Check for updates

Journal of Food Processing and Preservation

WILEY

RESEARCH ARTICLE OPEN ACCESS

Effects of Different Infrared Wavelength and Pretreatments on the Drying of Persimmon

Begüm Arkain | Habib Kocabiyik

Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye

Correspondence: Habib Kocabiyik (kocabiyikh@comu.edu.tr)

Received: 28 August 2025 | **Revised:** 2 April 2026 | **Accepted:** 9 April 2026

Academic Editor: Poulami Jha

Keywords: cluster analysis | drying | drying kinetics | edible coatings pretreatment | persimmon | quality

ABSTRACT

Persimmon's high-water content and its physiological structure being prone to deterioration shorten its shelf life. In this sense, there is a great need to research alternative methods to extend shelf life and preserve product quality. This study investigates the effects of edible coating applications applied to persimmon dried at different infrared wavelengths on drying kinetics and some quality properties. The trials were carried out at 400-W emitter input power, middle and short infrared wavelengths and 1.5 m^2 s^{-1} air velocity without pretreatment (control), and with pretreatment. Drying time varied depending on pretreatments and infrared wavelengths. The best results in terms of drying kinetics, shorter drying time (58 min), lower specific energy consumption (10.59 MJ kg^{-1}_{water}) and higher diffusion coefficient (1.12 10^{-7} m^2 s^{-1}) were obtained by drying the slices pretreated with citric acid + ascorbic acid and using short wave infrared energy. In contrast to the results obtained with middle wave infrared energy, in terms of quality characteristics, slices pretreated with guar gum using short wave infrared energy showed lower shrinkage (63.88%) and higher rehydration ratio (3.24). The colour was significantly better preserved in slices treated with citric acid + ascorbic acid for both short (12.21) and middle (9.06) wavelengths.

1 | Introduction

Persimmon (*Diospyros kaki* L.) is a fruit belonging to the Ebenaceae family, originally from China, and widely distributed from tropical to temperate regions of Asia and Central South America [1, 2]. As can be seen from the distinctive orange colour of the fruit, it also contains important pigments such as anthocyanins, phenolic substances and carotenoids [3]. Thanks to the rich nutritional content of the fruit, it has been stated that it strengthens the immune system and lowers high blood pressure and cholesterol [4]. In addition to being consumed fresh, it has had many uses in recent years, such as sauces, ice cream, salads, jams and marmalade [5]. The external appearance, aroma, nutritional aspect and medicinal value of the fruit have caused it to be in high demand in international markets. There are quite a lot of varieties with different usage methods. Among these, the widely known *Rojo Brillante* variety has recently increased in popularity due to its high productivity and commercial quality [6]. In addition to these advantageous aspects, it is a variety that has many benefits for human health with a rich nutrient content. Due to the high-water content of persimmon and its physiological structure being suitable for deterioration, shelf life is limited to a few days [7]. Drying is one of the most widely used methods for long-term preservation of fruits without spoilage after harvest. During drying, a significant part of the water of the product is removed and the product is made more concentrated. In addition, there is a continuous physical and structural change in the size of the product because of the internal collapse of the particles [8].

The traditional hot-air drying method is widely applied for agricultural products. Due to the high sugar content in fruit, hot air drying requires high temperatures and long drying times, which can lead to negative changes in flavour, colour, texture

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

Copyright © 2026 Begüm Arkain and Habib Kocabiyik. *Journal of Food Processing and Preservation* published by John Wiley & Sons Ltd.

and degradation of heat-sensitive compounds in the final product [9]. Freeze drying is recommended for drying agricultural products because it is effective in preserving bioactive compounds. However, it has disadvantages such as long drying time and high operational costs [10, 11]. To prevent such negative changes, studies that pretreatments applied to the product before drying have revealed significant effects on the quality characteristics of the final product [12]. Studies in the literature examine chemical pretreatments, such as immersion in sugar, acid, salt, alkali and sulphite solutions, as well as physical pretreatment methods like hot water, steam, microwave blanching and ultrasound [13]. Additionally, edible hydrocolloid coatings (such as arabic gum, guar gum, xanthan gum, tragacanth gum and sodium alginate) have become widely used as pretreatments for fruits and vegetables before drying, especially in recent years. Examples include, arabic gum-coated carrots [14], apple–xanthan gum [15], sweet cherry–guar and xanthan gum [16], orange slices–guar gum [17], wolfberry–carboxymethyl cellulose [18], purple sweet potato- sodium alginate [19] and papaya starch [20]. Edible coatings are stated to improve the nutritional value and sensory properties of dried fruits and vegetables, thereby increasing shelf life and maintaining food safety and product quality [18, 21]. However, further research on drying methods and product specificity is needed to fully explore the potential of edible coatings as a pretreatment option. In our previous study, we examined the effects of edible coating pretreatments on the drying of persimmon with medium wavelength infrared energy to see differences between varieties [22]. We did not find any studies on the effects of edible coating pretreatments on the drying of persimmon with infrared energy at different wavelengths, specific to the product and drying method. Therefore, the aim of this study was to investigate the effects of different pretreatments, including edible coatings, on drying kinetics and quality characteristics of persimmon dried with infrared energy at different wavelengths.

2 | Materials and Methods

2.1 | Sample Preparation

In this study, fruits of the "Rojo Brillante" variety were selected for the drying experiments. For each pretreatment and drying condition, samples were collected in subgroups taken from a single batch. The samples were obtained from a local producer during the same harvest season. Interbatch biological variability was not evaluated within the scope of this study. The findings reflect the process effects only within the specific batch examined and should be validated across different harvests or independent batches. Samples were stored in a refrigerator at +4°C before drying experiments to preserve freshness. Before the drying trials, the samples were taken to the laboratory and remained there for 2 h to reach room temperature. For the initial moisture content of persimmon, the samples were kept in an oven at 105°C for 24 h, and the initial moisture content was determined as 82.33% ± 0.5% (wet basis) ($4.56\,kg_{water} \cdot kg^{-1}_{dry\,matter}$).

The fruits selected for the trial were first washed and sliced into 5 mm using a slicer. Approximately 250 g of sample was used in each drying trial. The pretreatments applied to the samples are given in Table 1. Previous studies have suggested that acid solutions should be applied at concentrations ranging from 0.1% to 5% [23], whereas coating solutions should be applied at concentrations ranging from 0.1% to 3% [14, 24, 25]. For coating solutions, when solutions were prepared at the recommended concentration ranges prior to the experiment, it was determined that the solution would be very viscous. Therefore, considering the preliminary studies conducted before the experiment, a solution at a concentration of 0.0025% was found to be more suitable. Furthermore, in preliminary treatment studies using gum and acid solutions, a 3-min immersion time has been found to be sufficient [26]. The solutions used in the pretreatments were prepared using water at 22°C. The chemicals used for pretreatments were completely dissolved in water at room temperature. They were kept under refrigerator conditions until the experiment. Before the immersion process, the solutions were taken into the laboratory environment and the solutions were used to immersion.

TABLE 1 | Pretreatments applied to the samples.

