Vol.2, No.9, 1097-1100 (2010)
doi:10.4236/health.2010.29162

Quantitative assessment of heavy metals in some tea marketed in Nigeria

——Bioaccumulation of heavy metals in tea

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Received 12 March 2010; revised 18 May 2010; accepted 4 June 2010.

ABSTRACT

Bioaccumulation of heavy metals in tea marketed in Nigeria was investigated. Four major and most consumed brand of tea were selected for the present study. Both aqueous and dry methods were used. Total contents of metal were determined by digesting 1g of each brand using a mixture (3:1) concentrated nitric acid (NNO_3) and hypochlorous acid ($HCLO_4$). The second method involved hot water extract of tea samples. After boiling and filtration, the residue was evaporated to near dryness and digested with concentrated HNO_3 and $HCLO_4$ as described above. Results indicate that Zn, Cd, Cu, and Pb were present in lowest concentrations in ascending order for which there were two significant differences between the four sources of samples. The general characteristics of heavy metal concentrations in aqueous extract showed high level of Fe and Mg in a descending order. Going by the correlation study of our result indicates that there is no significant relationship between the two elements of Fe and Mg, though, the numerical values of the two elements varied widely among the samples. These differences may have major impact on human health. However, the beneficial effects of tea are in a fairly narrow concentration range between the essential and the toxic level. In conclusion, the variations in heavy metals content of tea brands may be due to geographical, seasonal changes and the chemical characteristics of the growing regions.

Keywords: Bioaccumulation; Tea; Heavy Metals; Human Health; Toxic Level

1. INTRODUCTION

Exposure to various metal containing components of tea varied widely and may have varying health implications [1]. Depending on the origin of tea leaves, heavy metals accumulation can be derived naturally by soil contamination, use of pesticides and fertilizers [2]. Some trace metals Cr, Fe, Co, Ni, and Zn are essential for growth of organisms, while other heavy metals Pb, Cd, Hg and As are not only biologically non essential, but toxic [3]. A very important biological property of metals is their tendency to bioaccumulations. Bioaccumulation is therefore essential in hazard evaluation strategies. For example, calculation of percent available of Aluminum (Al) and Zinc (Zn) in tea consumed by human showed that tea can provide 37.2% of the daily dietary intake of Al, the percent available for absorption in the intestine is only 1.78% for overall mean concentration [4]. Similarly, daily dietary intake of Zn was 2.13% while percentage available for absorption in the intestine was 0.72% [5]. Thus chronic metal toxicity may often characterized by tissue/organ damage resulting in mortalities which are related to secondary physiological disturbances [5,6]. The extent of physiological disturbances depends upon uptake and bioaccumulation of metals [3,7].

Considering that an estimated amount of 18 billion teacups are consumed daily in the world [1,8,9] its economic and social importance are unprecedented. In Nigeria, people drink tea by the bowl because of its therapeutic value. It is valuable in the treatment and prevention of many diseases [8].

The presence of heavy metals in tea has become world-wide study. For example, the concentrations of Fe and Cu in Poland [10], Cu in India and US [9], Se in Pakistan [11], As in Iran [2,12], Al in China [13] and in Lithuania [14] have recently become the subject of wide spread concern, since beyond the tolerable limits they become toxic [15,16]. Determination of harmful and toxic heavy metals in different tea marketed in Nigeria gives direct information on the significance of these elements in tea beverages. Lack of basal data on the contents of heavy metals in tea and the regulated on the maximum allowable and safe concentration of metal in tea are needed. This predicated the present study to determine the quantitative assessment of heavy metal contaminants in some popular tea marketed in Nigeria.

2. MATERIALS AND METHODS

Several samples of tea leaves which are commonly consumed in Nigeria were procured from provisional stores. Accordingly each sample tea was coded to conceal the original source. The code is tagged by a letter designating the type of tea, that is black tea-Lip; green tea-Gin; white tea-Tia and Top. Three replicate samples of each tea were quantified using two different standard methods of [11,17].

Total contents of metals were determined by having a portion of one g of sample tea digested in 12 mL of a mixture (3:1 v/v) concentrated HNO_3 and $HClO_4$. The mixture was heated until the solution turned white. The digested sample was filtered and transferred to a 100ml flask and the volume was adjusted to the mark with 5% HNO_3 acid. This digestion procedure was validated by using the reference certified material of National Agency for Food and Drug Administration and Control (NAFDAC) [18].

