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Microwave and traditional brewing methods of Iranian black tea: bioactive compounds, antioxidant activity and heavy metals

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Abstract

Black tea, which is obtained from the leaves of small tree *Camellia sinensis*, is a popular drink that has been consumed for centuries all around the world. In this study, a sample of Iranian black tea was brewed by two methods of microwave and traditional brewing and their extracts were then assessed using 2,2-diphenyl-1-picrylhydrazyl (DPPH) and ferric reducing/antioxidant power (FRAP) assays to determine their phenolic and flavonoid contents as well as heavy metal (HM) (copper, nickel, chromium, cadmium and lead) content. It was observed that there is a direct relationship between the antioxidant activity with their phenolic and flavonoid contents. The highest and lowest antioxidant activities were observed for samples brewed by microwave at 360 W for 2.5 min and 900 W for 7.5 min, respectively. As the brewing power and time increased, the antioxidant activity decreased. Brewing tea by microwave and traditional methods caused a significant reduction in the amount of heavy metals, which was lower than the allowable limit according to the Iranian national standards. These results demonstrate the importance of exposure time and radiation power when tea is prepared by microwave.

Keywords: Black tea; Tea extract; Brewing; Antioxidant; Heavy metals.

Introduction

Tea is the most broadly used aromatized beverage worldwide and its consumption has a long record. As a drink, it originates using green leaves of *Camellia sinensis*, which contain compounds such as polyphenols, caffeine, and catechins, that possess medicinal properties. For example, a group of catechins that are extracted from *Camellia sinensis* green leaves are shown to exhibit anti-cancer effects and extend the life of healthy cells. Due to its nutritional, specific taste, agricultural and financial value, both tea leaves and its extract are used in several industries, including food, cosmetics and beverages (Chen et al., 2020; Ghasemzadeh-Mohammadi et al., 2017; Li et al., 2020). Because of the importance of these elements, many studies have been carried out on tea plants (Wang et al., 2020; Zhang et al., 2020). Besides the presence of the antioxidant compounds, other ingredients such as essential elements that exist in the tea plant have both

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disadvantages and advantages for the human body. For example, it has been found that aluminum is a critical agent increasing the effect of the dementia of Alzheimer's illness (Fung et al., 2003). On the other hand, presence of heavy metals (HMs) was already proved in many studies (Idrees et al., 2020; Seenivasan et al., 2008). Soil, nutrients, fertilizers, and pesticides used during plant growth are some of the sources of HMs, which can persist in tea and affect human health. Therefore, it is a matter of concern to study concentration of these elements in teas. Most of the organics in tea are heat-sensitive and for their extraction, low-temperature preparations are required in order to prevent the possibility of their hydrolysis or thermal degradation (Pereira & Meireles, 2007). One of the recently used extraction techniques is Microwave-Assisted Extraction (MAE) technology which is a speedy and well-organized technique designed for rapid extraction of compounds from solid matrices. Because of the shorter extraction time, it is supposed that antioxidant contents of tea can be preserved more effectively. Moreover, it can be regarded a greener method based on environmental standards (Ahmad et al., 2021; Farahmandfar, Asnaashari, & Bakhshandeh, 2019). To the best of our knowledge, MAE as a novel brewing approach, and parameters affecting it (such as microwave time and power) on the extraction of antioxidant ingredients and HM content has not yet been studied for the Iranian black tea. This research aimed to reveal how MAE and the conventional tea brewing method can affect the Iranian black tea extract. MEA parameters which can affect the extraction were also studied.

Materials and methods

The tea sample in this study was obtained from a local market in Sari (north of Iran) close to a tea farm and processing factory (Rasht-Gilan). Folin-Ciocalteu reagent was obtained from Merck-Millipore (Darmstadt, Germany). 2,2-diphenyl-1-picrylhydrazyl (DPPH), hydrochloric acid (HCl) and tert-butylhydroquinone were purchased from Sigma-Aldrich (St. Louis, MO). For the ferric reducing/antioxidant power (FRAP) method, sodium phosphate buffer (pH 6.6), potassium ferricyanide, ferric chloride (Sigma), and trichloroacetic acid (Merck-Millipore) were used. All other chemicals were of analytical grade (Merck) and used without further purifications.