Preprocessing	Code	Description
Arabic gum	*AG*	0.0025%
Xanthan gum	*XG*	0.0025%
Guar gum	*GG*	0.0025%
Citric acid	*CA*	3%
Ascorbic acid	*AA*	1%
Citric acid + ascorbic acid	*CAAA*	0.2%CA + 1%AA
Blanching	*B*	70°C

2.2 | Drying Tests

Drying experiments to determine the effect of process variables on the drying kinetics of Trabzon persimmons and the quality parameters of dried Trabzon persimmons were conducted in the laboratory of the Department of Agricultural Machinery, Faculty of Agriculture, Çanakkale Onsekiz Mart University. An experimental setup developed for drying different agricultural products using infrared energy was used. The drying setup, measuring $500 \times 300 \times 500$ mm, was made of 2-mm thick stainless-steel sheet. Two infrared lamps with a power of 1200 and 1500 W were placed inside the dryer. The distance between the infrared heaters and the drying surface (sample surface) was set to 20 cm and kept constant throughout all experiments. To obtain different infrared power (different radiation intensity) from the infrared heaters, a pyranometer (CMP 11, Kipp&Zonen, Netherlands) operating in the 0.3–2.8-μm wavelength measurement range and with a sensitivity of 7–14 $\mu V\,W/m^2$ was used. An experimental setup is shown schematically in Figure 1. The same electrical input conditions have been set for the emitters. To ensure equal conditions in terms of energy consumption and drying kinetics at the start, the input power of the emitters has been kept constant (400 W). Naturally, the radiation loads may vary depending on the wavelength of the emitters. Under the same electrical power conditions, 3650 W/m^2

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

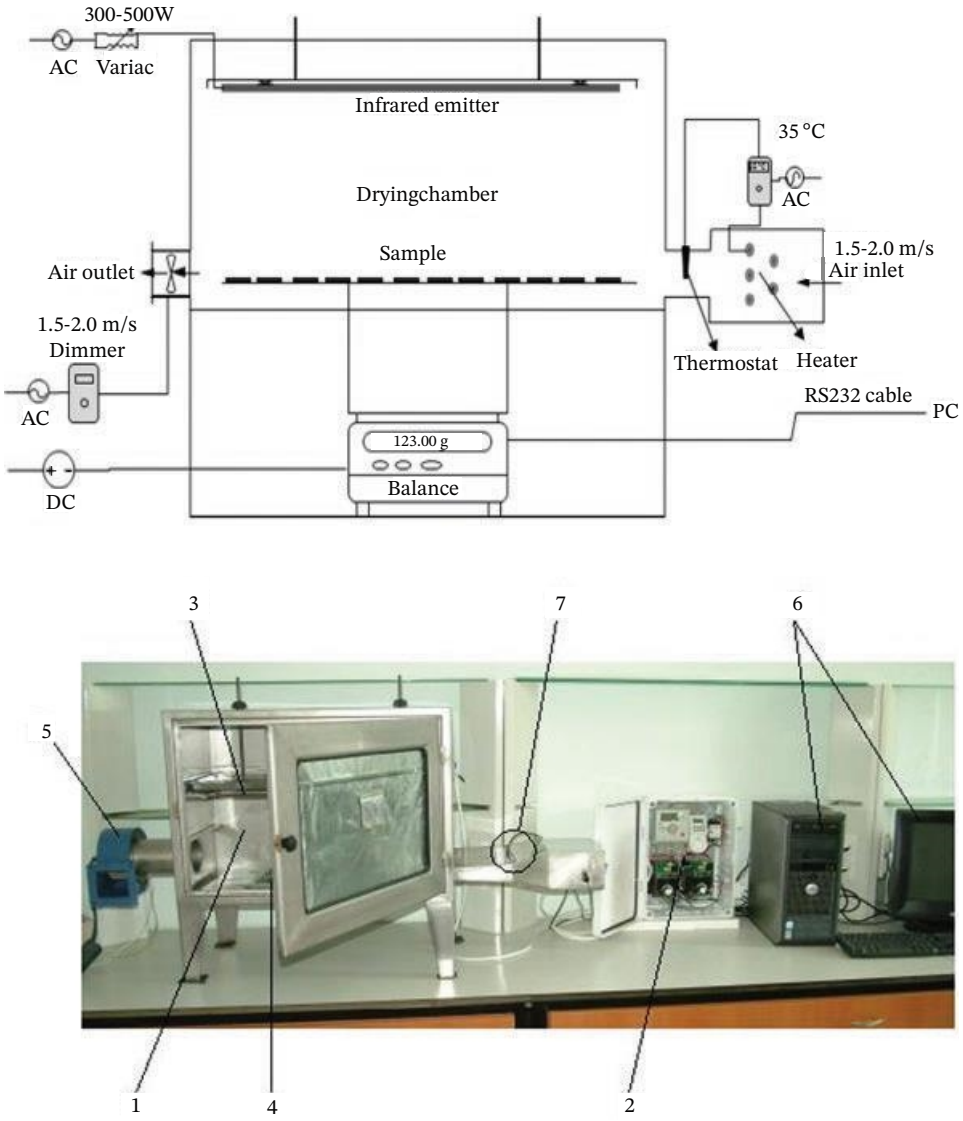


FIGURE 1 | Experimental setup of infrared dryer: 1—drying cabinet, 2—control panel, 3—infrared heat source, 4—drying tray, 5—fan, 6—computer, and 7—thermostat.

($\lambda = 2.4 - 2.7\,\mu$m) appears in short-wave infrared energy and 1210 W/m^2 ($\lambda = 1.0 - 1.4\,\mu$m) appears in middle-wave infrared energy. In drying experiments conducted with short and midwave infrared energy, the air velocity was kept constant ($v = 1.5\,\text{ms}^{-1}$), and the experiments were carried out with and without pretreatment (control). The inlet air temperature was measured at 25°C ± 2°C during drying, and no heating was applied. The dryer was adjusted and idled for approximately 10 min before each trial to achieve the required drying conditions. The persimmon slices were arranged in a thin layer on a drying tray (400 × 250 mm) made of Teflon material [27]. The mass change in the samples was measured with a Precisa XB 3200C precision balance with an accuracy of 0.01 g and transferred to the computer at 3-min intervals via Balint software.

2.3 | Drying Kinetics

The studies conducted with persimmon stated that the final moisture content should be between 25% and 30% [4, 28]. Therefore, the samples were dried until the final moisture content was 25% of the wet basis. The drying rate of the samples was calculated using the following Equation ((1) [29].

$$\text{DR} = \frac{M_{t+\text{dt}} - M_t}{\text{d}_\text{t}} \tag{1}$$

where DR is the drying rate ($\text{kg}_{\text{water}} \cdot \text{kg}^{-1}_{\text{dry matter}}\,\text{min}^{-1}$); M_{t+dt} is the moisture content at time $t + \text{dt}$ is the $\text{kg}_{\text{water}} \cdot \text{kg}^{-1}_{\text{dry matter}}\,\text{min}^{-1}$; M_t is the moisture content at time t ($\text{kg}_{\text{water}} \cdot \text{kg}^{-1}_{\text{dry matter}}\,\text{min}^{-1}$); t is time (min).

2.4 | Specific Energy Consumption

The electrical energy consumed by the drying system's equipment was measured using a digital electricity meter, and the total energy consumption was determined. Specific energy consumption (E_s) was defined as the amount of energy required to remove a unit amount of water from the samples during drying and calculated using Equation ((2) [30].

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

$$Es = \frac{E_T}{M_W} \quad (2)$$

where E_s is the specific energy consumption (MJ kg^{-1}_{water}), E_T is total energy consumption (MJ), and M_W is the mass of water removed (kg).

2.5 | Effective Diffusion Coefficient

According to Fick's second law, the effective diffusion coefficient D_{eff} is defined as the rate of moisture loss over time. This model assumes that the product's cellular structure remains intact and that internal moisture migration occurs solely through diffusion [31]. The estimation of this parameter assumes a constant geometry, which disregards the effects of shrinkage. Additionally, it should be noted that these assumptions may affect the absolute values of D_{eff}. The effective diffusion coefficient of the samples was calculated using the following equations [32].

$$MR = \frac{M_t - M_e}{M_0 - M_e} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{2n+1}\exp\left(\frac{-D_{eff}(2n+1)_2\pi^2 t}{4L^2}\right) \quad (3)$$

where MR is the moisture ratio; M_t is the moisture content at time t ($kg_{water} \cdot kg^{-1}_{dry\,matter}\,min^{-1}$); M_e and M_0 are the equilibrium and initial moisture content ($kg_{water} \cdot kg^{-1}_{dry\,matter}\,min^{-1}$), respectively. D_{eff} is the effective diffusion coefficient ($m^2\ s^{-1}$); L is the thickness of the half slice of the dried product (m); t is time (s).

