Vol. 17(4), pp. 47-58, October-December, 2023
DOI: 10.5897/AJPAC2023.0903
Article Number: 00A371E71432
ISSN: 1996-0840

http://www.academicjournals.org/AJPAC

ACADEMIC JOURNALS
expand your knowledge

African Journal of Pure and Applied Chemistry

Full Length Research Paper

Influence of duration and temperature of infusion on the heavy metal contents of some groups of tea in Nigeria

Tomori, Wasiu Bolaji[1,3]*, Oyewumi, Tolulope Oyelekan[1,2] and Omale Peter Enefola[3]

[1]Department of Chemistry, Federal University of Technology, Akure, Ondo State, Nigeria.
[2]Department of Chemistry, Wayne State University, Detroit, USA.
[3]Department of Chemistry, Nigerian Defence Academy, Kaduna, Nigeria.

Received 19 August, 2023; Accepted 20 October, 2023

Consumption of tea has been recommended not only for its taste and aroma but also for its medicinal importance, and these factors may contribute to public health concerns. The physicochemical characteristics of tea groups (green, black, and medicinal tea) were investigated using standard procedures. 2 g of each tea group and type were infused for 10 min at 60 and 80°C, and the extract was digested with a 2:1 mixture of HNO_3 (65%) and H_2O_2 (30%) and then analyzed using Flame Atomic Absorption Spectrophotometry (FAAS) for Cd, Pb, Cu, Zn and Fe. The moisture content for green tea ranged from 6.75 to 7.50%, black tea from 5.50 to 8.50%, and medicinal/herbal tea from 7.50 to 13.25%, while the pH of the infusion at 60 and 80°C was found to be 7.0. The moisture content of medicinal tea was higher among the tea groups, as was their ash content, which was less than 8% for all groups and types of tea products. Furthermore, it was also found that the heavy metal content increases with an increase in infusion temperature for all similar brands of tea, except for some brands of medicinal tea. This may be due to plant species, soil conditions, and other environmental factors. There is no carcinogenic or noncarcinogenic health risk from elements in all tea brands and groups for both adults and children. However, there is a relative risk for children over adults, especially from Pb. Therefore, frequent consumption of all tea types and groups under investigation should be discouraged among children.

Key words: Green tea, black tea, medicinal tea, infusion characteristics, health risk, Nigeria.

INTRODUCTION

The increasing popularity of tea consumption has garnered attention worldwide (Mendal et al., 2015; Chiang et al., 2020). It is greatly admired for its delightful aroma, taste, and physiological or medicinal functions in the body

*Corresponding author. E-mail: wbtomori@futa.edu.ng.

(Adunola and Okunola, 2016; Chiang et al., 2020). Tea is an aromatic beverage prepared from the cured leaves, roots, internodes, and stems of aromatic plants and consumed by infusion or steeping in hot water (Zaharaddeen et al., 2015; Ezeunala et al., 2022). It varies in composition and quality depending on the blend of tea or the curing process. The most popular types are green tea, black tea, and Oolong (Gramza-Michalowska and Bajerska-Jarzebowska, 2007; Mahurpawar, 2015), which are obtained from the leaves, buds, roots, and internodes of the *Camellia sinensis* plant and prepared and cured by different methods. There are also tea products from other plant species such as Senna (*Cassia augustifolia*), Moringa (*Moringa oleifera*), Ginger (*Zingiber officinale*), Jasmine (*Jasminum officinale*), etc. (Pathaw et al., 2022), and hibiscus (Nguyen and Van-Chuyen, 2020).

The nutritional composition of teas varies around protein, carbohydrate, and vitamins with some micro and macro mineral elements (Mendal et al., 2015; Chiang et al., 2020). The growing interest in the consumption of tea stems from the presence of polyphenolic compounds (other phytochemicals) that are present (Pathaw et al., 2022), such as epigallocatechin 3-gallate (EGCG), Theaflavins, Catechins, L-theanine, Caffeine, etc., that exhibit antioxidant, lowering cholesterol, and anticancer activities (Nguyen and Van-Chuyen, 2020). The scavenging of free radicals generated in the body makes them the most often consumed beverage after water (Gramza-Michalowska and Bajerska-Jarzebowska, 2007). However, apart from the healthy phytochemicals contained in tea, there are other nonnutritional components like heavy metals that are detrimental to the continuous usage of tea over a long period of time (Chiang et al., 2020).

Heavy metals are, however members of an ill-defined subset of elements, they include the transition metals, some metalloids, lanthanides, and actinides. In terms of health and well-being, heavy metals are elements that are toxic, carcinogenic, teratogsnic, and mutagenic to the human system, capable of causing acute or chronic health conditions including death, when consumed in large excess. Examples include zinc, manganese, iron, copper, mercury, titanium, molybdenum, aluminum, strontium, silver, etc (Rahman and Singh, 2019; Dasharathy et al., 2022; Miletic et al., 2023). Some of these heavy metals are essential micronutrients that also contribute to our daily nutrient requirements despite the health hazards associated with their consumption (Carazo et al., 2021; Aljohani et al., 2023). There are several methods available for the assessment of carcinogenic and noncarcinogenic potentials of these heavy metals, including the empirical deduction (Bentum et al., 2011; Liao et al., 2022), *in-vitro* assessment (Chen et al., 2020), etc. The most commonly employed are the empirical deductions based on certain assumptions (Atta et al., 2023; Hu et al., 2023).

In a country like Nigeria where tea plants are seldom grown locally, the products are usually imported. Although, the National Agency for Food and Drug Administration and Control (NAFDAC) is responsible for strict regulation of these items, it has been found worldwide that tea contains some amount of heavy metals (Achudume and Owoeye, 2010; Patrick-Iwuanyanwu and Udowelle, 2017; Pourramezani et al., 2019) that could be injurious to health if not checked. The majority of work available in literature often talks about beneficial effects from the phytochemical constituent's point of view, but only limited resources are available locally on heavy metal content and its potential cause of carcinogenic and noncarcinogenic public health risks. Hence, this study aimed at elucidating the infusion characteristics (pH, ash and moisture contents, heavy metal dependency on temperature) of different groups of tea and thus estimating the potential public health risk from the selected heavy metals in Nigeria.

MATERIALS AND METHODS

Determination of moisture and ash content of tea samples

Fifteen different brands of tea popularly consumed and sold in various retail outlets in Nigeria were randomly purchased. We considered the fermentation (curing) process and the tea plant species (green tea, black tea, and medicinal tea products) while making selection. Each tea samples were carefully removed from the tea bags, and 2 g was weighed into a preheated, pre-weighed crucible. The moisture content was determined by gravimetry (Pojić et al., 2015), a temperature of 110 ± 5°C. Also the ash content was determined for each tea sample. 2 g of each tea were then placed, in a muffle furnace with the heating temperature reset finally to 575±25°C for ash and the ash content is determined via gravimetry (Pojić et al., 2015).

Determination of tea infusion pH

Two grams of tea samples were weighed into a beaker containing 100 ml of preheated hot distilled water at 60°C on a thermo-regulated water bath (Zhang et al., 2017). The tea leaves were allowed to infuse for 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, and 60 min. The hot water extract (tea infusion) at a particular infusion time was removed and allowed to cool to room temperature, and the pH was subsequently taken with an already standardized pH meter (SETRAPHS 25) (Długaszek and Kaszczuk, 2020). The aforementioned procedure was repeated for the hot water extraction at 80°C and each experiment was conducted in triplicate.