Tea brewing

For traditional brewing, 2.00 g of the finely powdered tea sample was poured into 100.0 mL distilled water to prepare a 2% w/v mixture and kept at 100°C for 20 min. For MAE, the same amount of tea was poured into 100.0 mL of distilled water and was subjected to three 900, 600, and 360 W power settings in a microwave oven (LG company, Korea, Model MH8265 DIS), for three different times of 2.5, 5.0 and 7.5 min (Spigno & De Faveri, 2009).

Phenolic content

In order to determine phenolic content of the tea extract, a previously developed method (Farahmandfar, Asnaashari, Asadi, & Beyranvand, 2019; Farahmandfar et al., 2017) was employed with small modifications. Briefly, 100.0 µL of the tea sample was added to 500.0 µL of 10% w/v folic acid. The solution was then mixed with 1.000 mL distilled water, held at ambient temperature for 1 min, mixed with 1.5 mL of 20% w/v sodium carbonate, and transferred to a test tube. After keeping the mixture for 2 h in a dark place at 25°C, to determine its phenolic content, the absorbance of the solution was recorded at 760 nm by a spectrophotometer (T80+ UV/Vis spectrophotometer, Purkinje General, Malaysia), against standard solutions.

Flavonoid content

The colorimetric aluminum chloride technique was applied for flavonoid determination of tea sample (Asadi & Farahmandfar, 2020; Farahmandfar et al., 2017).

Briefly, 0.5 mL solution of the sample was blended with 1.5 mL of methanol, 0.1 mL of

10% w/v aluminum chloride, 0.1 mL of 1.0 mol/L potassium acetate, and 2.8 mL of distilled water. After holding the mixture in a dark place at room temperature for 30 min, the absorption of the samples was recorded at 415 nm to evaluate its flavonoid content. Quercetin was used to construct a standard calibration curve, and the results were presented in mg of quercetin per 100 g of extract.

DPPH

Anti-radical activity of the extract using DPPH was studied according to Farahmandfar and Aziminezhad (2021) with slight changes. For this purpose, different concentrations of the prepared extract were added to 2.7 mL of DPPH radical (6×10^{-5} mol/L) solution and using a spectrophotometer, radical reduction of DPPH samples was measured by adsorption monitoring in 517 nm. The inhibitory effect was expressed as a percentage and calculated according to Eq. (1).

Radical Scavenging activity%= A_{DPPH}-A_s/A_{DPPH}×100 (1)

Where, A_s and A_{DPPH} are the absorbance of the sample including the extract and absorbance of DPPH solution, respectively.

FRAP

The reducing power of the samples was carried out according to Farahmandfar, Tirgarian, Dehghan, and Nemati (2020). To carry out this test, 2.5 mL of the extract with different concentrations (500, 1000, 1500, 2000 and 2500 mg/kg) were mixed with 2.5 mL of mixture of sodium phosphate buffer (0.2 mol/L, pH 6.6) and 2.5 mL potassium ferricyanide solution (1% w/v) and incubated at 50 °C for 20 min. After that, 2.5 mL of 10% w/v trichloroacetic acid solution was added to the samples to stop the reaction. Sample was then placed in a centrifuge (FAR TEST, Model VS 4000 C, Iran) at 3000 rpm for 8 min. 5.0 mL of the supernatant was taken and diluted with 5.0 mL of distilled water containing 1.0 mL of 0.1% w/v ferric chloride solution. Finally, the absorbance of the solution was recorded at 700 nm.

Heavy metal determination

For dry digestion of dry Iranian black tea, a method suggested by Pourramezani et al (2019) was followed. 5.0 g of the sample was burnt in an electric furnace at 450± 5°C for 8 h. The ash was dissolved in 5.0 mL of concentrated hydrochloric acid to be digested and then the mixture was diluted by distilled water to 50.0 mL and its HM content was determined by flame atomic absorption spectroscopy (Perkin-Elmer, model 100, USA) Lead (Pb), copper (Cu), cadmium (Cd), nickel (Ni) and chromium (Cr) were determined separately. The HM determination for the extract was performed according to Ting et al. (2013). 10.0 g of powdered tea was poured into 200 mL of water in a 500 mL round flask and stirred at 250 rpm for 1 h using a rotary (REMI, Model RS-24 Plus, India) at 25°C. This blend was then filtered using a vacuum pump (EYELA, A1000, Japan) and the collected herbaceous extract was analyzed by atomic absorption spectrometer. Concentration of each HM was obtained using Eq. (2).

$$C = \frac{Gs\times v}{w} \quad (2)$$

C= metal concentration in solid sample (mg/kg)

Gs=metal concentration in digested solution (mg/L)

V=dilution volume (50 mL)

W= weight of dry sample (10.0 g)

Statistical analysis

In our investigation, we managed the statistical analysis of the data with SPSS software v. 16, applying a completely randomized design in addition to a one-way analysis of variance. Later, Duncan's test was carried out to correlate the mean values of the samples (three replicates) at a confidence interval of 95%.

