canning, use in beverages, and drying [2]. Among them, drying stands out as a crucial processing technique for extending shelf life and yielding products rich in phenolic compounds and vitamins [10].

In Xinjiang, China, fruit farmers harvest ripe apricots and employ a natural drying process by placing them in rocky desert areas and shaded shelters until they transform into dried apricots. This method, characterized by its low cost and simple structure, aligns with contemporary low-carbon principles and the trend toward sustainable development [11]. Not only does it mitigate unnecessary waste of fresh apricots and optimize resource utilization, but it also enhances the economic viability of fresh apricots, thereby generating income for the fruit farmers [12]. It is worth noting that apricot fruits are particularly vulnerable to rain, dust, and animal interference during the natural drying process, and the natural environmental conditions during the drying process are uncontrollable [13]. Toğrul et al. [14] investigated the efficacy of open-air sun drying and solar-dryer drying methods for apricot fruits. The results showed that solar drying used the thermal energy accumulated during daylight hours to sustain drying processes throughout the night, and the duration required to achieve final drying conditions ranged from 68 to 78 h, contrasting with the 112 h required for open-air sun drying. Karabulut et al. [15] examined the impact of open-air drying on the coloration of dried apricots. The results revealed that sun drying fresh apricots induces browning of the fruit. However, the browning results from the formation of quinones from phenolic substances catalyzed by phenolase. Hu et al. [11] studied the effects of various natural drying methods on the drying characteristics of apricots. The results showed that apricots subjected to hanging tree-drying conditions exhibited the slowest drying rate (302 h). In contrast, apricots dried in open-air drying conditions exhibited the fastest drying rate (192 h), while those under shade drying conditions experienced an intermediate drying rate (212 h). Abdel-Rahman et al. [10] explored the influence of open-air drying on the drying characteristics of date palms. Their findings revealed a positive correlation between the drying rate of date palms and sunlight intensity, while a negative correlation was observed with relative humidity levels of the surrounding environment. Currently, only a few studies have explored the drying characteristics and quality alterations of apricots through natural drying methods. Hence, the selection of appropriate drying technologies plays an important role in the quality control of dried apricots.

In addressing the prevalent issue of substantial post-harvest losses and limited shelf life of *Diaogan apricots* in Xinjiang, China, this study investigated two natural drying methods (open-air drying in rocky desert areas and shade drying) to dry *Diaogan apricots* and explored better-quality natural drying and processing methods. Therefore, the objective of this study is to explore the effects of the two natural drying methods on the drying kinetics, color attributes, textural characteristics, microstructural changes, nutritional composition, and antioxidant capacity of *Diaogan apricots*.

2. Materials and Methods

2.1. Materials

The samples used in the experiment were *Diaogan apricots*, sourced from Wuqi Agricultural Orchard, Yongning Town, Alar City, Xinjiang Uygur Autonomous Region, China (41°25′2.95″ N, 79°38′46.70″ E, 1346 m above sea level). Harvesting took place on 10 July

2023. Post-harvest, only fresh *Diaogan apricots* with a consistent size (the average diameter is 34.15 ± 0.43 mm and the weight is 26.55 ± 0.71 g) and devoid of surface damage, diseases, or pests were selected. These selected dried apricot samples were subsequently placed in a cold storage environment maintained at a constant temperature and humidity ($4 \text{ }^{\circ}\text{C} \pm 0.5 \text{ }^{\circ}\text{C}$, $90 \pm 5\%$) for refrigeration for one day before undergoing testing.

The experimental site was chosen within the rocky desert in Yongning Town, Alar City, Xinjiang Uygur Autonomous Region. The test duration spanned from 11 July 2023 to 20 July 2023, during which two distinct natural drying methods were implemented.

2.2. Natural Drying Methods

The drying experiment for *Diaogan apricots* started on 11 July 2023. Throughout the testing period, the ambient temperature fluctuated within a range of $18.9\text{--}45.1 \text{ }^{\circ}\text{C}$, whereas the ambient relative humidity varied between 8.7 and 43.5% RH. The experimental method involved both shade drying and open-air drying in the rocky desert, as shown in Figure 1. First, the fresh *Diaogan apricots* were removed from cold storage and allowed to acclimate to room temperature. Second, the dust adhering to the surface of the peel was washed off. Finally, any residual moisture on the surface of the dried apricots was dried, and then they were transferred to the natural drying field and placed in both the sunshade and ventilation shed within the rocky desert for drying, as shown in Figure 1a,b.



Figure 1. Two methods of natural drying: (a) open-air drying in rocky desert; (b) shade drying.

2.2.1. Open-Air Drying in Rocky Desert

A black sunning net is essential for open-air drying in the rocky desert field. The net was laid out on the cobblestone of the rocky desert and aligned in parallel with the natural convective wind direction, as shown in Figure 2. During daylight hours, the black sunning net absorbs solar radiation and transmits the generated heat energy to the pebbles. A portion of this heat energy is transferred to the *Diaogan apricots*, while the remainder is retained within the cobblestones. In the absence of a heat source at night during the natural drying process, the heat accumulated in the cobblestones during the day serves to maintain warmth throughout the night. Consequently, the *Diaogan apricots* use this residual heat from the cobblestones to undergo a gradual dying process overnight.

2.2.2. Shade Drying

The traditional shade drying process does not introduce any additional heat sources; instead, it mainly depends on natural environmental fluctuations to harness wind energy to modulate the internal temperature within the shed. The top of the sunshade ventilation canopy features a semi-circular arc, which is covered by a sunshine plate. In addition, the top semi-arcs at the front and rear exits are sealed with a sunshine plate. Within the drying rack, the inner section of both the left and right sides consists of three layers of sunning nets

made from 316 stainless steel. Each layer of stainless steel screen is spaced at intervals of 500 mm, with a mesh size of 10 mm (Figure 3). Throughout the day, the sunlight permeates the shed via the sunlight panel on the top of the shed, thereby providing a heat source for the drying of *Diaogan apricots*. Furthermore, during the night, the heat source amassed at the top of the sunshade ventilation shed provides thermal insulation for the drying of *Diaogan apricots*. Given the open configuration of the sunshade and ventilation canopy, the heating area for the *Diaogan apricots* is extensive during the drying process, the upper and lower ventilation is strong, and the drying rate is fast.

