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Quantitative Assessment of Heavy Metals from Selected Tea Brands Marketed in Zaria, Nigeria

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Abstract: *Six brands of tea comprising two locally processed teas, two imported teas, one unprocessed tea and one herbal tea (coded as LIT, AKT, AHT, GET, UNT and HBT, respectively) were obtained and analysed for their heavy metal concentrations. The tea samples were coded to conceal the original source. The analysed metals were zinc (Zn), lead (Pb), cadmium (Cd) and iron (Fe), and the results were compared with both World Health Organization (WHO) and European Union (EU) standards. The obtained concentrations of Zn, Pb, Cd and Fe were 2.322–3.460 mg l^{-1}, 0.03–0.266 mg l^{-1}, 0.025–0.042 mg l^{-1} and 0.15–0.876 mg l^{-1}, respectively. Generally, the levels of metal content in all brands were comparable with the values set by both the WHO and EU except for Fe and Pb, where the concentrations were slightly higher in some samples. The variations in heavy metal concentrations of the tea brands were attributed to geographical changes, seasonal changes and chemical characteristics of the growing regions.*

Keywords: Tea brands, heavy metal concentration, tea infusion, atomic absorption spectrometry, *Camellia sinensis*

1. INTRODUCTION

Tea is one of the most popular beverages in the world after water and is prepared from the leaves of the shrub *Camellia sinensis*. It is an aromatic beverage that is commonly prepared by pouring hot or boiled water over cured leaves of the tea plant. Tea is also an infusion of the dried leaves of *Camellia sinensis*, a member of the Theacea family, in water.[1,2]

Tea can generally be divided into categories based on the way it is processed. Some varieties include yellow, green, Oolong (or wulang), black (called red tea in China) and post-fermented tea (or black tea for the Chinese). Green and black teas are the most popular types of tea.[3] Green tea is produced by drying and steaming the leaves, whereas black tea is obtained after a fermentation process.

Catechins, which are a type of antioxidant, and the amino acid L-theanine, which modulates the psychoactive effect of caffeine, are present in tea and contribute to its taste.[4] Tea is rich in polyphenolic compounds. These compounds also present in red wine, fruit and vegetables. Theaflavins (antioxidant polyphenols that are formed from the condensation of flavan-3-ols in tea) also contribute to the tea taste.[4]

Considering that approximately 18–20 billion tea cups are consumed daily worldwide,[2,5] its economic and social importance are unprecedented. Tea is also valuable in the treatment and prevention of many diseases.[2] Moreover, tea is known to eradicate fatigue, stimulate mental powers and elevate energy levels. Although tea contains caffeine, the amount of caffeine is far less than that in coffee and therefore produces a milder and more beneficial effect. Tea also acts as a nerve sedative, which frequently relieves headaches.

Many elements that are present in food at major, minor and trace levels are reported to be essential to human well-being; however, the excessive ingestion of these elements can cause severe health problems.[6] The optimum concentration required for this purpose widely varies depending on the type of element and the age and sex of the consumers.[7] The human body requires both metallic and non-metallic elements for healthy growth, development and proper functioning. Thus, the determination of these elements in beverages, water, food, plant and soil is of utmost importance and is currently the subject of studies by various researchers.[8] The study of trace elements in tea is notably vital because these elements play important roles in the complex metabolic pathways in the human system, and their deficiencies or excesses may cause diseases.[3]

Heavy metals can generally be introduced into the environment and consequently, living organisms through air, water, food or soil.[9,10] However, the degree of their concentrations depends on the type of heavy metals and the activities that occur in a particular area.[11]

Several attempts have been made by many researchers to assess the quality of tea using chemical analysis. Metallic constituents of tea leaves are usually different according to the type of tea (green or black) and geographical sources.[2,12] Sahito et al. reported the contents of 15 essential trace and toxic elements in some green tea samples and their infusion.[13] Karimi et al. worked on the concentrations and health risks of metals in tea samples that were marketed in Iran.[14] Tea can be contaminated with heavy metals during the growth period and manufacturing processes, which may increase the metal burden in the human body. Depending on the origin of the tea leaves, heavy metals can naturally accumulate because of soil contaminants, pesticides and fertilisers. The main sources of heavy metals in plants are their growth media, nutrients, agro inputs and soil.[15]

This paper aims to determine the elemental composition of different brands of tea in Zaria markets in Nigeria and to compare the result with the standard and available literature to provide both researchers and consumers with information on the mineral contents of different tea brands.

