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Investigation of Heavy Metal Content of Turkish Teas and Tea Infusions

Türk Çaylarının ve Çay Demlemelerinin Ağır Metal İçeriğinin Araştırılması

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Turkish tea, tea infusion, brewing period, brewing additives, heavy metals

Abstract

A procedure for the determination of heavy metals (HMs) aluminum, manganese, iron, copper, zinc and nickel) in Turkish teas of different brands, years, and forms (leaves, sachets, etc.), which were most widely consumed in Turkey, was developed. The samples obtained from local market were digested by wet ashing technique via HNO3-H2O2 and they were analyzed with high recovery (94% to 98%), precision, accuracy and repeatability via flame atomic absorption spectrometry (F-AAS) and graphite furnace AAS for their HM content. The regression coefficients were above 0.99, and the detection limits were in the range of 0.0065-0.1846 ppm. The performance and accuracy of the method was determined by analyzing "Certified Reference Material GBW 08501-Peach Leaves." The results obtained were in agreement with the standard values for the HMs analyzed. Thus, the method proposed here may be used in a wide range of applications for to establish a relationship among the composition, processing, storage of tea plant and brewing conditions of tea.

Özet

Bu çalışmada Türkiye'den çok tüketilen farklı marka, yıl ve formdaki (yaprak, poşet vb.) Türkçaylarındaki ağır metallerin (HMs) alüminyum, mangan, demir, bakır, çinko ve nikel tayini için bir yöntem geliştirildi. Yerel piyasadan temin edilen numuneler, HNO3-H2O2 kullanılarak yaş kül etme yöntemiyle kül edildi ve ağır metal içerikleri alev atomik absorpsiyon spektrometresi (F-AAS) ve grafit fırın-AAS ile yüksek geri kazanım verimiyle (%94 ila %98), hassasiyetle, doğrulukla ve tekrarlanabilirlikle analizedildi. Regresyon katsayılarının 0,99'un üstünde olduğu, saptama limitlerinin 0,0065-0,1846 ppm aralığında olduğu görülmüştür. Yöntemin performansı ve doğruluğu, "Sertifikalı Referans Malzemesi GBW 08501-Şeftali Yaprağı" analize dilerek belirlendi. Ağır metaller için elde edilen sonuçların analiz edilen standart değerlerle uyumlu olduğu görülmüştür. Bu nedenle, burada önerilen yöntemin, çaybitkisinin içeriği, işlenmesi, depolanması ve demleme koşulları arasında ilişki kurmak için geniş bir uygulama yelpazesinde kullanılabileceği görülmüştür.

1. INTRODUCTION

Unsustained anthropogenic activities caused unprecedented and upsurging contamination of ecosystems with heavy metals (HMs) and metalloids (e.g., Al, Ni, Cu, Zn and Mn), which are persistent pollutants with (bio)accumulative nature, leading to contamination of environment and food chains and thus posing great public health concern (Arora and Chauhan, 2021; Bolan et al., 2003, 2013; Wieczorek-Dabrowska et al., 2013).HMs and metalloids intaken by humans through food chain cause epigenetic and genetic complications meaning that the damage is transferrable to future generations (Salnikow and Zhitkovich, 2008).

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Tea, which is obtained by infusion of the leaves of the plant Camellia Sinensis, is the second most widely consumed beverage worldwide after water ("U.S. tea market - statistics & facts | Statista," 2022). Research has shown that Camellia Sinensis can extract HMs and metalloids from the soil, transport them up through its shoots, and finally accumulate them in its leaves without harming its other metabolic functions (Leitenmaier and Küpper, 2013). Therefore, tea infusion contains the HMs that the plant has hyper-accumulated. Teas with a higher percentage of old leaves would have higher metal loads since as the plant ages there would be more time for it to accumulate HMs. For instance, researchers have found that aluminum concentrations in old leaves were 20 times higher than in younger leaves (Leitenmaier and Küpper, 2013). Moreover, industrial processing conditions of tea plant such as twisting and water-removal stages was also observed to increase HM content of the plant. Another important factor affecting HM concentration is infusion period. Research has shown that as the infusion period gets longer the metal load can increase 10 – 50% as compared to infusion for 3 minutes (Schwalfenberg et al., 2013). A striking finding was that while aluminum concentration of all teas was at significant level after 3 minutes of infusion 20% of the teas exceeded the total daily limit for safe aluminum intake when the infusion period exceeded 15 minutes (Flaten, 2002).Therefore, assessment and monitoring of the concentrations of heavy metals and metalloids, which are potentially hazardous and toxic and thus a real threat to living organisms, is of great importance to guarantee consumer safety (Liu et al., 2021).