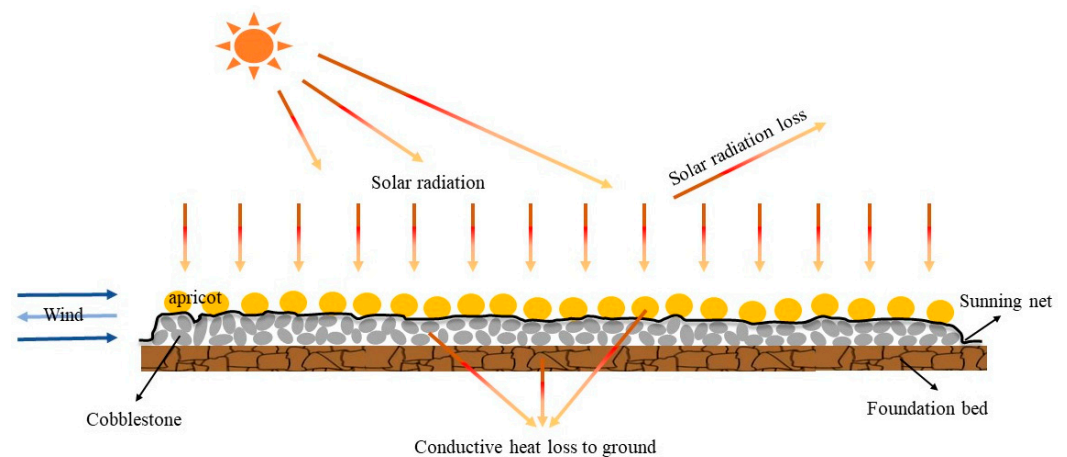


Figure 2. Schematic diagram of the structure of the open-air drying field in rocky desert.

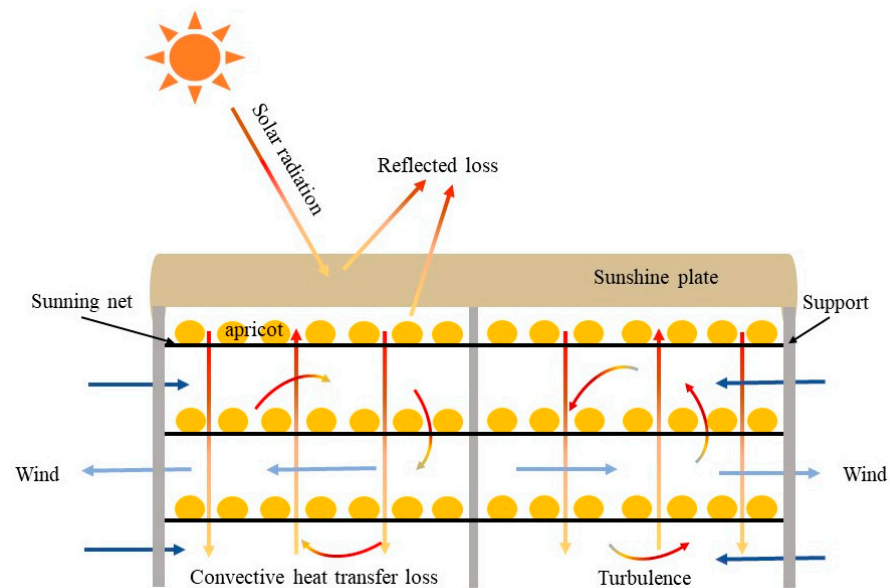


Figure 3. Schematic diagram of the structure of the sunshade and ventilation canopy.

2.3. Methods

In the experiment, 400 *Diaogan apricots* were selected as test samples and duly marked. The samples were then randomly distributed onto both an open-air drying black drying net and a shading drying stainless steel drying net for natural drying tests. The temperature of the *Diaogan apricots* was monitored using a handheld thermal imaging thermometer (model: UTi260B, temperature measurement range: $-15\text{ }^{\circ}\text{C}$ – $550\text{ }^{\circ}\text{C}$, infrared resolution: 256×192 , produced by Uni-Trend Technology (Guangdong) Co., Ltd., Dongguan, China). Temperature, humidity, and light intensity variations in both the open-air drying and shading drying environments were monitored using a temperature, humidity, and light sensor (model: TM-TH-4G; temperature measurement range: -40 – $85\text{ }^{\circ}\text{C}$, accuracy: $\pm 0.2\text{ }^{\circ}\text{C}$; humidity

measurement range: 0–100%, accuracy: $\pm 3\%$; light measurement range: 0–200 KLUX, accuracy: $\pm 5\% + 10$; Xuzhou Tengmao Cold Chain Technology Co., Ltd., Xuzhou, China). In addition, the weight of the *Diaogan apricots* was measured every 2 h using an electronic precision balance (model: Pioneer CP series, range 0–3200 g, accuracy 0.001 g, Ohouse Instruments Co., Ltd., Changzhou, China). The drying process continued until the samples reached a safe moisture level consistent with preserved dried apricots ($<15\%$ moisture content on a wet basis), after which data recording ceased.

2.4. Drying Kinetics

2.4.1. Moisture Ratio

The moisture ratio (MR) of fresh *Diaogan apricots* during the drying process is shown as follows [16]:

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad (1)$$

where M_0 is the moisture content of *Diaogan apricots* at the initial moment, M_t is the moisture content at time t , and the M_e is the moisture content at equilibrium.

Because the M_e is much lower than M_0 and M_t , the Equation (1) could be simplified as follows:

$$MR = \frac{M_t}{M_0} \quad (2)$$

2.4.2. Drying Rate

The formula for calculating the drying rate of *Diaogan apricots* during the drying process is shown in Equation (3) [17].

$$DR = \frac{M_{t1} - M_{t2}}{t_1 - t_2} \quad (3)$$

where DR is the drying rate of the moisture change from the time to the moment during the drying process of the *Diaogan apricot*, ($\% \cdot h^{-1}$); t_1 and t_2 are the drying times of the *Diaogan apricot*, h ; M_{t1} is the dry base moisture content at the t_1 moment, $\%$; and M_{t2} is the dry base moisture content at the t_2 moment.

2.5. Color

The portable spectrophotometer (model: DS-700D, measurement wavelength range: 400–700 nm, resolution: 0.01%, CHNSpec Technology (ZHEJIANG) Co., Ltd., Hangzhou, China) was used to measure the color of the *Diaogan apricots* in the CIELAB color space, where the larger the L^* , the higher the lightness of the surface of the dried apricot peel; the a^* value indicates the degree of redness if positive and greenness if negative, and b^* value indicates yellowness if positive and blueness if negative. The smaller the color change value ΔE , the smaller the difference between the sample before and after drying. Prior to measurement, calibration was performed using black and white standards, and each set of dried apricot samples was subjected to three measurements, with the average value being used. The color difference value (ΔE) of *Diaogan apricots* was calculated using Equation (4) [18].

$$\Delta E = \sqrt{(L_1^* - L^*)^2 + (a_1^* - a^*)^2 + (b_1^* - b^*)^2} \quad (4)$$

where L_1^* , a_1^* , and b_1^* are the color of fresh *Diaogan apricot* and L^* , a^* , and b^* indicate the color of the dried *Diaogan apricot*.