2. EXPERIMENTAL

All solvents and reagents were of analytical grade. Distilled water was used as the solvent to prepare the solution, and all glassware was washed, cleaned and dried.

2.1 Sample Collection and Preparation

Several commonly consumed tea samples were randomly procured from local retail outlets in Zaria, Kaduna state. Six brands of tea, which comprised two locally processed teas, two imported processed teas, one unprocessed tea and one herbal tea, were coded as LIT, AKT, AHT, GET, UNT and HBT, respectively, obtained and packed in a transparent paper bag. The tea samples were coded to conceal the original source.

2.2 Preparation of Tea Infusion

Exactly 2 g of each tea sample was added to 100 ml of boiling water. The mixture was left to cool at room temperature for 10 min and subsequently filtered to obtain a clear solution for further processing. Each tea sample was infused in hot water for 5 and 10 min. The pH values of all tea infusions were potentiometrically determined.

2.3 Sample Analysis

The total metal contents were determined by digesting 1 g of tea sample in 12 ml of a mixture (3:1 v/v) of concentrated HNO_3 and $HClO_4$. The mixture was heated until the solution turned white. The digested sample was filtered and transferred to a 100 ml flask, and the volume was adjusted to the mark with 5% HNO_3 acid. This digestion procedure was validated using the reference certified material of the National Agency for Food and Drug Administration and Control (NAFDAC).[15]A flame atomic absorption spectrometer (FAAS Perkin Elmer Analyst 350) was used to quantify the heavy metal concentrations.[16] The calibration standard curves provided the basis to quantify the metal contents.

3. RESULTS AND DISCUSSION

The results of the 6 different tea brand samples that were heated for 5 and 10 min are as follows:

3.1 pH of the Tea Samples

Table 1: pH of the 6 tea samples.

Tea samples	pH of tea	
	5 min	10 min
LIT	5.373 ± 0.02	5.412 ± 0.01
AKT	5.350 ± 0.01	5.383 ± 0.01
AHT	5.320 ± 0.01	5.370 ± 0.01
HBT	5.504 ± 0.02	5.581 ± 0.01
GET	5.181 ± 0.01	5.222 ± 0.01
UNT	6.302 ± 0.01	5.930 ± 0.01

Note: The results were reported as mean ± standard deviation.

Table 1 shows that UNT has the highest pH at both 5 and 10 min. From the correlation table, the analysis of variance (ANOVA) of pH in all 6 samples is significantly different, except the 2 pairs AHT and AKT and LIT and AKT at 5 min. There is also a significant difference between all samples except LIT and AHT at 10 min of boiling time. All pH values are less than 7.0.

3.2 Zinc (Zn)

Table 2: Zn content in the 6 tea brands.

Tea samples	Conc. of Zn (mg l^{-1})	
	5 min	10 min
LIT	2.950 ± 0.02	3.362 ± 0.01
AKT	2.520 ± 0.01	3.254 ± 0.58
AHT	2.322 ± 0.58	3.460 ± 0.06
HBT	3.026 ± 0.06	2.590 ± 0.06
UNT	2.340 ± 0.10	2.791 ± 0.06
GET	2.581 ± 0.06	2.711 ± 0.58

Note: The results were reported as mean ± standard deviation.

Table 2 shows that the tea samples that were infused for 10 min of boiling time have higher zinc (Zn) concentration than those that were infused for 5 min of boiling time for all tea samples except HBT. As an essential trace element, Zn plays an important role in various cell processes such as growth, brain development and part of the tooth, muscle and bone formation.[17] Zn supplementation reduces the duration of malaria and respiratory infections. Zn deficiency may also limit the effectiveness of vitamin A supplementation and cause loss of sense of touch and smell.[18] Zn is an essential trace element, and its content in tea infusions is within the permissible limit of WHO.[8] Therefore, it cannot be considered a threat.

3.3 Lead (Pb)

Table 3: Pb content in the 6 brands of tea.

Tea samples	Conc. of Pb (mg l^{-1})	
	5 min	10 min
LIT	0.099 ± 0.10	0.106 ± 0.00
AKT	0.118 ± 0.10	0.030 ± 0.06
AHT	0.068 ± 0.06	0.049 ±0.10
HBT	0.179 ± 0.10	0.266 ±0.06
GET	0.008 ± 0.06	0.036 ± 0.10
UNT	0.097 ± 0.10	0.069 ± 0.06

Note: The results were reported as mean ± standard deviation.