Determination of infusible tea heavy metals

Two grams of tea samples were weighed into a beaker containing 100 ml of preheated hot distilled water at 80°C on a thermo-regulated water bath and was allowed to infuse for 10 min. The infused content was filtered into another beaker and heated to almost dryness over a gentle heating in a fume cupboard and thereafter cooled to room temperature. A 15 ml 2:1 mixture of (65%) HNO_3 and (30%) H_2O_2 was added to digest the extract and heated warmly over a Bunsen burner in a fume cupboard until the samples were thoroughly digested. The digested samples were then quantitatively filtered into a standard 50 ml volumetric flask and made up to mark with distilled water. The digests were analyzed for

Cd, Pb, Cu, Zn, and Fe using the Flame Atomic Absorption Spectrophotometer (FAAS) (Buck Scientific 210 VGP). The sample procedure was adopted for a 60°C infusion temperature, and each sample was replicated three times. A blank sample was incorporated into each procedure, except that no tea sample was included (Zhang et al., 2017).

Non-carcinogenic and carcinogenic health risks

Non-carcinogenic health risk, as shown in Equations 1 to 3, were applied to determine the chronic daily intake (CDI), hazard quotient (HQ), and hazard index (HI), respectively, for the potential risks of toxic elements for adults and children via ingestion exposure routes (Eze et al., 2021; Jajere et al., 2023).

$$CDI = \frac{Cw\ X\ DI\ X\ ABS\ X\ EF\ X\ ED}{BW\ X\ AT} \quad (1)$$

where Cw (mg/kg) is the heavy metals concentration in tea infusion, ABS (no unit, 0.001) is the dermal absorption factor, DI (L/day; 0.59 L/day for adults and 0.30 L/day for children (Naveed and Hameed, 2014) is the estimated daily average intake of tea, EF (days/year) represents the annual exposure frequency, ED (years) is exposure duration (70 year for adult; 6 years for children), BW (kg) is bodyweight (70 kg for adults and 15 kg for children), and AT (days) is the average time (Ese et al., 2021). The HQ for individual potentially toxic elements was estimated using the ratio of the calculated mean daily intake (CDI, mg/kg/day) of the metal ingested through tea infusion to the reference dose (RfD) (Olagunju et al., 2020) (Equation 2). The sum of all the hazard quotients gives the total potential health risks or hazard index (HI).

$$HQ = \frac{CDI}{RfD} \quad (2)$$

where CDI and RfD are expressed in mg/kg/day. The values of the RfD and cancer slope factor for different metals studied were obtained from Olagunju et al. (2020). Hazard Index (HI) is used in order to evaluate the entire non-carcinogenic health impacts caused by exposure to all pollutants (Equation 3).

$$HI = HQCd + HQPb + HQCu + HQZn + HQFe \quad (3)$$

The computed HI is interpreted as 1 < HI < 1 that is there is the possibility of non-carcinogenic impacts if greater than 1 or the exposed person is unlikely to experience non-carcinogenic health impacts when less than 1. The cancer risk is usually estimated using the Incremental Lifetime Cancer Risk (ILCR) (Equation 4) and is the possibility of a person developing any type of cancer over a lifetime as a result of daily exposure to a given daily amount of a carcinogenic element.

$$ILCR = CDI\ x\ CSF$$

where CSF is the cancer slope factor. The allowable limits are considered to be 10^{-6}, and less than 10^{-4} for both single and multi-element carcinogens (Ese et al., 2021).

Statistical analysis

The results are expressed as mean ± standard deviation using Data Analysis from Microsoft Excel, 2013.

RESULTS AND DISCUSSION

Moisture and ash contents of a group of tea in Nigeria

The moisture and ash contents of the various groups of tea are shown in Table 1 while the infusion pH characteristics at 60 and 80°C at a 5 min gradation from 5 to 60 min are presented in Figures 1 and 2, respectively. Heavy metal concentrations at those infusion temperatures for green, black, and medicinal teas were presented in Table 2, while the health risk assessments are presented in Tables 3 to 5.

The moisture content is generally an index used to estimate the average shelf-life of a product; the higher the moisture content the lower its shelf-life and vice versa (Aroyeun et al., 2017). Table 1 shows the results for % moisture content for different tea products (groups) listed under three main categories as Green, Black, and Medicinal tea. All types of green tea have a percentage moisture content of about 7.5%, except for QGT which had 6.75%. This shows that the product may probably withstand mold growth for the labelled period of storage (Aroyeun et al., 2017). Moisture content may vary from one tea to the next depending on the drying time and nature of the tea involved. For Black tea, the % moisture content varied for all tea types under this category but lies between 7.70 and 8.50%. The percentage moisture content is high for all brands of medicinal tea and falls between 7.50 and 13.25%. The high values obtained in this result for medicinal tea were consistent with the observations of Rao and Xiang (2009) and Kumar and Kumar (2014), who attributed this observation to the significant characteristics of the medicinal plant. Overall, the moisture content values for black tea < green tea < medicinal tea. Generally, a moisture content that is less than 7% has a long shelf life, during which they are fresh and free from microbial contamination (Kumar and Kumar, 2014).

The ash content provides a crude detail as regards the quantification of the inorganic constituents present in food and is also a measure of food safety or roughly the amount of mineral component present in a food commodity (Afify et al., 2017). The ash content for green tea varied between 3.75% for Dakin's green and 5.75% for Twinning Green tea; and this may be due to nature of the tea leaves, cultivation medium, or agricultural practices, etc (Dawodu et al., 2013). The values were all within the specified range of 4.00 to 8.00% prescribed by Punyasiri, (2011) as a limit. Green tea therefore contains enough inorganic mineral content, which could be a source of mineral nutrients for the body. The moisture content values obtained for the medicinal tea group were slightly higher than the two other group, they were all within the specified limit 4.00 to 8.00%. Consumers of medicinal tea are therefore likely to consume more mineral elements than any other consumers of other tea

Table 1. Moisture and ash contents of some groups of tea in Nigeria.

Tea category	Tea product†	Moisture content (%)	Ash content (%)
	DGT	7.50 ± 0.0000	4.75 ± 1.0610
	TGT	7.50 ± 0.7071	5.75 ± 0.3536
Green tea	CGT	7.50 ± 0.0000	3.75 ± 0.3536
	QGT	6.75 ± 0.3536	4.50 ± 0.7071
	HGL	7.00 ± 0.7071	5.00 ± 1.4142
	MT	7.25 ± 0.3536	6.14 ± 1.2120
	LYT	7.70 ± 2.1213	7.00 ± 0.0000
Black tea	TT	5.50 ± 0.7071	4.75 ± 1.0607
	SBT	8.50 ± 0.0000	7.00 ± 2.1210
	PCT	7.50 ± 0.7071	4.77 ± 0.3860
	AMT	13.25 ± 2.4749	7.75 ± 0.3536
	BHT	9.25 ± 0.3536	7.75 ± 0.3536
Medicinal tea	HHT	7.50 ± 0.7071	6.50 ± 0.7071
	Q T	8.50 ± 1.4142	7.00 ± 1.4142
	MHT	7.50 ± 0.0000	8.00 ± 0.0000

†Dakin`s green tea-DGT, Twinning green tea-TGT, Ceylon green tea-CGT, Qualitea Green tea-QGT, Hillway green label-HGL, Master tea-MT, Lipton yellow tea-LYT, Top tea-TT, Shanghai Bozheng`s –SBT, Princess horse Ceylon tea-PCT, Abuademoringa tea-AMT, 3 Bellarina herb tea-BHT, Heladiv herb tea-HHT, Qihuang (tranquilizing and brain nourishing tea)-QT, Mind herb tea-MHT.