Results and discussion

Total phenolic and flavonoids content

Phenolic compounds are secondary metabolites of plants that have at least one hydroxyl group in their aromatic ring. Through donating electrons, these compounds act as anti-radical agents and a barrier to oxidative disease progression (Dai & Mumper, 2010). Flavonoids are classified as phenolic compounds which typically have a 15-carbon structure, two phenolics, and one heterocyclic ring. Studies have indicated that plant-based flavonoids could prevent *Helicobacter pylori* infections (Ahmed & Eun, 2018; Ardalani et al., 2020). As depicted in Table 1, the tea sample obtained by MAE method could make a significant difference in terms of the phenolic and flavonoid contents compared to tea sample obtained from the traditional method ($p<0.05$). The total phenolic and flavonoid content of tea sample brewed in the microwave oven (except 900 W; 7.5 min) was significantly higher than that of traditional method. So, it can be concluded that microwave radiation can have a positive effect on the extraction of bioactive compounds. The infusion treatments in the microwave oven heated for 2.5 min at 360 W had the highest total phenolic (3224.9 mg GAE/100 g of extract) and flavonoid content (2237.4 mg QE/100 g of extract) while those heated at 900 W for 7.5 min had the lowest value. Spigno and De Faveri (2009) showed significantly greater amounts of the phenolic compounds extracted in a short time through tea brewing using MAE compared to the traditional extraction method. The findings of Krishnan and Rajan (2016) are in consistent with our observations which showed that MAE is more efficient in flavonoids extraction. Studies on brown microalgae, banana peel, tea, and pomegranate peel also supported the higher effectiveness of the MAE compared to the traditional technique (Kaderides et al., 2019; Yuan et al., 2018). MAE might be more effective because the heat is transferred to the sample through the dual mechanism of ion conduction and bipolar rotation (Pasrija & Anandharamakrishnan, 2015), and because radiation destroying the plant matrix and releasing the plant compounds into the solvent (Cassol et al., 2019; Routray & Orsat, 2012). We observed that as the power and the time of the microwave process increases, the total phenolic and flavonoid content of tea extract decreases. Higher radiation power and longer extraction time also significantly decreased the bioactive components content. As a result, phenolic and flavonoid compounds might be degraded if they are radiated for a long-term in a microwave oven (Oussaid et al., 2018; Routray & Orsat, 2012). Destruction of antioxidant compounds during the microwave process occurs at high brewing time and with intense radiation power.

Table 1- Phenolic and flavonoid content of tea determined after extracting by two brewing methods.

Treatment	Power (W)	Temperature (˚C)	Time (min)	Total phenolic content (mg GAE/100 g extract)	Flavonoid content (mg QE/100 g extract)
Microwave	900		7.5	2540.22± 3.00 [i]	1764.99± 2.08 [i]
	900		5.0	2870.22± 0.61 [f]	1992.69± 0.42 [f]
	900		2.5	3011.79± 3.83 [d]	2090.38± 2.66 [d]
	600		7.5	2820.39± 0.71 [g]	1958.31± 0.49 [g]
	600		5.0	3011.89± 2.72 [d]	2090.44± 1.89 [b]
	600		2.5	3150.88± 0.53 [b]	2186.35± 0.37 [d]
	360		7.5	2968.18± 1.52 [e]	2060.28± 1.05 [e]
	360		5.0	3022.71± 1.11 [c]	2097.91± 0.77 [c]
	360		2.5	3224.90± 0.60 [a]	2237.42± 0.42 [a]
Traditional		100	20.0	2690.86± 2.04 [h]	1868.93± 1.42 [h]

* Mean± SD
* Means with different letters within column indicate significant differences at $P< 0.05$

