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Influence of Basic Drying Techniques on Color, Protein and Mineral Composition of Coriander Leaves

İlknur ALİBAŞ[1], Aslıhan YILMAZ[1]
[1]Bursa Uludağ Üniversitesi, Ziraat Fakültesi, Biyosistem Mühendisliği Bölümü, 16059, Nilüfer / Bursa
[1]https://orcid.org/0000-0002-1898-8390, [2]https://orcid.org/0000-0002-4913-905X
✉: ialibas@uludag.edu.tr

ABSTRACT
Coriander leaves were weighed at 20 ± 0.02 g and dried with natural drying at shade, convective drying at 50°C and 1 m s^{-1} air velocity, and microwave drying at 200 and 800 W. The drying periods were led 4680, 630, 85, and 16.50 minutes for natural, 50°C, 200 W, and 800 W, respectively. Whereas energy consumption was not recorded in natural drying, energy consumption at 50°C, 200 W, and 800 W was recorded as 10.290, 0.283, and 0.220 kWh, respectively. The closest results to fresh leaves in terms of color parameters were measured at 800 W, followed by 200 W. Similarly, at 800 and 200 W, the most successful results were obtained with regard to calcium, magnesium, and iron. Also, it was analyzed that the chlorophyll content, protein, phosphorus, potassium, and zinc were preserved at the maximum level in the 800 W microwave drying method. Although all drying methods cause similar reductions for sodium, it was determined that manganese was well preserved at 200 W. Among the dried samples, the highest copper level was analyzed in natural drying and microwave drying at 800 W. To sum up, the most convenient drying technique for coriander leaves was 800 W in terms of drying and quality parameters.

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Temel Kurutma Tekniklerinin Kişniş Yaprağının Renk, Protein ve Mineral İçeriği Üzerine Etkisi

ÖZET
Kişniş yaprakları 20 ± 0.02 g tartılmış ve gölgede doğal kurutma, 50°C ve 1 m s^{-1} hava hızında konvektif kurutma ve 200 ve 800 W'da mikrodalga kurutma yöntemleri ile kurutulmuştur. Kurutma süreleri doğal, 50°C, 200 W ve 800 W için sırasıyla 4680, 630, 85 ve 16.50 dakika olarak ölçülmüştür. Doğal kurutmada herhangi bir enerji tüketimi kaydedilmezken, 50°C, 200 W ve 800 W'ta enerji tüketimi sırasıyla 10.290, 0.283 ve 0.220 kWh olarak hesaplanmıştır. Renk parametreleri bakımından taze örneğe en yakın sonuçlar 800 W'ta, ardından 200 W'ta kurutulan örneklerde ölçülmüştür. Benzer şekilde 800 ve 200 W'ta kalsiyum, magnezyum ve demir açısından en başarılı sonuçlar elde edilmiştir. Ayrıca, 800 W mikrodalga kurutma yönteminde kurutulan örneklerde klorofil içeriği, protein, fosfor, potasyum ve çinkonun maksimum düzeyde korunduğu tespit edilmiştir. Tüm kurutma yöntemleri sodyum için benzer azalmalara neden olsa da, manganın 200W'da en yüksek düzeyde korunduğu belirlenmiştir. Kurutulan örnekler arasında en yüksek bakır seviyesi doğal ve 800 W mikrodalga kurutma yönteminde kurutulan örneklerde analiz edilmiştir. Özetle, kişniş yaprakları için kurutma ve kalite parametreleri açısından en uygun kurutma tekniği 800 W olmuştur.

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INTRODUCTION

Coriander is an aromatic plant and annual herbaceous species from the Umbelliferae family (Sarimeseli, 2011). The high amount of fiber, protein, vitamins A and C, iron, zinc, calcium, and phosphorus in coriander is significant for human nutrition (Yilmaz & Alibas, 2017).

One of the most effective ways of four-season consuming coriander, which has an important place and benefit in human nutrition, is drying (Hihat et al., 2017). With drying, the water, which is in high proportions in the material, is significantly removed; thus, transportation, storage, and packaging become easier (Alibas et al., 2021; Boyar et al., 2022).

The most common and elderly drying method known for spice production is the natural drying method, which is done by laying in the shade (Yilmaz & Alibas, 2017). Although it seems like an important advantage that there is no energy consumption in the natural drying method, the method has also drawbacks such as long drying period, large drying area, high labor requirement, mold and aflatoxin growth in the product due to high moisture content in closed areas, and being vulnerable to rodents and insects of products. Therefore, more hygienic and technological methods, such as convective and microwave drying, are being developed today (Hihat et al., 2017).

On the other hand, it is an indisputable fact that convective drying, which is the most broadly way for drying almost all kinds of agricultural products, causes excessive loss of color, odor, and minerals in spices due to the long drying time (Yilmaz & Alibas, 2017; Yilmaz et al., 2021). Therefore, microwave drying is a drying method used as an alternative to the natural drying method for drying aromatic plants because of many advantages such as short drying times, low energy requirement, uniform drying, better preservation of vitamins, protein, and nutrients, and preventing color and odor losses (Hihat et al., 2017; Yilmaz & Alibas, 2017).

Some studies have been found in the literature about drying coriander leaves. However, it has been observed that there is no study cooperatively examining the energy consumption, thermal properties, color parameters, chlorophyll content, protein, and nutritional elements of dried coriander leaves. The main focus of the study is this deficiency in the literature.

The objectives of the study were i) drying coriander with convective, microwave, and natural dehydration techniques, ii) comparing of energy consumption of different drying methods, iii) detecting the color parameters, chlorophyll content, protein, and minerals of raw and dried coriander leaves, iv) determining the most appropriable dehydration technique regarding both drying and quality parameters.

MATERIAL and METHOD

Drying Material

Coriander (*Coriandrum sativum* L.) was harvested from the garden of a producer in Nilüfer, Bursa, Türkiye. Right after the harvesting process, the products were brought to the laboratory without losing time, and they, surrounded by wet pillows, were stored in a humidity-controlled cooler at +4°C until the drying process so that they did not lose their initial moisture content. All drying processes, except natural drying, were completed within 24 hours. Also, 20 ± 0.02 g samples were used in each drying process, and the leaves were selected from healthy and representative of the average.

Drying Systems

Convective and microwave drying processes were carried out using a combined dryer (Electrolux, EVY7800AAX, U.S.A.) whose operating circumstances were 3000 W, 50 Hz, and 230 ± 10 V. While the convective drying mode of the dryer, whose drying area was 410 x 329 mm, operates with a sensitivity of 5°C between 30 and 300°C, the microwave mode runs at ten output powers between 100 and 1000 W.

Natural drying was fulfilled in a shaded room without sunlight at 25°C and 60% ±5 relative humidity. The weight reduction was measured manually every three hours during drying.

In the study, 50°C, broadly used to dehydrate fruits and vegetables, especially spices, was used to represent convective drying. Also, an air velocity of 1 m s^{-1} in convective drying ensured hot air circulation in the dryer. On the other hand, the microwave-drying process was symbolized by low output power at 200 W and high output power at 800 W to preserve the nutrients, especially color, in spices and green leafy products. The time-dependent weight loss data were collected instantly with a data logger located under the drying area of the dryer for both drying techniques.

In both drying methods, the dryer's energy consumption was measured with the help of a mono-phase electric counter, and the difference between the initial and final readings on the electric counter was calculated by the total energy consumption.

Mathematical Modeling of Drying Data

Coriander leaves were kept in a dry air sterilizer at 105°C for 24 hours to determine the initial moisture content. Based on the initial and final weights, the moisture content of the material with respect to the dry basis was determined with the following equation (Eq 1).

$$MC_{db} = (W_{total} - W_{dry\ matter}) / (W_{dry\ matter}) = (W_{water}) / (W_{dry\ matter}) \quad (1)$$

where: MC_{db} is moisture content on the dry basis ($kgwater\ kg^{-1}{}_{dry\ matter}$), W_{total} is the initial weight (g), W_{water} is the water weight (g), and W_{dry} matter is the dry weight of the leaves (g).

