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Effect of different drying methods on bioactive potential and nutrients of medlar fruit

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In the study, medlar samples were dried using natural drying in the shade at 25 °C, convective drying at 40, 50, and 60 °C, microwave drying at 200, 400, and 600 W, and combined drying with a combination of convective drying temperatures and microwave output powers. In order to precisely determine the effect of the method used, each drying technique was considered in a comprehensive framework. The moisture content of medlar was reduced from 74.07 to 11.75%. While the drying process took the longest time in shade drying, the drying process took the shortest time at 600 W–60 °C. The closest results to fresh product in terms of total protein content were found at 400 W. In addition, phosphorus, potassium, sodium and copper contents were maximised at 600 W–60 °C. The maximum contents for magnesium and manganese were 400 W–40 °C, while for zinc, it was 600 W–40 °C. After fresh products, the highest calcium was obtained at 600 W, and the highest iron was obtained at 200 W. The bioactive potential of medlar samples was evaluated in terms of extractable, hydrolysable and bioaccessible phenolic fractions by total phenolic content and antioxidant capacity assays. In terms of TPC, the bioaccessibility of the samples was highest when natural drying was used. The highest bioaccessibility values for ABTS, DPPH and CUPRAC were obtained at natural drying, 200 W–50 °C and 400 W–60 °C, respectively. As a result, DPPH was the most suitable antioxidant capacity determination method due to high results.

Keywords Medlar, Protein, Nutrients, Total phenolic, Antioxidant capacity

Medlar (*Mespilus germanica* L.) is a fruit species belonging to the '*Rosaceae*' family, whose fruit can be consumed, soft seeded, wild, growing as a border tree[1,2]. Wild fruits have attracted great interest in recent years due to their high nutritional value and their use in alternative medicine. Medlar fruit is rich in bioactive compounds such as antioxidants, phenolic and organic acids. Thanks to its antioxidant properties, it helps to eliminate harmful toxins[3]. The fruit contains high amounts of mineral content, vitamins A and C[1]. Vitamin C is effective in strengthening the immune system and vitamin A is effective in protecting eye health[2]. In addition, medlar fruits, which are rich in fibre, are also effective in the treatment and prevention of diabetes, cardiovascular diseases and some cancers[4].

Drying is one of the most suitable preservation techniques used to maintain the quality and stability of fresh fruits and vegetables after harvest, prevent decay and chemical deterioration caused by microorganisms in the product, and provide longer shelf life[5]. It also provides convenience during drying, storage, packaging and transport[6]. The natural drying in the shade is one of the oldest and most common drying techniques. The products dry for a very long time, and large areas are needed for drying[7]. Due to drying in open areas, micro-moulds are formed in the product and exposed to dust, soil, insects, and other microorganisms[8,9]. Convective drying, developed to eliminate the disadvantages of shade drying, is a widely used drying method today[10]. However, long drying times and high energy consumption occur in this method and cause losses in the product's aroma, taste, colour and nutrient content[11,12]. The microwave drying method has many advantages, such as shorter drying time, low energy consumption, less loss in quality characteristics and preservation of nutrient content compared to the convective drying method[13,14]. However, microwave drying requires high investment costs and causes deformations such as explosion, splitting, and burning at high microwave powers[15,16]. Low microwave power is used together with convective drying to avoid these disadvantages. Thus, shorter drying times and lower energy consumption occur[17,18]. In addition, examining the effect of combined microwave-convective drying method on nutrient content and bioactive potential is also important in determining product quality. The bioactive potential is evaluated using spectrophotometric analyses such as ABTS, CUPRAC and

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DPPH to determine the products' total antioxidant capacity and phenolic content. Various methods were used to compare the values and to determine the most appropriate method to be used. Different products' nutrient content and bioactive potential differ according to the drying method applied and the dried product. In this regard, a series of studies have been carried out in microwave, convective and combined microwave-convective drying methods in different products and still continue to be carried out. However, the effect of these drying methods on nutrient content and bioactive potential has not yet been clearly defined. Further studies are needed to reveal the full effect of the drying method and the product specifically. Therefore, the aim of this study was (i) to investigate the effect of microwave and convective drying methods, including combined microwave-convective drying methods, on the macro and micronutrients and bioactive potential of medlar, (ii) to determine the most appropriate method to be used for the antioxidant analysis of medlar.

Materials and methods

Medlars (*Mespilus germanica* L.) were obtained from a local farmer in the Orhaneli district of Bursa. Permission has been obtained from the farmer to collect the plant material. The samples were kept in an atmospherically controlled cooler to prevent moisture loss. In the trials, the samples were dried whole without removing the seeds.

Chemicals

The chemicals used for phenolic and antioxidant content analyses in medlar are as follows-analytical grade Gallic acid 91,215 (Fluka, St. Louis, Missouri, USA), Folin-Ciocalteu reagent (FCR), Trolox ((±)-6-hydroxy-2,5,7,8 tetramethylchromane-2-carboxylic acid) (238813), Neocuproine (2,9-dimethyl-1,10-phenanthroline) (N1501), 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) (D9132), ABTS (2,2′-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt) (A1888) were all purchased from (Aldrich, St. Louis, Missouri, USA).

Drying systems and processes

Convective, microwave and combined drying trials were carried out with a multifunctional dryer (Electrolux, EVY7800AAX, USA) with 230 ± 10 V~, 50 Hz and 3000 W specifications. The dimensions of the drying chamber were 800 × 430 × 210 mm, and the area of the drying tray of the dryer was 410 × 320 mm. The dryer can operate at ten different microwave output powers, with the microwave power range from 100 to 1000 W and at all temperatures between 30 °C and 230 °C, with an accuracy of 5 °C. In addition, the dryer had a combined drying feature, where all output powers from 100 to 600 W and all temperature levels were used together. The drying methods applied to the medlar samples are given in Table 1.

Total protein, macro and micronutrient analysis

Total protein analysis was carried out according to the Kjeldahl method, which consists of three steps: digestion, distillation and titration[19]. Total protein content (TP) was calculated by multiplying the amount of nitrogen by a special coefficient[20,21].

Fresh and dried samples' phosphorus content (P) was determined using a spectrophotometer (Spectrum SP-UV-300SRB, Germany). Sodium (Na), potassium (K) and calcium (Ca) were determined by the Eppendorf Elex 6361 flame photometer. Iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) contents were analysed by ICP-OES (Perkin Elmer, OPTIMA 2100 DV, USA).

Bioactive compounds of medlars

Extraction stage of bioactive compounds

Three separate extractions were prepared from samples for antioxidant capacity and phenolic content analysis: extractable phenolic fraction (EPF), a hydrolysable phenolic fraction (HPF) and bioaccessible phenolic fraction (BPF). For EPF and HPF, according to the procedure of Vitali et al.[22], 2 g fresh/0.5 g dried sample was mixed with 15 mL methanol/H_2O/HCl (80:10:1 v/v) mixture and homogenised in a shaker water bath at 20 °C for 2 h, centrifuged at 3500 min^{-1} for 10 min at 4 °C and then the supernatant was taken as EPF. To the residue, 20 mL H_2SO_4/methanol (1:10 v/v) was added and homogenised again in a shaker water bath at 85 °C for 20 h. After centrifugation at 3500 min^{-1} for 10 min at 4 °C, the supernatant was stored as HPF.

Similarly, bioaccessible extracts were prepared for the in-vitro enzymatic extraction procedure by treating the fruit samples with gastrointestinal enzymes. The procedure was adapted to mimic digestive conditions (pH 2 and 37 °C for stomach; pH 7.2 and 37 °C for intestinal digestion). After the digestion procedure, the mixture was centrifuged (3500 rpm, 10 min, 15 °C), and the supernatant was taken as the BPF. The extracts were kept at−18 °C until analyses[22].

Drying methods	Drying conditions		
Natural drying (shade)	25 °C ± 1 and 60% ± 5 relative humidity		
Convective drying	40, 50, and 60 °C and an air velocity of 1 m s^{-1}		
Microwave drying	200, 400, and 600 W		
Combined drying	200 W–40 °C 200 W–50 °C 200 W–60 °C	400 W–40 °C 400 W–50 °C 400 W–60 °C	600 W–40 °C 600 W–50 °C 600 W–60 °C

Table 1. Drying methods applied to the samples

Total phenolic compounds

The Folin-Ciocalteu method, which is based on a redox reaction in which phenolic compounds are converted into oxidises by reducing the Folin-Ciocalteu reagent in a basic medium, was used to determine the total phenolic content of the medlar samples. All process stages were performed according to[15].