2.6. Textural Characteristics

The textural characteristics of *Diaogan apricots*, including hardness, chewiness, and adhesiveness, were determined using an ultra-stable system texture analyzer (model: TA.XT Express C, measurement accuracy 0.1%, resolution 0.001 mm, Stable Micro Systems, Godalming, UK). Using the P35 probe, the texture analysis parameters were set as follows:

the measurement speed was set to 4 mm/s, the measurement speed was 1 mm/s, the measured speed was 6 mm/s, the strain variable was 30%, the trigger was 10 g, and the time interval between the two measurements of the probe was 5 s. Three tests were conducted for each group of dried apricot samples, and the results were averaged.

2.7. Microstructure

The microstructure of various naturally dried apricots was examined using a Hitachi electron scanning microscope (model: SU3500, accelerating voltage: 20 kV, resolution: ≤ 0.7 nm, magnification: $1000\times$, Hitachi High-Tech Co., Ltd., Tokyo, Japan). Samples with dimensions of 5 mm $\times$ 5 mm were affixed to the observation table using conductive glue, sprayed with gold for 30 s, and then observed under a load voltage of 10 kV.

2.8. Rehydration Ratio

Feng et al. [19] described the rehydration method for dried products, which served as the basis of our study with some modifications incorporated. Ten different naturally dried apricots were selected and placed into a constant-temperature water bath (model: YH-ZK6D, accuracy: ± 0.1 °C, temperature range 25–100 °C, Yuhua Instrument Co., Ltd., Gongyi, China) filled with pure water for 40 min. Notably, the temperature of the constant temperature water bath was set to 40 °C. Following rehydration, the dried apricots were removed from the water bath and allowed to drain for 20 min. Subsequently, the weight of the rehydrated dried apricots was measured repeatedly by suspending them. After each measurement, the hanging dried apricots were returned to their original positions, and weighing ceased once a balanced state was attained. Finally, the rehydration ratio (RR) of the dried apricots was calculated using Equation (5) [13].

$$RR = \frac{m_t}{m_0} \quad (5)$$

where m_0 is the weight of the dried apricots before rehydration, g, and m_t is the weight of the dried apricots at the moment t after rehydration, g.

2.9. Nutritional Properties

2.9.1. Titratable Acids and Soluble Solids

The method used by Aubert et al. [20] for determining the titratable acid and soluble solids of a sample was adopted with some modifications. A 50.0 g *Diaogan apricots* sample was placed into a mortar and ground, followed by filtering and centrifugation at 4 °C and 4000 r/min in a high-speed refrigerated centrifuge (model: MGL-16MA, speed: 0–16,500 r/min, Shanghai, China) for 10 min to obtain the supernatant. The soluble solids content of dried apricot samples was determined using a portable refractometer (model: PAL-3, range: Brix 0.0–93.0%, accuracy: Brix ± 0.1 %, Atago Scientific Instruments Co., Ltd., Tokyo, Japan). Dried apricot samples weighing 10 g were dissolved in 100 mL of distilled water and subsequently titrated with 0.1 M of NaOH solution until reaching a pH of 8.1. The titratable acid content in the dried apricot samples was then determined, and the results were reported as citric acid content.

2.9.2. Total Phenol and Ascorbic Acid Content

In accordance with the phenolic extraction protocol outlined by Nistor et al. [21], the total phenolic content of dried apricot samples was determined using the Folin–Ciocalteu method. The results were expressed as gallic acid equivalents (mg GAE/g d.b). Based on the method outlined by Wei et al. [22] for the quantification of ascorbic acid content in *Diaogan apricot* samples, the 2,6-dichloroindifol titration method was used, with certain modifications. A solution containing 2.0 g of *Diaogan apricot* sample was diluted in 100 mL of 20% oxalic acid solution, stirred evenly for 20 min using a magnetic stirrer (Model: IT-09C15, speed: 200–2000 r/min, Shanghai Yiheng Scientific Instruments Co., Ltd., Shanghai, China), and left for 60 min. After filtration, 10 mL of the solution was

titrated with 2,6-dichloroindifol reagent, with the end point indicated by a reddish hue that remained stable for at least 15 s. The content of ascorbic acid was expressed as mg ascorbic acid per 100 g of dry weight (d.b).

2.10. Antioxidant Activity Assay

The method for preparing antioxidant active extracts was adapted from An et al. [23] with modifications. Dried apricot samples weighing 1.0 g were placed in a beaker and thoroughly mixed with 20 mL of 80% ethanol solution. The mixture was then subjected to ultrasonic treatment in a constant-temperature water bath at 25 °C and 150 W (Model: QQ6-200AL, ultrasonic power 70–180 W, Taiming Environmental Protection Technology Co., Ltd., Wuxi, China) for 30 min. Subsequently, the mixture was centrifuged at 8000 rpm at 4 °C for 15 min using a high-speed refrigerated centrifuge to obtain the supernatant. The resulting extracted dried apricot samples were used to determine the antioxidant activity, with the results expressed as Trolox equivalents (mM Trolox/g d.b).

2.10.1. DPPH

The method for assessing the scavenging ability of *DPPH* free radicals was adapted from Nistor et al. [21], with certain modifications. Briefly, 2.0 mL of the test solution was mixed with 2.0 mL of 0.1 mM *DPPH* solution and incubated in darkness for 30 min. The absorbance of the mixed solution was measured at a wavelength of 517 nm using a UV/VIS spectrophotometer (model: Alpha-1860Plus, wavelength range: 190–1100 nm, Shanghai Lab-Spectrum Instrument Co., Ltd., Shanghai, China). The total antioxidant capacity is expressed as *DPPH*, as shown in Equation (6).

$$DPPH = (A_1 - A_2 + 0.0081) \div 1.14144 \times V_1 \div (V_1 \div V_2 \times W) \quad (6)$$

where A_1 is the absorbance value of the blank sample; A_2 is the absorbance value of the measured sample; V_1 is the volume of the sample in the reaction, μL ; V_2 is the volume of the added extraction solution, mL; and W is the mass of the sample, g.