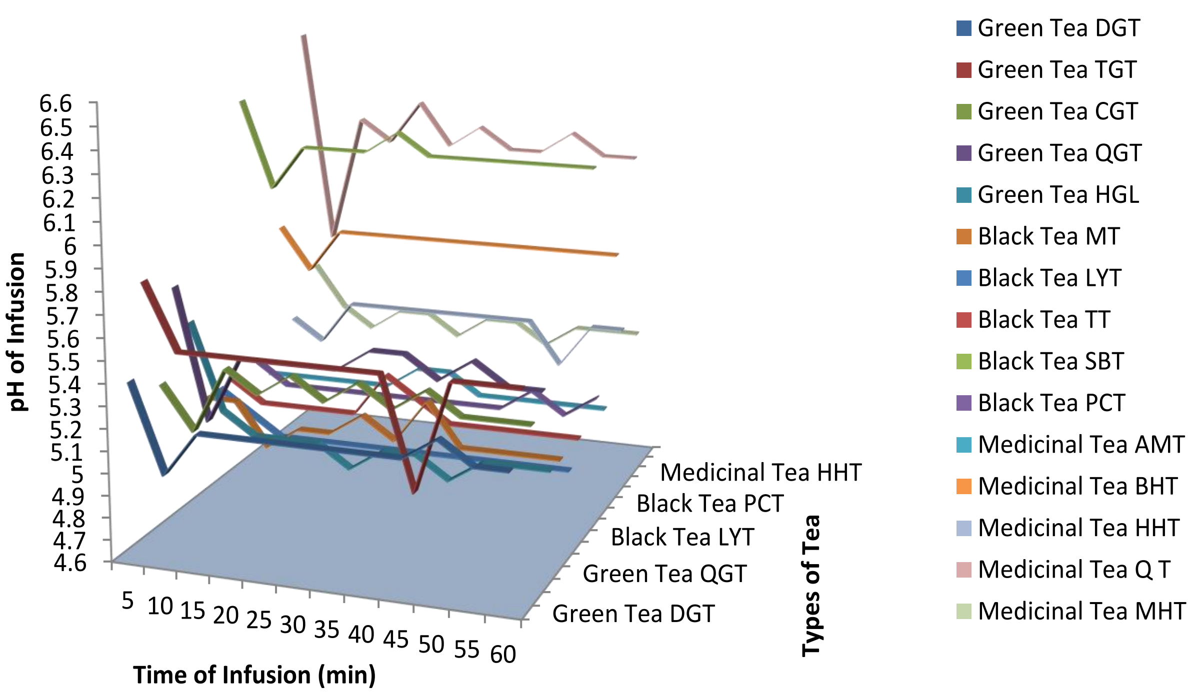

Figure 1. pH variation with time for different tea types at 60°C.

products. The ash content value varied for green tea < black tea < medicinal tea.

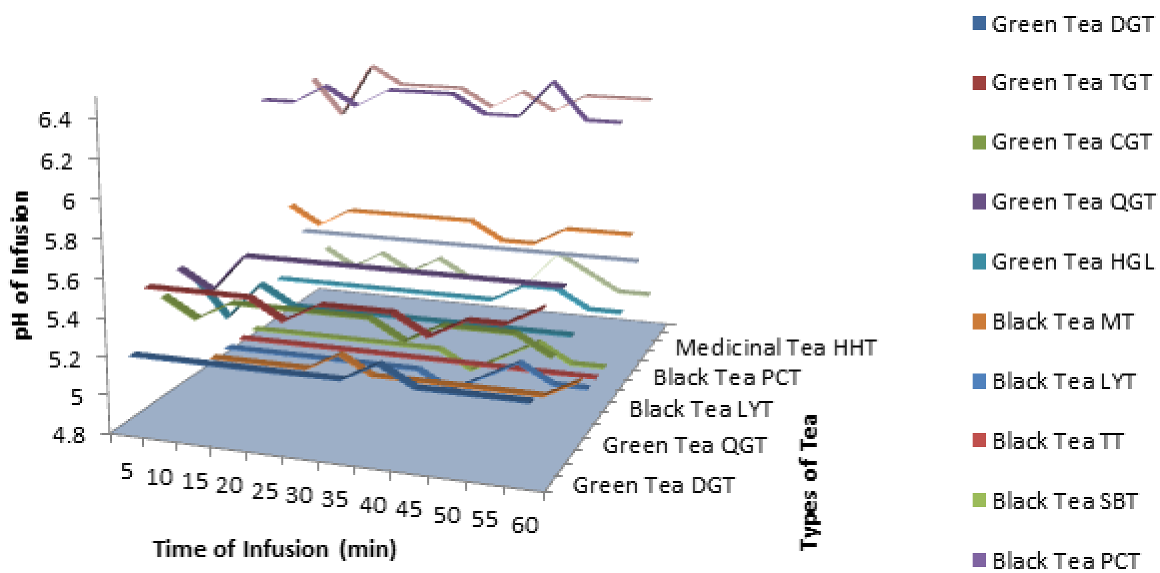

Figure 2. pH variation with time for different tea types at 80°C.

pH variation of tea infusion at 60 and 80°C

pH variations with temperature are as shown in Figures 1 and 2. The pH values for all samples were lower than 7.0 at both 60 and 80°C infusion temperatures. Chiang et al. (2020) reasoned that the acidity may be due to the release of acidic polyphenol oxidation polymerization products dissolved in tea infusions with increasing duration of brewing. There is, however an established correlation between the taste and pH value; the lower the pH, the bitter the tea infusion taste, according to Kumar and Kumar (2014). Black tea has a lowest pH among the tea sample products throughout 5 to 60 min of infusion time as shown in Figure 1. The trend of pH values showed a high pH at 5 min of infusion time, followed by an observable decrease at 10 min followed by seemingly constant pH values for the rest of the infusion time. Similar observations in infusion pH behavior with time of the infusion were found teas, with medicinal tea having the highest overall pH value as shown in Figure 1. The 5 min infusion time at 60°C is enough to get the best taste out of the various tea types. This decrease in pH as infusion time increased was attributed to the increased release of acidic polyphenol oxidation polymerization products dissolved in tea infusions with increasing duration of brewing (Chiang et al., 2020).