DPPH radical scavenging activity

The antioxidant activity of tea samples for two brewing methods including MAE and traditional brewing methods can be seen in Table 2. Analysis of variance showed a significant difference between the antioxidant activity of tea sample obtained by MAE method and tea sample obtained using the traditional method ($p<0.05$). MAE showed higher antioxidant activity in all concentrations compared to the traditional brewing methods. The microwave oven is known as an appropriate equipment for phenolic compounds extraction compared to the conventional method (Yuan et al., 2018). The rotation of water molecules in the electric field of the microwave oven produces heat which helps to release the phenolic compounds more efficiently (Cassol et al., 2019). Janda et al. (2020) determined antioxidant activities of five coffees with different brewing methods. They tested AeroPress, drip, espresso machine, French press, and simple infusion methods. The results revealed that the sort of brewing techniques had a significant influence on the antioxidant activities of the samples. The lowest radical scavenging activity was reported for the coffee from the espresso machine, and the highest value was related to the AeroPress brewing method. The antioxidant activities for all treatments, DPPH free radical inhibition were enhanced as the concentration of tea extract was increased from 500 to 2500 mg/kg. The highest level of the free radical inhibition was observed at 2500 mg/kg sample brewed at 360 W for 2.5 min. Researchers declared higher concentrations of the extracts showed higher antioxidant activity levels and confirmed the results of this research (Calderón-Oliver & Ponce-Alquicira, 2021; Farahmandfar, Naeli, Naderi, & Asnaashari, 2019; Rehder et al., 2021; Yuan et al., 2018)

Table 2- DPPH radical scavenging activity (%) in tea extract derived from the conventional and microwave brewing methods.

Treatment	Power (W)	T (°C)	Time (min)	The concentration of sample extract 500 (mg/kg)	1000 (mg/kg)	1500 (mg/kg)	2000 (mg/kg)	2500 (mg/kg)
Microwave	900		7.5	9.88± 0.01[i]	25.56± 0.03[i]	32.20± 0.04[i]	46.37± 0.05[i]	50.54± 0.06[i]
	900		5	11.15± 0.00[f]	28.85± 0.01[f]	36.34± 0.01[f]	52.34± 0.01[f]	57.05± 0.01[f]
	900		2.5	11.71± 0.01[d]	30.29± 0.04[d]	38.17± 0.05[d]	54.96± 0.07[d]	59.91± 0.08[d]
	600		7.5	10.96± 0.00[g]	28.35± 0.01[g]	35.72± 0.01[g]	51.44± 0.01[g]	56.07± 0.01[g]
	600		5	11.71± 0.01[d]	30.30± 0.03[d]	38.17± 0.03[d]	54.97± 0.05[d]	59.92± 0.05[d]
	600		2.5	12.24± 0.00[b]	31.67± 0.01[b]	39.90± 0.01[b]	57.46± 0.01[b]	62.63± 0.01[b]
	360		7.5	11.53± 0.01[e]	29.84± 0.02[e]	37.60± 0.02[e]	54.15± 0.03[e]	59.02± 0.03[e]
	360		5	11.74± 0.00[c]	30.39± 0.01[c]	38.29± 0.01[c]	55.13± 0.02[c]	60.09± 0.02[c]
	360		2.5	12.52± 0.00[a]	32.41± 0.01[a]	40.83± 0.01[a]	58.80± 0.01[a]	64.09± 0.01[a]
Traditional		100	20	10.45± 0.01 [h]	27.06± 0.02[h]	34.09± 0.03[h]	49.09± 0.04[h]	53.51± 0.04[h]

* Means with different letters within column indicate significant differences at P<0.05

* Mean± SD

Ferric reducing/antioxidant power

Reducing power is often used as an indicator of electron donation which is an important mechanism to determine the antioxidative activity of the phenolic compound. The existence of reductants such as antioxidants in the tested materials reduces ferric ions (Fe^{3+}), so decreasing the capacity of antioxidant compounds is an index of its antioxidative activity. The effect of reducing power is shown in Table 3. In this study, the extract obtained from MAE indicated significant differences in antioxidant activities compared with the tea sample obtained from the traditional brewing method ($p<0.05$). The results revealed that the reducing power of Fe^{3+} was in correlation with the concentration of the sample. The tea sample under the 360 W, 2.5 min, (2500.0 mg/kg) condition, using microwave brewing method gave the maximum reduction power of 4.712%. For all treatments, the reducing powers were enhanced as the concentration of tea samples was increased from 500.0 to 2500.0 mg/kg. Yuan et al. (2018) stated the highest iron (III) reduction power and the highest DPPH radical inhibition, in the case of various brown macroalgae species extracts, reported for the treatments obtained by MAE.