2.10.2. FRAP

First, 0.1 mL of the test solution was mixed with 4.9 mL of *FRAP* solution composed of 300 mM of acetate buffer, 20 nM of FeCl_3 solution, and 10 mM of 2,4,6-tripyridinyltriazine solution at a ratio of 10:1:1 ($v/v/v$). The mixture was then incubated for 30 min at 37 °C, after which absorbance values were measured at a wavelength of 593 nm using a UV/VIS spectrophotometer. The total antioxidant capacity was expressed as *FRAP*, as shown in Equation (7).

$$FRAP = (A_3 - A_4 - 0.0134) \div 2.4832 \times V_3 \div (V_3 \div V_4 \times W) \quad (7)$$

where A_3 is the absorbance value of the measured sample; A_4 is the absorbance value of the blank sample; V_3 is the volume of the sample in the reaction, μL ; V_4 is the volume of the added extraction solution, mL; and W is the mass of the sample, g.

2.10.3. ABTS

The method employed by Sun et al. [24] for evaluating the radical scavenging capacity of *ABTS* was adapted with some modifications. Briefly, 0.1 mL of the test solution was mixed with 3.9 mL of *ABTS* cationic solution and incubated at 25 °C for 60 min. Subsequently, the absorbance value was measured at a wavelength of 734 nm using a UV/VIS spectrophotometer. The total antioxidant capacity was expressed as *ABTS*, as shown in Equation (8).

$$ABTS = (A_5 - A_6 + 0.0012) \div 1.4042 \times V_5 \div (V_5 \div V_6 \times W) \quad (8)$$

where A_5 is the absorbance value of the blank sample; A_6 is the absorbance value of the measured sample; V_5 is the volume of the sample in the reaction, μL ; V_6 is the volume of the added extraction solution, mL; and W is the mass of the sample, g.

2.11. Data Processing

The experimental data were statistically analyzed using Office Excel 2020 software. Data processing and plotting were conducted using Origin 2018 software. Statistical analysis was performed using SPSS 27.0 software, and one-way ANOVA and the Duncan multi-range test were used to analyze the significant differences between samples ($p < 0.05$). All trials were repeated three times, and the test results were expressed as the mean positive and negative standard deviation.

3. Results and Discussion

3.1. Drying Characteristics

3.1.1. Drying Kinetics Curves

Figure 4 illustrates the moisture ratio of *Diaogan apricots* dried using various drying methods in the natural drying process. It is evident that the moisture ratio decreases with increasing drying time. During the natural drying process, significant differences were observed in the drying time of *Diaogan apricots* ($p < 0.05$). Specifically, open-air drying in the rocky desert required approximately 136 h, while shade drying required about 172 h. The drying time for open-air drying of *Diaogan apricots* in the rocky desert was reduced by 26.47% compared to shade drying, a trend consistent with the findings of Hu et al. [11]. The results were similar.

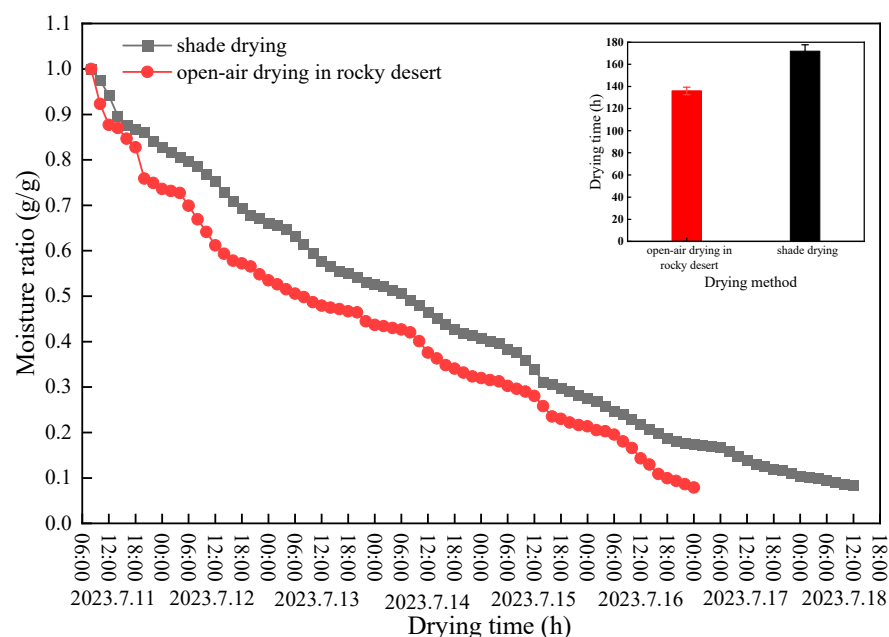


Figure 4. Effect of natural drying method on drying curve of *Diaogan apricots*.

3.1.2. Drying Rate

Figure 5 illustrates the variations in solar radiation intensity and drying rate throughout the natural drying. It is evident that the natural drying process constitutes a continuous and uninterrupted changing process [25]. However, the drying rate was significantly influenced by natural environmental factors. On 13 July 2023, the weather conditions were cloudy and overcast, with the highest solar intensity being $815 \text{ W}\cdot\text{m}^{-2}$, which was 12.27% lower than that observed on sunny days. Moreover, it was noted that the drying rate of *Diaogan apricots* subjected to open-air drying in the rocky desert was lower compared to that of shade-dried *Diaogan apricots*. Therefore, between 0800 h on 11 July 2023 and 1800 h

on 12 July 2023, the drying rate of *Diaogan apricots* exhibited an initial increase followed by a subsequent decrease with rising light intensity. Specifically, the drying rate of dried apricots subjected to open-air drying in the rocky desert reached 0.172 g/g·h, whereas the drying rate under shade ventilation reached 0.114 g/g·h. Abdel-Rahman et al. [10] observed that the drying curve of dates during open-air drying exhibits variations corresponding to changes in solar intensity and temperature, which is similar to the trend of the drying curve observed during the natural drying process of apricots. From 1800 h on 12 July 2023 to 1200 h on 18 July 2023, during the middle and late stages of natural drying, the drying rate under various drying conditions was proportional to the ambient sunlight intensity of the day. In addition, the drying rate accelerated with the enhancement of sunlight intensity, with the peak drying rate observed around 1400 h. Dried apricots undergoing open-air drying in the rocky desert are exposed to solar radiation and benefit from auxiliary heating of pebbles on the ground. Consequently, the drying rate during open-air drying in the rocky desert surpasses that observed during shade drying. Given that there is no solar radiation at night, the drying rate decreases, and the relative humidity in the environment rises. *Diaogan apricots* utilize the heat energy accumulated during the day to facilitate gradual drying throughout the night, ultimately reaching an equilibrium state with the external environment. Toğrul et al. [26] found that the drying rate of fruits was not periodically constant; rather, it exhibited an initial increase followed by a decrease in response to variations in sunlight radiation intensity, which may be attributed to the use of different drying methods [14]. Furthermore, other factors, such as energy conversion and ventilation conditions in the natural environment, could also influence the drying rate.