If Equation ((3) is simplified by taking the first term of the series for long drying times, it becomes Equation ((4).

$$MR = \frac{8}{\pi^2}\exp\left(\frac{-\pi^2 D_{eff}\, t}{4L^2}\right) \quad (4)$$

The slope k of the ln (MR) plot plotted against drying time was calculated according to Equation ((5).

$$D_{eff} = \frac{4k.L^2}{\pi^2} \quad (5)$$

2.6 | Volumetric Change

Volumetric change, namely shrinkage ratio (%S), was calculated based on the changes in the volumes of six numbered slices before and after drying and defined as a percentage change (Figure 2). The volumes of the slices were determined using the displacement method in a graduated cylinder and poppy seeds, and the volumetric change was calculated using the following equation [22].

$$\%S = \frac{V_f - V_d}{V_f}100 \quad (6)$$

where %S is the volumetric change and V_d and V_f represent the volume of dried and fresh persimmon slices, respectively.

2.7 | Rehydration Ratio

The rehydration property (R_r) is considered one of the quality indices of the dried product and shows the physical and chemical changes of the product during drying [33]. Using the masses before and after rehydration, the rehydration ratios of the slices were calculated with the following equation [34].

$$R_r = \frac{M_r}{M_d} \quad (7)$$

where $R_r$is the rehydration ratio and M_d and M_r are the masses of dried and rehydrated persimmon slices, respectively.

2.8 | Colour Features

$L*$ (lightness), $a*$ (redness/greenness) and $b*$ (yellowness/blueness) parameters were measured in CIE Lab* colour space with a Minolta CR-400 Chroma meter (Minolta Co., Osaka, Japan) to determine the colour changes of 10 slices before and after drying (Figure 2). Total colour change (ΔE) was calculated using the following equation [22].

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} = \sqrt{\left(L_f^* - L_d^*\right)^2 + \left(a_f^* - a_d^*\right)^2 + \left(b_f^* - b_d^*\right)^2} \quad (8)$$

where f and d indices indicate the colour features of fresh and dry slices, respectively.



FIGURE 2 | Positions of the product on the tray (C: colour measurements and S: volume measurements).

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

2.9 | Statistical Analysis

Minitab R21.4 statistical software (StatSoft, Inc., Tulsa, Oklahoma, United States) was used to determine the effect of independent variables (wavelength and pretreatment) on drying time, E_s, D_{eff}, R_r, $\%S$ and ΔE. ANOVA test was performed at a 5% significance level. Calculations were performed using the general linear model. Differences between means were determined by the Tukey multiple comparisons test at a 5% confidence level. The experiments were carried out in three replications. Interactions between variables were analyzed using principal component analysis (PCA) and Pearson correlation analysis. In addition, cluster analysis was performed based on drying kinetics (DT, D_{eff}, and E_s) and quality characteristics ($\%S$, R_r, and ΔE) of persimmon slices to determine the similarity between different drying methods. OriginPro 2024 (OriginLab Corporation, Northampton, Massachusetts, United States) was used for PCA and cluster analysis.

3 | Results and Discussion

3.1 | Drying Kinetics

Changes in moisture content of persimmon depending on drying time are shown in Figure 3. It was found that the shortest drying time was in the samples with *CAAA* solution as a pretreatment using a short-wave infrared emitter, whereas the longest drying time was in the samples with *CAAA* solution pretreatment using a middle infrared emitter (Figure 3.) *CAAA* pretreatment led to prolonged drying times at the middle infrared emitter, whereas it decreased drying times at the short infrared emitter. With the different pretreatments applied, the drying times of the samples varied between 58 and 88 min in the trials where the short wavelength emitter was used, whereas it varied between 93 and 150 min in the trials where the middle wavelength emitter was used. The effects of wavelength, pretreatment and interactions of these factors on drying time were to be significant ($p < 0.05$).

The blanching pretreatment reduced drying times at both wavelengths, as it facilitates faster water removal by causing damage and changes to the cell walls and membranes, resulting in shorter drying times. Oshima et al. [35] similarly found that blanching pretreatment reduced drying times. It is seen that gum solutions generally cause an increasing effect on drying times. Since gum solutions form a thick film layer around the fruits and vegetables to be dried, it causes a decrease in permeability and prevention of moisture transfer [21]. Other researchers have also stated that gum solutions prevent the removal of water from the product [16].

In convective drying of persimmon, shorter drying times occurred in ultrasound and osmotic dehydration pretreatments [12]. Arabic gum pretreatment had an increasing effect on drying time in the convective drying of carrots [14].

The drying rate changes of persimmon samples as a function of moisture content are shown in Figure 4. At the same moisture content and pretreatment, higher drying rates were realized in the drying with short wavelength emitter. A constant rate drying period was not observed during drying with the short-wave infrared emitter. In contrast, a trend like the constant rate drying period was observed during drying with the middle wave infrared emitter. Therefore, there was to be a clear difference in drying rate between the wavelengths. In the drying process using the short wavelength emitter, *CAAA* pretreatment substantially increased the drying rate compared with using the middle wavelength emitter (Figure 4). In the hot air drying of persimmon using blanching pretreatment, a drying period with a decreasing rate was observed during the whole drying process; no drying period with a constant rate was observed, and the blanching process affected the drying rate [7].

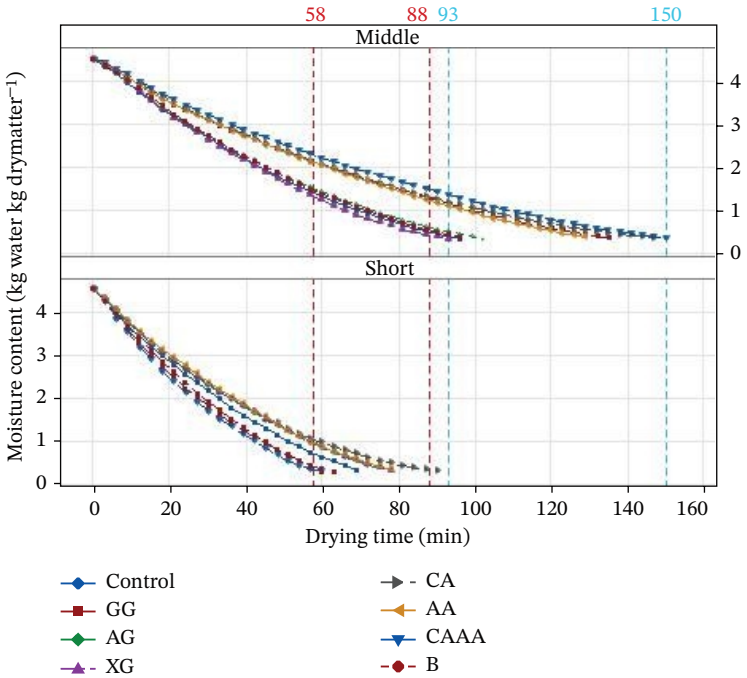


FIGURE 3 | Moisture content curves according to drying time.

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

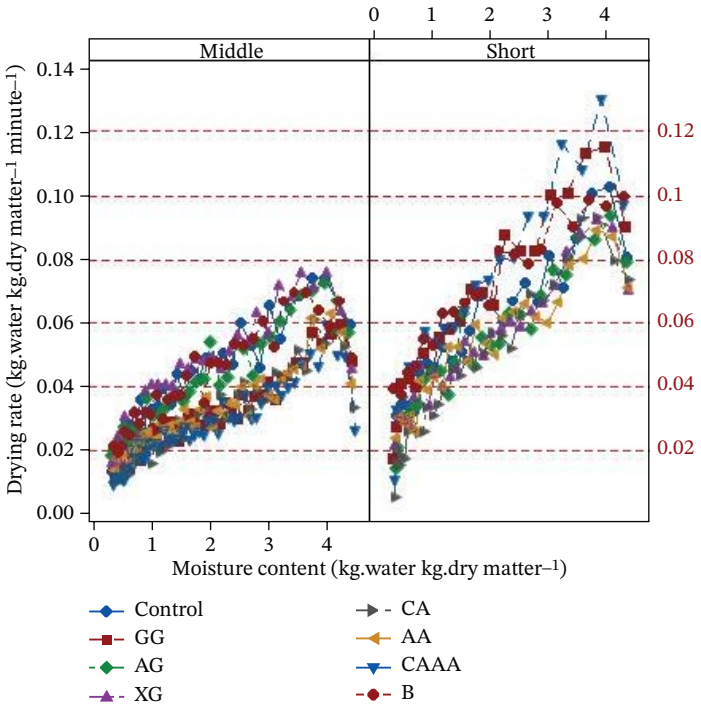


FIGURE 4 | Drying rate curves according to moisture content.