The drying rate of the leaves was detected by considering the next formulation (Eq 2):

$$DR = (M_{t+dt} - M_t) / d_t \quad (2)$$

where: DR is the drying rate ($kg_{water}\ kg^{-1}{}_{dry\ matter}\ min^{-1}$), $Mt+dt$ is the moisture content at $t+dt$ time ($kg_{water}\ kg^{-1}{}_{dry\ matter}$), and dt is the drying time at t time (min).

The time-dependent moisture ratios of coriander leaves were found with the help of the following equation (Eq 3):

$$MR = (M - M_e) / (M_o - M_e) \quad (3)$$

where: MR is the moisture ratio, M is the moisture content at any time ($kg_{water}\ kg^{-1}{}_{dry\ matter}$), M_o is the initial moisture content ($kg_{water}\ kg^{-1}{}_{dry\ matter}$), and M_e is the equilibrium moisture content ($kg_{water}\ kg^{-1}{}_{dry\ matter}$). Since all drying processes were carried out under controlled conditions where the relative humidity did not change, this value was accepted as zero (Yilmaz & Alibas, 2017).

Experimental moisture ratio data were converted into prediction ones by means of the NLREG 6.2 statistical program using five different thin-layer drying equations in Table 1. The coefficient of determination (R^2), standard errors (SEE), root mean square errors ($RMSE$), and chi-square (χ^2) of the estimation were calculated by the same program. The R^2 was used as the main criterion in the selection of the model closest to the experimental data. Also, SEE, $RMSE$, and χ^2 values were evaluated as secondary criteria in the selection of equations with the same R^2 value, respectively (Alibas et al., 2020).

Thermal Properties

Thermal properties such as specific heat, thermal conductivity, thermal diffusivity, and thermal effusivity of coriander leaves as a function of moisture content regarding the dry base were detected by calculating. The specific heat and thermal conductivity of different drying techniques were calculated by Equations 4 and 5, respectively (Alibas & Yilmaz, 2022).

$$Cp = 837 + 3348\ (M/(1+M)) \quad (4)$$

$$k = 0.49 - 0.44\ \exp(-0.206\ M) \quad (5)$$

where: Cp is the specific heat of the leaves ($J\ kg^{-1}\ K^{-1}$) and k is the thermal conductivity ($Wm^{-1}\ K^{-1}$).

The thermal diffusivity and thermal effusivity of the drying processes were calculated using the densities of the leaves. Density, thermal diffusivity, and thermal diffusivity values were determined using the following equations (Eq 6, 7, and 8), respectively (Alibas & Yilmaz, 2022).

$$\rho = 147.95\ (M / M_0) + 691.46 \quad (6)$$

$$\alpha = k / (\rho\ Cp) \quad (7)$$

$$e = \sqrt{(\boldsymbol{k\ \rho\ Cp})} \quad (8)$$

where: ρ is the density of the leaves ($kg\ m^{-3}$), α is the thermal diffusivity ($m^2\ s^{-1}$), and e is the thermal effusivity ($W\ m^{0.5}\ m^{-2}\ K^{-1}$).

Color Parameters

The color parameters of coriander leaves were determined with the help of a colorimeter (Konica, Minolta CR10, Japan) running according to the CIELAB principle. According to the method, L^*, a^* b^*, C, and $\alpha°$ are represented the brightness, greenness, yellowness, chroma, and hue angles, respectively (Alibas & Yilmaz, 2022).

On the other hand, some indicators, known as total color difference (ΔE), browning index (BI), and whitening index (WI), are used to express the color changes that occur in the leaves during drying. Accordingly, ΔE, x, BI, and WI were determined using Equations 9, 10, 11, and 12, respectively.

$$\Delta E = \sqrt{(\boldsymbol{L_f - L_d})^2 + (\boldsymbol{a_f - a_d})^2 + (\boldsymbol{b_f - b_d})^2} \quad (9)$$

$$x = (a + (1.75\ L)) / [(5.645\ L) + (a - (3.012\ b))] \quad (10)$$

$$BI = [100\ \ (x - 0.31)] / 0.17 \quad (11)$$

$$\mathrm{WI} = 100 - \sqrt{((100 - L)^2 + a^2 + b^2)} \quad (12)$$

Total Protein and Nutrients

Total protein analysis was carried out as to the Kjeldahl method (Alibas et al., 2021). The Kjeldahl method takes place in three stages: combustion, distillation, and titration. In the first step of the combustion process, 5 g of combustion salt and 15 ml of H_2SO_4 with 99% purity were added to the 0.2 - 0.5 g thoroughly crushed sample taken into the combustion tube. The combustion tubes, which were taken to the combustion block by adding boiling stone, were first burned at 200 - 250°C for 30 minutes and then at 350 - 380°C for 60 minutes. During the burning process, the samples were checked, and the burning process was continued until the sample colors turned blue-green. During the combustion stage, the organic components in the samples reacted with the oxygen in the chemical mixtures, and the organic components were decomposed. At the end of the combustion, 100 ml of distilled water was added to the samples in the combustion tubes and allowed to cool.

In the second stage, the distillation process, the cooled solutions in the combustion tubes were placed in the distillation device, and 4-5 ml of 40% sodium hydroxide was added to the solution automatically. The distillation process was continued until a total of 100 - 150 ml of distillate (ammonium borate) was collected. After the distillation process was completed, the tip of the reflux cooler was washed with distilled water and cleaned before each experiment.

In the titration step, which is the last step, the ammonium borate solution was neutralized by titration with 0.1 M H_2SO_4 solution using an automatic burette. The total nitrogen (*N*) amount was calculated from the amount of acid consumed for the titrated solution. The total protein content was determined by multiplying the calculated total nitrogen amount with the protein conversion coefficient.

Mineral contents of coriander leaves were also determined by the Kacar method. In the analysis, a nitric-perchloric acid mixture was used and all macro and micronutrients except boron were measured. A solution was prepared in an Erlenmeyer by adding a nitric-perchloric acid mixture (4:1 v/v) to the samples with a mass of 0.2 - 0.5 g. The mixture was homogenized by shaking the erlenmeyer slightly. The upper surface of the Erlenmeyer was closed with a watch glass and left to stand in the fume hood for 20-30 minutes. After waiting, the samples were rested in a water bath at 30-40°C for 24 hours. At the end of this period, the samples were taken to the heater tray in the fume hood, and the temperature of the heater tray was gradually increased up to 200°C. Thus, most of the nitric acid in the solution was removed, and the solution got a light yellow color. The heating process gradually increased until a light yellow color appeared. After the intensive white smoke of perchloric acid completely covered the Erlenmeyer, the wet burning process was continued for at least 30 minutes. When the intensive smoke disappeared and the 1 ml colorless liquid remaining in the Erlenmeyer became clear, the solution was taken from the heating plate and left to cool. After the solution was cooled to room temperature, it was washed with distilled water and taken into a 100 ml flask. The solution was made ready for measuring by completing the volume of the flask with distilled water and shaking it well. Phosphorus contents of the samples were measured with a UV-VIS spectrophotometer (PG Instrument, T60 Split Beam UV/VIS, UK); however, a flame photometer (Eppendorf, Elex 6361, Germany) was used for sodium, potassium, and calcium. Also, iron, copper, zinc, and manganese were analyzed with an ICP-OES (Perkin Elmer, OPTIMA 2100 DV, USA) (Alibas et al., 2020).

Data Analysis

The averages, standard errors of estimated, and LSD analyses of the data obtained in the study were analyzed with the JMP Pro 14 statistical program. All drying and quality parameters were performed in triplicate except for the color measurements performed in 20 replications. The time-dependent moisture content obtained from the experimental drying data was modeled through the NLREG 6.2 statistical program using five thin-layer drying models presented in Table 1. Drying constants and coefficients in these thin-layer drying models were determined with the help of the same statistical program.