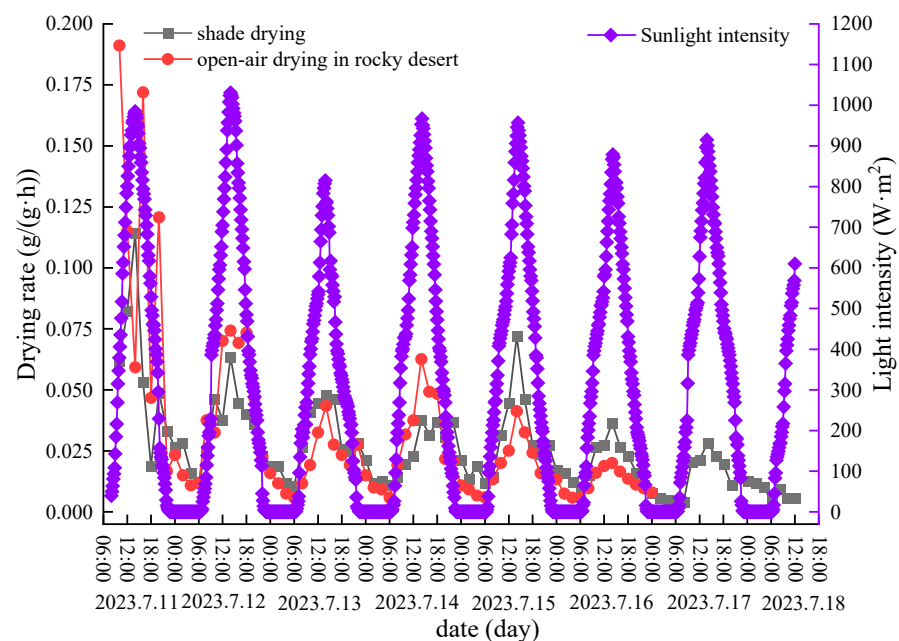


Figure 5. Effect of natural drying methods on the drying rate of *Diaogan apricots*.

3.2. The Effect of the Natural Drying Method on the Color of *Diaogan apricots*

Color serves as a crucial quality indicator not only for fresh fruits but also for dried products, directly influencing consumer acceptance and purchasing decisions [27,28]. Throughout the natural drying process, distinct alterations in color parameters, including brightness L^* , red-green a^* , yellow-blue b^* , and color difference ΔE , were observed across various drying methods (Table 1).

Table 1. Effect of different drying methods on the color of dried apricots.

Category	 Fresh	 Shade Drying	 Rocky Desert Drying
L^*	64.39 ± 1.38^a	52.21 ± 0.57^b	49.18 ± 0.80^b
a^*	10.37 ± 0.30^b	18.23 ± 0.25^a	16.39 ± 0.81^a
b^*	48.49 ± 0.41^a	35.21 ± 0.72^c	31.94 ± 0.18^b
ΔE	-	19.66 ± 0.24^a	23.27 ± 0.87^a

Note: According to Duncan's test, different letters ^a, ^b, and ^c in the same columns showed significant differences ($p < 0.05$).

Table 1 shows a comparison of the L^* , a^* , b^* , and ΔE values of *Diaogan apricots* obtained through shade drying and open-air drying in the rocky desert in relation to the colors of fresh *Diaogan apricots*. The L^* and b^* values of dried apricots were lower than those of fresh *Diaogan apricots*, while the values were higher, indicating a significant decrease in L^* and b^* ($p < 0.05$) and a significant increase in a^* ($p < 0.05$) after drying. These changes may be attributed to oxidation and Maillard reactions [15]. There was no significant difference between L^* and a^* under natural drying conditions, but there was for b^* ($p < 0.05$). During the process of open-air drying in the rocky desert, the sunlight radiation resulted in a decrease in the surface brightness (L^*) and blue and yellow (b^*) components of fresh *Diaogan apricots*, while the red and green (a^*) components increased. In the shade drying process, the roof baffle partially obstructs the sunlight radiation, resulting in shade-dried apricots with higher L^* , a^* , and b^* compared to those subjected to open-air drying in the rocky desert. In addition, shade-dried apricots demonstrated lower color difference (ΔE) and a better color retention rate, which was consistent with the trend of the impacts of different drying methods on the color retention rate of beetroot, as reported by Malakar et al. [17]. However, during the natural drying process, the *Diaogan apricots* are exposed to sunlight leading to browning, which reduces the color of the *Diaogan apricots*. The browning of *Diaogan apricots* is attributed to the oxidation of phenolic substances and ascorbic acid into corresponding quinones catalyzed by enzyme activity, particularly under high temperatures [15].

3.3. Effect of Natural Drying on the Textural Characteristics of *Diaogan apricots*

The textural characteristics of fruits are an important indicator of consumers' choice to purchase [18]. The hardness, springiness, adhesiveness, and chewiness of open-air-dried apricots exhibited significant differences compared to those of fresh samples ($p < 0.05$), as shown in Table 2. In comparison to the textural characteristics of open-air-dried apricots, fresh *Diaogan apricots* displayed lower hardness, adhesiveness, and chewiness while exhibiting higher elasticity. During open-air drying in the rocky desert, fresh *Diaogan apricots* are placed directly on the rocky desert, exposing them to direct sunlight radiation. Consequently, the apricot peel undergoes rapid dehydration and forms a crust. The hardness, adhesiveness, and chewiness of the *Diaogan apricots* are enhanced during the drying process, while the springiness is reduced. Shade drying involves placing fresh *Diaogan apricots* under an awning to prevent direct sunlight irradiation on the surface of the apricot peel, thereby preventing crust formation and effectively retaining the color of the *Diaogan apricot*. As *Diaogan apricots* lose water and shrink during the shade-drying process, their hardness, adhesiveness, and chewiness are enhanced, while springiness is reduced. In summary, the hardness, low springiness, strong adhesiveness, and chewiness of apricots dried in the rocky desert were 14.71%, 18.89%, and 35.79% higher than the values of those subjected to shade drying, respectively. Therefore, shade-dried *Diaogan apricots* exhibit superior textural properties.

Table 2. Effect of natural drying on the textural characteristics of *Diaogan apricots*.