Much effort has been devoted to investigating HM exposure due to tea consumption, but there is relatively less work on effect of brewing conditions and styles on extraction efficiency of HMs into tea infusion and determination of HMs heavy metals in commercial teas in the Turkish market. Thus, this study aimed at investigating Al, Ni, Cu, Zn and Mn levels in tea infusions of Turkish teas with respect to production year and brewing styles. On the basis of the data we obtained from this study, we proposed possible relations among effect of brewing styles, periods, and commercial presentation forms (e.g., packaging and whether teas are offered as leaves and in sachets) and possible health implications for humans.

2. MATERIALS AND METHOD

Copper (Cu), zinc (Zn) and manganese (Mn) were analyzed via Unicam 929 Flame Atomic Absorption Spectrometer (F-AAS) at 324.8, 213.9 and 279.5 nm, respectively. Nickel (Ni) and aluminum (Al) analysis were made via GBC-904-PBT Graphite Furnace Atomic Absorption (GF-AAS) Spectrometer. In all F-AAS experiments, baseline corrections are made via deuterium lamp in all AAS measurements. W.C. Heraus oven is used for drying the tea plant samples. Wet ashing was performed on Stuart scientific hotplate SH 3. Tea samples were dried in WC Heraus Haneau oven at 105 °C until they reached constant weight. The tea samples were stored in air-tight polypropylene (PP) containers or bags in desiccators until analysis. All of the glassware and PP containers were soaked in 10 % (v/v) HNO_3 solution for 48 h before usage. All the reagents employed were of analytical reagent grade HNO_3 (65 %), HCl (37 %), H_2O_2 (30 %) and $NaHCO_3$were obtained from Merck, Darmstadt, Germany and they were used as they were received. The solutions were prepared with distilled water obtained from Jencons Autostill 4000X. 65% HNO_3 was obtained from Carlo-Erba, Italy. The stock metal solutions (1000 mg L^{-1}) were prepared from metal foils or powders with 99.99 % purity obtained from Merck, Darmstadt, Germany. 1000 ppm solutions of copper and manganese metals were prepared by dissolving 1.000 g of metals in 50 mL of 6 mol L^{-1} HNO_3 and then adding 2 drops of concentrated HNO_3, zinc and aluminum solutions were prepared by dissolving 1.000 g of the metals in 5 mol.L^{-1} HCl, nickel solution by dissolving1.000 g of nickel in 20 mL of concentrated HNO_3 followed by addition of a few drops of concentrated HNO_3 and then all the solutions were diluted to 1.0 L with deionised water. For accuracy studies for zinc and manganese peach leaves with the name "Certified Reference Material GBW 08501-Peach Leaves prepared in China" was employed. For accuracy studies for copper, "Certified Reference Material NIST (National Institute of Standards and Technology) SRM (Standard Reference Material) 1547; NIST, Gaithersburg, MD, USA-Peach Leaves" was employed. Tea samples were obtained from local market.

2.1. Determination of moisture content of tea samples

1.000 g of tea samples, which produced in different years and were processed in different factories, were dried in an oven at 105 °C for 2h until constant weight was attained. The average moisture content of five different tea samples was found to be 86.4 ± 3.1 %.

2.2. Preparation of tea infusions Calibration studies

The dried tea samples were grounded in agate mortar as to have particle size of 0.3–0.5 mm. Three parallel 2.000 g samples were taken from each tea brand. Tea samples were brewed from each parallel sample according to TS 3907-March 1983. According to this standard, the samples were boiled on hot-plate at about 130°C in hot distilled water of 100 mL in glass beakers, which were capped with watch-glasses, for 6 minutes. Followingly they were filtered through black ribbon ashless filter papers. 50 mL of the eluates were taken and onto each eluate 10 mL concentrated HNO_3 was added. The solutions were then heated on hotplate until the color of the tea infusion attained light color. Then 5 mL 30% H_2O_2 were added onto each solution and the solutions were heated at about 130°C on hotplate until white colored moist residues were obtained. Onto the residues, 1 mL of 1.0 mol L^{-1} HNO_3 and 15 mL of distilled water were added. Then the solutions were heated on hot plates for 10–15 min to dissolve the salts. Finally they were filtered through black ribbon filter papers and their final volumes were made 50 mL with distilled water in volumetric flasks. The solutions were placed in air-tight PP containers.