Table 1. Thin-layer drying equations used in modeling experimental data (Alibas & Yilmaz, 2022)
Çizelge 1. Deneysel verilerin modellenmesinde kullanılan ince tabaka kurutma denklemleri (Alibas & Yilmaz, 2022)

Model Number	Equation number	Equation
1	Page	$MR = \exp(-kt^n)$
2	Logaritmic	$MR = a\exp(-kt) + c$
3	Two-term exponential	$MR = a\exp(-kt) + (1-a)\exp(-kat)$
4	Midilli et al.	$MR = a\exp(-kt^n) + bt$
5	Alibas	$MR = a\exp\left((-kt^n) + (bt)\right) + g$

MR, moisture ratio; *a, b, g, n,* drying coefficients; *t*, drying period, min; *k,* drying constant, min^{-1}.

RESULTS and DISCUSSION

Drying Kinetics of Coriander Leaves

Figure 1 shows the time-dependent moisture content of coriander leaves dried by natural, convective, and microwave drying methods. According to the figure, the longest drying time was recorded in natural drying (4680 minutes), while the shortest drying period was found at 800 W (16.50 minutes). Microwave drying technique at 800 W, determined as the shortest drying period among all drying techniques, took 283.64, 38.18, and 5.15 times shorter than natural drying, convective drying at 50°C, and microwave drying methods at 200 W, respectively. Also, the drying period decreased with the increase in microwave output power. Sarimeseli (2011) dried coriander leaves via microwave drying at 180, 360, 540, 720, and 900 W. They noted that 900 W took 3.5, 2.63, 1.75, and 1.25 times shorter than 180, 360, 540, and 720 W, respectively. Hihat et al. (2017) dried coriander leaves by convective drying at 40, 60, 80, 100, and 120°C and microwave drying at 100, 300, 500, 700, and 900 W. Also, they determined that the drying time decreased with increasing both the drying temperature and the microwave output power. Silva et al. (2008) dried coriander leaves in a convective drying technique at 50°C. They obtained findings parallel to our study in terms of drying time. In research in which coriander leaves were dried at 55°C by convective drying method, Venkanna et al. (2019) highlighted that the drying time was 2.63 times shorter than the finding we recorded at 50°C. Yilmaz & Alibas (2017) dried coriander leaves at 50°C and noted that the drying period was 3.71 times shorter than our findings.

Figure 2 includes the drying rates of coriander leaves dried using natural, convective at 50°C, and microwave drying at 200 and 800 W. According to the figure, the lowest average drying rate was determined in the natural drying method with 0.00034 kg_{water} kg_{DM}^{-1} min^{-1}, but the highest one in the microwave drying method at 800 W with 0.24933 kg_{water} kg_{DM}^{-1} min^{-1}. The highest average drying rate at 800 W, determined as the shortest drying time, was 40.15 and 5.97 times higher than convective drying at 50°C and microwave drying at 200 W, respectively. Also, the drying rate determined in the natural drying method was 18.26 and 122.84 times lower than 50°C and 200 W. The average drying rate increased with the increase in microwave output power. Similar findings were detected by some researchers (Sarimeseli, 2011; Yilmaz & Alibas, 2017; Mouhoubi et al., 2022).

Modeling of Drying Data

Figure 3 gives the time-dependent experimental and estimated moisture contents of coriander leaves dried by natural, convective, and microwave drying methods. Accordingly, we observed that 78% of the separable moisture ratio evaporated away from the product in the 420th minute of the drying period at 50°C. However, we determined that the separable moisture ratio removed from the coriander leaves at the same time in the natural drying trials was only 5%. Similarly, 23.10% of the separable moisture was removed from the product in the tenth minute of the drying time at 200 W. Strikingly, in the same period, 76.97% of the separable moisture evaporated from the product at 800 W. Similar results were found in similar studies in the literature (Lutovska et al. 2016; Yilmaz & Alibas, 2017; Alibas et al. 2021).

Table 2 shows the statistical parameters, namely the coefficient of determination (R^2), the standard errors of the estimated (*SEE*), the root mean square error (*RMSE*), and the chi-square (χ^2), as well as drying constants and coefficients between the experimental drying data and the predicted ones obtained through five different thin-layer drying equations. Accordingly, the closest estimation results to the experimental ones in natural drying, microwave drying at 800 W, and convective drying at 50°C were obtained with the Midilli et al. equation. On the other hand, the closest estimated results to the experimental ones at 200 W were determined by the Alibas' equation. Similarly, in a study in which coriander leaves were dried at 50°C by convective drying method, Silva et al. (2008) obtained the closest approximation to the experimental results with the Midilli et al. equation. In an investigation in which coriander leaves were dried at 100 W, Yilmaz & Alibas (2017) determined the closest estimate to the experimental data with the Alibas' model. Similarly, Aral & Beşe (2016) stated that the closest estimation data to the experimental results of hawthorn fruit dried at 50°C were obtained with the Midilli et al. equation. In a study in which amaranth leaves were dried at 200 W, Mujaffar & Loy (2016) found the closest approximation to experimental MR with the Alibas' model.

With the increase of microwave output power, the drying constant (k) of the most successful model also increased. The lowest drying constant was obtained in natural drying and microwave drying at 200 W.

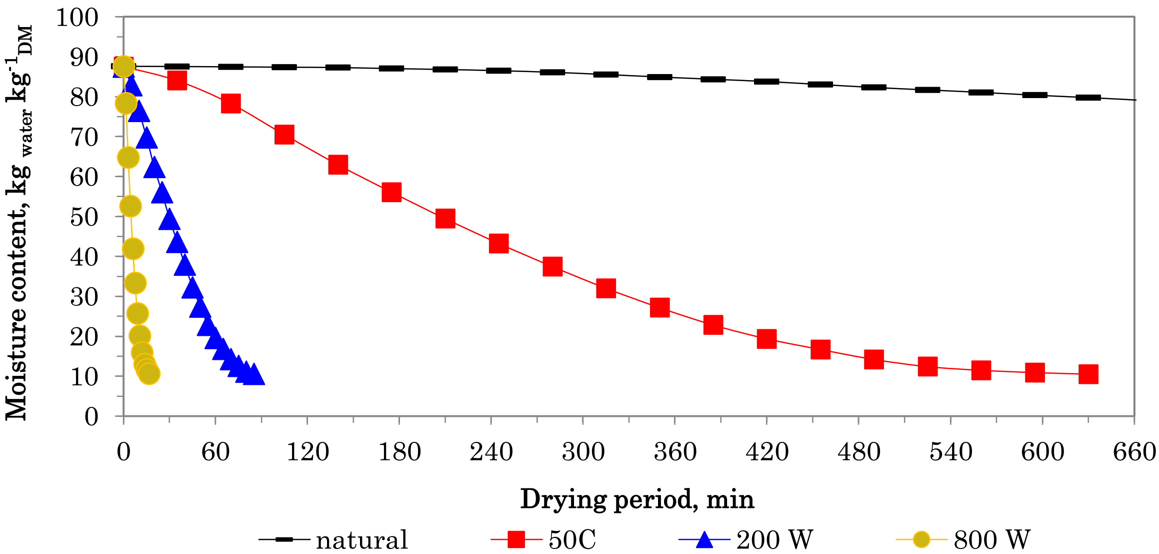

Figure 1. The time-dependent moisture content of coriander leaves dried by natural, convective, and microwave drying methods

Şekil 1. Doğal, konvektif ve mikrodalga kurutma yöntemleriyle kurutulan kişniş yapraklarının zamana bağlı nem içeriği