Total antioxidant capacities

The antioxidant capacity of medlar samples was determined via free radical scavenging assays, namely $TEAC_{CUPRAC}$ (cupric reducing antioxidant capacity), $TEAC_{DPPH}$ (2.2-diphenyl-1-picrylhy-drazyl), and $TEAC_{ABTS}$ (2.2-azinobis-(3-ethyl-benzothiazoline-6-sulfonic acid). The analytical procedures were performed according to the modified method defined in[23]. The results regarding the antioxidant capacity were indicated as µmol Trolox equivalent per g dry weight.

The in vitro bioaccessibility of phenols, which indicates how much of the product can be taken up by the metabolism, for both the total phenolic components and the $TEAC_{ABTS}$, $TEAC_{DPPH}$, and $TEAC_{CUPRAC}$-based antioxidant capacities was calculated with the following equation using the readings of the extractable, hydrolysable, and bioaccessible samples' reading[24].

$$B\% = \frac{B}{E+H} \times 100 \quad (1)$$

where: *B%* is the in vitro bioaccessibility (%), *E* is the extractable fractions (mg GAE/100 g dw (dry weight)) for total phenolic compounds and µmol Trolox g^{-1} dw for antioxidant capacity), *H* is the hydrolysable fractions (mg GAE/100 g dw for total phenolic compounds and µmol Trolox g^{-1} dw for antioxidant capacity) and *B* is the bioaccessible fractions (mg GAE/100 g dw for total phenolic compounds and µmol Trolox g^{-1} dw for antioxidant capacity).

Data analysis

The study was designed according to the randomised plot design method. All trials and analyses were carried out in 3 replicates, while colour measurements were carried out in 20 replicates for each drying trial. All analyses were performed in triplicate. The obtained results were analysed in terms of the LSD (Least Significant Difference) with the JMP 7.0 statistical program.

Results and discussion

Drying period

The initial moisture content of medlars was reduced from 74.07 ± 0.04% to 11.75 ± 0.07%. Table 2 shows the drying times for the different drying methods. Shade drying had the longest drying time (22,500 min). The shortest drying time was 600 W–60 °C combined microwave-convective drying method with both the highest applied drying temperature and the highest microwave output power (17 min). At 600 W–60 °C, which is the shortest drying method, 1323.53 times shorter drying time was recorded compared to shade drying.

In the study in which convective drying method was utilised in the drying of medlar, it was determined that the drying time of medlar dried at 60 °C was 6.51 times longer than the findings in our study[25]. Chiau et al.[26] dried medlar at 60 °C in 338 min using a convective dryer. The drying time was 3.86 times shorter than our findings.

	DP (min)
DM	**
ND	22500.00 ± 91.22[a]
40 °C	12180.00 ± 83.72[b]
50 °C	3498.00 ± 55.43[c]
60 °C	1305.00 ± 30.60[d]
200 W	100.50 ± 1.15[e]
400 W	57.50 ± 1.30[e]
600 W	31.00 ± 0.58[e]
200 W–40 °C	93.00 ± 1.01[e]
200 W–50 °C	71.00 ± 1.15[e]
200 W–60 °C	53.50 ± 0.29[e]
400 W–40 °C	50.40 ± 0.23[e]
400 W–50 °C	43.00 ± 0.14[e]
400 W–60 °C	33.50 ± 0.23[e]
600 W–40 °C	29.00 ± 0.43[e]
600 W–50 °C	23.00 ± 0.58[e]
600 W–60 °C	17.00 ± 0.14[e]

Table 2. Drying time for medlar samples *DM* drying methods, *ND* natural drying, *DP* drying period (min). $^{**}p < 0.01$; The differences between the columns are significant. ± standard errors of estimated.

Total protein content

The protein change in medlars dried by different methods compared to fresh products is shown in Table 3. The range of change in TP was maximum 9.17–20.04 g kg^{-1} in convective drying and minimum 19.71–25.15 g kg^{-1} in microwave drying. The table shows that 400 W gave the closest results to fresh samples regarding TP content. The protein content of the products dried by this drying method was 1.04 times lower in fresh samples. On the other hand, the highest loss in TP content was obtained in convective drying at 60 °C. However, the protein content measured at 60 °C was 2.86 times lower compared to fresh samples. Strikingly, convective drying had no statistically significant effect on protein content, but microwave drying had a statistically significant impact on the same parameter.

Yılmaz and Alibas[13] dried purple basil leaves using natural, convective and microwave methods and measured the maximum protein content in convective drying. In a study in which basil leaves were dried by different drying methods, Danso-Boateng[27] found the highest protein content in microwave drying after fresh product.

The concentration of macro and micronutrients

The effect of various drying methods on the macronutrients of medlar compared to fresh products is shown in Table 3. Combined drying had the highest deviation for P and K (P: 0.40–0.75 g kg^{-1}; K: 4.21–6.89 g kg^{-1}). The lowest P and K content deviation methods were convective and microwave drying, respectively (P: 0.49–0.53 g kg^{-1}; K: 4.51–5.73 g kg^{-1}). The closest drying methods to the fresh product in terms of preservation of P and K were 600 W–60 °C combined drying. The high P and K content in the samples dried by this drying method proved that high microwave power, high temperatures and airflow did not affect P and K content. Interestingly, the high P and K content at 600 W, the highest microwave power, indicates that although the microwave energy penetrating the product is high, the drying time is relatively short. Therefore, the samples are not affected by the generated high energy. On the other hand, in natural drying, P content decreased significantly at 400 W and 200 W–60 °C. Similarly, natural drying and convective drying at 60 °C caused a significant loss of K content. The P measured in the natural drying was 2.11 times lower than that of the fresh sample, while it was 1.12 times lower at 600 W–60 °C. In addition, K content decreased by 15.65% at 600 W–60 °C compared to the fresh product. In contrast, the K content measured at 600 W–60 °C was 95.70% and 96.22% lower than those analysed at natural and 60 °C, respectively.

According to Table 3, the maximum range of change in Mg and Ca content was recorded in combined drying (Mg: 0.31–0.70 g kg^{-1}; Ca: 0.87–1.85 g kg^{-1}). The minimum change was recorded in microwave drying for Mg and convective drying for Ca (Mg: 0.36–0.50 g kg^{-1}; Ca: 1.31–1.54 g kg^{-1}). The highest Mg and Ca contents were obtained at 400 W–40 °C and 600 W, respectively. The lowest Ca and Mg contents were measured in samples dried at 200 W–50 °C. This decrease in the two nutrients at 200 W–50 °C is due to the combined effect of microwave and convective drying. Both the longer penetration of microwave energy into the product and the product's exposure to the airflow are the reasons for the low concentration. The recorded Ca content decreased by 8.48% at 600 W compared to fresh samples but increased by 2.46 times compared to 200 W–50 °C. 400 W–40 °C caused a 15.26% decrease in Mg content compared to the fresh product. Moreover, Mg measured at 400 W–40 °C was 2.25 times higher than 200 W–50 °C. Convective drying had no statistically significant effect