The effect of brewing period (6, 15 and 30 min) on extraction of HMs into tea infusion by preparing tea infusions according to the method TS 3907-March 1983 but employing different infusion periods. The effect of additives (sugar and NaHCO3) were investigated by preparing tea infusions according to the method TS 3907-March 1983 but adding 1.00g $NaHCO_3$ or 1.00g sugar to each 100 mL distilled water during infusion. Concentration of HM ions in tea infusions were then determined via F-AAS.

2.3. Calibration studies

Six metal ions, namely, aluminum, manganese, iron, copper, zinc and nickel were determined in tea leaves and tea infusions. Cu, Zn and Mn analysis were made via Unicam 929 Flame Atomic Absorption Spectrometer (F-AAS) at 324.8, 213.9 and 279.5 nm, respectively. Ni and Al analysis were made via GBC-904-PBT Graphite Furnace Atomic Absorption (GF-AAS) Spectrometer. In all F-AAS experiments, baseline corrections were made via deuterium lamp in all AAS measurements. The calibration graphs were plotted and the method was assessed for its analytical characteristics by determining the limit of detection (LOD) and the limit of quantification (LOQ) values as presented in Table 1.

Table 1. Analytical characteristics of the method

Al	*Fe*	*Zn*	*Mn*	*Ni*	*Cu*	*Metal Ion*
309.3	241.8	324.8	279.5	232.0	213.9	***Wavelength (nm)***
3.0-10	2.0-6.0	0.3-1.0	1.0-3.0	1.0-5.0	1.0-5.0	***Linearrange (ppm)***
0.9991	0.9910	0.9904	0.9986	0.9715	0.9907	R^2
0.0114	0.0612	0.2126	0.1657	0.0797	0.0841	***Slope***
0.0003	0.0021	0.0073	0.0017	0.0077	0.0142	***Intercept***
0.0180	0.0270	0.0065	0.0090	0.0120	0.1846	***LOD (ppm)***
0.5360	0.0743	0.0198	0.0270	0.0365	0.0560	***LOQ (ppm)***

LOD was calculated from the equation as 3.3 times the standard deviation (n = 10) of the reagent blank and LOQ as10 times the standard deviation of the reagent blank. The LOD values for solution were multiplied by the dilution factor, which was 25 calculated by taking into consideration that there was 2.000 g of sample in 50 mL sample solution.

2.4. Investigation of the Precision of the Method

Precision of the method employed in this study was investigated from the standard deviations of the three different brands of tea samples studied in five parallels Tea infusions of the samples were wet digested with a mixture of HNO_3 and H_2O_2. Tea infusions were wet digested until wet light yellow residues were obtained. Then onto the residues 30 mL distilled water was added and the solutions were heated until boiling. The sample solutions with black residues were filtered through black ribbon ashless filter papers. The final volumes of the solutions were made to be 50 ml with water.

2.5. Investigation of the Accuracy of the Method

Investigation of the accuracy of the method was performed via standard peach leaves -"Certified Reference Material GBW 08501-Peach Leaves- Made in China". First the moisture content of the peach leaves was determined by drying 0.5 g of peach leaf sample in the oven at 105°C for 2 hours until the samples attained constant weight. Then the peach leaf samples of 0.500 g were wet digested on hotplate at about 130°C. Following this, on each sample solution 5 ml 30% H_2O_2 was added.

3. RESULTS AND DISCUSSIONS

Tea brewing was performed according to the method TS 3907- March 1983. Concentrations of HM's in thus obtained tea infusions are presented in Table 2 (TS 3907- March 1983, Tea-Preparation of Liquor for use in Sensory Test).

Table 2. Concentration of heavy metal ions in tea infusion obtained via distilled water