Infusion at a higher temperature (Figure 2) generally shows an increase in the amount of extractible material from the tea leaves (an increase in solubility in an aqueous medium) (Kumar and Kumar, 2014). There is a striking observation that pH at 80°C is generally slightly lower than pH at 60°C for the corresponding time of infusion. The pH value is generally lower than 7.0 for the tea infusion of all tea groups under consideration as is the case with 60°C infusion temperature. Therefore, heating water to near boiling may not necessarily give a better taste to the tea given a slight drop in pH between the two temperatures. A somewhat constant pH value for each brand of tea across the infusion time interval of 5 to 60 min was observed at this temperature as shown in Figure 2. Generally, the pH of black tea is the lowest and this may account for its more bitter taste compared to green and medicinal tea.

Heavy metal content of tea infusions

The concentrations of selected heavy metals in various groups of tea at infusion temperatures of 60 and 80°C are shown in Table 2. For all brands of green, black, and medicinal tea, there is an observed increase in heavy metal content with an increase in infusion temperature. There is always an increase in those brands of medicinal tea over the other two brands. There is, however, no observed significant difference at P>0.05 for the concentrations when the infusion temperatures increase from 60 to 80°C across the brands and types of tea. The presence of cadmium and lead, being non-essential nutrients in plant and animal nutrition (Mahurpawar, 2015), should be regulated, both were found to be lower than the FAO/WHO (2011) limit shown in Table 2. However, when their concentrations are high in plant tissues, they become lethal to humans and animals when consumed (Ghinwa and Bohumil, 2009). Exposure to Cd and Pb reduces the activity of antioxidant enzymes, which points to a decrease in the antioxidant potential of the body as a result of supplying factors that enhance cellular oxidation processes (Winiarska-Mieczan, 2018).

Table 2. Heavy metal contents (mg/kg) (mean±SD) of different tea group at 60 and 80°C infusion temperatures.

Tea category	Brand	Temp. (°C)	Cd	Pb	Cu	Zn	Fe
Green tea	DGT	60	Nd	0.060±0.005	0.372±0.042	0.408±0.059	1.156±0.303
		80	0.001±0.000	0.084±0.030	0.594±0.194	0.813±0.103	1.739±0.193
	TGT	60	0.002±0.000	0.302±0.054	0.337±0.055	0.308±0.053	0.773±0.160
		80	0.01±0.001	0.329±0.073	0.478±0.074	0.335±0.042	1.368±0.187
	CGT	60	0.001±0.000	0.087±0.016	0.341 ±0.028	0.392±0.051	1.233±0.522
		80	0.002±0.001	0.146±0.062	0.466±0.069	0.525±0.021	1.980±0.180
	QGT	60	0.002±0.001	0.195±0.051	0.391±0.041	0.363±0.095	1.283±0.340
		80	0.009±0.003	0.270±0.021	0.391±0.030	0.438±0.102	1.718±0.430
	HGL	60	0.024±0.007	0.390±0.028	0.394±0.059	0.439±0.113	0.928±0.018
		80	0.054±0.010	0.519±0.037	0.402±0.037	0.568±0.052	1.022±0.253
Black tea	MT	60	0.010±0.001	0.448±0.034	0.399±0.051	0.240±0.103	1.189±0.380
		80	0.018±0.004	0.482±0.139	0.575±0.079	0.293±0.013	1.285±0.358
	LYT	60	0.006±0.001	0.068±0.008	0.389±0.002	0.334±0.054	1.035±0.117
		80	0.006±0.000	0.113±0.013	0.498±0.096	0.435±0.103	1.944±0.141
	TT	60	0.007±0.001	0.106±0.007	0.412±0.081	0.386±0.093	0.770±0.286
		80	0.008±0.001	0.182±0.086	0.507±0.122	0.563±0.083	1.202±0.161
	SBT	60	0.007±0.001	0.248±0.042	0.365±0.139	0.293±0.105	1.002±0.042
		80	0.015±0.007	0.301±0.028	0.443±0.135	0.314±0.044	1.009±0.354
	PCT	60	0.001±0.000	0.049±0.059	0.203±0.022	0.402±0.042	1.047±0.022
		80	0.002±0.000	0.160±0.022	0.281±0.042	0.402±0.028	1.566±0.028
Medicinal tea	AMT	60	0.117±0.049	0.788±0.096	0.432±0.099	0.286±0.037	1.894±0.371
		80	0.039±0.040	0.923±0.242	0.248±0.091	0.322±0.098	1.712±0595
	BHT	60	0.043±0.042	0.242±0.950	0.429±0.153	0.303±0.016	1.354±0.241
		80	0.003±0.000	0.298±0.087	0.415±0.090	0.520±0.037	1.164±0.144
	HHT	60	0.004±0.001	0.399±0.110	0.456±0.008	0.431±0.191	1.259±0.231
		80	0.037±0.008	0.385±0.011	0.342±0.105	0.412±0.006	1.567±0.671
	QT	60	0.001±0.000	0.127±0.008	0.371±0.044	0.314±0.045	0.920±0.155
		80	0.007±0.002	0.301±0.028	0.444±0.035	0.569±0.073	1.002±0.042
	MHT	60	0.005±0.001	0.084±0.010	0.304±0.061	0.381±0.167	1.182±0.592
		80	0.002±0.000	0.574±0.059	0.428±0.079	0.356±0.062	1.153±0.141
FAO/WHO*			0.2	0.3	0.5	1.0	0.8

[†]Dakin`s green tea-DGT, Twinning green tea-TGT, Ceylon green tea-CGT, Qualitea green tea-QGT, Hillway green label-HGL, Master tea-MT, Lipton yellow tea-LYT, Top tea-TT, Shanghai Bozheng`s –SBT, Princess horse Ceylon tea-PCT, Abuade Moringa tea-AMT, 3 Bellarina herb tea-BHT, Heladiv herb tea-HHT, Qihuang (tranquilizing and brain nourishing tea)-QT, Mind herb tea-MHT.
Source: FAO/WHO (2011).

It is important to examine food products containing significant amounts of antioxidant components in order to use them in a daily diet to prevent the hazardous effects of toxic metals on the human body. Tea is an excellent

Table 3. Chronic daily intake of the selected metals in groups of tea in Nigeria.