		Macronutrients (g kg^{-1}(dw))			
	TP	*P*	K	Ca	Mg
DM	**	**	**	**	**
Fresh	26.24 ± 0.41^{a}	0.84 ± 0.016^{a}	7.97 ± 0.04^{a}	2.33 ± 0.01^{a}	$0.81 \pm 10^{-2\,a}$
ND	15.48 ± 0.38^{h}	0.40 ± 0.005^{g}	3.52 ± 0.03^{j}	1.38 ± 0.02^{g}	$0.33 \pm 6\ 10^{-3\,hi}$
40 °C	16.88 ± 0.25^{g}	0.51 ± 0.005^{de}	5.68 ± 0.09^{cd}	1.31 ± 0.01^{h}	$0.45 \pm 10^{-2\,e}$
50 °C	20.04 ± 0.42^{ef}	0.49 ± 0.003^{e}	5.53 ± 0.06^{d}	1.37 ± 0.02^{g}	$0.46 \pm 6\ 10^{-3\,e}$
60 °C	9.17 ± 0.16^{j}	0.53 ± 0.009^{d}	3.51 ± 0.08^{j}	1.54 ± 0.01^{e}	$0.46 \pm 6\ 10^{-3\,e}$
200 W	19.71 ± 0.33^{ef}	0.42 ± 0.010^{fg}	4.54 ± 0.10^{h}	1.47 ± 0.02^{f}	$0.41 \pm 7\ 10^{-3\,f}$
400 W	25.15 ± 0.11^{b}	0.40 ± 0.015^{g}	4.51 ± 0.09^{h}	1.25 ± 0.02^{i}	$0.36 \pm 9\ 10^{-3\,g}$
600 W	21.54 ± 0.23^{d}	0.48 ± 0.012^{e}	5.73 ± 0.01^{c}	2.15 ± 0.02^{b}	$0.50 \pm 4\ 10^{-3\,d}$
200 W–40 °C	19.19 ± 0.58^{f}	0.50 ± 0.009^{de}	5.84 ± 0.03^{c}	1.01 ± 0.01^{k}	$0.35 \pm 8\ 10^{-3\,g}$
200 W–50 °C	23.19 ± 0.66^{c}	0.44 ± 0.007^{f}	4.21 ± 0.09^{i}	0.87 ± 0.01^{m}	$0.31 \pm 7\ 10^{-3\,i}$
200 W–60 °C	13.04 ± 0.29^{i}	0.40 ± 0.006^{g}	4.76 ± 0.08^{g}	1.60 ± 0.01^{d}	$0.55 \pm 4\ 10^{-3\,c}$
400 W–40 °C	21.63 ± 0.36^{d}	0.60 ± 0.006^{c}	4.80 ± 0.04^{g}	1.85 ± 0.01^{c}	$0.70 \pm 9\ 10^{-3\,b}$
400 W–50 °C	22.77 ± 0.10^{c}	0.48 ± 0.011^{e}	4.75 ± 0.08^{g}	0.96 ± 0.01^{l}	$0.32 \pm 3\ 10^{-3\,hi}$
400 W–60 °C	16.15 ± 0.60^{gh}	0.44 ± 0.004^{f}	5.02 ± 0.05^{f}	1.19 ± 0.02^{j}	$0.34 \pm 6\ 10^{-3\,gh}$
600 W–40 °C	13.38 ± 0.29^{i}	0.57 ± 0.017^{c}	5.85 ± 0.03^{c}	1.41 ± 0.02^{g}	$0.46 \pm 9\ 10^{-3\,e}$
600 W–50 °C	20.33 ± 0.15^{e}	0.49 ± 0.010^{e}	5.24 ± 0.07^{e}	1.19 ± 0.02^{j}	$0.40 \pm 10^{-3\,f}$
600 W–60 °C	14.02 ± 0.30^{i}	0.75 ± 0.005^{b}	6.89 ± 0.03^{b}	1.29 ± 0.01^{hi}	$0.46 \pm 10^{-2\,e}$

Table 3. Total protein, macronutrients of fresh and dried medlar samples *DM* drying methods, *ND* natural drying, *TP* total protein, *P* phosphorus, *K* potassium, *Ca* calcium, *Mg* magnesium. $^{**}p < 0.01$; The differences between the columns are significant. ± standard errors of estimated.

on P, Ca and Mg content but significantly impacted K. Also, microwave drying statistically affected P and K but not Ca and Mg. Accordingly, Ca, P and Mg contents also increased with the increase in the applied microwave output power (Table 3).

It presents the effect of various drying methods on the micronutrients of medlar in comparison with fresh ones (Table 4). The maximum change in Na and Cu content was in combined drying (Na: 0.1774–0.2868 g kg^{-1}; Cu: 0.0030–0.0059 g kg^{-1}). The minimum change in the same nutrients was in convective and microwave drying, respectively (Na: 0.1687–0.2428 g kg^{-1}; Cu: 0.0037–0.0040 g kg^{-1}). The closest results to the fresh product in terms of Na and Cu were obtained in combined drying at 600 W–60 °C. This increase in the two nutrients at 600 W–60 °C is due to the short exposure of the product to both high temperature and high microwave power. Interestingly, although the microwave energy penetrating the product at the highest microwave power of 600 W and the resulting heat was high, it did not damage the product due to the very short drying time. In the natural drying method, excessively long drying time caused the Na and Cu contents in the product to decrease. Compared to fresh samples, the Na content recorded in the natural drying increased by 91.46% but was 52.02% lower than that dried at 600 W–60 °C. Cu content at 600 W–60 °C was 1.14 times lower than fresh products but 2.46 times higher than natural drying.

The method with the highest deviation in Fe and Zn content was combined drying (Fe: 0.0083–0.0210 g kg^{-1}; Zn: 0.0031–0.0050 g kg^{-1}). The method with the lowest deviation in the same nutrients was convective drying (Fe: 0.0102–0.0168 g kg^{-1}; Zn: 0.0031–0.0038 g kg^{-1}). The maximum and minimum deviation for Mn was in combined and microwave drying, respectively (Mn: 0.0017–0.0035 g kg^{-1}; Mn: 0.0021–0.0030 g kg^{-1}). The highest Fe, Mn and Zn contents were recorded at 200 W, 400 W–40 °C and 600 W–40 °C, respectively. The lowest Mn and Zn contents were measured in natural drying. The main reason for the nutrient losses in natural drying is the increased contact of the product with air due to the very long drying time, i.e., increased product oxidation. On the other hand, the lowest Fe content was determined at 200 W–50 °C combined drying. Also, the Fe content measured at 200 W was 2.71 times higher than at 200 W–50 °C. Similarly, compared to fresh products, Mn content decreased 1.14 times at 400 W–40 °C but increased 2.97 times in natural drying. Furthermore, Zn decreased 1.39-fold at 600 W–40 °C compared to fresh samples but increased 1.69-fold compared to natural drying. Convective drying had no statistically significant effect on micronutrients. Remarkably, although the drying time was short in microwave drying, a statistically significant change occurred in nutrients such as Na, Cu and Zn. Thus, Cu and Zn contents also increased with increasing microwave output power (Table 4).

In general, it can be said that the closest drying methods to fresh product in terms of protein content, macro and micronutrients are microwave and combined drying. This shows that medlar can maintain its protein content and nutrient content when dried by these two methods. Natural drying of medlar and drying at high temperature such as 60 °C caused a loss in nutrient and protein content. In addition, in the combinations of 200 W (200 W–50 °C and 200 W–60 °C), a significant loss in nutrient content occurred due to exposure of the product to both microwave energy and high temperatures, albeit at low doses (Tables 3 and 4).

Pető et al.[28] reported that the P, K, Fe and Mn contents of medlar samples dried by convective drying at 70 °C were similar to our findings. In addition, the Na content they recorded was 4.02 times lower than in our study. Ozcan and Uslu[29] emphasised that guava's Ca and Mg content dried at 540 W using the microwave