Table 3- Ferric reducing antioxidant power in tea extract derived from the conventional and microwave brewing methods

Treatment	Power (W)	T (°C)	Time (min)	Ferric reducing antioxidant power (%)				
				500 (mg/kg)	1000 (mg/kg)	1500 (mg/kg)	2000 (mg/kg)	2500 (mg/kg)
Microwave	900		7.5	1.74± 0.00[i]	2.17± 0.00[i]	3.11± 0.00[i]	3.38± 0.00[i]	3.72± 0.00[i]
	900		5	1.97± 0.00[f]	2.44± 0.00[f]	3.51± 0.00[f]	3.82± 0.00[f]	4.19± 0.00[f]
	900		2.5	2.06± 0.00[d]	2.57± 0.00[d]	3.69± 0.00[d]	4.01± 0.00[d]	4.40± 0.01[d]
	600		7.5	1.93± 0.00[g]	2.40± 0.00[g]	3.45± 0.00[g]	3.75± 0.00[g]	4.12± 0.00[g]
	600		5	2.06± 0.00[d]	2.57± 0.00[d]	3.68± 0.00[d]	4.01± 0.00[d]	4.41± 0.00[d]
	600		2.5	2.16± 0.00[b]	2.68± 0.00[b]	3.85± 0.00[b]	4.19± 0.00[b]	4.60± 0.00[b]
	360		7.5	2.03± 0.00[e]	2.53± 0.00[e]	3.63± 0.00[e]	3.95± 0.00[e]	4.34± 0.00[e]
	360		5	2.07±0.00[c]	2.57± 0.00[c]	3.70± 0.00[c]	4.02± 0.00[c]	4.42± 0.00[c]
	360		2.5	2.21±0.00[a]	2.75± 0.00[a]	3.94± 0.00[a]	4.29± 0.00[a]	4.71± 0.00[a]
Traditional		100	20	1.84±0.00[h]	2.29± 0.00[h]	3.29± 0.00[h]	3.58± 0.00[h]	3.93± 0.00[h]

* Means with different letters within column indicate significant differences at $P<0.05$
* Mean± SD

Heavy metals content

Some of the required daily elements may be supplied through the regular consumption of tea. The proper function of the human body requires the proper function of important enzymes, which require the participation of some HMs that can be found in tea (e.g., copper, iron, manganese, and zinc) (Atasoy et al., 2019; SeyyediBidgoli et al., 2020).

However, other elements, such as Cr, Cd, Ni, and Pb, can have adverse or toxic effects on human health (Atasoy et al., 2019). The concentrations of HMs copper, nickel, chromium, cadmium, and lead in dry tea and its extracts obtained from various tea brewing methods are shown in Table 4. Data were obtained following the standard method suggested by AOAC (AOAC, 2020). Calibration curve of each heavy metal was drawn with working standard solution before testing. As can be seen, the concentration of Pb in all samples ranged from 0.04 to 3 mg/kg. The maximum amount of Pb belonging to the dry sample was higher than the allowable limit recommended by Iranian national standard (Std. No.623) which is 1.0 mg/kg. In a study by SeyyediBidgoli et al. (2020) the concentration of Pb in Iranian black tea was determined as 0.125± 0.103 mg/kg which was lower than our report which is due to the difference in samples examined.

Ni concentration ranged from 0.22 to 3.60 mg/kg. The maximum amount of Ni belonging to the dry sample. Researchers also reported Ni value around 0.097± 0.078 mg/kg in their study (SeyyediBidgoli et al., 2020). Nickel is a toxic metal and there is no safe limit for it according to the national standard of Iran. The concentration of Cu value in this study was determined between 0.15 to 77.50 mg/kg. The highest concentration of Cu was detected for the dry sample, which was higher than the allowable limit according to the Iranian national standards (50 mg/kg).