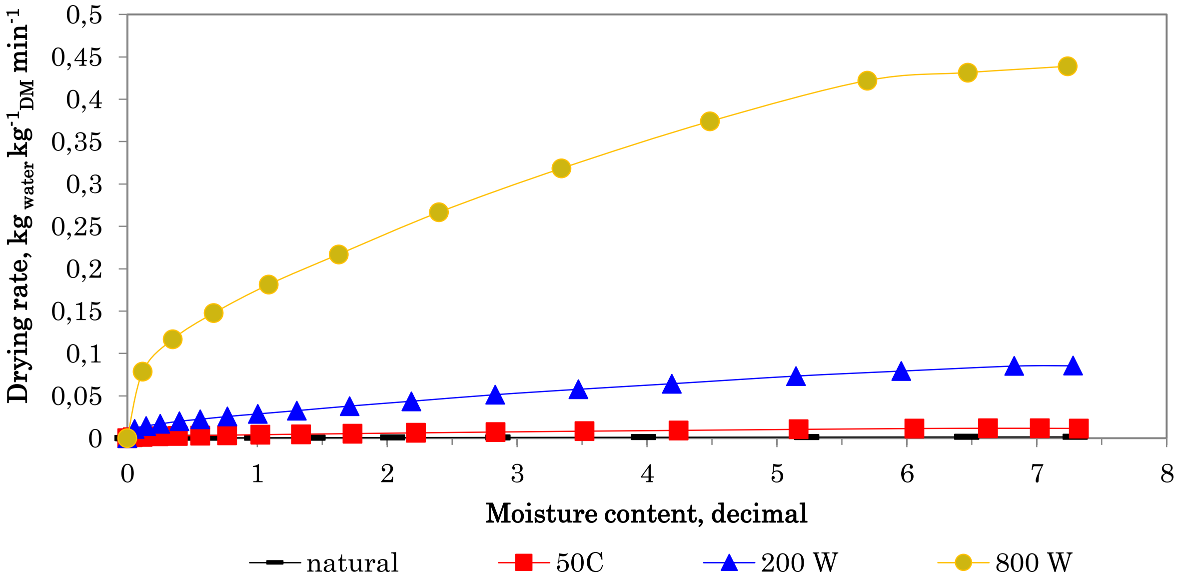

Figure 2. The drying rates of coriander leaves dried by natural, convective, and microwave drying methods
Şekil 2. Doğal, konvektif ve mikrodalga kurutma yöntemleriyle kurutulan kişniş yapraklarının kuruma oranları

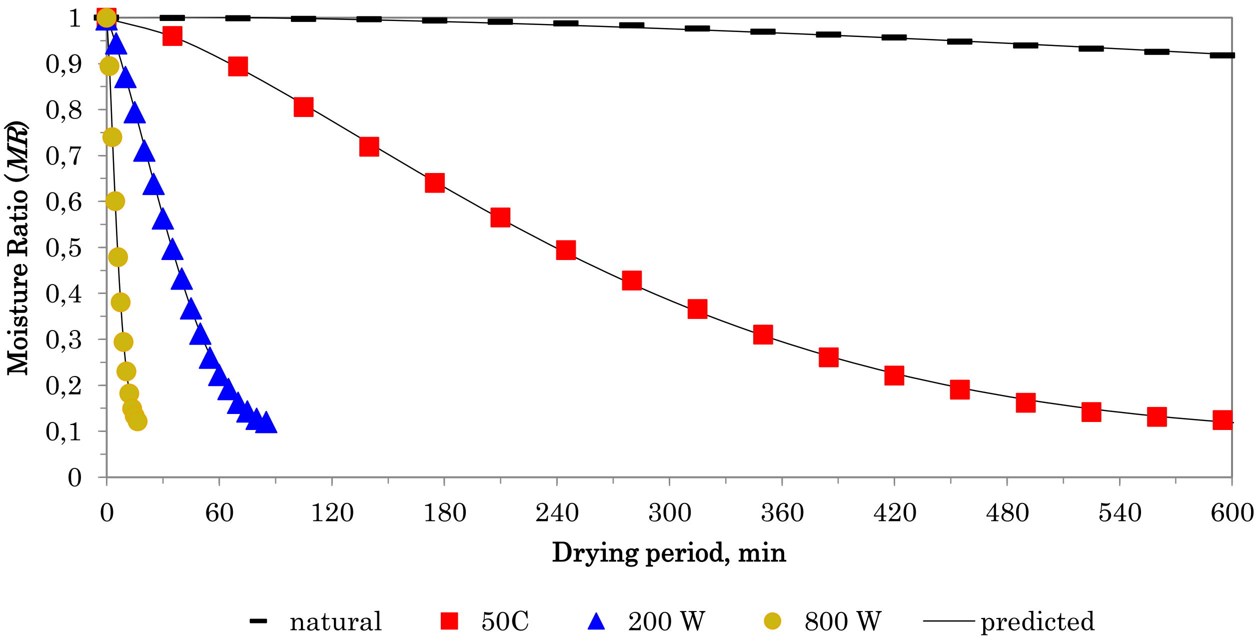

Figure 3. The moisture ratios of coriander leaves dried by natural, convective, and microwave drying methods
Şekil 3. Doğal, konvektif ve mikrodalga kurutma yöntemleriyle kurutulan kişniş yapraklarının nem oranları

Total Energy Consumption

Table 3 reflects the total energy consumption of natural, convective, and microwave drying methods. We noted that convective drying causes considerably higher energy consumption than microwave drying. Accordingly, we found that the energy consumption recorded in the convective drying method at 50°C was 36.36 and 46.77 times higher than at 200 and 800 W, respectively. Also, the total energy consumption decreased with the increase in microwave output power. Wang et al. (2004) dried potato slices with different microwave power densities and found that energy consumption decreased with increasing microwave power density. In an investigation in which tomato slices were dried with different microwave output powers, Çelen & Kahveci (2013) reported that the total energy consumption increased with the decrease in microwave output power. In a study on drying basil leaves, Alibas et al. (2021) emphasized that the energy consumption recorded in the convective drying method at 50°C was quite high compared to the microwave drying method. Alibas & Yilmaz (2022) dried orange slices with microwave and convection drying methods and found that the total energy consumption decreased with the increase in microwave output power. Also, they determined that the energy consumption was at the maximum level of 50°C, the lowest temperature applied in the study.

Table 2. Statistical parameters, drying constant and coefficients related to thin layer drying equations used in modeling coriander leaves dried by natural, convective and microwave drying methods

Çizelge 2. Doğal, konvektif ve mikrodalga kurutma yöntemleriyle kurutulan kişniş yapraklarının modellenmesinde kullanılan ince tabaka kurutma denklemlerine ilişkin istatistiksel parametreler, kuruma sabiti ve katsayılar