	Micronutrients (g kg^{-1}(dw))				
	Na	Fe	Cu	Mn	Zn
DM	**	**	**	**	**
Fresh	$0.4360 \pm 4\ 10^{-3\ a}$	$0.0437 \pm 7\ 10^{-4\ a}$	$0.0067 \pm 6\ 10^{-5\ a}$	$0.0040 \pm 6\ 10^{-5\ a}$	$0.0070 \pm 8\ 10^{-5\ a}$
ND	$0.1498 \pm 3\ 10^{-3\ l}$	$0.0091 \pm 3\ 10^{-4\ lm}$	$0.0024 \pm 4\ 10^{-5\ k}$	$0.0013 \pm 10^{-5\ k}$	$0.0030 \pm 4\ 10^{-5\ i}$
40 °C	$0.2392 \pm 5\ 10^{-3\ def}$	$0.0103 \pm 4\ 10^{-4\ k}$	$0.0043 \pm 7\ 10^{-5\ d}$	$0.0022 \pm 6\ 10^{-5\ efg}$	$0.0038 \pm 5\ 10^{-5\ f}$
50 °C	$0.2428 \pm 6\ 10^{-3\ def}$	$0.0102 \pm 5\ 10^{-4\ kl}$	$0.0041 \pm 6\ 10^{-5\ e}$	$0.0019 \pm 6\ 10^{-5\ i}$	$0.0031 \pm 6\ 10^{-5\ hi}$
60 °C	$0.1687 \pm 3\ 10^{-3\ k}$	$0.0168 \pm 5\ 10^{-4\ fg}$	$0.0033 \pm 4\ 10^{-5\ i}$	$0.0030 \pm 8\ 10^{-5\ c}$	$0.0036 \pm 4\ 10^{-5\ fg}$
200 W	$0.2015 \pm 8\ 10^{-3\ hi}$	$0.0225 \pm 3\ 10^{-4\ b}$	$0.0040 \pm 8\ 10^{-5\ e}$	$0.0030 \pm 7\ 10^{-5\ c}$	$0.0044 \pm 5\ 10^{-5\ de}$
400 W	$0.1760 \pm 5\ 10^{-3\ k}$	$0.0160 \pm 3\ 10^{-4\ gh}$	$0.0037 \pm 2\ 10^{-5\ fg}$	$0.0021 \pm 2\ 10^{-5\ gh}$	$0.0031 \pm 5\ 10^{-5\ hi}$
600 W	$0.2543 \pm 9\ 10^{-3\ cd}$	$0.0128 \pm 10^{-4\ ij}$	$0.0037 \pm 2\ 10^{-5\ f}$	$0.0021 \pm 2\ 10^{-5\ fg}$	$0.0046 \pm 7\ 10^{-5\ cd}$
200 W–40 °C	$0.2278 \pm 2\ 10^{-3\ fg}$	$0.0210 \pm 8\ 10^{-4\ c}$	$0.0036 \pm 6\ 10^{-5\ gh}$	$0.0017 \pm 2\ 10^{-5\ j}$	$0.0033 \pm 3\ 10^{-5\ gh}$
200 W–50 °C	$0.1940 \pm 4\ 10^{-3\ ij}$	$0.0083 \pm 2\ 10^{-4\ m}$	$0.0036 \pm 6\ 10^{-5\ fgh}$	$0.0017 \pm 2\ 10^{-5\ j}$	$0.0031 \pm 6\ 10^{-5\ hi}$
200 W–60 °C	$0.2328 \pm 4\ 10^{-3\ efg}$	$0.0180 \pm 3\ 10^{-4\ e}$	$0.0030 \pm 10^{-4\ j}$	$0.0027 \pm 5\ 10^{-5\ d}$	$0.0033 \pm 10^{-4\ hi}$
400 W–40 °C	$0.2167 \pm 10^{-2\ gh}$	$0.0137 \pm 3\ 10^{-4\ i}$	$0.0042 \pm 3\ 10^{-5\ d}$	$0.0035 \pm 5\ 10^{-5\ b}$	$0.0047 \pm 10^{-4\ bc}$
400 W–50 °C	$0.1774 \pm 9\ 10^{-3\ jk}$	$0.0155 \pm 4\ 10^{-4\ h}$	$0.0039 \pm 9\ 10^{-5\ e}$	$0.0020 \pm 5\ 10^{-5\ hi}$	$0.0043 \pm 4\ 10^{-5\ de}$
400 W–60 °C	$0.2255 \pm 5\ 10^{-3\ fg}$	$0.0195 \pm 3\ 10^{-4\ d}$	$0.0035 \pm 9\ 10^{-5\ hi}$	$0.0023 \pm 4\ 10^{-5\ e}$	$0.0037 \pm 4\ 10^{-5\ f}$
600 W–40 °C	$0.2460 \pm 9\ 10^{-3\ cd}$	$0.0170 \pm 3\ 10^{-4\ efg}$	$0.0054 \pm 2\ 10^{-5\ c}$	$0.0025 \pm 9\ 10^{-5\ d}$	$0.0050 \pm 5\ 10^{-5\ b}$
600 W–50 °C	$0.2716 \pm 3\ 10^{-3\ bc}$	$0.0126 \pm 3\ 10^{-4\ j}$	$0.0052 \pm 4\ 10^{-5\ c}$	$0.0021 \pm 4\ 10^{-5\ gh}$	$0.0032 \pm 3\ 10^{-2\ hi}$
600 W–60 °C	$0.2868 \pm 8\ 10^{-3\ b}$	$0.0173 \pm 4\ 10^{-4\ ef}$	$0.0059 \pm 7\ 10^{-5\ b}$	$0.0023 \pm 4\ 10^{-5\ ef}$	$0.0042 \pm 9\ 10^{-5\ e}$

Table 4. Micronutrients of fresh and dried medlar samples *DM* drying methods, *ND* natural drying, *Na* sodium, *Fe* iron, *Cu* cupper *Mn* manganese, *Zn* zinc. $^{**}p < 0.01$; The differences between the columns are significant. ± standard errors of estimated.

drying method was higher than convective drying at 70 °C. Similar to our study, Yılmaz and Alibas[13] reported that Zn and Cu contents of purple basil leaves dried by natural drying method were lower than convective and microwave drying methods. Arslan and Ozcan[30] found that the K content of dried tomato slices was higher in microwave drying compared to convective drying. Orak et al.[31] stated that convective drying at 65 °C negatively affected strawberry fruit's Zn, Cu, Fe, Ca, K, P and Mg contents. Ozcan et al.[32] reported that sun drying caused a decrease in Ca, Fe, Mn, Na and Zn contents of basil leaves.

Total phenolic compounds

Drying is a widely used method for food products, and the preservation of phenolic content is essential for the bioactive potential and its health effects[33]. Table 5 shows fresh and dried medlar samples' extractable, hydrolysable and bioaccessible phenolic fractions and bioaccessibility values. Combined drying had the highest variation for EPF and HPF (EPF: 196.09–328.56 mg GAE/100 g dw; HPF: 222.42–345.33 mg GAE/100 g dw). The method with the least variation was microwave drying (EPF: 163.13–246.31 mg GAE/100 g dw; HPF: 238.89–289.18 mg GAE/100 g dw). For BPF, the maximum deviation values ranged between 238.36 and 379.68 mg GAE/100 g dw in convective drying, while the minimum deviation values ranged between 186.15 and 191.83 mg GAE/100 g dw in microwave drying. For bioaccessibility, the maximum deviation ranged between 24.26 and 54.84% in combined drying, while the minimum deviation ranged between 61.71 and 62.19% in convective drying. The closest EPF of TPC to the fresh product was recorded in the 600 W–60 °C combined drying. In this method, phenolics were less exposed to thermal effects due to shorter drying times. Thus, TPC content was higher. The closest HPF and BPF to fresh product were recorded at 60 °C. Natural drying for EPF of TPC and both natural drying and combined drying at 400 W–60 °C for HPF of TPC caused significant losses. Moreover, the lowest BPF was recorded at 200 W–40 °C. Strikingly, EPF, HPF and BPF of TPC were at a very low content in the natural drying. Despite the low contents in EPF, HPF and BPF, the bioaccessibility was higher than the other drying methods with 71.18%. EPF and HPF of TPC were relatively high at 200 W–40 °C; the bioaccessibility value was the lowest among all methods with 24.26%. On the other hand, convective drying had a statistically insignificant effect on EPF and HPF as well as bioaccessibility of TPC. However, the effect of the method on the BPF of TPC was statistically significant. Moreover, BPF also increased with increasing convective drying temperature. Furthermore, the effect of microwave drying on the EPF and BPF of TPC was statistically significant, and the EPF of TPC increased with the increase of microwave output power.