Brand Name	Production Date	Expiry Date	AVERAGE HM CONCENTRATION in TEA INFUSION(mg L^{-1})					
			Al	Mn	Fe	Cu	Zn	Ni
Rize Turist Tea	01.04.1994	01.04.1996	34.4	8.32	0.174	0.168	0.200	0.127
Çaykur Camelia	28.05.1995	28.05.1997	35.4	7.32	0.287	0.203	0.169	0.117
Çaykur Çayçiçeği	09.08.1996	09.08.1998	33.8	5.91	0.267	0.112	0.164	0.153
Çaykur Camelia	13.12.1997	13.12.1997	26.4	6.78	0.239	0.094	0.168	0.170
Çaykur Çayçiçeği	19.12.1998	19.12.1998	22.8	6.48	0.247	0.194	0.157	0.153
Çaykur Çayçiçeği	01.12.1997	01.12.2000	18.0	7.90	0.206	0.032	0.180	0.200
Rize Turist Tea	24.03.1997	24.03.1999	29.6	7.96	0.267	0.050	0.170	0.190
Lipton Earl Grey	09.08.1997	09.08.1999	42.8	11.5	0.313	0.084	0.242	0.203
Cavkur Filiz Lüks	02.06.1998	02.06.2001	26.0	7.41	0.303	0.163	0.179	0.200
Lipton Earl Grey Tea	09.04.1998	09.04.2000	17.6	11.0	0.303	0.104	0.220	0.197
Rize Tourist Tea	19.09.1997	19.09.1999	11.6	8.17	0.305	0.188	0.167	0.163
LiotonYellow Label	13.07.1998	13.07.2000	34.6	12.6	0,344	0.049	0.251	0.200
Cavkur Camelia	12.12.1998	12.12.2000	11.6	7.47	0.211	0.088	0.166	0.200
Caykur Filiz Lüks	09.02.1998	09.02.2001	32.2	6.50	0.140	0.155	0.169	0.150
Rize Tourist Tea	14.08.1998	14.08.2000	11.2	5.06	0.173	0.171	0.141	0.182
Of Çaysan Camlıca Filizi	18.09.1997	18.09.2000	44.4	7.92	0.181	0.138	0.188	0.230
YeşimÇay Hanımeli	20.08.1997	20.08.2000	41.4	7.12	0.158	0.112	0.211	0.223
Rize Tourist Tea	25.02.1998	25.02.2000	28.4	7.06	0.193	0.086	0.167	0.196
Gıda 2000 Kırçayı Filizi	11.09.1997	11.09.2000	26.4	5.95	0.361	0.083	0.166	0.223
Obaçay Red Package	05.06.1996	05.06.1999	22.0	6.28	0.277	0.092	0.169	0.200
Akfa Tea Luxury Harvest	01.07.1997	01.06.2000	31.2	8.09	0.229	0.089	0.190	0.190

It was observed that except for Mn, concentrations of all other HM in Turkish tea infusions were relatively low as compared to the values indicated for tea in the literature (Ashraf and Mian, 2008; Karimi, n.d.). Mn concentration of Turkish tea infusions, which ranged from 75 to325 mg mL^{-1}, corresponds to the upper levels of those reported in the literature, which is 35.5-110.8 mg mL^{-1}(Matsushima et al., 1993; Mehra and Baker, 2007).

HM concentrations in tea samples with older production dates were considerably lower than those in the newer production dates. This was contradicting the results indicated in other studies (Leitenmaier and Küpper, 2013). However, taking into consideration the Chernobyl accident suffered in 1986 in Ukraine (Gökmen et al., 2005)and the nuclear elements that have been scattered into the environment have undergone radioactive decay thereby ending up polluting the environment with HMs (Corcho Alvarado et al., 2014; Neiva et al., 2016; Nugraha et al., 2022, 2019). Tea being a hyper-accumulator plant accumulates HMs and metalloids in its leaves and over the years the amount of HMs in the leaves increases due to this accumulation (Leitenmaier and Küpper, 2013). Thus, the HM concentration in tea infusions of the tea samples of older dates was higher. Moreover, Nugraha et al. (2022) have reported that soil samples containing natural radio nuclides at high concentrations contained HMs at high concentrations and these HMs in the soil decreased in the sequence Zn >Pb> Cr > Cu > Ni > Cd (Nugraha et al., 2022). Our results were also in line with this finding.

It was observed that while the HM concentrations in the teas of a certain brand were the highest, their concentrations in the teas of another brand were the lowest. This pronounced difference in HM content of the tea samples might be due to the difference in the fauna and soil structure the tea plants were collected from since such a difference would directly affect both the type and the amount of HMs that accumulate in the plant (Seenivasan et al., 2008; Xu et al., 2022; Yaylali-Abanuz and Tüysüz, 2009). Another factor for this difference may be methods the companies entail in processing teas (Nkansah et al., 2016; Zhang et al., 2018)as well as the packaging materials these teas were kept in and the storage conditions they were stored (Deshwal and Panjagari, 2020). Furthermore, the physical properties (i.e., odor, color and particle dimension) of tea samples rich in HMs were different from the tea samples with lower HM concentrations. For instance, the tea samples of the brand, the HM concentrations of which were found to be the lowest, were almost odorless, had light color and bigger particle size.