Tea category	Brand	Temp. (°C)	Adult chronic daily intake					Children chronic daily intake				
			Cd	Pb	Cu	Zn	Fe	Cd	Pb	Cu	Zn	Fe
Green tea	DGT	60	0	5.06E-07	3.14E-06	3.44E-06	9.74E-06	0	1.2E-06	7.44E-06	8.16E-06	2.31E-05
		80	8.43E-09	7.08E-07	5.01E-06	6.85E-06	1.47E-05	2E-08	1.68E-06	1.19E-05	1.63E-05	3.48E-05
	TGT	60	1.69E-08	2.55E-06	2.84E-06	2.6E-06	6.52E-06	4E-08	6.04E-06	6.74E-06	6.16E-06	1.55E-05
		80	8.43E-08	2.77E-06	4.03E-06	2.82E-06	1.15E-05	2E-07	6.58E-06	9.56E-06	6.7E-06	2.74E-05
	CGT	60	8.43E-09	7.33E-07	2.87E-06	3.3E-06	1.04E-05	2E-08	1.74E-06	6.82E-06	7.84E-06	2.47E-05
		80	1.69E-08	1.23E-06	3.93E-06	4.43E-06	1.67E-05	4E-08	2.92E-06	9.32E-06	1.05E-05	3.96E-05
	QGT	60	1.69E-08	1.64E-06	3.3E-06	3.06E-06	1.08E-05	4E-08	3.9E-06	7.82E-06	7.26E-06	2.57E-05
		80	7.59E-08	2.28E-06	3.3E-06	3.69E-06	1.45E-05	1.8E-07	5.4E-06	7.82E-06	8.76E-06	3.44E-05
	HGL	60	2.02E-07	3.29E-06	3.32E-06	3.7E-06	7.82E-06	4.8E-07	7.8E-06	7.88E-06	8.78E-06	1.86E-05
		80	4.55E-07	4.37E-06	3.39E-06	4.79E-06	8.61E-06	1.08E-06	1.04E-05	8.04E-06	1.14E-05	2.04E-05
Black tea	MT	60	8.43E-08	3.78E-06	3.36E-06	2.02E-06	1E-05	2E-07	8.96E-06	7.98E-06	4.8E-06	2.38E-05
		80	1.52E-07	4.06E-06	4.85E-06	2.47E-06	1.08E-05	3.6E-07	9.64E-06	1.15E-05	5.86E-06	2.57E-05
	LYT	60	5.06E-08	5.73E-07	3.28E-06	2.82E-06	8.72E-06	1.2E-07	1.36E-06	7.78E-06	6.68E-06	2.07E-05
		80	5.06E-08	9.52E-07	4.2E-06	3.67E-06	1.64E-05	1.2E-07	2.26E-06	9.96E-06	8.7E-06	3.89E-05
	TT	60	5.9E-08	8.93E-07	3.47E-06	3.25E-06	6.49E-06	1.4E-07	2.12E-06	8.24E-06	7.72E-06	1.54E-05
		80	6.74E-08	1.53E-06	4.27E-06	4.75E-06	1.01E-05	1.6E-07	3.64E-06	1.01E-05	1.13E-05	2.4E-05
	SBT	60	5.9E-08	2.09E-06	3.08E-06	2.47E-06	8.45E-06	1.4E-07	4.96E-06	7.3E-06	5.86E-06	2E-05
		80	1.26E-07	2.54E-06	3.73E-06	2.65E-06	8.5E-06	3E-07	6.02E-06	8.86E-06	6.28E-06	2.02E-05
	PCT	60	8.43E-09	4.13E-07	1.71E-06	3.39E-06	8.82E-06	2E-08	9.8E-07	4.06E-06	8.04E-06	2.09E-05
		80	1.69E-08	1.35E-06	2.37E-06	3.39E-06	1.32E-05	4E-08	3.2E-06	5.62E-06	8.04E-06	3.13E-05
Medicinal tea	AMT	60	9.86E-07	6.64E-06	3.64E-06	2.41E-06	1.6E-05	2.34E-06	1.58E-05	8.64E-06	5.72E-06	3.79E-05
		80	3.29E-07	7.78E-06	2.09E-06	2.71E-06	1.44E-05	7.8E-07	1.85E-05	4.96E-06	6.44E-06	3.42E-05
	BHT	60	3.62E-07	2.04E-06	3.62E-06	2.55E-06	1.14E-05	8.6E-07	4.84E-06	8.58E-06	6.06E-06	2.71E-05

Table 3. Contd.

		80	2.53E-08	2.51E-06	3.5E-06	4.38E-06	9.81E-06	6E-08	5.96E-06	8.3E-06	1.04E-05	2.33E-05
	HHT	60	3.37E-08	3.36E-06	3.84E-06	3.63E-06	1.06E-05	8E-08	7.98E-06	9.12E-06	8.62E-06	2.52E-05
		80	3.12E-07	3.25E-06	2.88E-06	3.47E-06	1.32E-05	7.4E-07	7.7E-06	6.84E-06	8.24E-06	3.13E-05
	QT	60	8.43E-09	1.07E-06	3.13E-06	2.65E-06	7.75E-06	2E-08	2.54E-06	7.42E-06	6.28E-06	1.84E-05
		80	5.9E-08	2.54E-06	3.74E-06	4.8E-06	8.45E-06	1.4E-07	6.02E-06	8.88E-06	1.14E-05	2E-05
	MHT	60	4.21E-08	7.08E-07	2.56E-06	3.21E-06	9.96E-06	1E-07	1.68E-06	6.08E-06	7.62E-06	2.36E-05
		80	1.69E-08	4.84E-06	3.61E-06	3E-06	9.72E-06	4E-08	1.15E-05	8.56E-06	7.12E-06	2.31E-05

Table 4. Hazard quotients for the selected group of tea in Nigeria for adults and children.

Tea category	Brand	Temp. (°C)	HQ for adults					HQ for children				
			Cd	**Pb**	**Cu**	**Zn**	**Fe**	**Cd**	**Pb**	**Cu**	**Zn**	**Fe**
Green tea	DGT	60	0	0.000144	7.84E-05	1.15E-05	1.39E-05	0	0.000343	0.000186	2.72E-05	3.3E-05
		80	8.43E-06	0.000202	0.000125	2.28E-05	2.09E-05	0.00002	0.00048	0.000297	5.42E-05	4.97E-05
	TGT	60	1.69E-05	0.000727	7.1E-05	8.65E-06	9.31E-06	0.00004	0.001726	0.000169	2.05E-05	2.21E-05
		80	8.43E-05	0.000792	0.000101	9.41E-06	1.65E-05	0.0002	0.00188	0.000239	2.23E-05	3.91E-05
	CGT	60	8.43E-06	0.00021	7.19E-05	1.1E-05	1.48E-05	0.00002	0.000497	0.000171	2.61E-05	3.52E-05
		80	1.69E-05	0.000352	9.82E-05	1.48E-05	2.38E-05	0.00004	0.000834	0.000233	0.000035	5.66E-05
	QGT	60	1.69E-05	0.00047	8.24E-05	1.02E-05	1.54E-05	0.00004	0.001114	0.000196	2.42E-05	3.67E-05
		80	7.59E-05	0.00065	8.24E-05	1.23E-05	2.07E-05	0.00018	0.001543	0.000196	2.92E-05	4.91E-05
	HGL	60	0.000202	0.000939	8.3E-05	1.23E-05	1.12E-05	0.00048	0.002229	0.000197	2.93E-05	2.65E-05
		80	0.000455	0.00125	8.47E-05	1.6E-05	1.23E-05	0.00108	0.002966	0.000201	3.79E-05	2.92E-05
Black tea	MT	60	8.43E-05	0.001079	8.41E-05	6.74E-06	1.43E-05	0.0002	0.00256	0.0002	0.000016	3.4E-05
		80	0.000152	0.001161	0.000121	8.23E-06	1.55E-05	0.00036	0.002754	0.000288	1.95E-05	3.67E-05
	LYT	60	5.06E-05	0.000164	8.2E-05	9.38E-06	1.25E-05	0.00012	0.000389	0.000195	2.23E-05	2.96E-05

Table 4. Contd.