Category	Hardness (N)	Springiness	Adhesiveness	Chewiness (N)
Fresh	14.42 ± 1.60 ^c	2.03 ± 0.13 ^a	3.03 ± 0.25 ^c	5.31 ± 0.19 ^c
Shade-dried	46.95 ± 0.84 ^b	1.74 ± 0.20 ^{ab}	21.89 ± 0.30 ^b	29.26 ± 0.33 ^b
Open-air drying in rocky desert	55.05 ± 1.18 ^a	1.67 ± 0.03 ^{abc}	26.99 ± 0.69 ^a	45.57 ± 0.35 ^a

Note: According to Duncan's test, different letters ^a, ^b, and ^c in the same column showed significant differences ($p < 0.05$).

3.4. Microstructure

Differences in the microstructure of the surface of dried apricot slices between open-air drying in the rocky desert and shade drying are shown in Figure 6. Compared with open-air drying in the rocky desert, the microstructure of *Diaogan apricots* exhibits more honeycomb holes with a larger diameter. During the open drying process in the rocky desert, the daily solar radiation intensity is at its peak, accompanied by high temperatures. Consequently, the dried apricot peel experiences rapid water loss, leading to the clogging and crusting of flesh pores and ultimately resulting in deformation or tearing of the tissue structure [29]. A similar phenomenon was also observed in the drying process of mango studied by Li et al. [30]. During the shade-drying process, the drying rate of *Diaogan apricots* was relatively uniform, resulting in a slower water loss rate. In addition, fewer flesh holes were blocked, and the crusting phenomenon was minimized.

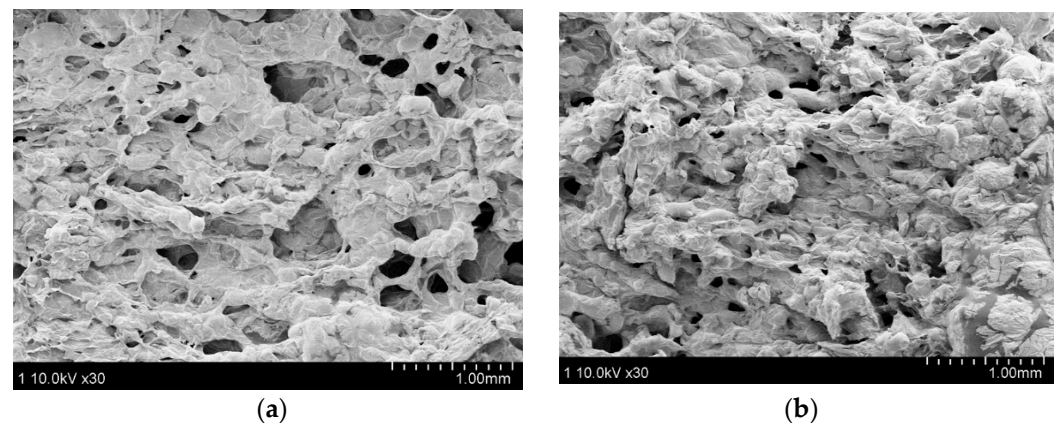


Figure 6. Effect of natural drying on the microstructure of *Diaogan apricots*: (a) shade drying; (b) open-air drying in the rocky desert.

3.5. Effect of Natural Drying on the Rehydration Ratio of *Diaogan apricots*

The results of the rehydration rate of *Diaogan apricots* dried using two natural drying methods are shown in Figure 7. The rehydration ratio of dried apricots dried subjected to shading ventilation was 3.74 g/g, while the rehydration ratio of open-air-dried apricots in the rocky desert was 3.29 g/g. The rehydration ratio of dried apricots dried by shading ventilation was significantly higher than that of dried apricots open-air-dried in the rocky desert ($p < 0.05$). From Table 1 and Figure 6b, it is evident that numerous folds appear on the surface of the peel of dried apricots, while the pulp cells collapse and harden, hindering the entry and exit of water. Ultimately, this results in a reduction of the rehydration of dried apricots, which is determined by the microstructure of the product [13]. Based on Table 1 and Figure 6a, the surface of the dried apricot exhibits fewer wrinkles, resulting in a smaller color difference. This microstructure reveals numerous pores and honeycomb structures, indicating good water permeability, which is 13.68% higher than that of apricots subjected to open-air drying in the rocky desert.

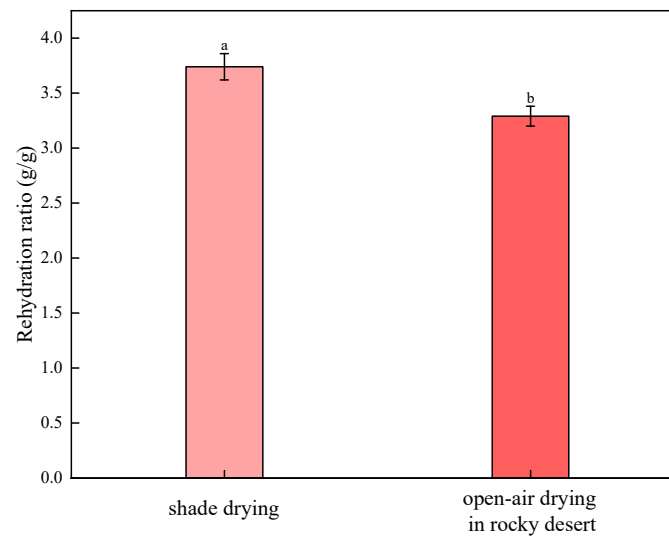


Figure 7. Effect of natural drying on the rehydration ratio of *Diaogan apricots*. Values with different letters in each column are considered significantly different ($p < 0.05$).