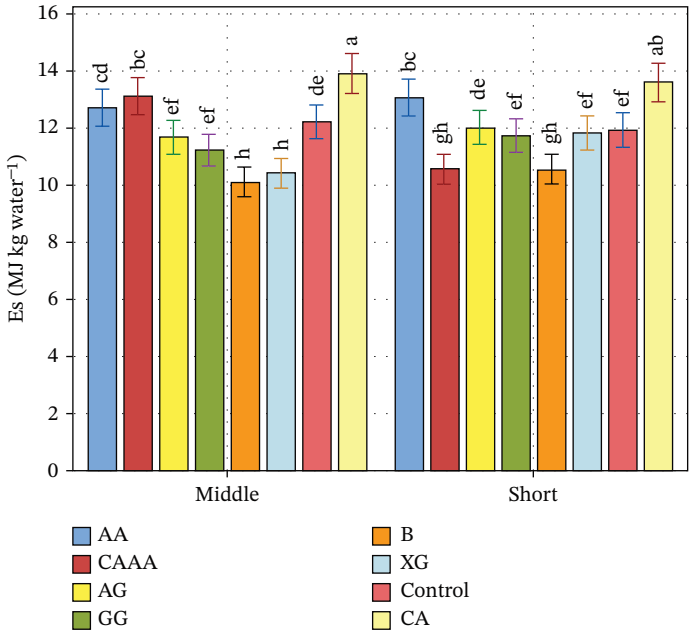


FIGURE 5 | Variations of specific energy consumption according to wavelength and pretreatment.

3.2 | Specific Energy Consumption

The specific energy consumption values required to remove water from the product during the drying of persimmon slices are given in Figure 5. Although the E_s value ranged between 10.57 and 13.62 MJ kg^{-1}_{water} in the trials using short wave infrared emitter, it ranged between 10.13 and 13.93 MJ kg^{-1}_{water} in the trials using middle wave emitter. The highest E_s value was obtained in the drying conditions subjected to *CA* pretreatment by the middle wave emitter; in contrast, the lowest E_s value was obtained in the drying conditions subjected to *B* treatment at the middle wave emitter. Interestingly, whereas lower E_s values were obtained in the drying conditions with the shortest drying time and *CAAA* pretreatment at the short wave, higher E_s values were obtained at the middle wave under the same pretreatment condition. The effect of wavelength, pretreatment and interactions of these factors on E_s was statistically significant ($p < 0.05$). Drying rates increased in the blanching pretreatment, resulting in lower specific energy consumption due to shorter drying times.

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

E_s in microwave drying of persimmon slices having different thicknesses varied between 12.18 and 27.66 MJ kg^{-1}_{water} [31]. Compared with studies with other products and drying methods, drying persimmon by infrared energy required a lower E_s value. It was observed that generally, the pretreatments applied in the drying of persimmon had a significant effect on energy savings.

3.3 | Effective Diffusion Coefficient

The variation of D_{eff} values of persimmon according to wavelength and pretreatment is shown in Table 2. As the D_{eff} value varied between $0.75 \cdot 10^{-7}$ and $1.12\,10 - 7\,m^2\ s^{-1}$ in the trials using short wave infrared energy source, it was between $0.42 \times 10^{-7} - 0.72\,10^{-7}\,m^2\ s^{-1}$ in the trials using middle wave infrared energy. The highest D_{eff} value was determined in drying trials using short wave infrared energy and *CAAA* pretreatment. The lowest D_{eff} value occurred in middle wave drying trials using *CAAA* pretreatment (Table 2). *CAAA* pretreatment resulted in higher drying speeds, shorter drying times, lower energy consumption and higher diffusion coefficient values in short-wave emitter drying. This is due to the short-wave emitter being able to pass through the *CAAA* coating barrier more easily. In particular, the barrier created by *CA* applications prevented the flow of energy to the product and the passage of water from the product. The samples dried by the middle wave with *AG, GG* and acid solutions (*CA, AA* and *CAAA*) had lower D_{eff} values compared with the control. At trials by short wave energy, the D_{eff} values of the samples treated with *AG, XG* and acid (*CA* and *AA*) solutions were lower than the D_{eff} values of the control group. In addition, it was clearly seen that higher D_{eff} values occurred in all trials with short wave infrared energy compared with the trials with middle wave infrared energy. The effect of wavelength, pretreatment and their interactions on the D_{eff} was found to be significant ($p < 0.05$).

In hot air drying of persimmon pretreated using ultrasound, D_{eff} varied between $1.17 \cdot 10^{-8}$ and $9.49 \cdot 10^{-9}\,m^2\ s^{-1}$ [12]. Convectively dried sour cherries with *GG* pretreatment had higher D_{eff} values compared with control samples, and D_{eff} was significantly affected by pretreatment [36].

3.4 | Volumetric Change

Volumetric change (shrinkage) occurring in foodstuffs during drying is defined as a physical quality parameter that affects the textural quality of the dried product [37]. In drying trials by short wave emitter with different pretreatments, %*S* ranged between 61.27% and 68.98% in persimmon slices, whereas in drying trials by middle wave emitter, volumetric change ranged between 65.32% and 73.99%. The highest %*S* values were obtained in the samples pretreated with *XG* at middle wavelength, whereas the lowest %*S* values were obtained in the samples pretreated with *AA* at short wavelength (Table 2). Although the effect of wavelength on %*S* was significant, the effect of pretreatment was insignificant ($p > 0.05$).

TABLE 2 | D_{eff}, %*S*, R_r and ΔE values of persimmons.

Wavelength	Pretreatment	D_{eff} $(m^2\ s^{-1})$	%*S*	R_r	ΔE
Middle	Control	0.68×10^{-7fg}	71.19 ± 9.29^{ns}	2.98 ± 0.05^{ab}	14.70 ± 2.53^{ns}
	AA	0.47×10^{-7h}	65.32 ± 19.14^{ns}	2.92 ± 0.18^{ab}	12.43 ± 5.67^{ns}
	CA	0.44×10^{-7hi}	72.18 ± 4.39^{ns}	2.91 ± 0.27^{ab}	14.77 ± 8.06^{ns}
	CAAA	0.42×10^{-7i}	69.21 ± 10.74^{ns}	2.81 ± 0.07^{ab}	9.06 ± 5.41^{ns}
	GG	0.46×10^{-7hi}	71.37 ± 5.85^{ns}	2.69 ± 0.12^{b}	14.15 ± 6.95^{ns}
	XG	0.72×10^{-7ef}	73.99 ± 7.92^{ns}	3.29 ± 0.38^{a}	9.46 ± 5.08^{ns}
	AG	0.64×10^{-7g}	69.28 ± 10.65^{ns}	3.19 ± 0.39^{ab}	7.78 ± 4.18^{ns}
	B	0.65×10^{-7g}	67.85 ± 7.83^{ns}	2.75 ± 0.04^{ab}	17.09 ± 5.34^{ns}
Short	Control	0.89×10^{-7c}	68.98 ± 8.31^{ns}	3.14 ± 0.05^{ab}	19.93 ± 4.09^{ns}
	AA	0.80×10^{-7d}	61.27 ± 8.36^{ns}	2.89 ± 0.09^{ab}	17.70 ± 10.7^{ns}
	CA	0.75×10^{-7e}	61.32 ± 6.26^{ns}	2.77 ± 0.02^{ab}	16.51 ± 8.31^{ns}
	CAAA	1.12×10^{-7a}	64.09 ± 8.97^{ns}	3.01 ± 0.03^{ab}	12.21 ± 3.21^{ns}
	GG	1.06×10^{-7b}	63.88 ± 2.11^{ns}	3.24 ± 0.33^{ab}	17.70 ± 4.76^{ns}
	XG	0.80×10^{-7d}	63.66 ± 7.08^{ns}	2.98 ± 0.04^{ab}	13.28 ± 2.47^{ns}
	AG	0.82×10^{-7d}	67.63 ± 4.96^{ns}	2.94 ± 0.08^{ab}	12.24 ± 7.18^{ns}
	B	1.05×10^{-7b}	64.69 ± 12.00^{ns}	2.91 ± 0.14^{ab}	13.76 ± 3.93^{ns}

Note: Tukey test: There is no difference between the treatments shown with the same letters in the same column ($p > 0.05$). ns: no statistical difference. ±: standard deviation.