		80	5.06E-05	0.000272	0.000105	1.22E-05	2.34E-05	0.00012	0.000646	0.000249	0.000029	5.55E-05
	TT	60	0.000059	0.000255	8.68E-05	1.08E-05	9.27E-06	0.00014	0.000606	0.000206	2.57E-05	0.000022
		80	6.74E-05	0.000438	0.000107	1.58E-05	1.45E-05	0.00016	0.00104	0.000254	3.75E-05	3.43E-05
	SBT	60	0.000059	0.000597	7.69E-05	8.23E-06	1.21E-05	0.00014	0.001417	0.000183	1.95E-05	2.86E-05
		80	0.000126	0.000725	9.33E-05	8.82E-06	1.21E-05	0.0003	0.00172	0.000222	2.09E-05	2.88E-05
	PCT	60	8.43E-06	0.000118	4.28E-05	1.13E-05	1.26E-05	0.00002	0.00028	0.000102	2.68E-05	2.99E-05
		80	1.69E-05	0.000385	5.92E-05	1.13E-05	1.89E-05	0.00004	0.000914	0.000141	2.68E-05	4.47E-05
	AMT	60	0.000986	0.001898	9.1E-05	8.04E-06	2.28E-05	0.00234	0.004503	0.000216	1.91E-05	5.41E-05
		80	0.000329	0.002223	5.23E-05	9.05E-06	2.06E-05	0.00078	0.005274	0.000124	2.15E-05	4.89E-05
	BHT	60	0.000362	0.000583	9.04E-05	8.51E-06	1.63E-05	0.00086	0.001383	0.000215	2.02E-05	3.87E-05
		80	2.53E-05	0.000718	8.74E-05	1.46E-05	1.4E-05	0.00006	0.001703	0.000208	3.47E-05	3.33E-05
Medicinal tea	HHT	60	3.37E-05	0.000961	9.61E-05	1.21E-05	1.52E-05	0.00008	0.00228	0.000228	2.87E-05	3.6E-05
		80	0.000312	0.000927	7.21E-05	1.16E-05	1.89E-05	0.00074	0.0022	0.000171	2.75E-05	4.48E-05
	QT	60	8.43E-06	0.000306	7.82E-05	8.82E-06	1.11E-05	0.00002	0.000726	0.000186	2.09E-05	2.63E-05
		80	0.000059	0.000725	9.36E-05	1.6E-05	1.21E-05	0.00014	0.00172	0.000222	3.79E-05	2.86E-05
	MHT	60	4.21E-05	0.000202	6.41E-05	1.07E-05	1.42E-05	0.0001	0.00048	0.000152	2.54E-05	3.38E-05
		80	1.69E-05	0.001382	9.02E-05	1E-05	1.39E-05	0.00004	0.00328	0.000214	2.37E-05	3.29E-05

food source of various phytochemicals that could mitigate the continuous intake of Cd and Pb observed.

The infusion of micronutrients such as Cu, Fe, and Zn from tea leaves into the water through leaching makes tea a dietary source of these minerals for consumers because they are important in the living system for a variety of physiological functions. Notwithstanding, excessive consumption of these trace elements can lead to hyperaccumulation in the cells and exert toxic effects on the human body through interference with the body's physiological processes. Physiological processes like absorption of nutrient, biomolecules to maintain their protein structure, function, and cell proliferation. Hampering this function thus creating stress, including certain genetic disorders and they can therefore be considered ecological toxins (Street et al., 2006; Tomori, 2019). Results for micronutrients shown in Table 2 indicated an increase in the amount of Cu, Zn, and Fe in the infusion as temperature increases between 60 and 80°C. However, unlike Cd and Pb, there is no large variation of one particular group of tea over the other. DGT has the highest content in both Cu (0.594 mg/kg) and Zn (0.813 mg/kg) while those

Table 5. Hazard index and incremental lifetime cancer risk for the selected group of tea in Nigeria.

Tea category	Brand	Temp. (°C)	Adult HI	Children HI	Adult ILCR Cd	Children ILCR Cd	Adult ILCR Pb	Children ILCR Pb
Green Tea	DGT	60	0.000248	0.000589	0	0	5.95E-08	1.41E-07
		80	0.00038	0.000901	1.38E-09	3.28E-09	8.33E-08	1.98E-07
	TGT	60	0.000833	0.001977	2.76E-09	6.56E-09	2.99E-07	7.11E-07
		80	0.001003	0.00238	1.38E-08	3.28E-08	3.26E-07	7.74E-07
	CGT	60	0.000316	0.000749	1.38E-09	3.28E-09	8.63E-08	2.05E-07
		80	0.000505	0.001199	2.76E-09	6.56E-09	1.45E-07	3.44E-07
	QGT	60	0.000594	0.001411	2.76E-09	6.56E-09	1.93E-07	4.59E-07
		80	0.000841	0.001997	1.24E-08	2.95E-08	2.68E-07	6.35E-07
Black Tea	HGL	60	0.001248	0.002961	3.32E-08	7.87E-08	3.87E-07	9.18E-07
		80	0.001818	0.004314	7.46E-08	1.77E-07	5.15E-07	1.22E-06
	MT	60	0.001268	0.003009	1.38E-08	3.28E-08	4.44E-07	1.05E-06
		80	0.001457	0.003458	2.49E-08	5.9E-08	4.78E-07	1.13E-06
	LYT	60	0.000318	0.000755	8.29E-09	1.97E-08	6.74E-08	1.6E-07
		80	0.000463	0.001099	8.29E-09	1.97E-08	1.12E-07	2.66E-07
	TT	60	0.000421	0.000999	9.67E-09	2.3E-08	1.05E-07	2.49E-07
		80	0.000643	0.001525	1.11E-08	2.62E-08	1.8E-07	4.28E-07
	SBT	60	0.000753	0.001788	9.67E-09	2.3E-08	2.46E-07	5.84E-07
		80	0.000966	0.002291	2.07E-08	4.92E-08	2.98E-07	7.08E-07
Medicinal Tea	PCT	60	0.000193	0.000458	1.38E-09	3.28E-09	4.86E-08	1.15E-07
		80	0.000492	0.001166	2.76E-09	6.56E-09	1.59E-07	3.76E-07
	AMT	60	0.003006	0.007132	1.62E-07	3.84E-07	7.81E-07	1.85E-06
		80	0.002633	0.006249	5.39E-08	1.28E-07	9.15E-07	2.17E-06
	BHT	60	0.00106	0.002516	5.94E-08	1.41E-07	2.4E-07	5.69E-07
		80	0.000859	0.002038	4.15E-09	9.84E-09	2.95E-07	7.01E-07
	HHT	60	0.001118	0.002653	5.53E-09	1.31E-08	3.96E-07	9.39E-07
		80	0.001342	0.003183	5.11E-08	1.21E-07	3.82E-07	9.06E-07
	QT	60	0.000412	0.000978	1.38E-09	3.28E-09	1.26E-07	2.99E-07
		80	0.000905	0.002149	9.67E-09	2.3E-08	2.98E-07	7.08E-07
	MHT	60	0.000333	0.000791	6.91E-09	1.64E-08	8.33E-08	1.98E-07
		80	0.001513	0.003591	2.76E-09	6.56E-09	5.69E-07	1.35E-06

at 80°C, while CGT (1.98 mg/kg) and LYT (1.94 mg/kg) have the highest in Fe. These results show that green tea is more beneficial than both black and medicinal tea in terms of these micronutrients. The infusion concentration of these micronutrients is comparable to those of India and South Africa as reported by Karak et al. (2016) although slightly lower. The concentrations of both Cu and Zn were found to be below the FAO/WHO (2011) of Fe were above the specified limit of 0.8 mg/kg by the FAO/WHO standard (2011). The total metal components in tea plants depend on many factors, primarily the age of the tea leaves, but also the soil conditions, rainfall, altitude, genetic makeup of the plant, etc., and all these subsequently influence the metal concentrations in the infusion. The preparation method (infusion time, temperature, tea-water ratio) also has a great influence on the infusion concentrations as evident in the higher concentration of these metals at 80 over 60°C.