3.6. Effect of Natural Drying on Chemical Properties and Antioxidant Activity of Dried Apricots

3.6.1. Titratable Acidity and Soluble Solids Content

The soluble solids and titratable acid content of the sample have a significant impact on the flavor of the sample, and they are important indicators for evaluating the flavor and drying method of a sample [31]. The soluble solids, titratable acidity, and solid–acid ratio of fresh and open-air-dried apricots were compared and analyzed (Figure 8). The soluble solids content of fresh *Diaogan apricots* was lower compared to those subjected to shade drying and open-air drying in the rocky desert, measuring 19.98 ± 0.45 g/100 g, 25.16 ± 0.92 g/100 g, and 22.29 ± 0.41 g/100 g, respectively. Conversely, the titratable acid content of fresh *Diaogan apricots* was higher compared to those subjected to shade drying and open-air drying in the rocky desert, with values of 1.72 ± 0.03 g/100 g, 1.05 ± 0.04 g/100 g, and 1.19 ± 0.04 g/100 g. The soluble solids content of open-air dried apricots was higher than that of fresh apricots, while the titratable acid content was lower, suggesting sugar accumulation and organic acid degradation during the drying process. This trend aligns with previous studies on apricots, kiwifruit, and mangoes [32]. During periods of high daytime temperatures, the polyphenol oxidase in *Diaogan apricots* subjected to open-air drying in the rocky desert was inactivated, causing browning and degradation of the soluble solids in the apricots [14]. The degree of browning observed in shade-dried *Diaogan apricots* was lower, indicating effective retention of soluble solids. Therefore, the soluble solids content of *Diaogan apricots* subjected to open-air drying in rocky desert conditions was lower than that of shade-dried apricots. Elevated temperatures cause rapid moisture loss from the skin of *Diaogan apricots*, resulting in the appearance of crusting on the fruit's surface (Figure 6b). The holes in the pulp of *Diaogan apricots* become clogged and collapse, effectively retaining the titratable acid within the fruit. Therefore, the titratable acid content of *Diaogan apricots* subjected to open-air drying in rocky desert conditions is higher than that of shade-dried *Diaogan apricots*.

3.6.2. Total Phenolic and Ascorbic Acid Content

Phenols and ascorbic acid are important antioxidants in apricot fruit that fight bacterial infections [33]. The changes in total phenols and ascorbic acid contents in apricots dried in the rocky desert conditions were compared and analyzed (Figure 9). There were significant differences in the contents of total phenols and ascorbic acid between fresh *Diaogan apricots* and those dried in the rocky desert ($p < 0.05$). The total phenolic content of shade-dried *Diaogan apricots* was 14.63 mg GAE/g, while the total phenolic content of *Diaogan apricots* dried in open-air conditions in the rocky desert was 9.31 mg GAE/g, indicating a 36.36%

difference between the two drying methods. The ascorbic acid content of shade-dried *Diaogan apricots* was 23.56 mg/g, while the ascorbic acid content of *Diaogan apricots* dried in rocky desert conditions was 18.27 mg/g, indicating a 22.45% difference between the two drying methods. In summary, shade-dried *Diaogan apricots* exhibited the highest total phenolic content and ascorbic acid content, with minimal losses. Sun et al. [24] observed that the total phenol and ascorbic acid content of citrus fruits decreased with increasing drying time under open-air-drying and hot-air-drying conditions.

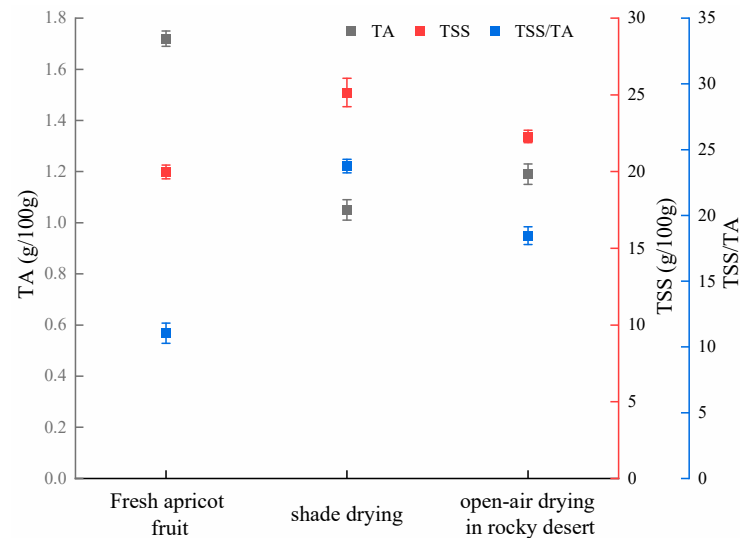


Figure 8. Changes in TSS, TA, and TSS/TA of naturally dried apricots.

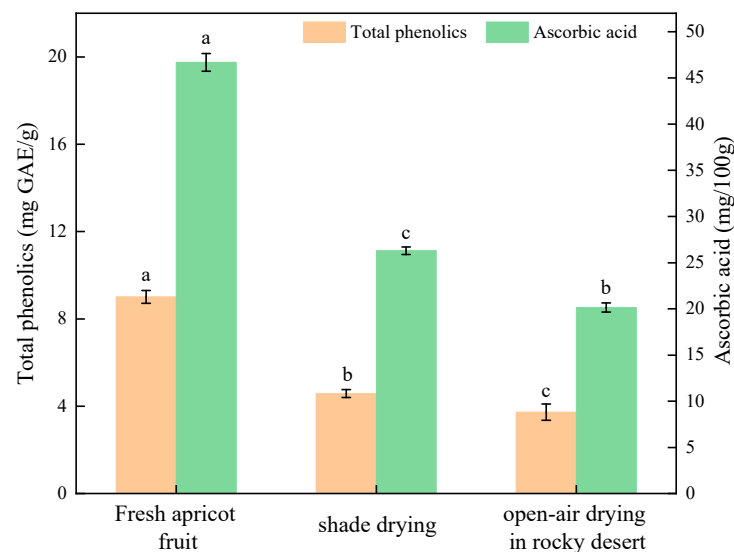


Figure 9. Changes in total phenols and ascorbic acid content of naturally dried apricots. Values with different letters in each column are considered significantly different ($p < 0.05$).

3.6.3. Antioxidant Activity

The antioxidant capacity of dried apricots was evaluated using DPPH, FRAP, and ABTS methods, and the effects of open-air drying on the antioxidant activity of dried apricots are shown in Figure 10. Compared with fresh *Diaogan apricots*, the DPPH radical scavenging capacity decreased by 22.39% in shade-dried apricots and by 54.18% in apricots dried in open-air conditions in the rocky desert. The antioxidant capacity measured using FRAP decreased by 33.94% and 47.81% in shade-dried and open-air dried apricots, respectively, whereas the free radical scavenging capacity measured using ABTS decreased by 50.06% and 59.23%, respectively. From Figure 10a–c, it is evident that the antioxidant