Model	Natural Drying at 25°C and 60% relative humidity in a shade room								
	R^2	*SEE*	*RMSE*	χ^2	*k*	*n*	*a*	*b*	*g*
1	0.9995	0.0073	$1.4005\ 10^{-2}$	$3.6921\ 10^{-4}$	0.0088	1.6014			
2	0.9917	0.0293	$1.8051\ 10^{-13}$	$6.5165\ 10^{-26}$	0.0006		2.1585		-1.1033
3	0.9991	0.0093	$8.4764\ 10^{-3}$	$1.3525\ 10^{-4}$	0.0005		2.0282		
4	0.9998	0.0044	$5.3166\ 10^{-5}$	$6.0301\ 10^{-9}$	0.0002	1.6302	1.0024	$8.0254\ 10^{-6}$	
5	0.9994	0.0085	$1.4055\ 10^{-10}$	$4.5153\ 10^{-20}$	1.0999	1.0001	1.0439	1.2805	
Model	Convective Drying at 50°C								
	R^2	*SEE*	*RMSE*	χ^2	*k*	*n*	*a*	*b*	*g*
1	0.9980	0.0141	$1.2031\ 10^{-2}$	$1.3750\ 10^{-4}$	0.0075	1.3400			
2	0.9918	0.0295	$1.3922\ 10^{-10}$	$1.9382\ 10^{-20}$	0.0094		1.2409		-0.1803
3	0.9988	0.0109	$6.4355\ 10^{-3}$	$3.9344\ 10^{-5}$	0.0011		1.9168		
4	0.9997	0.0057	$1.3509\ 10^{-4}$	$1.9262\ 10^{-8}$	0.0019	1.4738	0.9980	0.0001	
5	0.9997	0.0059	$3.8086\ 10^{-10}$	$1.6212\ 10^{-19}$	0.9999	1.7802	0.9153	-0.0011	
Model	Microwave Drying at 200 W								
	R^2	*SEE*	*RMSE*	χ^2	*k*	*n*	*a*	*b*	*g*
1	0.9993	0.0081	$2.1177\ 10^{-3}$	$5.0451\ 10^{-6}$	0.0062	0.0001			
2	0.9946	0.0234	$8.4615\ 10^{-14}$	$8.5916\ 10^{-27}$	0.0001		1.3120		-0.2688
3	0.9994	0.0075	$1.2980\ 10^{-3}$	$1.8953\ 10^{-6}$	0.0153		0.0325		
4	0.9995	0.0065	$9.1239\ 10^{-5}$	$1.0703\ 10^{-8}$	0.0009	1.4112	0.9930	0.0004	
5	0.9998	0.0043	$9.0998\ 10^{-10}$	$1.1465\ 10^{-18}$	0.0002	2.1200	0.9185	-0.0131	
Model	Microwave Drying at 800 W								
	R^2	*SEE*	*RMSE*	χ^2	*k*	*n*	*a*	*b*	*g*
1	0.9975	0.0164	$1.0763\ 10^{-2}$	$1.1584\ 10^{-4}$	0.0001	1.2023			
2	0.9937	0.0271	$1.4370\ 10^{-2}$	$2.2527\ 10^{-4}$	0.1167		1.1120		0.0011
3	0.9976	0.0159	$1.0743\ 10^{-5}$	$1.1541\ 10^{-9}$	0.0099		1.7735		
4	0.9998	0.0047	$6.9568\ 10^{-11}$	$5.8077\ 10^{-21}$	0.0899	1.3458	1.0005	0.0045	
5	0.9998	0.0055	$1.5195\ 10^{-9}$	$3.0787\ 10^{-18}$	0.0499	1.4728	0.9103	-0.0260	

Thermal Properties

Tables 4 and 5 include the average thermal and average thermal properties per unit time of coriander leaves dried with different drying methods. Accordingly, the highest average thermal properties were obtained in the natural drying method. On the other hand, the lowest average thermal properties in the unit of time were obtained by the same method. However, the lowest average thermal properties and the highest average thermal properties per unit time were determined at 800 W. Also, the average thermal properties per unit time increased with the increase of microwave output power, but the average thermal properties decreased. Esmaiili et al. (2007) detected the thermal diffusivity of seedless grapes dried at 50°C as 9.60 x 10^{-8} m^2 s^{-1}. Yu et al. (2015) calculated the thermal conductivity, specific heat, and thermal diffusivity of canola seed dried at 50°C as 0.22 W m^{-1} K^{-1}, 2766 J kg^{-1} K^{-1}, and 7.3 x 10-8 m^2 s^{-1}, respectively. Olaoye & Ogunleye (2018) detected the specific heat and thermal diffusivity of ginger slices dried at 45°C as 1568 J kg^{-1} K^{-1} and 3.149 m^2 s^{-1}. Lemus-Mondaca et al. (2021) stated that the density, specific heat, thermal diffusivity, thermal conductivity, and thermal effusivity of stevia leaves dried at 40°C were 116.20 kg m^{-3}, 3340 J kg^{-1} K^{-1}, 4.36 m^2 s^{-1}, 0.169 W m^{-1} K^{-1}, and 225.98 W $s^{0.5}$ m^{-2} K^{-1}, respectively.

Color Parameters and Total Chlorophyll Concentration

Table 6 shows the color parameters, total color difference, browning index, whitening index, and total chlorophyll concentration of coriander leaves dried with different drying methods. According to the table, brightness (L^*), greenness (a^*), yellowness (b^*), chroma (C), and hue angle (α°) results closest to the fresh product were obtained in samples dried at 800 W. However, the lowest color parameters were detected in the convective drying method at 50°C. While the maximum total color difference was measured in the samples dried in the convective drying method at 50°C, the minimum ones occurred in the samples dried at 800 W. The total color difference in the samples dried at 800 W was 19.28%, 88.04%, and 50.41% lower than the microwave drying at 200 W, convective drying at 50°C, and natural drying methods, respectively. In the convective drying method at 50°C, the forced airflow, which was effective during the long drying period, caused an increase in oxidation and so significant losses in color parameters.

Table 3. The operating parameters of coriander leaves dried by different methods
Çizelge 3. Farklı yöntemlerle kurutulan kişniş yapraklarının kuruma parametreleri

Methods	***DRP*** **	***ADR*** **	***EC*** **
	min	kg $_{water}$ kg^{-1}$_{DM}$ min^{-1}	kWh
Natural	4680.00 ± 75.50^{a}	0.00034 ± 0.00001^{c}	0.000 ± 0.000^{c}
50°C	630.00 ± 8.66^{b}	0.00621 ± 0.00009^{c}	10.290 ± 0.141^{a}
200 W	85.00 ± 2.89^{c}	0.04177 ± 0.00142^{b}	0.283 ± 0.010^{b}
800 W	16.50 ± 0.29^{c}	0.24933 ± 0.00436^{a}	0.220 ± 0.004^{bc}

**P<0.01, Column mean values with different superscripts are significantly different. ±SEE
DRT: drying period (min^{-1}), *ADR*: the average drying rate (kg $_{water}$ kg^{-1}$_{DM}$ min^{-1}), and *EC*: energy consumption (kWh)

Table 4. The average thermal properties of coriander leaves dried by different methods
Çizelge 4. Farklı yöntemlerle kurutulan kişniş yapraklarının ortalama termal özellikleri

Methods	A_{Cp} ** J kg^{-1} K^{-1}	A_k ** W m^{-1} K^{-1}	A_ρ ns kg m^{-3}	A_a ** m^2 s^{-1}	A_e ** W s$^{0.5}$ m^{-2} K^{-1}
Natural	3526.75 ± 41.15^{a}	0.3269 ± 0.0079^{a}	804.14 ± 27.25	1.12 x 10^{-07} ± 1.91 x 10$^{-09\ a}$	963.69 ± 27.37^{a}
50°C	3147.46 ± 46.67^{b}	0.2402 ± 0.0041^{b}	757.92 ± 23.77	9.59 x 10^{-08} ± 1.01 x 10$^{-09\ b}$	756.93 ± 8.86^{b}
200 W	3188.08 ± 20.29^{b}	0.2463 ± 0.0008^{b}	760.37 ± 8.85	9.72 x 10^{-08} ± 3.02 x 10$^{-10\ b}$	772.70 ± 3.67^{b}
800 W	3127.04 ± 10.83^{b}	0.2357 ± 0.0013^{b}	755.66 ± 3.89	9.50 x10^{-08} ± 2.24 x 10$^{-10\ b}$	746.15 ± 4.91^{b}

**P<0.01, ns not significant, Column mean values with different superscripts are significantly different. ±SEE A_{Cp}: the average specific heat (J kg^{-1} K^{-1}), A_k: the average thermal conductivity (W m^{-1} K^{-1}), A_ρ: the average density (kg m^{-3}), A_a: the average thermal diffusivity (m^2 s^{-1}), and A_e: the average thermal effusivity (W s$^{0.5}$ m^{-2} K^{-1}).