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Shrinkage values of persimmon dried convectively (40°C and 60°C, 0.5 m^2 s^{-1} air velocity) after different osmotic treatments varied between 52.95% and 86.30% [38]. In peach and apple slices dried by infrared energy, lower $\%S$ values were obtained in samples pretreated with xanthan gum solution than in control samples [15, 39].

3.5 | Rehydration Ratio

Rehydration ratio is the ability of dried products to regain their moisture content and is an important parameter determining the quality of the products [40]. The $R_r$values varied between 2.77 and 3.24 in the trials by short wave infrared energy emitter with different pretreatments applied, whereas it varied between 2.69 and 3.29 in the trials by middle wave energy emitter. The lowest and highest R_r values occurred in the samples pretreated with *GG* and *XG* at the middle wave, respectively. The R_r values obtained in all drying trials were to be very close (Table 2). Surprisingly, the highest R_r and $\%S$ values were recorded in the samples subjected to *XG* pretreatment with middle wave infrared energy. This can be attributed to less closure of the pores during product shrinkage. The effect of wavelength and pretreatment factor interactions, except for individual factors on R_r, was statistically significant ($p < 0.05$).

The factors affecting the rehydration ratio can be listed as physical and chemical changes in the product due to drying, drying conditions, the composition of the product to be dried and pretreatments applied to the product [41]. Persimmon pretreated with ascorbic acid and dried in 80°C hot air had the lowest R_r [23]. The rehydration ratio of sweet cherries coated with guar gum was significantly higher than that of the control. It was also emphasized that the samples coated with guar gum have a higher volume and porous structure; in other words, dried products with higher rehydration ratios can be obtained [16]. Salehi and Inanloodoghouz [36] also reached similar results in the study conducted with sour cherries.

3.6 | Colour Features

The variation of the total colour change of persimmon slices after drying according to wavelength and pretreatment is presented in Table 2. The ΔE of the slices dried using short wave infrared energy ranged between 12.21 and 19.93, whereas the ΔE of the slices dried with middle wave infrared energy was between 7.78 and 17.09. For both infrared wavelengths, the least ΔE, namely colour conservation, happened in the trials where *AG* pretreatment was used. On the other hand, the highest ΔE, namely the highest colour loss, was recorded in the control samples at drying by short wave infrared energy. In addition, higher ΔE occurred in slices with *GG* and *AA* pretreatment than the other pretreatment at drying by short wave infrared energy. Wavelength and pretreatment individually had a significant effect on ΔE ($p < 0.05$), but their interaction was not significant ($p > 0.05$).

The pretreatments applied inhibited pigment change, helping preserve the product's colour during drying. Salehi and Satorabi [15] found lower ΔE in apple samples immersed in xanthan gum solution compared with the control group. On the other hand, Fadaie et al. [42] determined the range of $10.09 - 20.04\ \Delta E$ of persimmons dried by infrared energy (200, 300 and 400 W), and the ΔE values had a similar range to that of our study.

Guar gum pretreatment of orange slices was found to be effective in reducing discolouration, and it was stated that the hydrophilic surface of edible coatings helps to gain water molecules present in the slices, forming a hydrocolloid (gum) film on the surface of the product and consequently reducing ΔE [17]. Surprisingly, a different trend was observed in the results of this study for guar gum pretreatment than the results of Eftekhari et al. [17]. During the drying process using infrared energy, water molecules in the samples are transported directly into the layers within the product via thermal radiation through molecular vibration, resulting in intense and rapid energy transfer. In a product with high sugar content, such as Trabzon persimmon, when the water content decreases and the temperature rises, sugar molecules break down and new bioactive compounds and brown pigments emerge, thus causing a greater loss of colour in the product.

3.7 | PCA

PCA was used to show the positive or negative directional positions of the interactions of the studied factors and variables analyzed with each other. The drying kinetics (DT, E_s and D_{eff}) and quality characteristics (R_r, $\%S$ and ΔE) were separated into two different components, accounting for 73.76% of the total cumulative value (Figure 6). The PC1 component had an axis value of 46.56%, whereas the PC2 component had an axis value of 27.20%. E_s—R_r, ΔE—$\%S$ and DT—D_{eff} were located at opposite positions on the axes when all characteristics were analyzed. Among these, DT—E_s, D_{eff}—R_r were in the same region.

Shorter drying times and lower E_s were observed in the trials with *CAAA* and *B* pretreatment at short wavelength, which showed similar behavioural effects between DT—E_s. It can be said that the acid solution and blanching pretreatments accelerate the removal of moisture as they destroy the tissue wall of the product. Higher D_{eff} and R_r occurred in *GG* and *CAAA* pretreated trials with short wavelength, and therefore, these variables show similar behavioural effects with each other and can be said to be in the same region.

3.8 | Pearson Correlation Analysis

The negative and positive correlations between the drying kinetics including the operational characteristics of the drying process and the quality characteristics of the dried persimmons are shown in Figure 7. A strong negative correlation (r: −0.96; $p < 0.05$) was found between D_{eff}—DT. Moderate positive correlations were found between E_s – DT and %SDT with r: 0.46, 0.52 ($p < 0.05$) and between R_r—D_{eff} with r: 0.43 ($p < 0.05$), respectively. On the other hand, negative moderate correlations were determined between $\%S$—$D_{\text{eff}}$with r: −0.52 ($p < 0.05$).

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

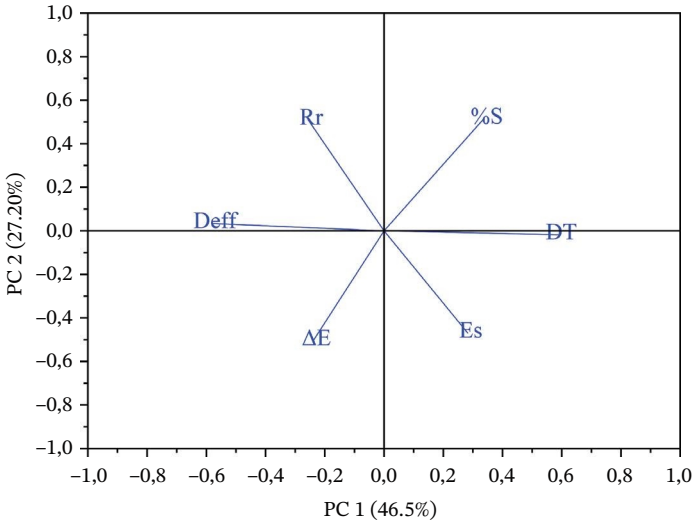


FIGURE 6 | Principal component analysis (PCA) of drying kinetics and quality characteristics.