Table 4- The heavy metals concentrations in mg per kilogram

Treatments	Power (W)	Temperature (˚C)	Time (min)	Cu (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
Microwave	900		7.5	0.22	0.22	0.001>	0.01	0.10
	900		5	0.19	0.53	0.001>	0.02	0.20
	900		2.5	0.39	0.32	0.001>	0.04	0.07
	600		7.5	0.15	0.51	0.001>	0.01	0.14
	600		5	0.28	0.88	0.001	0.04	0.14
	600		2.5	0.16	0.44	0.001>	0.02	0.13
	360		7.5	0.28	0.48	0.001>	0.03	0.21
	360		5	0.33	0.38	0.001>	0.05	0.12
	360		2.5	0.33	0.23	0.001>	0.04	0.04
Traditional		100	20	0.30	0.38	0.001>	0.03	0.11
Dry sample				7.75	3.60	1.72	1.42	3.00

In a study by SeyyediBidgoli et al. (2020) the concentration of Cu in Iranian black tea was reported as 0.173± 0.107 mg/kg. The concentration of Cd in all of our samples was between 0.01 to 1.42 mg/kg. The highest concentration of Cd was also calculated for the dry sample which was higher than the allowable limit recommended by Iranian national standard (0.1 mg/kg). In contrast with this study, SeyyediBidgoli et al. (2020) recorded a lower concentration for Cd for dry black Iranian tea (0.045± 0.064 mg/kg). Concentration of Cr in all samples ranged from 0.001 to 1.72 mg/kg. The highest concentration of Cr was also recorded for the dry sample. which was higher than the allowable limit recommended by the Iranian national standards (4 µg/kg). Ghale Askari et al. (2020) reported the concentration of Cr in their research on dry black Iranian tea as 0.4 mg/kg which was lower than our study.

Conclusions

According to the findings of this study, the microwave method was more efficient than the conventional method of brewing in terms of extracting the greatest amount of phenolic compounds and antioxidants from Iranian black tea. On this process, it was discovered that time and microwave power played a significant role. Additionally, because the procedure takes less time with the microwave approach, it can be considered a good way to extract antioxidants from tea. It was also found that concentration of Cu, Cd, Ni and Pb HMs the examined tea was higher than maximum contamination level suggested by the Iranian standards; therefore, preventive measures should be taken such as cultivating plants away from industrial zone and roads and avoiding the use of excessive contaminated chemical fertilizers.

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روش‌های دم کردن مایکروویو و سنتی چای سیاه ایرانی: ترکیبات زیست فعال، فعالیت آنتی اکسیدانی و فلزات سنگین

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چکیده

چای سیاه که از برگ درختچه *Camellia sinensis* به‌دست می‌آید، نوشیدنی محبوبی است که قرن‌هاست در سراسر جهان مصرف می‌شود. در این تحقیق، نمونه‌ای از چای سیاه ایرانی به دو روش مایکروویو و دم‌آوری سنتی تهیه شد و عصاره های حاصل از آن با استفاده از آزمون‌های دی فنیل پیکریل هیدرازیل (DPPH) و احیاء کنندگی آهن/ قدرت آنتی‌اکسیدانی (FRAP) و محتویات فنولیک و فلاونوئید و همچنین میزان فلزات سنگین (HMs) (مس، نیکل، کروم، کادمیوم و سرب)، مورد ارزیابی قرار گرفت. مشاهده شد که بین فعالیت آنتی‌اکسیدانی با محتوای فنلی و فلاونوئیدی آنها رابطه مستقیم وجود دارد. بیشترین و کمترین فعالیت آنتی‌اکسیدانی برای نمونه‌های دم‌آوری شده توسط مایکروویو به‌ترتیب در نسبت توان ۳۶۰ وات- زمان ۲/۵ دقیقه و توان ۹۰۰ وات- زمان ۷/۵ دقیقه گزارش شد لذا با افزایش توان و زمان دم کردن، فعالیت آنتی‌اکسیدانی کاهش یافت. دم کردن چای به روش مایکروویو و سنتی باعث کاهش قابل توجهی در میزان فلزات سنگین که کمتر از حد مجاز طبق استانداردهای ملی ایران بود، گردید. این نتایج اهمیت زمان قرار گرفتن در معرض اشعه و قدرت تشعشع را هنگام تهیه چای با مایکروویو نشان می‌دهد.

واژه‌های کلیدی: چای سیاه، عصاره چای، دم‌کردن، آنتی‌اکسیدان، فلزات سنگین.

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