Table 5. The average thermal properties per unit time of coriander leaves dried by different methods
Çizelge 5. Farklı yöntemlerle kurutulan kişniş yapraklarının birim zamanda ortalama termal özellikleri

Methods	δ_{Cp} ** J kg^{-1} K^{-1} min^{-1}	δ_k ** W m^{-1} K^{-1} min^{-1}	δ_ρ ** kg m^{-3} min^{-1}	δ_a ** m^2 s^{-1} min^{-1}	δ_e ** W s$^{0.5}$ m^{-2} K^{-1} min^{-1}
Natural	0.754 ± 0.009^{d}	6.99 x 10^{-05} ± 1.68 x10^{-06d}	0.172 ± 0.006^{d}	2.39 x 10^{-11} ± 4.07 x10^{-13d}	0.206 ± 0.006^{d}
50°C	4.996 ± 0.074^{c}	3.81 x 10^{-04} ± 6.56 x10^{-06c}	1.203 ± 0.038^{c}	1.52 x 10^{-10} ± 1.60 x10^{-12c}	1.201 ± 0.014^{c}
200 W	37.507 ± 0.239^{b}	2.90 x 10^{-03} ± 9.90 x10^{-06b}	8.946 ± 0.104^{b}	1.14 x 10^{-09} ± 3.55 x10^{-12b}	9.091 ± 0.043^{b}
800 W	189.517 ± 0.656^{a}	1.43 x 10^{-02} ± 7.59 x10^{-05a}	45.797 ± 0.236^{a}	5.76 x 10^{-09} ± 1.36 x10^{-11a}	45.221 ± 0.298^{a}

**P<0.01, Column mean values with different superscripts are significantly different. ±SEE δ_{Cp}: the average specific heat per unit time (J kg^{-1} K^{-1} min^{-1}), δ_k: the average thermal conductivity per unit time (W m^{-1} K^{-1} min^{-1}), δ_ρ: the average density per unit time (kg m^{-3} min^{-1}), δ_a: the average thermal diffusivity per unit time (m^2 s^{-1} min^{-1}), and δ_e: the average thermal effusivity per unit time (W s$^{0.5}$ m^{-2} K^{-1} min^{-1}).

The highest results in terms of the browning index were recorded in samples dried in the convective drying method at 50°C. While the browning index closest to the fresh product was measured in the samples dried in the microwave drying method at 200 W, the lowest ones were obtained in the samples dried by the natural drying method. The browning index decreased with the increase of microwave output power; that is, the color of the samples was lightened. The closest whitening index to fresh samples was obtained in samples dried at 800 W, followed by samples dried in microwave drying at 200 W and natural drying methods, respectively. The drying method with the lowest whitening index, that is, a high rate of darkening in the samples, was determined as 50°C. The whitening index of the samples dried by the convective drying method is 36.13% lower than the fresh samples.

Sarimeseli (2011) determined that the yellowness, chroma, and hue angles of coriander leaves dried at 720 W were higher than microwave drying at 180, 360, 540, and 900 W. Yilmaz & Alibas (2017) stated that the brightness of coriander leaves dried with the natural drying method is 1.26 times higher than our findings. Also, the brightness of coriander leaves dried at 50°C was parallel to our study. On the other hand, similar to our study, the lowest results for greenness, yellowness, chroma, and hue angle were determined in the convective drying method at 50°C. In a study in which mint leaves were dried using natural, convective, and microwave drying methods, Kripanand et al. (2015) obtained the closest brightness and greenness to the fresh product in the samples dried at 900 W, but the lowest ones in the samples dried at 65°C. Also, they emphasized that with the increase of microwave output power, color parameters closer to the fresh product are obtained. Raja et al. (2019) underlined that the maximum total color change in *Carica papaya* L. leaves was measured in samples dried by convective drying method at 50°C. In a study in which thyme leaves were dried by natural, convective, and microwave drying methods, Yilmaz et al. (2021) determined that the highest losses in terms of brightness, greenness, yellowness, chroma, hue angle, and total color difference were measured in samples dried by convective drying technique at 50°C. The lowest browning index was obtained in the samples dried in the natural drying method; however, the lowest whitening index was also found in the samples dried by the convective drying method at 50°C. In an investigation in which basil leaves were dried in the shade using convective and microwave drying techniques, Alibas et al. (2021) emphasized that the greenness, yellowness, chroma, and hue angle closest to the fresh product were obtained at fresh 700 W.

The highest total chlorophyll concentration was measured in samples dried at 800 W, followed by the lowest ones found in fresh samples and samples dried by convective drying method at 50°C, respectively. The results obtained at 800 W, where the highest chlorophyll content was recorded, were 1.08, 1.33, and 1.17 times higher than the samples dried by natural drying, convective drying at 50°C, and microwave drying at 200 W, respectively. In a study in which green tea leaves were dried by natural drying, sun drying, convective drying at 60, 80, and 100°C, and microwave drying at 800 W, Roshanak et al. (2016) emphasized that the chlorophyll content closest to the fresh product was obtained in the samples dried by microwave drying method at 800 W. In an investigation in which coriander leaves were dried via convective at 50°C and microwave drying methods at 100, 500, and 1000 W, Yilmaz & Alibas (2017) measured the lowest chlorophyll concentration were dried samples at 50°C, followed by fresh samples. Yilmaz et al. (2021) dried thyme leaves by natural drying in the shade, convective drying at 50°C, and microwave drying at 200, 600, and 1000 W. They measured the highest chlorophyll concentration in samples dried by natural drying and microwave drying at 1000 W but the lowest ones at 50°C. Alibas et al. (2021) dehydrated the basil leaves through natural drying, convective drying at 50°C, and microwave drying at 100, 300, 500, 700, and 900 W. They determined that the highest concentration of chlorophyll was achieved at 700 W.

Table 6. Color parameters and chlorophyll content of coriander leaves dried via different techniques
Çizelge 6. Farklı tekniklerle kurutulan kişniş yapraklarının renk parametreleri ve klorofil içeriği

Method	*L** **	*a** **	*b** **	*C* **	*α°* *	*ΔE* **	*BI***	*WI* **	*TCC* ** *nmol cm⁻²*
Fresh	45.43 ± 0.29[a]	-6.67 ± 0.11[a]	26.10 ± 0.89[a]	26.94 ± 0.86[a]	104.40 ± 0.51[a]	0.00 ± 0.00[a]	68.05 ± 3.24[ab]	39.11 ± 0.16[a]	231.17 ± 6.87[e]
Natural	35.00 ± 0.32[d]	-4.60 ± 0.26[c]	18.73 ± 0.47[c]	19.30 ± 0.46[c]	103.83 ± 0.87[a]	12.95 ± 0.66[d]	61.68 ± 2.00[b]	32.19 ± 0.23[c]	331.26 ± 8.77[b]
50°C	31.33 ± 0.50[e]	-3.87 ± 0.10[d]	18.67 ± 0.28[c]	19.06 ± 0.29[c]	101.69 ± 0.11[b]	16.19 ± 0.91[e]	74.56 ± 2.02[a]	28.73 ± 0.46[d]	268.70 ± 4.05[d]
200 W	37.10 ± 0.57[c]	-4.90 ± 0.11[bc]	20.97 ± 0.53[b]	21.54 ± 0.50[b]	103.22 ± 0.57[ab]	10.27 ± 0.38[c]	68.08 ± 4.30[ab]	33.51 ± 0.68[c]	306.77 ± 4.73[c]
800 W	38.70 ± 0.75[b]	-5.27 ± 0.08[b]	21.07 ± 0.37[b]	21.72 ± 0.38[b]	104.04 ± 0.15[a]	8.61 ± 0.29[b]	63.01 ± 0.24[b]	34.95 ± 0.58[b]	358.44 ± 7.16[a]

** $P<0.01$, * $P<0.005$, Column mean values with different superscripts are significantly different. ±SEE
*L**, Brightness; *a**, greenness; *b**, yellowness; *C*, chroma; *α°*, hue angle (°), *ΔE*, total color difference; *BI*, browning index; *WI*, whitening index; *TCC*, total chlorophyll content (nmol cm^{-2}).