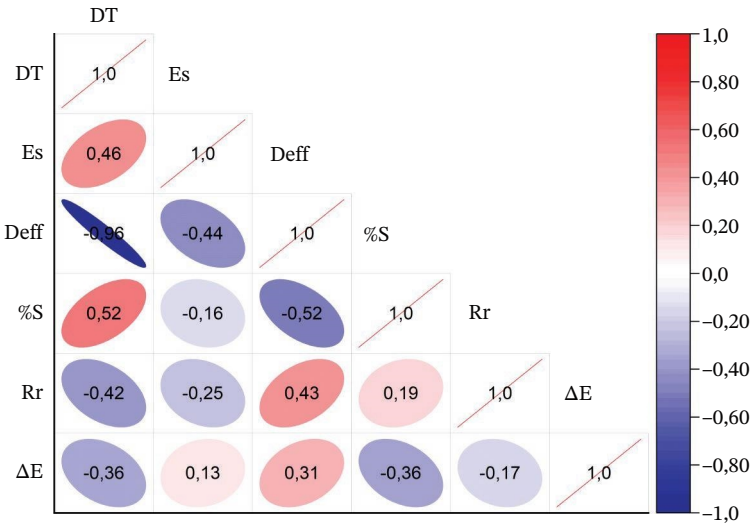


FIGURE 7 | Correlations between drying kinetics and quality characteristics.

3.9 | Cluster Analysis

A cluster analysis based on dendrograms of drying kinetics (*DT*, D_{eff} and E_s) and quality characteristics of the dried product (%*S*, R_r and Δ*E*) was performed to determine the similarities between different drying combinations using different pretreatment and two different infrared wavelengths. Euclidean distance method was used for clustering analysis. In the clustering analysis, the similarity approach was taken and a similarity limit of higher than 75% was taken as a basis. Drying combinations with high similarity were expressed with the same colour clusters. In terms of drying kinetics, the similarity values of the drying combinations ranged between 1.02% and 98.89%; the short *AG-XG*, short *AG-XG* and short *AA*; short *CAAA-B*; middle wave *C-XG*; middle *C-XG* and B; middle *CA-CAAA*; short GG and short *CAAA-B*; middle *GG-AA*; short *CA* and middle *C-XG-B*; and short *C* and short *AG-XG-AA* combinations were more than 90% similar to each other (Figure 8a). The similarity values of drying combinations for quality characteristics ranged between 0.64% and 95.79%. The closest drying combinations—middle *C-GG*, middle *C-GG* and *CA*, short *XG-B*, short *CA-AA*, short *CAAA*–middle *AA* and middle *AG-CAAA*—had similarity values above 90% (Figure 8b). When all characteristics were evaluated together, the similarity values varied between 2.60% and 97.18%. Short *CAAA-B*, short *AG-XG*, middle *C-B*, middle *CA-CAAA*, *CAAA-B* with short *GG*, *AA* with short *AG-XG* and middle *GG-AA* drying combinations had similarity values higher than 90% (Figure 8c).

In terms of drying kinetics, the experiments in which short wavelength emitters were used and the edible coatings *AG* and *XG* pretreated were highly similar. It can be said that this is due to the thickening and water binding properties of both gum solutions. It was observed that gum solutions generally had a prolonging effect on drying times. It can be said that this prolongation effect is because the gums form a thick film layer on the product. Similarly, Boateng [43] and de Menezes Rodrigues et al. [44] also stated that gum solutions inhibit moisture transfer. Interestingly, the results of the trials with *GG* and *CAAA-B* pretreatment, which were considered as physical, chemical and edible coatings, were highly similar to each other at using short wave.

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

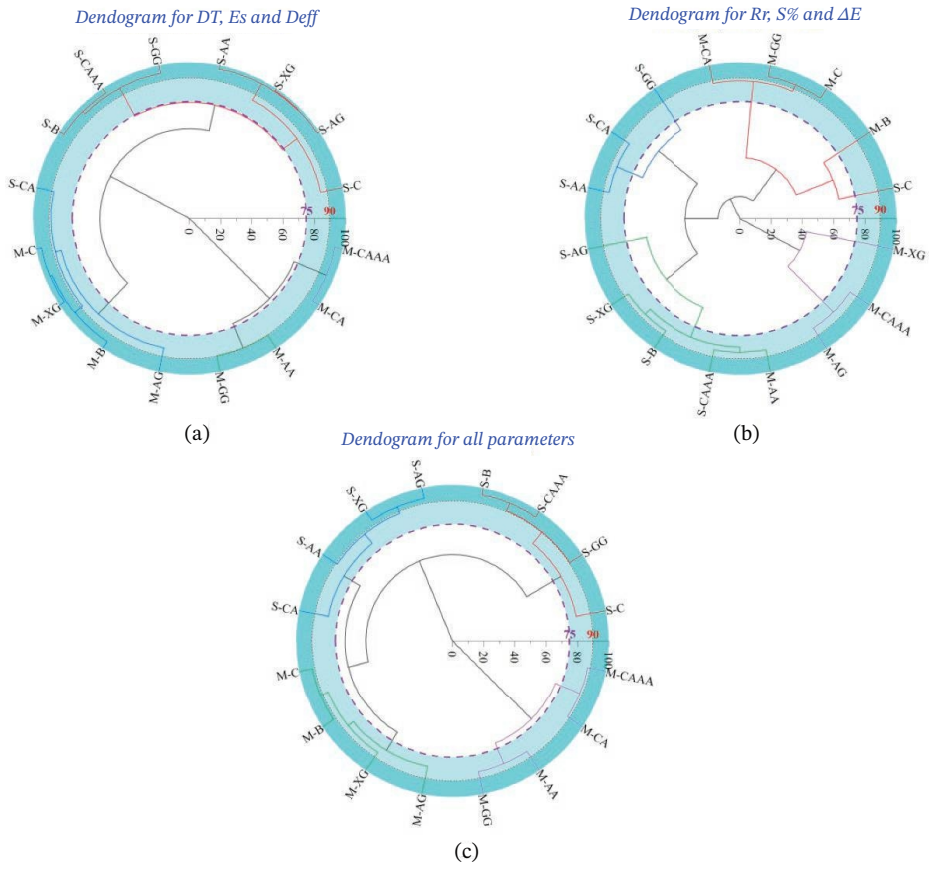


FIGURE 8 | Circular dendrogram of the drying combinations based on (a) drying kinetics characteristics, (b) quality characteristics and (c) all characteristics. (M-C: middle wave—control, M-GG: middle wave—guar gum, M-AG: middle wave—arabic gum, M-XG: middle wave—xanthan gum, M-CA: middle wave—citric acid, M-AA: middle wave—ascorbic acid, M-CAAA: middle wave—ascorbic acid + citric acid, M-B: middle wave—blanching; S-C: short wave—control, S-GG: short wave—guar gum, S-AG: short wave—arabic gum, S-XG: short wave—xanthan gum, S-CA: short wave—citric acid, S-AA: short wave—ascorbic acid, S-CAAA: short wave—ascorbic acid + citric acid, S-B: short wave—blanching).

4 | Conclusion

This study investigated the effects of different wavelengths and pretreatments on drying kinetics (DT, DR, D_{eff} and E_s) and some quality (ΔE, R_r and $\%S$) characteristics of persimmon. The drying time was varied depending on pretreatments and wavelengths. Regarding drying kinetics, shorter drying time, lower E_s and higher D_{eff} values occurred by drying the slices pretreated with *CAAA* and using short wave infrared energy. In contrast to the results obtained for middle wave infrared energy, the results obtained for quality characteristics using short wave infrared energy showed lower $\%S$ and higher R_r in slices pretreated with *GG*. The best colour retention, namely the lowest ΔE, occurred in slices treated with *CAAA* for both short and middle wavelengths. In this context, it can be recommended to use *CAAA* and *GG* solutions as pretreatment in the drying of persimmon. Further research is needed to develop reliable analytical methods for operational parameters, including different infrared radiation intensities and nutritional qualities aspects. In this regard, optimization studies evaluating drying, quality and nutritional content cumulatively will make significant contributions to the literature.