EPF and BPF of TPC of medlar samples convectively dried at 60 °C recorded by Suna[34] were 1.30 times lower than our results. In the mentioned study, EPF measured at 180 W was consistent with our results, while HPF was 1.48 times lower than our results. Also, the BPF of TPC measured at 180 W was 1.63 times higher than our results. Zia and Alibas[35] reported that the bioaccessibility of microwave dried blueberries was higher than convective dried ones. In the study conducted by Horuz et al.[17], TPC values of cherries dried by convective drying were found to be lower compared to combined drying. They stated that this may be due to prolonged exposure to oxygen and thermal degradation of phenolics. In a study in which kiwifruit samples were dried

	Total phenolic compounds (mg GAE 100 g^{-1} dw)			
	EPF	HPF	BPF	B%
DM	**	**	**	**
Fresh	362.34 ± 8.43^{a}	417.15 ± 2.69^{a}	417.42 ± 1.81^{a}	53.56 ± 0.63^{c}
ND	85.35 ± 2.05^{m}	220.70 ± 0.25^{h}	217.78 ± 3.80^{f}	71.18 ± 1.71^{a}
40 °C	126.40 ± 1.13^{l}	259.83 ± 1.09^{f}	238.36 ± 4.30^{d}	61.71 ± 0.80^{b}
50 °C	171.70 ± 2.37^{k}	279.80 ± 6.08^{e}	280.64 ± 2.80^{c}	62.19 ± 1.09^{b}
60 °C	255.65 ± 2.74^{ef}	358.14 ± 5.78^{b}	379.68 ± 4.23^{b}	61.89 ± 1.39^{b}
200 W	163.13 ± 3.03^{k}	259.75 ± 4.83^{f}	189.98 ± 1.49^{gh}	44.97 ± 1.15^{d}
400 W	172.95 ± 3.32^{k}	238.89 ± 3.04^{g}	186.15 ± 2.99^{gh}	45.20 ± 0.68^{d}
600 W	246.31 ± 0.76^{f}	289.18 ± 4.77^{e}	191.83 ± 2.20^{g}	35.82 ± 0.19^{g}
200 W–40 °C	306.17 ± 8.14^{c}	279.34 ± 2.64^{e}	141.99 ± 1.61^{k}	24.26 ± 0.16^{j}
200 W–50 °C	219.21 ± 5.19^{gh}	284.44 ± 4.82^{e}	170.42 ± 1.50^{i}	33.87 ± 0.86^{g}
200 W–60 °C	267.33 ± 2.90^{de}	251.45 ± 4.55^{fg}	173.72 ± 1.94^{i}	33.49 ± 0.26^{g}
400 W–40 °C	225.38 ± 8.72^{g}	345.33 ± 4.04^{c}	155.86 ± 3.55^{j}	27.36 ± 1.12^{i}
400 W–50 °C	211.14 ± 5.08^{hi}	256.72 ± 6.35^{f}	183.40 ± 2.19^{h}	39.22 ± 0.54^{f}
400 W–60 °C	196.09 ± 6.33^{j}	222.42 ± 7.85^{h}	229.36 ± 2.48^{e}	54.84 ± 1.22^{c}
600 W–40 °C	202.41 ± 4.79^{ij}	321.15 ± 1.38^{d}	221.18 ± 1.98^{f}	42.26 ± 0.65^{e}
600 W–50 °C	280.03 ± 1.84^{d}	278.86 ± 4.25^{e}	172.80 ± 0.60^{i}	30.92 ± 0.12^{h}
600 W–60 °C	328.56 ± 3.38^{b}	283.05 ± 2.23^{e}	219.81 ± 2.23^{f}	35.94 ± 0.16^{g}

Table 5. Extractable, hydrolysable, and bioaccessible phenols fraction and in vitro bioaccessibility of total phenolic content for fresh and dried medlar samples *DM* drying methods, *ND* natural drying, *TPC* total phenolic compounds (mg GAE 100 g^{-1} dw), *EPF* extractable phenolic fractions, *HPF* hydrolysable phenolic fractions, *BPF* bioaccessible phenolic fractions, *B%* in vitro bioaccessibility. $^{**}p < 0.01$;The differences between the columns are significant. ± standard errors of estimated.

by convective drying, an increase in TPC content was reported compared to fresh samples. It was stated that this was due to water loss during drying, which resulted in an increase in the concentration of most chemical compounds in kiwifruit[36]. Samoticha et al.[37], in their study with aronia, found that TPC decreased significantly at 50 °C due to long drying times. Horecki et al.[38] emphasised that both long drying times and low temperatures reduce TPC. In parallel with our results, Zia and Alibas[15] reported that HPF of TPC in cranberry was higher than EPF and BPF.

Total antioxidant capacities

EPF, HPF and BPF values of antioxidant capacities of fresh and dried samples as Trolox equivalent (TEAC) according to DPPH, CUPRAC and ABTS methods and bioaccessibility calculated according to these parameters are shown in Table 6.

$TEAC_{DPPH}$ method

The data on the antioxidant capacity of medlar using $TEAC_{DPPH}$ method are shown in Table 6. The maximum deviation for EPF and HPF was recorded in the combined drying (EPF: 330.48–394.79 µmol Trolox 100 g^{-1} dw; HPF: 95.76–116.27 µmol Trolox 100 g^{-1} dw). The least deviation was in microwave drying (EPF: 386.80–391.56 µmol Trolox 100 g^{-1} dw; HPF: 115.14–117.80 µmol Trolox 100 g^{-1} dw). The maximum deviation values for BPF and bioaccessibility were determined in combined drying (BPF: 105.69–189.01 µmol Trolox 100 g^{-1} dw; %B: 23.75–37.29) and the minimum deviation values were determined in convective drying (BPF: 47.31–57.09 µmol Trolox 100 g^{-1} dw; %B: 9.60–12.99). Depending on the short drying time, EPF and BPF values of $TEAC_{DPPH}$ were highest at 600 W–40 °C and 200 W–50 °C, respectively. The table shows that the highest results for the HPF of $TEAC_{DPPH}$ were recorded at 200 and 600 W. However, EPF and HPF of $TEAC_{DPPH}$ were lowest at 200 W–60 °C. Similarly, BPF also decreased significantly in the natural drying method. This is due to the increase in oxidation in the product due to the long drying time. Moreover, the highest bioaccessibility was realised at 200 W–50 °C and the lowest at natural drying due to high BPF concentration. On the other hand, the effect of convective drying on EPF and HPF of $TEAC_{DPPH}$ was statistically significant. Nevertheless, this drying method did not affect the BPF of $TEAC_{DPPH}$. Similarly, microwave drying method did not show any significant relationship with any phenolic fraction of $TEAC_{DPPH}$.

According to the table's data, the extractable, hydrolysable and bioaccessible phenolic fractions were quite high for all drying methods, indicating that phenols present in fresh and dried medlar can be efficiently used for their antioxidant properties.

$TEAC_{CUPRAC}$ method

The data on the antioxidant capacity of medlar using the $TEAC_{CUPRAC}$ method are shown in Table 6. For EPF, maximum and minimum deviations were determined in combined drying (EPF: 154.47–394.88 µmol Trolox 100 g^{-1} dw) and microwave drying (EPF: 121.11–215.91 µmol Trolox 100 g^{-1} dw), respectively. For HPF, convective (HPF: 42.18–64.41 µmol Trolox 100 g^{-1} dw) and microwave drying (HPF: 44.09–53.02 µmol Trolox 100 g^{-1} dw) were the methods with the highest and lowest deviations, respectively. The highest change for BPF and bioaccessibility was determined in combined drying (BPF: 110.51–174.53 µmol Trolox 100 g^{-1} dw; %B: 33.07–86.36). The least change was detected in convective drying (BPF: 22.98–52.76 µmol Trolox 100 g^{-1} dw; %B: 15.15–19.97). EPF and BPF of $TEAC_{CUPRAC}$ reached the highest level at 600 W–60 °C and 400 W–60 °C, respectively, while HPF reached the maximum level at 60 °C and 400 W–40 °C. However, EPF, HPF and BPF of $TEAC_{CUPRAC}$ caused significant losses in the natural drying. The highest bioaccessibility was found at 400 W–60 °C. In contrast, the lowest bioaccessibility was found in the natural drying method. Convective drying had a statistically significant effect on the EPF of $TEAC_{CUPRAC,}$ and increasing the temperature increased this value. However, microwave drying had a statistically significant effect on EPF and bioaccessibility.

$TEAC_{ABTS}$ method

The antioxidant capacity for medlar using the $TEAC_{ABTS}$ method is given in Table 6. Convective drying was the method with the highest deviation for EPF and bioaccessibility (EPF: 15.26–19.11 µmol Trolox 100 g^{-1} dw; %B: 32.93–47.19). The method with the lowest deviation was microwave drying (EPF: 17.20–18.79 µmol Trolox 100 g^{-1} dw; %B: 39.02–41.71). The highest deviation for HPF and BPF was in the combined drying (HPF: 10.79–23.43 µmol Trolox 100 g^{-1} dw; BPF: 9.18–16.45 µmol Trolox 100 g^{-1} dw) and the lowest deviation for microwave drying (HPF: 20.80–23.85 µmol Trolox 100 g^{-1} dw; BPF: 15.80–16.15 µmol Trolox 100 g^{-1} dw). The highest EPF and BPF values of $TEAC_{ABTS}$ were reached at 60 °C and 600 W–40 °C, respectively. In contrast, the highest HPF was measured in samples dried at 200 W and 600 W–40 °C. Natural drying resulted in a significant loss in EPF, while the combined drying methods at 200 W–60 °C and 400 W–40 °C resulted in high decreases in HPF and BPF, respectively. Interestingly, the highest bioaccessibility was observed in natural drying, while 60 °C and 400 W–40 °C had the lowest bioaccessibility. Convective drying had a statistically significant effect on the BPF of $TEAC_{ABTS}$. Microwave drying had a statistically significant effect on EPF.