The effect of brewing period on HM content of tea infusion was investigated. Tea infusions were obtained according to method TS 3907- March 1983, but brewing was performed for 6, 15 and 30 minutes. The results are presented in Table 3.

Table 3. Effect of brewing period on amount of HMs extracted into Tea Infusion

AVERAGECONCENTRATIONSIN TEAINFUSION(mg L^{-1})					
METAL ION	**INFUSION PERIOD (min.)**	**Çaykur Camelia Pck. 05.28.1995**	**Çaykur Çayfilizi Pck. 08.09.1996**	**Rize Tourist Tea Pck. 19.09.10.1997**	**Rize Tourist Tea Pck. 02.09.1998**
Al	6	35.4	33.8	35.6	35.8
	15	36.2	27.2	32.8	39.9
	30	36.2	28.2	33.6	41.0
Mn	6	7.32	5.91	8.17	5.06
	15	9.24	6.90	9.13	6.63
	30	11.9	9.84	11.0	8.25
Fe	6	0.29	0.27	0.30	0.17
	15	0.01	0.17	0.05	0.05
	30	0.18	0.25	0.14	0.08
Cu	6	0.20	0.11	0.19	0.17
	15	0.15	0.09	0.09	0.11
	30	0.07	0.05	0.04	0.03
Zn	6	0.17	0.16	0.17	0.14
	15	0.08	0.10	0.10	0.07
	30	0:16	0.19	0.15	0.15
Ni	6	0.12	0.10	0.16	0.18
	15	0.18	0.18	0.20	0.23
	30	0.21	0.23	0.22	0.19

It was observed that brewing period impact on the amount of HM extracted from the tea samples into tea infusions.

Effect of employment of different additives ($NaHCO_3$ and sugar), which is a common practice in Turkey for obtaining darker infusion colors, during brewing on extraction of HMs into tea infusion was investigated and the results are presented in Table 4.

Aside from few exceptions, addition of additives, such as $NaHCO_3$ and sugar, which are commonly employed in Turkey during tea infusion for to obtain darker infusion color and to shorten infusion periods, was observed to increase the amount of HMs extracted into tea infusion. It was observed that sugar was a stronger extraction agent than $NaHCO_3$ in extraction of HMs during tea infusion.

Table 4. Effect of Employment of $NaHCO_3$ and Sugar During Infusion on Amount of HMs Extracted into Tea Infusion

INFUSION STYLE	METAL ION	AVERAGE CONCENTRATIONS of HMs EXTRACTED INTO TEA INFUSION(mg L^{-1})			
		Rize Tourist Tea Pck.04.01.1994	Çaykur Çayçiçeği Pck.08.09.1996	Çaykur Çayçiçeği Pck.12.02.1997	Çaykur Çayçiçeği Pck. 12.19.1998
With $NaHCO_3$	Al	34.0 (-1.16%)*	24.8 (-26.6%)*	28.8 (+60.0%)*	23.1 (+2.63%)*
	Mn	6.98 (+16.1%)*	8.70 (+47.2%)*	8.91 (-12.8%)*	7.83 (+20.8%)*
	Fe	0.15 (-16.5%)*	0.16 (-62.8%)*	0.26 (+20.8%)*	0.80 (-36.8%)*
	Cu	0.13 (-23.8%)*	0.10 (-7.14%)*	0.25 (+21.6%)*	0.26 (+32.1%)*
	Zn	0.18 (-9.5%)*	0.25 (+19.2%)*	0.25 (+40.6%)*	0.21 (+36.3%)*
	Ni	0.19 (+47.2%)*	0.23 (+50.3%)*	0.16 (-1.5%)*	0.21 (+37.3%)*
With sugar	Al	17.8 (-48.3%)*	34.2 (+1.18%)*	28.0 (+55.6%)*	43.8 (+92.1%)*
	Mn	6.49 (-22.0%)*	7.59 (+28.4%)*	9.30 (+17.7%)*	7.26 (+12.0%)*
	Fe	0.26 (+48.3%)*	0.23 (+15.2%)*	0.16 (+23.8%)	0.32 (+31.6%)*.
	Cu	0.14 (+48.3%)*	0.12 (+25.9%)*	0.19 (+.17%)*	0.14 (+8.60%)*
	Zn	0.14 (-35.3%)*	0.12 (+25.9%)*	0.19 (+.17%)*	0.14 (+8.60%)*
	Ni	0.14 (-35.3%)*	0.12 (+25.9%)*	0.17 (-66.5%)*	0.20 (+28.8%)*

* The numbers in the parenthesis are the differences between the values obtained with and without addition of the additives

3.1. Investigation of the Accuracy of the Method

The metal ion concentrations found in these tea infusions and the relative standard deviations (RSD%) are presented in Table 5.