Noncarcinogenic and carcinogenic estimates of selected heavy metals

The noncarcinogenic procedure entails the initial calculation of chronic daily intake (CDI) which is shown in Table 3. The results obtained across all metals, groups of tea, and between the two temperatures were generally low for both adults and children. However, the total CDI for selected metals across all the groups of tea was higher for Cu, Zn, and Fe. This should not pose any concern because these elements are micronutrients and tea could therefore serve as a dietary compliment to their daily requirements (Atasoy et al., 2019; Jurowski et al., 2023). This is highest in Fe for children, followed by Fe in adults, then Cu, and Zn. The studied potential risk for the elements recorded as hazard quotient (HQ) is less than 1 across all elements and groups of tea for both adults and children (Table 4). Consequently, the HQ suggests an acceptable level of noncarcinogenic health risk for the selected tea groups from Nigeria. Total HQ for Pb is highest among the selected elements in children followed by Pb in adults. This presents a health concern because children are known to have a higher duodenal absorption rate and are more susceptible to Pb poisoning. A simiilar observation was observed for the total hazard index (THI) (Table 5) which is also higher for children in Pb for children than adults. This clearly suggests that children should be discouragedtable or exposure should be limited to the groups of tea under consideration in Nigeria. Potential health risk of elements can progressively manifest in risk of carcinogenic effects, since long term exposure to dangerous chemicals, including toxic elements could result in different kinds of cancer. The cancer risk of the toxic elements (Cd and Pb) measured as incremental lifetime cancer risk (ILCR) was less than 1×10^{-6} indicating there is no cancer health risk over lifetime consumption of the groups of tea for both adults and children. As with the CDI, HQ and HI, ILCR results were higher in Pb in children than in adults. This clearly shows that consumption of these tea groups should be minimal for children.

CONCLUSION AND RECOMMENDATION

The quality of tea depends on the quality of its infusion, primarily influenced by physicochemical parameters such as moisture content percentage, ash content percentage, pH value of the infusion, and most importantly, the type and species of cured tea. When comparing the physicochemical parameters of tea products available in Nigeria to the standards set by the International Standard Organization (ISO) and the Sri Lanka Tea Board (SLTB), it was found that they met the criteria for good quality. The percentage of moisture content for Green tea and Black tea indicates a longer shelf life in comparison to Medicinal tea. Additionally, the ash content for all tea brands was less than 8.0%, suggesting a low mineral content. All tea brands and groups generally have an infusion pH below 7.0, making them mildly acidic, contributing to their bitter taste, which is primarily dependent on the curing process.

The assessments of noncarcinogenic and carcinogenic potential risks from elements in the infused tea did not indicate any health risk to the public, both for adults and children. However, there is a relative risk for children, particularly concerning Pb. Therefore, it is recommended that children are not exposed to frequent consumption of all investigated tea types and groups.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Achudume AC, Owoeye D (2010). Quantitative assessment of heavy metals in some tea marketed in Nigeria. Health 2(9):1097-1100.

Adunola OE, Okunola TG (2016). Determination of Heavy Metals in Different Herbal Tea Samples Found in Lagos Nigeria. International Journal of Basic and Applied Chemical Sciences 6(2):75-78.

Afify AS, Abdalla AA, Elsayed A, Gamuhay B, Abu-Khadra AS, Hassan M, Ataalla M, Mohamed A (2017). Survey on the Moisture and Ash Contents in Agricultural Commodities in Al-Rass Governorate, Saudi Arabia in 2017. Assiut Journal of Agricultural Sciences 48(6):55-62.

Aljohani A, Alharbi S, Althobaiti R, Aljohani RA, Alnemari R, Arida HA (2023). Micronutrients' toxicity from causes to adverse effects: a review. International Journal of Medicine in Developing Countries 7(4):711-715.

Miletic A, Lučić M, Onjia A (2023). Exposure Factors in Health Risk Assessment of Heavy Metal(loid)s in Soil and Sediment. Metals 13(7):1266.

Aroyeun SO, Cordelia NJ, Okunade AF, Olalekan-Adeniran MA (2017). Evaluation of the ISO Quality (ISOQ) of 77 Imported Tea Clones (NGC 1-77) as Suitable Raw Materials for the Production of Black and Green tea in Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology 11(8):28-36.

Atasoy AD, Yesilnacar MI, Yildirim A, Atasoy AF (2019). Nutritional Minerals and Heavy Metals in Tea Infusions and Daily Intake of Human Body. Turkish Journal of Agriculture - Food Science and Technology 7(2):234-239.

Atta MI, Zehra SS, Dai DQ, Ali H, Naveed K, Ali I, Sarwar M, Ali B, Iqbal R, Bawazeer S, Abdel-Hameed UK and Ali I (2023) Amassing of heavy metals in soils, vegetables and crop plants irrigated with wastewater: Health risk assessment of heavy metals in Dera Ghazi Khan, Punjab, Pakistan. Frontiers in Plant Science 13:1080635.

Bentum JK, Anang M, Boadu KO, Koranteng-Addo EJ, Antwi EO. (2011). Assessment of Heavy Metals Pollution of Sediments from Fosu Lagoon in Ghana. Bulletin of the Chemical Society of Ethiopia