Karakaya[39] reported that phenolic compounds are responsible for the antioxidant activity of botanical extracts; therefore, the processes affecting the total phenolic content will also affect the antioxidant capacity. In this study, in general, it can be said that the antioxidant capacity and phenolic content of the samples dried by the combined drying method are proportional; in other words, total phenolic content and antioxidant capacity show a parallel trend to each other (Table 5).

Among the CUPRAC, ABTS, and DPPH methods used to determine antioxidant capacity, the DPPH method measured at higher concentrations was determined to be the most successful.

Suna[34] measured $TEAC_{CUPRAC}$ EPF of dried medlar samples as 125.77 µmol Trolox 100 g^{-1} at 180 W and $TEAC_{CUPRAC}$ BPF as 64.85 µmol Trolox 100 g^{-1} at 60 °C. In the study in which cornellian cherry samples were

	Total antioxidant capacities (μmol Trolox 100 g^{-1}dw)											
	$TEAC_{DPPH}$				$TEAC_{CUPRAC}$				$TEAC_{ABTS}$			
	EPF	HPF	BPF	B%	EPF	HPF	BPF	B%	EPF	HPF	BPF	B%
DM	**	**	**	**	**	**	**	**	**	**	**	**
Fresh	536.04 ± 1.79^{a}	142.59 ± 1.75^{a}	232.77 ± 2.50^{a}	34.30 ± 0.44^{bc}	415.97 ± 7.47^{a}	76.93 ± 1.84^{a}	200.94 ± 0.47^{a}	40.78 ± 0.55^{g}	27.06 ± 0.13^{a}	30.11 ± 0.32^{a}	24.30 ± 0.68^{a}	42.49 ± 1.10^{cde}
ND	384.20 ± 1.60^{d}	108.47 ± 0.41^{gh}	32.53 ± 4.98^{l}	6.60 ± 0.99^{j}	40.98 ± 2.36^{l}	37.65 ± 1.20^{i}	8.41 ± 0.14^{l}	10.71 ± 0.32^{k}	9.31 ± 0.49^{i}	16.27 ± 0.43^{g}	15.14 ± 0.20^{bcd}	59.16 ± 0.69^{a}
40 °C	384.42 ± 1.09^{d}	108.50 ± 1.37^{gh}	47.31 ± 1.20^{k}	9.60 ± 0.24^{i}	73.03 ± 1.92^{k}	42.18 ± 0.83^{h}	22.98 ± 0.21^{k}	19.97 ± 0.57^{i}	15.26 ± 0.34^{h}	19.10 ± 0.30^{e}	16.21 ± 0.19^{bc}	47.19 ± 0.52^{b}
50 °C	368.67 ± 2.68^{e}	106.59 ± 0.90^{h}	56.68 ± 0.30^{j}	11.93 ± 0.03^{h}	122.48 ± 2.68^{j}	53.17 ± 2.26^{cd}	26.65 ± 1.57^{k}	15.15 ± 0.49^{j}	16.32 ± 0.43^{g}	17.40 ± 0.28^{f}	15.23 ± 0.45^{bcd}	45.17 ± 1.14^{bc}
60 °C	340.78 ± 1.37^{g}	98.84 ± 0.30^{i}	57.09 ± 1.59^{j}	12.99 ± 0.38^{h}	249.16 ± 1.89^{d}	64.41 ± 0.47^{b}	52.76 ± 2.40^{j}	16.84 ± 0.85^{j}	19.11 ± 0.39^{b}	12.08 ± 0.44^{h}	10.27 ± 0.65^{fg}	32.93 ± 1.91^{i}
200 W	387.81 ± 3.74^{cd}	116.98 ± 0.89^{b}	175.98 ± 1.57^{cd}	34.86 ± 0.08^{b}	121.11 ± 0.78^{j}	45.96 ± 0.68^{fgh}	132.29 ± 0.68^{fg}	79.20 ± 1.01^{b}	17.54 ± 0.10^{ef}	23.85 ± 0.09^{b}	16.15 ± 0.52^{bc}	39.02 ± 1.28^{efg}
400 W	391.56 ± 1.59^{bc}	115.14 ± 0.52^{bcd}	177.54 ± 0.30^{c}	35.04 ± 0.08^{b}	129.62 ± 3.23^{j}	44.09 ± 0.72^{gh}	101.21 ± 0.63^{i}	58.31 ± 1.41^{d}	17.20 ± 0.09^{f}	21.09 ± 0.13^{d}	15.97 ± 0.05^{bc}	41.71 ± 0.16^{cde}
600 W	386.80 ± 0.80^{cd}	117.80 ± 0.30^{b}	154.62 ± 1.19^{ef}	30.64 ± 0.30^{de}	215.91 ± 6.56^{f}	53.02 ± 1.62^{cd}	129.41 ± 1.37^{g}	48.14 ± 0.55^{f}	18.79 ± 0.11^{bc}	20.80 ± 0.13^{d}	15.80 ± 0.46^{bc}	39.93 ± 1.24^{def}
200 W–40 °C	367.86 ± 2.27^{e}	106.67 ± 0.56^{h}	150.70 ± 0.30^{f}	31.76 ± 0.09^{d}	272.87 ± 2.27^{c}	49.57 ± 1.05^{def}	158.14 ± 1.27^{c}	49.05 ± 0.50^{f}	17.92 ± 0.10^{de}	17.30 ± 0.22^{f}	14.12 ± 0.97^{d}	40.07 ± 2.54^{def}
200 W–50 °C	392.87 ± 1.82^{bc}	114.03 ± 0.49^{cde}	189.01 ± 2.62^{b}	37.29 ± 0.51^{a}	187.21 ± 0.37^{g}	50.78 ± 0.94^{cde}	131.53 ± 0.62^{fg}	55.27 ± 0.46^{e}	18.81 ± 0.11^{bc}	22.05 ± 0.10^{c}	14.95 ± 0.84^{cd}	36.59 ± 2.01^{fgh}
200 W–60 °C	330.48 ± 3.03^{h}	95.76 ± 0.45^{j}	116.08 ± 1.08^{h}	27.24 ± 0.42^{f}	238.49 ± 3.15^{e}	50.91 ± 1.69^{cde}	139.17 ± 3.25^{e}	48.11 ± 1.27^{f}	16.19 ± 0.08^{g}	10.79 ± 0.10^{i}	11.64 ± 0.23^{e}	43.16 ± 1.05^{cd}
400 W–40 °C	347.69 ± 1.20^{f}	97.38 ± 0.98^{ij}	105.69 ± 2.39^{i}	23.75 ± 0.61^{g}	184.31 ± 5.70^{g}	62.98 ± 1.35^{b}	156.42 ± 0.97^{c}	63.33 ± 1.47^{c}	15.83 ± 0.17^{gh}	12.21 ± 0.22^{h}	9.18 ± 0.19^{g}	32.76 ± 0.70^{i}
400 W–50 °C	386.29 ± 1.50^{cd}	112.29 ± 0.59^{ef}	158.62 ± 2.58^{e}	31.81 ± 0.43^{d}	178.58 ± 0.73^{gh}	50.65 ± 1.66^{cde}	133.70 ± 0.52^{f}	58.33 ± 0.20^{d}	18.28 ± 0.13^{cd}	18.72 ± 0.13^{e}	16.25 ± 0.38^{bc}	43.92 ± 1.04^{bc}
400 W–60 °C	387.45 ± 3.82^{cd}	112.88 ± 1.46^{de}	172.23 ± 0.30^{cd}	34.43 ± 0.42^{bc}	154.47 ± 1.72^{i}	47.74 ± 2.34^{efg}	174.53 ± 1.88^{b}	86.36 ± 1.79^{a}	18.45 ± 0.29^{bcd}	22.69 ± 0.18^{c}	15.44 ± 0.35^{bcd}	37.52 ± 1.00^{fg}
600 W–40 °C	394.79 ± 3.89^{b}	116.27 ± 0.58^{bc}	170.14 ± 0.52^{d}	33.30 ± 0.34^{c}	172.89 ± 5.82^{h}	53.86 ± 1.07^{c}	110.51 ± 0.98^{h}	48.81 ± 1.55^{f}	18.73 ± 0.10^{bc}	23.43 ± 0.13^{b}	16.45 ± 0.03^{b}	39.04 ± 0.21^{efg}
600 W–50 °C	369.41 ± 1.21^{e}	109.88 ± 0.57^{fg}	141.87 ± 0.80^{g}	29.60 ± 0.16^{e}	281.41 ± 0.36^{c}	53.84 ± 21.18^{c}	113.36 ± 0.08^{h}	33.81 ± 0.09^{h}	17.78 ± 0.11^{def}	17.14 ± 0.18^{f}	11.76 ± 0.39^{e}	33.69 ± 1.06^{hi}
600 W–60 °C	349.84 ± 3.07^{f}	99.34 ± 1.61^{i}	154.77 ± 5.37^{ef}	34.47 ± 1.23^{bc}	394.88 ± 3.74^{b}	51.91 ± 0.60^{cd}	147.75 ± 1.20^{d}	33.07 ± 0.29^{h}	18.65 ± 0.26^{bc}	16.96 ± 0.13^{f}	10.89 ± 0.14^{ef}	35.94 ± 0.16^{ghi}