Nomenclature

$a*$	redness/greenness
AA	ascorbic acid
AG	Arabic gum
$b*$	yellowness/blueness
B	blanching
$CAAA$	citric acid + ascorbic acid
D_{eff}	effective diffusion coefficient ($m^2\ s^{-1}$)
DR	drying rate ($kg_{water} \cdot kg^{-1}_{dry\ matter}\ min^{-1}$)
DT	drying time (min)
E_s	specific energy consumption ($MJ\ kg^{-1}_{water}$)
E_T	total energy consumption (MJ)
GG	guar gum
L	thickness of the half slice of the dried product (m)
$L*$	lightness
M	middle wave
M_0	initial moisture content ($kg_{water} \cdot kg^{-1}_{dry\ matter}$)
M_d	mass of the dried persimmon slices
M_e	equilibrium moisture content ($kg_{water} \cdot kg^{-1}_{dry\ matter}$)
MR	moisture ratio
M_r	mass of the rehydrated persimmon slices

jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

M_t	moisture content at time t ($kg_{water} \cdot kg^{-1}_{dry\ matter}$)
M_{t+dt}	moisture content at $t + dt$ ($kg_{water} \cdot kg^{-1}_{dry\ matter}$)
M_W	mass of water removed (kg)
R_r	rehydration ratio
S	short wave
t	time (min)
V_d	volume of dried persimmon slices
V_f	volume of fresh persimmon slices
w.b.	wet basis
XG	xanthan gum
ΔE	total colour change
$\%S$	volumetric change

Author Contributions

Begüm Arkain: research, data collection, laboratory experiments, drafting and writing an article. **Habib Kocabiyik:** data analysis and finalizing the article.

Acknowledgements

The authors have nothing to report.

Funding

No funding was received for this manuscript.

Disclosure

This study includes a section of the research conducted as part of the Begüm Arkain's doctoral thesis.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. M. Nugraheni, W. Windarwati, and F. Rahmawati, "*Potential of Dyospirus khaki Baverage as Sources of Natural Antioxidant*," *Pakistan Journal of Nutrition* 12, no. 7 (2013): 620–627, https://doi.org/10.3923/pjn.2013.620.627.

2. K. Vivek, K. V. Subbarao, and B. Srivastava, "Effect of Thin-Layer Drying on the Quality Parameters of Persimmon Slices," *International Journal of Fruit Science* 21, no. 1 (2021): 587–598, https://doi.org/10.1080/15538362.2021.1919278.

3. M. S. De Jesus, H. C. Araujo, M. Denadai, et al., "Effect of Different Drying Methods on the Phenolic and Volatile Compounds of Persimmon (*Diospyros kaki* L.)," *Journal of Food Measurement and Characterization* 17, no. 3 (2023): 2576–2594, https://doi.org/10.1007/s11694-022-01803-6.

4. Z. Wei, Z. Duan, X. Tang, et al., "Effects of Microwave Drying on Nutrient Component and Antioxidant Activity of Persimmon Slices," *Journal of Food Measurement and Characterization* 16, no. 2 (2022): 1744–1753, https://doi.org/10.1007/s11694-021-01273-2.

5. E. Yildiz, A. Yilmaz, O. Gurbuz, and I. Alibas, "Effect of Drying Methods and Pre-Treatments on Bioactive Potential of Persimmon (*Diospyros kaki* L.)," *Journal of Food Measurement and Characterization* 18, no. 3 (2024): 2014–2029, https://doi.org/10.1007/s11694-023-02252-5.

6. W. Senadeera, G. Adiletta, B. Önal, M. Di Matteo, and P. Russo, "Influence of Different Hot Air Drying Temperatures on Drying Kinetics, Shrinkage, and Colour of Persimmon Slices," *Foods* 9, no. 1 (2020): 101, https://doi.org/10.3390/FOODS9010101.

7. İ. Doymaz, "Evaluation of Some Thin-Layer Drying Models of Persimmon Slices (*Diospyros kaki* L.)," *Energy Conversion and Management* 56 (2012): 199–205, https://doi.org/10.1016/J.ENCONMAN.2011.11.027.

8. A. R. Andino, F. Pieniazek, and V. Messina, "Texture of Bananas Submitted to Different Freeze Drying Cycle Applying Scanning Electron Microsocopy With Image Analysis Techniques," *Food Biophysics* 14, no. 1 (2019): 13–21, https://doi.org/10.1007/s11483-018-9551-6.

9. J. Politowicz, K. Lech, L. Sánchez-Rodríguez, et al., "Volatile Composition and Sensory Profile of Oyster Mushroom as Affected by Drying Method," *Drying Technology* 36, no. 6 (2018): 685–696, https://doi.org/10.1080/07373937.2016.1274903.

10. S. Duan, C. Ding, J. Lu, et al., "Study the Effect of Ultrasonic Pretreatment Combined With Electrohydrodynamics on Drying Characteristics and Volatile Components of Carrots," *Applied Food Research* 4, no. 2 (2024): 100634, https://doi.org/10.1016/j.afres.2024.100634.

11. Y. Liu, Z. Zhang, and H. Liandong, "High Efficient Freeze-Drying Technology in Food Industry," *Critical Reviews in Food Science and Nutrition* 62, no. 12 (2022): 3370–3388, https://doi.org/10.1080/10408398.2020.1865261.

12. H. Bozkir, and A. R. Ergün, "Effect of Sonication and Osmotic Dehydration Applications on the Hot Air Drying Kinetics and Quality of Persimmon," *LWT* 131 (2020): 109704, https://doi.org/10.1016/j.lwt.2020.109704.

13. L. Z. Deng, A. S. Mujumdar, Q. Zhang, et al., "Chemical and Physical Pretreatments of Fruits and Vegetables: Effects on Drying Characteristics and Quality Attributes–a Comprehensive Review," *Critical Reviews in Food Science and Nutrition* 59, no. 9 (2019): 1408–1432, https://doi.org/10.1080/10408398.2017.1409192.

14. Z. P. Mina, T. Kaseke, T. Fadiji, and O. A. Fawole, "Effect of Gum Arabic and Ethanol Pretreatments on Drying Kinetics and Quality Attributes of Dried Carrot Slices," *Heliyon* 8, no. 12 (2022): e12037, https://doi.org/10.1016/j.heliyon.2022.e12037.

15. F. Salehi, and M. Satorabi, "The Effects of a Gum-Based Edible Coating on Apple Slices Characteristics During Infrared Heating," *Journal of Food Biosciences and Technology* 12 (2022): 1–10, https://doi.org/10.30495/jfbt.2022.65051.10286.

16. F. Salehi, S. Ghazvineh, and M. Inanloodoghouz, "Effects of Edible Coatings and Ultrasonic Pretreatment on the Phenolic Content, Antioxidant Potential, Drying Rate, and Rehydration Ratio of Sweet Cherry," *Ultrasonics Sonochemistry* 99 (2023): 106565, https://doi.org/10.1016/j.ultsonch.2023.106565.

17. A. Eftekhari, F. Salehi, A. G. Ardabili, and N. Aghajani, "Effects of Basil Seed and Guar Gums Coatings on Sensory Attributes and Quality of Dehydrated Orange Slices Using Osmotic-Ultrasound Method," *International Journal of Biological Macromolecules* 253 (2023): Pt 4127056, https://doi.org/10.1016/j.ijbiomac.2023.127056.

18. F. Yu, Y. Li, W. Zhenfeng, X. Wang, N. Wan, and M. Yang, "Dehydration of Wolfberry Fruit Using Pulsed Vacuum Drying Combined With Carboxymethyl Cellulose Coating Pretreatment," *LWT* 134 (2020): 110159, https://doi.org/10.1016/j.lwt.2020.110159.

19. P. Liu, A. S. Mujumdar, M. Zhang, and H. Jiang, "Comparison of Three Blanching Treatments on the Color and Anthocyanin Level of the Microwave-Assisted Spouted Bed Drying of Purple Flesh Sweet Potato," *Drying Technology* 33, no. 1 (2015): 66–71, https://doi.org/10.1080/07373937.2014.936558.

20. M. Z. Islam, T. Saha, K. Monalisa, and M. M. Hoque, "Effect of Starch Edible Coating on Drying Characteristics and Antioxidant Properties of

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Papaya," *Journal of Food Measurement and Characterization* 13, no. 4 (2019): 2951–2960, https://doi.org/10.1007/s11694-019-00215-3.