Total Protein and Nutrients

Table 7 shows the macro and micronutrients, as well as the total protein content of fresh and dried coriander leaves. The total protein content closest to the fresh product was measured in samples dried at 800 W but the lowest ones at 50°C. In terms of total protein content, a decrease of 28.24% was recorded in samples dried at 800W compared to fresh products, while a decrease of 55.25% in samples dried at 50°C. On the other hand, the total protein content of coriander leaves dried by the natural drying method was found to be 44.81% lower than the fresh samples. However, we noted that the total protein content also increased with the increase in microwave output power. Danso-Boateng (2013) dried basil leaves with natural, convective, and microwave drying methods and emphasized that the highest total protein content was obtained by the microwave drying method.

Phosphorus (*P*) and potassium (*K*) contents closest to the fresh product were measured in samples dried at 800 W. While the lowest *P* was determined at 50°C, the highest *K* loss was determined in the samples dried by natural drying and convective drying methods at 50°C. While the highest calcium (*Ca*), magnesium (*Mg*), and iron (*Fe*) contents were recorded in the samples dried by microwave drying method at 200 and 800 W, the maximum losses for these minerals were obtained by natural drying and convective drying method at 50°C. The copper (*Cu*) content closest to fresh coriander leaves was measured in samples dried by microwave drying at 800 W and natural drying methods, and the *Cu* content of samples dried by these methods was 1.51 and 1.49 times lower than fresh samples, respectively. The closest manganese (*Mn*) content to fresh produce was recorded at 200 W, but the lowest ones were in natural drying and convective drying at 50°C. Accordingly, compared to the fresh samples, the *Mn* content in the samples dried at 200 W was 1.43 times lower than in the fresh samples but 1.97 and 2.01 times lower than samples dried using natural drying and convective drying at 50°C, respectively. The closest zinc (*Zn*) content to the fresh product was measured at 800 W. The zinc content of products dried by this method was 1.5 times lower than fresh leaves. On the other hand, the lowest *Zn* concentration was recorded at 50°C. The *Zn* content in the products dried at 50°C was 1.75 times lower than the fresh coriander leaves. Strikingly, we noted that the drying methods had no effect on the sodium (*Na*) content. In a study in which rosemary leaves were dried with different drying methods, Arslan & Özcan (2008) detected that the copper content was better preserved in the samples dried by the microwave drying method compared to convective drying. Aljuhaimi & Özcan (2018) dried the germinated peanut kernels using convective and microwave drying methods. They underlined that the potassium, phosphorus, calcium, iron, and zinc concentrations in the samples dried by the microwave drying method were higher than the convective ones. In a study in which thyme leaves were dried by natural, convective, and microwave drying methods, Yilmaz et al. (2021) noted that the potassium and zinc in the leaves dried at 1000 W, the highest microwave output power used, were preserved at the maximum level. Alibas et al. (2021) measured the maximum magnesium, sodium, potassium, and iron of basil leaves at 700 W after fresh coriander leaves. Also, they achieved the highest copper concentration in natural drying.

Table 7. Total protein and mineral composition of coriander leaves dried by different techniques

Çizelge 7. Farklı tekniklerle kurutulan kişniş yapraklarının toplam protein ve mineral içeriği

Method	*TP* ** *mg g⁻¹*	*P* ** *mg g⁻¹*	*K* ** *mg g⁻¹*	*Ca* ** *mg g⁻¹*	*Mg* ** *mg g⁻¹*	*Na* ** *mg g⁻¹*	*Fe* ** *mg g⁻¹*	*Cu* ** *µg g⁻¹*	*Mn* ** *µg g⁻¹*	*Zn* ** *µg g⁻¹*
Fresh	345.93 ± 3.12^{a}	5.38 ± 0.02^{a}	59.71 ± 0.48^{a}	17.82 ± 0.26^{a}	6.76 ± 0.24^{a}	4.29 ± 0.04^{a}	2.36 ± 0.08^{a}	18.34 ± 0.46^{a}	83.76 ± 0.82^{a}	41.31 ± 0.75^{a}
Natural	238.88 ± 2.23^{d}	4.13 ± 0.06^{c}	30.42 ± 0.24^{d}	9.77 ± 1.02^{c}	3.62 ± 0.11^{c}	1.93 ± 0.04^{b}	0.99 ± 0.05^{c}	12.25 ± 0.39^{b}	42.50 ± 1.43^{d}	24.27 ± 0.21^{cd}
50°C	222.44 ± 2.11^{e}	3.88 ± 0.05^{d}	29.96 ± 0.42^{d}	9.58 ± 0.16^{c}	3.50 ± 0.07^{c}	1.86 ± 0.03^{b}	0.89 ± 0.04^{c}	11.13 ± 0.40^{c}	41.62 ± 0.76^{d}	23.58 ± 0.65^{d}
200 W	249.90 ± 0.53^{c}	4.18 ± 0.05^{c}	37.97 ± 0.11^{c}	11.46 ± 0.83^{b}	4.78 ± 0.09^{b}	2.29 ± 0.04^{b}	1.40 ± 0.04^{b}	11.40 ± 0.38^{c}	58.46 ± 1.46^{b}	25.15 ± 0.40^{c}
800 W	269.76 ± 2.49^{b}	4.45 ± 0.06^{b}	45.80 ± 1.60^{b}	12.19 ± 0.69^{b}	4.89 ± 0.12^{b}	2.32 ± 0.07^{b}	1.46 ± 0.08^{b}	12.12 ± 0.23^{b}	56.21 ± 1.09^{c}	27.54 ± 0.29^{b}

** $P<0.01$, Column mean values with different superscripts are significantly different. ±SEE

TP, total protein content (mg g^{-1}); *P*, phosphorus (mg g^{-1}); *K*, potassium (mg g^{-1}); *Ca*, calcium (mg g^{-1}); *Mg*, magnesium (mg g^{-1}); *Na*, sodium (mg g^{-1}); *Fe*, iron (mg g^{-1}); *Cu*, copper (µg g^{-1}); *Mn*, manganese (µg g^{-1}); *Zn*, zinc (µg g^{-1}).

The linear correlations of quality parameters

Table 8 highlights the linear correlations among fresh and dried coriander leaf quality parameters. Although we found many significant negative and positive relationships in the study, we discussed relationships above 90%. Accordingly, we detected positive correlations between the brightness and whitening index, total protein, phosphorus, potassium, magnesium, iron, manganese, or zinc at the level of 98.70%, 93.81%, 92.68%, 94.66%, 91.56%, 92.30%, 91.61%, and 90.45%, respectively. On the other hand, we observed that the brightness had negative associations with greenness and total color difference at the rate of 92.81% and 96.23%. Also, we found negative relationships between greenness and whitening index, total protein, phosphorus, potassium, magnesium, or iron at the level of 90.79%, 91.52%, 91.58%, 90.75%, 90.02%, and 91.23%, respectively. On the other hand, we determined that yellowness had positive correlations with chroma and manganese at the level of 99.90% and 91.71%. Chroma had strong positive associations with phosphorus, manganese, or zinc at the level of 90.08%, 92.54%, and 90.17%, respectively. We found powerful negative correlations between total color change and whitening index, total protein, phosphorus, potassium, calcium, magnesium, iron, manganese, or zinc, all over 90%. However, the whitening index had positive correlations with total protein and potassium at the level of 90.46% and 91.85%, respectively.