Table 6. Extractable, hydrolysable, and bioaccessible phenols fraction and in vitro bioaccessibility of $TEAC_{DPPH}$, $TEAC_{CUPRAC}$, and $TEAC_{ABTS}$ for fresh and dried medlar samples *DM* drying methods, *ND* natural drying, $TEAC_{ABTS}$ (μmol Trolox 100 g^{-1} dw), $TEAC_{DPPH}$ (μmol Trolox 100 g^{-1} dw), $TEAC_{CUPRAC}$ method (μmol Trolox 100 g^{-1} dw), *EPF* extractable phenolic fractions, *HPF* hydrolysable phenolic fractions, *BPF* bioaccessible phenolic fractions, *B%* in vitro bioaccessibility. **$p < 0.01$; The differences between the columns are significant ± standard errors of estimated.

dried using four different techniques, Zia and Alibas[15] found that combined microwave-convective drying increased the EPF of $TEAC_{CUPRAC}$. In addition, the same drying method decreased the HPF of $TEAC_{ABTS}$. Zia and Alibas[35] reported that the HPF and BPF values of $TEAC_{ABTS}$ in blueberry samples dried by different drying methods were higher at 500 W than at 50 °C. In another convective drying study conducted with blueberries, it was found that high temperatures increased the antioxidant activity in the DPPH method. It was emphasised that this may be due to the short drying times[40]. In the study in which hawthorn was dried by different drying methods, it was reported that the antioxidant capacity values calculated by ABTS and DPPH methods were lower in convective drying[41]. In a drying study conducted by Horuz et al.[17], it was reported that the antioxidant capacity of sour cherries was adversely affected by high temperature and long drying time. Izli et al.[42] stated that the decrease in antioxidant capacity as a result of the drying process may be due to degradation of phenolic compounds or loss of antioxidant components of golden strawberry samples. Li et al.[43] emphasised that the decrease in antioxidant capacity as a result of the drying process may be due to the change in the chemical composition of the product or the loss of antioxidant components.

Linear correlations of measured parameters

Positive and negative linear correlations between nutrient contents and bioactive compounds of dried medlar samples are depicted in Table 7. When the relationships between nutrient contents were analysed, high linear correlations of 83% between K and P, 84% between Mg and Ca, 92% between Na and K and 83% between Mn and Mg were found. High positive correlations of 84%, 86% and 87% between Cu and Na, K and P, respectively, are remarkable. Positive and significant correlations of 76% and 70% were also found between Na and P and between Mn and Ca. Moderate positive relationships between Zn and P, Cu and Mn are 75%, 72% and 75%, respectively.

Significant correlations were observed between different antioxidant determination methods. In particular, strong and moderate correlations above 70% were observed. The EPF of $TEAC_{CUPRAC}$ showed a strong correlation of 97% with the EPF of TPC. Furthermore, the strong positive correlation value between the HPFs of $TEAC_{CUPRAC}$ and TPC was 91%. There is a positive correlation of 93% between the HPFs of $TEAC_{DPPH}$ and $TEAC_{ABTS}$. The EPF of $TEAC_{DPPH}$ correlated 90% with the BPF of $TEAC_{ABTS}$. There was a high correlation of 91% between the HPF of $TEAC_{DPPH}$ and the BPF of $TEAC_{ABTS}$. The value of the significant positive correlation between HPF and EPF of $TEAC_{DPPH}$ was 95%. A similar correlation was developed between BPF and the bioaccessibility of $TEAC_{DPPH}$. The value of the significant positive correlation between BPF and HPF of $TEAC_{ABTS}$ is 86%. The high correlation of 85% between the EPF of $TEAC_{DPPH}$ and the HPF of $TEAC_{ABTS}$ is also quite remarkable. Another positive correlation between the BPFs of $TEAC_{CUPRAC}$ and $TEAC_{DPPH}$ is 84%. Furthermore, the BPF of $TEAC_{CUPRAC}$ exhibited an 85% interaction with the bioaccessibility of $TEAC_{DPPH}$. Also, a moderate correlation of 74% between the EPFs of TPC and $TEAC_{ABTS}$ was detected. Not only is there a correlation between the BPF of $TEAC_{DPPH}$ and the EPF of $TEAC_{ABTS}$, but the correlation between the EPFs of $TEAC_{CUPRAC}$ and $TEAC_{ABTS}$ is also 73%. The positive correlations between the HPF of $TEAC_{CUPRAC}$ and the EPF of $TEAC_{ABTS}$ and between the bioaccessibility of $TEAC_{CUPRAC}$ and $TEAC_{DPPH}$ are 75% and 76%, respectively. A moderate correlation of 73% was found between BPF and the bioaccessibility of $TEAC_{CUPRAC}$.

On the other hand, the 77% negative correlation between BPF of TPC and TP and the 70% negative correlation between HPF of $TEAC_{ABTS}$ and Mg were also remarkable. Negative linear correlations of 74% and 75% were detected between the BPF of $TEAC_{ABTS}$ and P and Mg. Furthermore, negative linear correlations of 77%, 75% and 70% were detected between the EPF of $TEAC_{DPPH}$ and P, Mg and Mn, respectively. Similarly, the negative correlations of 73% and 74% between the HPF of $TEAC_{DPPH}$ and P and Mg were also quite remarkable.

Alibas et al.[44] dried apple peels using natural and microwave drying methods and found that almost all nutrients exhibited linear and significant relationships. In another study by Alibas et al.[10], basil leaves were dried using natural, convective and microwave drying methods and many significant linear relationships between nutrients were recorded. In a study by Yilmaz and Alibas[13] on the drying of purple basil leaves using different methods, they observed the presence of high correlations between Na and K, Mn and Mg. Zia and Alibas[35] emphasised that there were positive linear relationships between EPF of $TEAC_{CUPRAC}$ and EPF of TPC, and EPF of $TEAC_{ABTS}$.

Conclusion

In this study, natural drying in the shade (25 °C), convective drying (40, 50 and 60 °C), microwave drying (200, 400 and 600 W) and combined microwave-convective drying (200 W–40 °C, 200 W–50 °C, 200 W–60 °C, 400 W–40 °C, 400 W–50 °C, 400 W–60 °C, 600 W–40 °C, 600 W–50 °C and 600 W–60 °C) methods were applied to medlar (*Mespilus germenica* L.). The initial moisture content of medlar was 74.07%, and the final moisture content was reduced to 11.75%.

For the medlars natural drying lasted for 22,500 min, convective drying for 1305–12,180 min. The combined microwave-convective drying lasted between and 17 and 93 min. The longest drying time for medlar samples was in the shade drying method. The shortest drying time was 600 W–60 °C combined microwave-convective drying method.