capacity of dried apricots exhibited significant differences ($p < 0.05$). Notably, the DPPH free radical scavenging capacity, FRAP antioxidant capacity, and ABTS free radical scavenging capacity of dried apricots were 19.92 ± 0.22 mmol Trolox/g, 25.57 ± 0.54 mmol Trolox/g, and 21.93 ± 1.18 mmol Trolox/g, respectively. On the other hand, the DPPH free radical scavenging capacity, FRAP antioxidant capacity, and ABTS free radical scavenging capacity of apricots dried in the rocky desert were 11.76 ± 0.36 mmol Trolox/g, 20.20 mmol Trolox/g, and 17.76 ± 0.83 mmol Trolox/g, respectively. In summary, the antioxidant capacity of dried apricots subjected to shading and ventilation was stronger than that of the apricots that underwent open-air drying in the rocky desert. Specifically, the DPPH free radical scavenging capacity, FRAP antioxidant capacity, and ABTS free radical scavenging capacity were 40.96%, 21.01%, and 19.02% higher than the values of those open-air-dried in the rocky desert. During the drying process, the apricot fruit underwent open-air drying, and it was exposed to direct sunlight during the day, leading to the migration of antioxidant active substances within the dried apricot due to heat. This resulted in a decrease in the antioxidant activity of the dried apricot, which is consistent with findings reported by Nunes [34] and Podsedek et al. [35]. The conclusions of this study suggest that high temperatures led to a decrease in total phenol and ascorbic acid content, resulting in a decrease in antioxidant activity. Moreover, the temperature and cooling within the shed remained relatively uniform due to the sunlight panel on the roof, which effectively blocked direct sunlight. Consequently, the loss of antioxidant active substances in the *Diaogan* apricots was relatively small. Lukinac [36] and Perez-GiAlvez et al. [37] showed that prolonged exposure to sunlight resulted in the loss of antioxidant materials, leading to enzymatic browning. Furthermore, redox reactions led to a decrease in the antioxidant activity of materials [38]. Therefore, the choice of an appropriate drying method and temperature is crucial in preserving the antioxidant capacity of the sample.

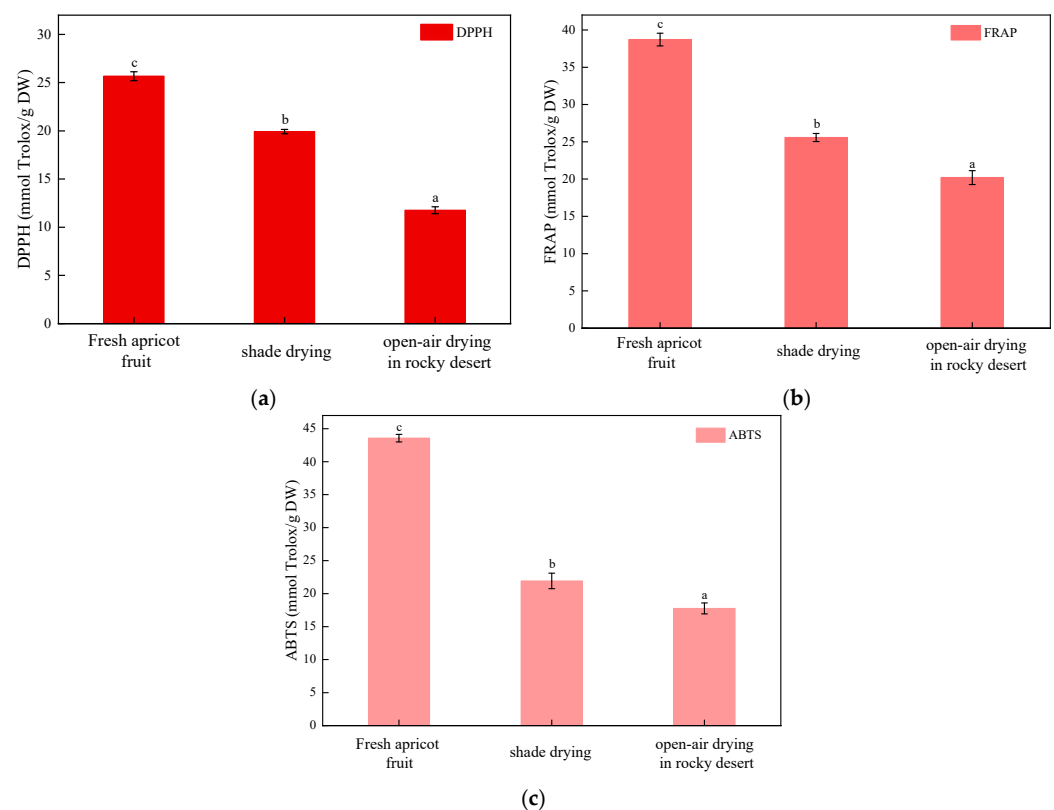


Figure 10. Changes in the antioxidant capacity of naturally dried apricots: (a) DPPH free radical scavenging ability; (b) FRAP antioxidant capacity; (c) ABTS free radical scavenging ability. Values with different letters in each column are considered significantly different ($p < 0.05$).

4. Conclusions

This study systematically explored the drying characteristics, color changes, textural characteristics, microstructure, and quality characteristics of *Diaogan apricots* under different natural drying conditions, which were, specifically, shade drying and open-air drying in the rocky desert. The results showed that (1) the drying time and drying rate of dried apricots were shorter and faster by 26.47% than those required for drying apricots in the rocky desert; (2) during the open-air drying process in the rocky desert, the dried apricot lost water rapidly, the crusting phenomenon appeared on the surface of the peel, the pore size of the pulp was blocked and collapsed, and the cell structure was damaged, resulting in poor rehydration and color and textural characteristics of the dried apricot; (3) the soluble solids contents of dried apricots were 2.31 g/100 g and 5.18 g/100 g higher than those of fresh *Diaogan apricots*, respectively, whereas the titratable acids were 0.53 g/100 g and 0.67 g/100 g lower than those of fresh *Diaogan apricots*, respectively; and (4) in comparison to the levels of total phenols and ascorbic acid found in dried apricots, those in apricots subjected to drying in the rocky desert were reduced by 58.60% and 49.17%, respectively. Conversely, apricots dried under shaded and ventilated conditions demonstrated increases of 36.36% and 22.45% in total phenols and ascorbic acid content, respectively, compared to those dried in the rocky desert. The antioxidant capacity of dried apricots subjected to shade surpasses that of open-air-dried apricots in the rocky desert. In summary, open-air drying of hanging-dried apricots in the rocky desert requires a shorter time, but it results in inferior color and texture properties alongside reduced retention rate of nutrients and antioxidant capacity. In contrast, shade drying hanging-dried apricots allows for a slower drying rate, but the method preserves the color of dried apricots more effectively, enhances their textural characteristics, and improves the retention rate of nutritional components and antioxidant capacity. Therefore, the superior quality of vacuum-shade-dried hanging-dried apricots renders them suitable for promotion and application. This research serves as a valuable reference for fruit farmers and producers in remote areas, offering essential data for the mechanized production of dried fruits.

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