25(2):191-196.
Chen X, Singh A, Kitts DD (2020). In-vitro bioaccessibility and bioavailability of heavy metals in mineral clay complex used in natural health products. Scientific Reports 10(1):8823.
Chiang SH, Tsou MF, Chang CY, Chen CW (2020). Physicochemical characteristics, sensory quality, and antioxidant properties of Paochung tea infusion brewed in cold water. International Journal of Food Properties 23(1):1611-1623.
Dasharathy S, Arjunan S, Maliyur BA, Murugasen V, Ramachandran S, Keshav R, Murugan R (2022). Mutagenic, Carcinogenic, and Teratogenic Effect of Heavy Metals. In Murugan, R., Saravanan, R. and Ponnusamy, M. (Ed). Heavy Metal-Induced Toxicity, Complications and the Therapeutic Role of Natural Products. *Evidence-Based* Complementary and Alternative Medicine 2022(ID 8011953):11.
Dawodu MO, Obimakinde O, Samuel O (2013). Trace Metal Concentrations in Some Tea Leaves Consumed in Ibadan, Nigeria. African Journal of Agricultural Research (46):5771-5775.
Długaszek M, Kaszczuk M (2020). Assessment of the nutritional value of various teas infusions in terms of the macro- and trace elements content. Journal of Trace Elements in Medicine and Biology 59:126428.
Eze VC, Ndife CT, Muogbo MO (2021). Carcinogenic and Non-carcinogenic Health Risk Assessment of Heavy Metals in Njaba River, Imo State, Nigeria. Brazilian Journal of Analytical Chemistry 8(33):57-70.
Ezeunala M N, Izebe K, Aboh M, Ijele I, Ibekwe N, Ezaka E, Oladosu P, Adigwe PO (2022). The use of common and exotic teas in managing covid-19 related symptoms. Journal of Phytomedicine and Therapeutics 21(2):875-882.
FAO/WHO (2011). Joint FAO/WHO Food Standards Programme, Codex Alimentarius Commission, Thirty-Fourth Session Geneva, Switzerland, 4-9 July 2011: Report of the Fifth Session of the Codex Committee on Contaminants in Foods, Hague, Netherlands, 21-25 March 2011.
Ghinwa MN, Bohumil V (2009). Toxicity and Sources of Pb, Cd, Hg, Cr, As, and Radionuclides in the Environment, Heavy metals in the environment. In Wang, L, K, Wang, M-U, S, Hung, Y-T, Shammas, N. K, Chen, J. P. (Ed). Handbook of Advanced Industrial and Hazardous Wastes Management, 1st Edition, CRC press, Boca Raton, pp. 13-63.
Gramza-Michalowska A, Bajerska-Jarzebowska J (2007). Leaves of *Camellia sinensis*: Ordinary Brewing Plant or Super Antioxidant Source? Food 1(1):56-64.
Hu C, Zhang X, Zhan N, Liu Y (2023). Current Status and Health Risk Assessment of Heavy Metals Contamination in Tea across China. Toxics 11(8):662.
Jajere SM, Jidda D, Goni MD, Sadiq MA, Adamu SG, Mohammed S, Saleh AS, Malah M, Musa HI, Tijjani AO (2023). Health Risk Assessment of Heavy Metals in Imported Frozen Fish Sold in *Damaturu* and *Maiduguri* Fish Markets, Nigeria. Sahel Journal of Veterinary Sciences 20(3):38-45.
Jurowski K, Kondratowicz-Pietruszka E, Krośniak M (2023). The Control and Comprehensive Safety Assessment of Heavy Metal Impurities (As, Pb, and Cd) in Green Tea Camellia sinensis (L.) Samples (Infusions) Available in Poland. Biological Trace Element Research, pp. 1-10.
Karak T, Paul RK, Kutu FR, Mehra A, Khare P, Dutta AK, Bora K, Boruah RK (2016). Comparative Assessment of Copper, Iron, and Zinc Contents in Selected Indian (Assam) and South African (Thohoyandou) Tea (Camellia sinensis L.) Samples and Their Infusion: A Quest for Health Risks to Consumer. Biological Trace Element Research 175(475)-487.
Kumar MK, Kumar MK (2014). The Comparative Data between Various Brands of Tea Powders and Green Tea. International Journal of Pharmaceutical Sciences and Research 5(8):454-459.
Liao J, Cui X, Feng H, Yan S (2022). Environmental Background Values and Ecological Risk Assessment of Heavy Metals in Watershed Sediments: A Comparison of Assessment Methods. Water 14(1):51.
Mahurpawar M (2015) Effects of Heavy Metals on Human Health. International Journal of Research Granthaalayah 530(516):1-7.
Mendal S, Benjamin B, Kujovic L, Malencia M (2015). Spectroscopic Determination of Total Iron Content in Black Tea. Bulletin of Chemists and Technologists of Bosnia and Herzegovina 44(25):29-32.
Naveed S, Hameed A (2014) Consumption of Tea in Professionals and Non-professionals. SOJ Pharmacy and Pharmaceutical Sciences 1(3):1-4.
Nguyen QV, Chuyen HV (2020). Processing of Herbal Tea from Roselle (*Hibiscus sabdari*ffa L.): Effects of Drying Temperature and Brewing Conditions on Total Soluble Solid, Phenolic Content, Antioxidant Capacity and Sensory Quality. Beverages 6(1):2.
Olagunju TE, Olagunju AO, Akawu IH, Ugokwe CU (2020). Quantification and Risk Assessment of Heavy Metals in Groundwater and Soil of Residential Areas around Awotan Landfill, Ibadan, Southwest- Nigeria. Journal of Toxicology and Risk Assessment 6:033.
Pathaw N, Devi KS, Sapam R, Sanasam J, Monteshori S, Phurailatpam S, Devi HC, Chanu WT, Wangkhem B (2022). A comparative review on the anti-nutritional factors of herbal tea concoctions and their reduction strategies. Frontiers in Nutrition 9:988964..
Patrick-Iwuanyanwu KC, Udowelle NA (2017). Monitoring of essential and toxic metals in imported herbal teas marketed in selectedcities in Southern Nigeria: A health risk assessment study. Journal of Applied Sciences and Environmental Management 21(6):1189-1196..
Pojić M, Kravić S, Stojanović Z (2015). Analytical Methods for Determination of Moisture and Ash in Foodstuffs. In Nollet L.M.L and Todra (Ed). Handbook of Food Analysis-Two Volumes Set, 3rd Edition, CRC press, Boca Raton, 1568p.
Pourramezani F, Akrami MF, Salmani MH, Dehghani Tafti A, Khalili Sadrabad E (2019). Evaluation of heavy metal concentration in imported black teain Iran and consumer risk assessments. Food Science and Nutrition 7(12):4021-4026.
Punyasiri N (2011). Standards of Tea for Ensuring Market Requirement, Tea Research Institute of Sri Lanka, ISO 3720:34.
Rahman Z, Singh VP (2019). The relative impact of toxic heavy metals (THMs) (arsenic (As), cadmium (Cd), chromium (Cr) (VI), mercury (Hg), and lead (Pb)) on the total environment: an overview. Environmental Monitoring and Assessment 191(7):419.
Rao Y, Xiang B (2009). Determination of Total Ash and Acid-insoluble Ash of Chinese Herbal Medicine Prunellae Spica by Near Infrared Spectroscopy. The Pharmaceutical Society of Japan, Research 129(7):881-886.
Street R, Száková J, Drábek O, Mladkova L (2006). The Status of Micronutrients (Cu, Fe, Mn, Zn) in Tea and Tea Infusions in Selected Samples Imported to the Czech Republic. Czech Journal of Food Sciences 24(2):62.
Tomori WB (2019). Dietary Contributions of Cu, Fe and Zn from *Gallus gallus domesticus and Numida meleagris.* FUTA Journal of Research in Sciences 15(1):124-133.
Winiarska-Mieczan A (2018). Protective effect of tea against lead and cadmium-induced oxidative stress—a review. Biometals 31(6):909-926.
Zaharaddeen NG, Ubam S, Babando A. Galadima A (2015). Quantitative Assessment of Heavy Metals from Selected Tea Brands Marketed in Zaria, Nigeria. Journal of Physical Science 26(1):43-51.
Zhang H, Jiang Y, Lv Y, Pan J, Duan Y, Huang Y, Zhu Y, Zhang S, Geng K (2017). Effect of water quality on the main components in Fuding white tea infusions. Journal of Food Science and Technology 54:1206-1211.