Fresh and dried samples were tested for different quality parameters such as total protein content, macro and micronutrient contents, total phenolic content and antioxidant capacity. The study measured the closest total protein content to fresh samples by microwave drying at 400 W. When the results of the macronutrients were analysed, the samples dried at 600 W–60 °C using the combined drying were found to be close to fresh samples in terms of P and K. In addition, the highest Ca and Mg contents were detected at 600 W and 400 W–40 °C, respectively. When the results of micronutrients were analysed, the highest contents of Na and Cu were measured at 600 W–60 °C. Also, the closest results to fresh samples were obtained at 200 W for Fe, 400 W–40 °C for Mn

TP	*P*	K	Ca	Mg	Na	Fe	Cu	Mn	Zn	TPC-EPF	TPC-HPF	TPC-BPF	TPC-B%	A-EPF	A-HPF	A-BPF	A-B%	D-EPF	D-HPF	D-BPF	D-B%	C-EPF	C-HPF	C-BPF	C-B%	
1.00	0.31	0.45	0.26	0.25	0.35	0.05	0.40	0.21	0.37	− 0.40	− 0.54	− 0.77	− 0.39	− 0.40	− 0.11	− 0.23	− 0.05	− 0.36	− 0.20	0.03	0.18	− 0.48	− 0.52	− 0.08	0.33	TP
	1.00	0.83	0.52	0.67	0.76	0.34	0.87	0.60	0.75	− 0.07	− 0.22	− 0.43	− 0.29	− 0.39	− 0.54	− 0.74	− 0.34	− 0.77	− 0.73	− 0.33	− 0.09	− 0.07	− 0.28	− 0.19	− 0.08	P
		1.00	0.47	0.55	0.92	0.39	0.86	0.42	0.68	− 0.10	− 0.46	− 0.61	− 0.38	− 0.36	− 0.32	− 0.50	− 0.19	− 0.66	− 0.55	− 0.17	0.06	− 0.13	− 0.48	− 0.11	0.05	K
			1.00	0.84	0.51	0.24	0.38	0.70	0.67	− 0.30	− 0.19	− 0.33	− 0.10	− 0.49	− 0.54	− 0.57	− 0.10	− 0.65	− 0.55	− 0.45	− 0.29	− 0.34	− 0.22	− 0.28	− 0.01	Ca
				1.00	0.60	0.25	0.53	0.83	0.68	− 0.14	− 0.05	− 0.39	− 0.29	− 0.43	− 0.70	− 0.75	− 0.30	− 0.75	− 0.74	− 0.45	− 0.25	− 0.20	− 0.08	− 0.16	0.00	Mg
					1.00	0.31	0.84	0.45	0.59	0.01	− 0.37	− 0.54	− 0.40	− 0.28	− 0.36	− 0.57	− 0.32	− 0.65	− 0.55	− 0.16	0.06	− 0.03	− 0.34	− 0.07	0.01	Na
						1.00	0.33	0.56	0.47	0.12	− 0.25	− 0.32	− 0.34	0.00	− 0.16	− 0.30	− 0.33	− 0.42	− 0.31	0.21	0.38	0.06	− 0.19	0.34	0.54	Fe
							1.00	0.53	0.72	− 0.07	− 0.26	− 0.49	− 0.37	− 0.24	− 0.26	− 0.55	− 0.40	− 0.59	− 0.49	− 0.08	0.13	− 0.06	− 0.30	− 0.12	0.04	Cu
								1.00	0.75	− 0.17	− 0.07	− 0.32	− 0.26	− 0.28	− 0.53	− 0.69	− 0.48	− 0.70	− 0.64	− 0.23	− 0.04	− 0.22	− 0.08	− 0.02	0.31	Mn
									1.00	− 0.26	− 0.20	− 0.49	− 0.30	− 0.31	− 0.27	− 0.46	− 0.27	− 0.57	− 0.44	− 0.12	0.07	− 0.29	− 0.26	− 0.04	0.29	Zn
										1.00	0.60	0.23	− 0.54	0.74	0.07	0.00	− 0.54	0.22	0.15	0.52	0.50	0.97	0.69	0.69	0.07	TPC-EPF
											1.00	0.62	− 0.08	0.68	0.19	0.20	− 0.38	0.45	0.33	0.22	0.07	0.61	0.91	0.30	− 0.16	TPC-HPF
												1.00	0.64	0.51	0.28	0.42	0.04	0.53	0.40	− 0.07	− 0.29	0.32	0.60	− 0.12	− 0.42	TPC-BPF
													1.00	− 0.22	0.14	0.32	0.55	0.23	0.16	− 0.51	− 0.67	− 0.43	− 0.13	− 0.66	− 0.48	TPC-B%
														1.00	0.58	0.48	− 0.48	0.64	0.62	0.73	0.59	0.73	0.75	0.66	0.26	A-EPF
															1.00	0.86	0.06	0.85	0.93	0.69	0.50	0.11	0.15	0.35	0.34	A-HPF
																1.00	0.44	0.90	0.91	0.46	0.21	0.04	0.16	0.17	0.09	A-BPF
																	1.00	0.19	0.15	− 0.39	− 0.49	− 0.48	− 0.47	− 0.51	− 0.40	A-B%
																		1.00	0.95	0.54	0.27	0.28	0.42	0.33	0.08	D-EPF
																			1.00	0.62	0.38	0.19	0.31	0.33	0.20	D-HPF
																				1.00	0.95	0.50	0.31	0.84	0.69	D-BPF
																					1.00	0.47	0.17	0.85	0.76	D-B%
																						1.00	0.69	0.64	− 0.01	C-EPF
																							1.00	0.45	− 0.03	C-HPF
																								1.00	0.73	C-BPF
																									1.00	C-B%

Table 7. Linear relationships between the measured parameters of medlar samples dried by different methods *TP* total protein (g kg^{-1}), *P* phosphorus (g kg^{-1}), *K* potassium (g kg^{-1}), *Ca* calcium (g kg^{-1}), *Mg* magnesium (g kg^{-1}), *Na* sodium (g kg^{-1}), *Fe* iron (g kg^{-1}), *Cu* copper (g kg^{-1}), *Mn* manganese (g kg^{-1}), *Zn* zinc (g kg^{-1}), *TPC* total phenolic compounds (mg GAE 100 g^{-1} dw), *A* $TEAC_{ABTS}$ (μmol Trolox 100 g^{-1} dw), *D* $TEAC_{DPPH}$ (μmol Trolox 100 g^{-1} dw), *C* $TEAC_{CUPRAC}$ method (μmol Trolox 100 g^{-1} dw), *EPF* extractable phenolic fractions, *HPF* hydrolysable phenolic fractions, *BPF* bioaccessible phenolic fractions, *B%* in vitro bioaccessibility (%), dw dry weight.

and 600 W–40 °C for Zn. Generally speaking, protein and nutrient content were preserved in samples dried by combined and microwave drying methods.

Bioactive potential was evaluated from the point of view of extractable, hydrolysable and bioaccesible phenolic fractions by total phenolic content and ABTS, DPPH and CUPRAC antioxidant capacity analyses. In terms of TPC, the bioaccessibility of the samples was highest in the natural drying, but the lowest one was at 200 W–40 °C combination. The highest bioaccessibility was recorded for $TEAC_{ABTS}$, $TEAC_{DPPH}$ and $TEAC_{CUPRAC}$ at natural drying, 200 W–50 °C and 400 W–60 °C, respectively. The lowest bioaccessibility was obtained in natural drying for $TEAC_{DPPH}$ and $TEAC_{CUPRAC}$, while convective drying (40 and 60 °C) and 400 W microwave drying for $TEAC_{ABTS}$. When evaluated within the scope of all tests performed on medlar samples and determination of bioactive potentials, $TEAC_{DPPH}$ was found to be the most suitable evaluation method for antioxidant capacity analysis. Thus, the DPPH analysis was superior to other analyses. Further work is needed to develop practical applications based on optimal drying techniques in integrated plants combining different drying methods to preserve the nutritional content of dried fruits.

Data availability

All data generated or analysed during this study are included in the article.

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Author contributions

IA: Conceived and designed the study, acquired data, revised the manuscript critically for important intellectual content, and approved the final version of the manuscript for publication.BA: Acquired data, analyzed and/or interpreted data, drafted the manuscript, and approved the final version of the manuscript for publication.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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