Table 5. Standard deviations of the measurements made in tea infusions

BRAND NAME	METAL ION	AVERAGE CONCENTRATION (mg L^{-1})	RSD (%)
Çaykur Kamelya P.D.: 13.12.1997 E.D.: 12.13.1999	Al	26.8	9.18
	Mn	6.57	2.37
	Fe	0.37	5.97
	Cu	0.10	9.38
	Zn	0.15	8.61
	Ni	0.22	1.69
Çaykur Filiz Lüks P.D.: 09.02.1998 E.D.: 09.03.2001	Al	30.6	0.46
	Mn	5.83	0.48
	Fe	0.44	10.7
	Cu	0.15	11.2
	Zn	0.18	9.10
	Ni	0.22	0.23
Lipton Yellow Label P.D.: 13.12.1997 E.D.: 23.12.1999	Al	35.0	9.64
	Mn	6.42	3.66
	Fe	0.35	4.93
	Cu	0.13	8.26
	Zn	0.17	12.6
	Ni	0.21	1.53

3.2. Investigation of the Accuracy of the Method

The accuracy of the method was determined via the "Certified Reference Material GBW 08501-Peach Leaves-Made in China". The dry matter content of the peach leaves was found to be 95.2%. HM concentrations in the solutions obtained from the standard peach leaf samples are presented in Table 6.

Table 6. HM concentration in standard peach leaves

METAL ION	CONCENTRATION INDICATED in the CERTIFICATE (mg L^{-1})	CONCENTRATION EXPERIMENTALLY FOUND (mg L^{-1})
Al	-	0.042±0.008
Mn	75.4±5.3	69.19±2.90
Fe	403±29	363.0±10.23
Cu	22.8±2.5	27.93±3.39
Zn	10.4±1.6	8.5±2.34
Ni	-	9.55±2.27

The precision and the accuracy of the method employed in this study were found to be high. HM ions, even if they existed as their complexes in tea infusion did not have any effect on the measurement and the F-AAS signal.

4. CONCLUSION

Tea infusions, which were obtained according to TS 3907-March 193 method (2g in 100 mL) were wet digested. The HM concentrations in the tea samples under investigation were: Al: 11.2-44.4 mg L^{-1}; Mn: 5.95 - 12.5 mg L^{-1}; Fe: 0.14 - 0.34 mg L^{-1}; Zn: 0.14 - 0.25 mg L^{-1}; Cu: 0.032 - 0.203 mg L^{-1} and Zn: 0.117 - 0.223 mg L^{-1}. It was observed that except for Mn, concentrations of all other HM in Turkish tea infusions were relatively low as compared to the values indicated for tea in the literature. Therefore, it was concluded that Turkish tea is of high quality. It was observed that HM concentration in tea infusion depends on many different parameters ranging from the properties of tea product (the environmental conditions where the plant was grown, the processing, storage and packaging that the factories entail in producing their products) and the brewing style, period and additives used during brewing. Tea infusions obtained from tea plants of younger age contained less HMs. The packaging material affected the HM content and HM concentrations in tea stored in paper based packages were lower as compared to those stored in other packaging materials. HM concentrations in tea infusions obtained from tea samples in sachets or with finer particles were observed to be higher than the infusions obtained from tea leaves of bigger particles. Longer brewing time and presence of additives generally employed during brewing in Turkey to improve the odor and/or color of tea infusions in Turkey (sugar and $NaHCO_3$) were observed to increase the HM concentration in the infusions. Therefore, shorter brewing times and no additives would be crucial to decrease the HM concentration in tea infusions. It was also observed that tea samples that had distinct odor, darker color and finer particle size provided infusions with higher HM concentrations. It may be also beneficial to consume tea after forming lactate or citrate complexes of HMs by adding milk or lemon into tea. Taking into consideration these parameters might be beneficial for tea drinkers in order to avoid excessive HM burden in their metabolisms that would minimize the negative health effects that may result from bioavailability of these HMs.

Author Contributions

All authors contributed equally to this work. They all read and approved the last version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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