21. E. J. Bassey, J. H. Cheng, and D. W. Sun, "Novel Nonthermal and Thermal Pretreatments for Enhancing Drying Performance and Improving Quality of Fruits and Vegetables," *Trends in Food Science & Technology* 112 (2021): 137–148, https://doi.org/10.1016/j.tifs.2021.03.045.

22. D. Or, B. Arkain, and H. Kocabiyik, "The Effect of Pretreatments on the Drying of Persimmon With Infrared Energy," *Journal of Food Process Engineering* 47, no. 5 (2024): 1–11, https://doi.org/10.1111/jfpe.14632.

23. S. Bölek, and E. Obuz, "Quality Characteristics of Trabzon Persimmon Dried at Several Temperatures and Pretreated by Different Methods," *Turkish Journal of Agriculture and Forestry* 38 (2014): 242–249, https://doi.org/10.3906/tar-1303-41.

24. A. López-Ortiz, I. Y. Pacheco Pineda, L. L. Méndez-Lagunas, et al., "Optical and Thermal Properties of Edible Coatings for Application in Solar Drying," *Scientific Reports* 11, no. 1 (2021): 10051, https://doi.org/10.1038/s41598-021-88901-5.

25. J. Hu, X. Sun, H. Xiao, et al., "Optimization of Conditions for a Freeze-Dried Restructured Strawberry Block by Adding Guar Gum, Pectin and Gelatin," *Plants* 11, no. 21 (2022): 2809, https://doi.org/10.3390/plants11212809.

26. H. E. Tahir, Z. Xiaobo, G. K. Mahunu, M. Arslan, M. Abdalhai, and L. Zhihua, "Recent Developments in Gum Edible Coating Applications for Fruits and Vegetables Preservation: A Review," *Carbohydrate Polymers* 224 (2019): 115141, https://doi.org/10.1016/j.carbpol.2019.115141.

27. H. Kocabiyik, N. Yilmaz, N. B. Tuncel, S. K. Sumer, and M. B. Buyukcan, "Drying, Energy, and Some Physical and Nutritional Quality Properties of Tomatoes Dried With Short-Infrared Radiation," *Food and Bioprocess Technology* 8, no. 3 (2015): 516–525, https://doi.org/10.1007/s11947-014-1418-3.

28. H. Bozkir, A. R. Ergün, E. Serdar, G. Metin, and T. Baysal, "Influence of Ultrasound and Osmotic Dehydration Pretreatments on Drying and Quality Properties of Persimmon Fruit," *Ultrasonics Sonochemistry* 54 (2019): 135–141, https://doi.org/10.1016/j.ultsonch.2019.02.006.

29. J. R. de Jesus Junqueira, J. R. do Carmo, L. Miyagusku, T. C. Balbinoti, M. de Carvalho Rafael Salgado Junqueira, and R. F. de Lucena, "Infrared Drying of Bocaiuva (*Acrocomia aculeata*) Slices: Drying Kinetics, Energy Consumption, and Quality Characteristics," *Food Biophysics* 19, no. 4 (2024): 885–894, https://doi.org/10.1007/s11483-024-09846-6.

30. S. Nasiroglu, and H. Kocabiyik, "Thin-Layer Infrared Radiation Drying of Red Pepper Slices," *Journal of Food Process Engineering* 32, no. 1 (2009): 1–16, https://doi.org/10.1111/j.1745-4530.2007.00195.x.

31. S. Çelen, "Effect of Microwave Drying on the Drying Characteristics, Color, Microstructure, and Thermal Properties of Trabzon Persimmon," *Foods* 8, no. 2 (2019): 84, https://doi.org/10.3390/foods8020084.

32. Y. Abbaspour-Gilandeh, A. Jahanbakhshi, and M. Kaveh, "Prediction Kinetic, Energy and Exergy of Quince Under Hot Air Dryer Using ANNs and ANFIS," *Food Science and Nutrition* 8, no. 1 (2020): 594–611, https://doi.org/10.1002/FSN3.1347.

33. E. Horuz, H. Bozkurt, H. Karataş, and M. Maskan, "Effects of Hybrid (Microwave-Convectional) and Convectional Drying on Drying Kinetics, Total Phenolics, antioxidant capacity, Vitamin C, Color and Rehydration Capacity of Sour Cherries," *Food Chemistry* 230 (2017): 295–305, https://doi.org/10.1016/j.foodchem.2017.03.046.

34. H. Kocabiyik, N. Yilmaz, N. B. Tuncel, S. K. Sumer, and M. Burak Buyukcan, "The Effects of Middle Infrared Radiation Intensity on the Quality of Dried Tomato Products," *International Journal of Food Science and Technology* 49, no. 3 (2014): 703–710, https://doi.org/10.1111/ijfs.12353.

35. T. Oshima, K. Kato, and T. Imaizumi, "Effects of Blanching on Drying Characteristics, Quality, and Pectin Nanostructures of Dried Cut-Persimmons," *LWT* 143 (2021): 111094, https://doi.org/10.1016/j.lwt.2021.111094.

36. F. Salehi, and M. Inanloodoghouz, "Effects of Gum-Based Coatings Combined With Ultrasonic Pretreatment Before Drying on Quality of Sour Cherries," *Ultrasonics Sonochemistry* 100 (2023): 106633, https://doi.org/10.1016/j.ultsonch.2023.106633.

37. M. Mahiuddin, M. Imran, H. Khan, C. Kumar, M. M. Rahman, and M. A. Karim, "Shrinkage of Food Materials During Drying: Current Status and Challenges," *Comprehensive Reviews in Food Science and Food Safety* 17, no. 5 (2018): 1113–1126, https://doi.org/10.1111/1541-4337.12375.

38. J. L. Corrêa, F. J. Lopes, R. E. de Mello Júnior, et al., "Drying of Persimmon Fruit (*Diospyros kaki* L.) Pretreated by Different Osmotic Processes," *Journal of Food Process Engineering* 44, no. 10 (2021): e13809, https://doi.org/10.1111/jfpe.13809.

39. F. Salehi, and M. Satorabi, "Effect of Basil Seed and Xanthan Gums Coating on Colour and Surface Change Kinetics of Peach Slices During Infrared Drying," *Acta Technologica Agriculturae* 24, no. 3 (2021): 150–156, https://doi.org/10.2478/ata-2021-0025.

40. S. Tan, Y. Wang, F. Wenwen, Y. Luo, S. Cheng, and W. Li, "Drying Kinetics and Physicochemical Properties of Kumquat Under Hot Air and Air-Impingement Jet Dryings," *Food Science and Biotechnology* 31, no. 6 (2022): 711–719, https://doi.org/10.1007/s10068-022-01080-5.

41. C. Ricce, M. L. Rojas, A. C. Miano, R. Siche, and P. E. D. Augusto, "Ultrasound Pre-Treatment Enhances the Carrot Drying and Rehydration," *Food Research International* 89 (2016): Pt 1701–708, https://doi.org/10.1016/J.FOODRES.2016.09.030.

42. M. Fadaie, S. H. H. Ghaboos, and B. Beheshti, "Characterization of Dried Persimmon Using Infrared Dryer and Process Modeling Using Genetic Algorithm-Artificial Neural Network Method," *Food Science and Technology* 17, no. 100 (2020): 189–200, https://doi.org/10.52547/fsct.17.100.189.

43. I. D. Boateng, "Recent Processing of Fruits and Vegetables Using Emerging Thermal and Non-Thermal Technologies. A Critical Review of Their Potentialities and Limitations on Bioactives, Structure, and Drying Performance," *Critical Reviews in Food Science and Nutrition* 64, no. 13 (2024): 4240–4274, https://doi.org/10.1080/10408398.2022.2140121.

44. G. de Menezes Rodrigues, V. A. dos Santos Garcia, C. M. Yoshida, F. M. Vanin, and R. A. de Carvalho, "Fruit-Based Leathers: A Comprehensive Review of Terminologies, Composition, and Quality Attributes," *Food Science and Engineering* 4, no. 2 (2023): 216–236, https://doi.org/10.37256/fse.4220232791.

Jfpp, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/jfpp/5484569 by Canakkale Onsekiz Mart Uni, Wiley Online Library on [27/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License