We found positive associations between total protein content and phosphorus, potassium, calcium, magnesium, iron, copper, manganese, or zinc at the rates of 98.13%, 96.41%, 95.59%, 96.34%, 97.63%, 94.09%, 95.84%, and 97.46%, respectively. Similarly, phosphorus had robust positive relations with potassium, calcium, magnesium, iron, copper, manganese, or zinc at the level of 94.62%, 90.81%, 92.71%, 94.10%, 92.53%, 93.83%, and 96.66%, respectively. On the other hand, we found strong positive correlations of over 90% between potassium and calcium, magnesium, iron, manganese, or zinc. Similarly, calcium had over 90% positive correlations with magnesium, iron, copper, manganese, or zinc. Also, we observed positive relationships between magnesium and iron, manganese, or zinc at the level of 98.99%, 98.08%, and 91.61%, respectively. Although iron had positive correlations with manganese and zinc at the level of 98.02% and 94.03%, there was a positive relationship between copper and zinc at the rate of 95.96%. Also, manganese had a strong positive correlation with zinc at a rate of 93.04%.

Alibas et al. (2020) determined that phosphorus had strong positive relationships with potassium and magnesium. They also emphasized highly positive associations between potassium and magnesium or copper. Alibas et al. (2021) stated a strong positive correlation between total protein and zinc, or phosphorus had positively correlated with calcium, magnesium, copper, and zinc. However, they found that calcium had significantly associated with magnesium, copper, zinc, and manganese. Also, they underlined a strong positive correlation between yellowness and chroma. Yilmaz & Alibas (2021) found a negative relationship between the whitening index and the total color difference. Also, they noted that

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Table 8. Linear correlations among measured quality parameters during drying of parsley leaves by different technique.
Çizelge 8. Maydanoz yapraklarının farklı tekniklerle kurutulması sırasında ölçülen kalite parametreleri arasındaki doğrusal korelasyonlar

*L**	*a**	*b**	*C*	*a°*	*ΔE*	*BI*	*WI*	*TCC*	*TP*	*P*	*K*	*Ca*	*Mg*	*Na*	*Fe*	*Cu*	*Mn*	*Zn*	
1.0000	-0.9281	0.8800	0.8946	0.4890	-0.9623	-0.2098	0.9870	-0.3242	0.9381	0.9268	0.9466	0.8639	0.9156	0.3947	0.9230	0.8319	0.9161	0.9045	*L**
	1.0000	-0.8292	-0.8534	-0.6886	0.8897	0.2073	-0.9079	0.3162	-0.9152	-0.9158	-0.9075	-0.8454	-0.9002	-0.4194	-0.9123	-0.8461	-0.8884	-0.8805	*a**
		1.0000	0.9990	0.1717	-0.8851	0.2729	0.7948	-0.4533	0.8725	0.8877	0.8804	0.8624	0.8726	0.1981	0.8667	0.8302	0.9171	0.8919	*b**
			1.0000	0.2154	-0.8953	0.2386	0.8133	-0.4485	0.8857	0.9008	0.8927	0.8691	0.8847	0.2174	0.8801	0.8412	0.9254	0.9017	*C*
				1.0000	-0.4037	-0.7031	0.5610	0.0923	0.4580	0.4511	0.4390	0.3477	0.4311	0.4176	0.4588	0.3802	0.3656	0.3712	*a°*
					1.0000	0.1211	-0.9371	0.3956	-0.9660	-0.9356	-0.9514	-0.9276	-0.9558	-0.4606	-0.9556	-0.8833	-0.9440	-0.9267	*ΔE*
						1.0000	-0.3540	-0.3261	-0.1020	-0.0557	-0.0905	0.0326	-0.0499	-0.3249	-0.0821	0.0091	0.0403	0.0035	*BI*
							1.0000	-0.2488	0.9046	0.8843	0.9185	0.8142	0.8822	0.4392	0.8897	0.7756	0.8668	0.8493	*WI*
								1.0000	-0.4831	-0.4548	-0.3946	-0.5377	-0.4600	-0.5027	-0.4909	-0.6121	-0.5054	-0.5872	*TCC*
									1.0000	0.9813	0.9641	0.9559	0.9634	0.5368	0.9763	0.9409	0.9584	0.9746	*TP*
										1.0000	0.9462	0.9081	0.9271	0.4916	0.9410	0.9253	0.9383	0.9666	*P*
											1.0000	0.9162	0.9601	0.4774	0.9550	0.8448	0.9480	0.9270	*K*
												1.0000	0.9417	0.4856	0.9552	0.9083	0.9518	0.9353	*Ca*
													1.0000	0.5068	0.9899	0.8730	0.9808	0.9161	*Mg*
														1.0000	0.5043	0.5213	0.4496	0.4620	*Na*
															1.0000	0.8950	0.9802	0.9403	*Fe*
																1.0000	0.8696	0.9596	*Cu*
																	1.0000	0.9304	*Mn*
																		1.0000	*Zn*

*L**, Brightness; *a**, greenness; *b**, yellowness; *C*, chroma; *a°*, hue angle (°), *ΔE*, total color difference; *BI*, browning index; *WI*, whitening index; *TCC*, total chlorophyll content (nmol cm^{-2}); *TP*, total protein content (mg g^{-1}); *P*, phosphorus (mg g^{-1}); *K*, potassium (mg g^{-1}); *Ca*, calcium (mg g^{-1}); *Mg*, magnesium (mg g^{-1}); *Na*, sodium (mg g^{-1}); *Fe*, iron (mg g^{-1}); *Cu*, copper (µg g^{-1}); *Mn*, manganese (µg g^{-1}); *Zn*, zinc (µg g^{-1}).

total protein had strong positive correlations with phosphorus, potassium, magnesium, copper, and manganese. However, they found that sodium had strongly associated with copper and manganese. Yilmaz et al. (2021) underlined a strong negative correlation between the whitening index and the total color difference, but the total color difference had a high positive correlation with zinc. However, they also reported a strong positive association between chroma and yellowness. They noted that phosphorus had robust positive associations with potassium, calcium, magnesium, copper, and manganese.

CONCLUSION

Coriander leaves, whose moisture content was 87.56% ± 0.04 and weight was 25 ± 0.02 g, were dried using natural drying, convective drying at 50°C, and microwave drying at 200 and 800 W until the final moisture content was 10.57 ± 0.07 in 4680, 630, 85, and 16.50 minutes, respectively. Experimental data were modeled using five different thin-layer drying equations. For all drying methods, except 200 W, Midilli et al. equation was determined as the most suitable model, but the Alibas equation obtained the best estimation at 200 W. While no energy consumption was required in the natural drying method, the energy consumption at 50°C, 200 W and 800 W was determined as 10.290, 0.283, and 0.220 kWh, respectively.While no energy consumption was required in the natural drying method, the energy consumption at 50°C, 200 W and 800 W was determined as 10.290, 0.283, and 0.220 kWh, respectively. The highest average thermal properties were obtained in the natural drying method but the lowest ones were at 800 W. Conversely, the lowest average thermal properties per unit time were detected in the natural drying method, but the highest results were at 800 W.

The closest color parameters to the fresh coriander leaves were determined at 800 W, followed by 200 W. Whereas the closest browning index to fresh samples was reached in samples dried at 200 W, the closest whitening index to fresh leaves was determined at 800 W. However, the highest chlorophyll content was measured in the microwave drying method at 800 W, and the lowest ones were obtained in the convective drying method at 50°C.

The closest results to fresh samples in terms of total protein, phosphorus, potassium, and zinc were found in samples dried at 800 W. However, the calcium, magnesium, and iron contents closest to fresh leaves were measured in samples dried at 800 and 200 W. After fresh samples, the highest copper concentration was obtained by natural drying and microwave drying at 800 W. Although the manganese results closest to the fresh samples were measured at 200 W, similar results were obtained in sodium content for all drying methods. In the study, the highest results in terms of both drying and quality parameters were recorded in the microwave drying method at 800 W.

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Author's Contributions

The contribution of the authors is equal.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

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