Table 3 shows that the samples show certain variations when the boiling time increases. The concentrations may change because of the intake level of lead (Pb) by various tea plants. However, those with sparingly low Pb concentrations are advisable for intake. The main source of Pb in tea samples can be their growth media such as soil. Tea plant is normally grown in high acidic soils, where Pb is more available for root uptake.[19] Pb is required in small amounts in the body. Pb that enters the respiratory and digestive systems is released to the blood, and more than 90% of Pb is accumulated in the bones, where it is stored and distributes itself to the body. Pb induces various toxic effects in humans at low doses with typical symptoms such as brain damage, anaemia, headache, convulsions and central-nervous-system disorders. It is particularly toxic to children because it causes potential permanent behaviour disorders in them.

Table 4 shows that the cadmium (Cd) concentration decreases when the boiling time increases for all tea samples except AKT and UNT, whose Cd concentration increases with increased boiling time. It can be assumed that Cd was first released and subsequently precipitated. Cd enters the blood stream when Cd-contaminated food or water is consumed, which can cause various harmful health effects such as severe irritation, vomiting, diarrhoea, lung damage and death. The U.S. Department of Health and Human Services determines that Cd and certain Cd-based compounds are probable or suspected carcinogens (substances that cause cancer). Therefore, it is advisable to drink tea with low Cd concentration.[8] The Cd present in the body from our diet is approximately 0.0004 mg per kg per day, which is approximately 10 times lower than the cadmium level that causes kidney damage from eating contaminated food.

3.4 Cadmium (Cd)

Table 4: Cd content in the 6 brands of tea.

Tea samples	Conc. of Cd (mg l^{-1})	
	5 min	10 min
LIT	0.036 ± 0.10	0.032 ± 0.58
AHT	0.034 ± 0.06	0.032 ± 0.10
AKT	0.031 ± 0.06	0.036 ± 0.06
HBT	0.027 ± 0.58	0.025 ± 0.06
GET	0.033 ± 0.01	0.030 ± 0.06
UNT	0.039 ± 0.10	0.042 ± 0.58

Note: The results were reported as mean ± standard deviation.

3.5 Iron (Fe)

Table 5: Fe content in the 6 tea samples.

Tea samples	Conc. of Fe (mg l^{-1})	
	5 min	10 min
LIT	0.759 ± 0.01	0.806 ± 0.01
AKT	0.558 ± 0.44	0.867 ± 0.46
AHT	0.626 ± 0.10	0.740 ± 0.01
GET	0.640 ± 0.01	0.633 ± 0.01
HBT	0.174 ± 0.01	0.159 ± 0.06
UNT	0.865 ± 0.01	0.876 ± 0.01

Note: The results were reported as mean ± standard deviation.

Table 5 shows that the iron (Fe) concentration increases when the boiling time increases, except HBT and GET, where it can be assumed that Fe is first released and subsequently probably precipitated. Although HBT has the highest iron concentration at both 5 and 10 min, which implies that HBT tea plants absorb more iron than other teas. Fe is an integral part of many proteins and enzymes that maintain good health, regulate cell growth and differentiation,[21] are involved in oxygen transport and facilitate the oxidation of carbohydrates, protein and fat to control the body weight, which is a notably important factor in diabetes. Excessive tea drinking should be avoided by anaemia-prone people.[21]

The dietary limit of Fe in food is 10–60 mg per day,[8,22] whereas its low amount causes gastrointestinal infection, nose bleeding and myocardial infarction.[18] If tea is not consumed until 1 h after eating, the inhibitory effect is significantly reduced.[23] Therefore, it is recommended that individuals with a high prevalence of Fe deficiency drink tea between meals and wait at least 1 h after eating before drinking tea.[24,25]

The tea samples that were analysed for heavy-metal concentrations of Zn, Pb, Cd and Fe from Saudi Arabia and Turkey were reported to be safe for human consumption.[26,27]

Table 6: Comparative table for WHO/EU drinking water standards.[8]

Tea samples	WHO standard in mg l^{-1}	EU standard in mg l^{-1}
Zn	3.000	Not mentioned
Pb	0.010	0.010
Cd	0.003	0.005
Fe	No guideline	0.200

4. CONCLUSION

The results of the concentrations of the studied heavy metals (Zn, Fe, Cd and Pb) in the tea samples show that the heavy-metal concentrations widely vary among different tea brands and types. The heavy-metal concentrations in all tea samples are comparable with both WHO and EU standards except for Pb, whose concentration is slightly higher than both WHO and EU standards. However, the levels of these metals call for serious concern because they may accrue and persist over time, particularly considering the rate by which people in Nigeria consume these types of tea.

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