Hot water extract of metals were determined by having a portion of one g of each brand boiled in 50 ml of distilled water for 10min in a porcelain cup and filtered. The residue was evaporated to near dryness and digested with concentrated HNO_3 as described earlier. The final volume of the solution was made up to 100 ml. Following digestion, ten drops of H_2O_2 were added and centrifuged. The acid digested sediments were filtered and capped.

A Perkin Elmer Analyst 300 flame atomic absorption spectrometer (AAS) (Central Science laboratory, Obafemi Awolowo University, Ile-Ife) was used to quantify the heavy metal concentrations [19]. Calibration standard curves provided the basis for quantifying metal contents for both sediments and plant tissues after the initial ashing digestion. Correlation coefficients for metals in plant tissues and sediments were found to be 99.59% and 99.54% respectively. Calibration curves, developed using standards, provided the basis for quantifying metals concentrations for analysis of plants tissues and sediments using both the dry and wet analysis techniques.

The data were statistically analyzed and the least significant differences (SD) at the 5% level used to separate means. The relationship between the different variables was elevated by a simple correlation and regression analysis [20].

3. RESULTS AND DISCUSSION

Results of the present study show the actual concentration of heavy metals in tea samples after digestion (**Table 1**). The metals present in lowest concentration (< 1.00 mg/kg) were Zn, Cd, Cu, and Pb in ascending order respectively, for which there were two significant differences between the four sources of samples. The sources differ with regard to Se and Fe contents, but similar with respect to Cu, Pb, and Zn and more substantially with respect to Fe and Mg with total metal content in Gin samples about double the other samples.

Table 2 shows the general characteristics of metal concentrations transferred to hot water extracts from brand of teas. The metals present in greatest concentration were Fe (442-1344 mg/kg), followed closely by Mg (123-239 mg/kg) and highly toxic element Cu (2-7 mg/kg). Except for Pb, all these metals are release very slowly from tea leaves because they are complexed by porphyrins [21]. The mean SD values of all determined heavy metals for the group of tea are indicated in the Tables. Going by the performed t-test the concentrations of heavy metals were not significantly different ($P > 0.05$). The numerical values of heavy metals concentrations of Fe and Mg contents varied widely among the samples. From the regression plot, it can be inferred that since the significant value is 0.414 which is far higher than 0.05 and the R and R square values are 0.586 and 0.344 respectively, that there is no significant relationship between the two elements (**Figure 1**). According to correlation study between heavy metals Fe-Mg, and Cd-Cu showed no significant relationship in all the tea samples, otherwise, the differences can have major impact on staying healthy. The excessive heat in tea boiling for example can alter the natural chemical nature of these metals.

The result of total contents of the studied heavy metals (As, Se, Zn, Fe, Mg, Cd,, Cu, Pb) in these teas compared to tea grown in other countries showed accumulation of different heavy metals, for example, studies have shown that Cu in Iranian, Lithuanian and Chinese tea [12-14] respectively, K in Pakistanis [1] and Pb in Tunisian tea [22] bioaccumulations. It goes to show the ability of these plants in accumulating metals. Other studies showed accumulation of Al [23] and Fe [10] in tea leaves. However, in the present study, Fe and Mg complexes are higher than other metals in tea marketed in Nigeria and may be due to high metal levels in the geographical locations and more to preferential absorption of these metals. The percent solubility of Fe and Mg revealed these are in form of least water soluble complexes.

From all indications, differentiation of metal contents

Table 1. Total (mean ± SD) contents of heavy metals in tea samples.

Samples	metal ions							
	As	Cd	Cu	Fe	Mg	Pb	Se	Zn
Lip	1.48 ± 0.01	0.01 ± 0.00	0.12 ± 0.02	2.39 ± 0.22	5.22 ± 2.54	0.03 ± 0.00	0.52 ± 0.01	0.02 ± 0.01
Tia	2.73 ± 0.01	0.31 ± 0.01	0.31 ± 0.04	0.99 ± 0.10	4.06 ± 2.16	0.13 ± 0.01	1.53 ± 0.01	0.01 ± 0.01
Top	1.48 ± 0.01	0.02 ± 0.02	0.12 ± 0.02	2.23 ± 0.21	2.31 ± 1.47	0.33 ± 0.02	3.21 ± 0.01	0.01 ± 0.00
Gin	3.17 ± 0.01	0.39 ± 0.01	0.34 ± 0.05	0.99 ± 0.10	2.96 ± 1.75	0.27 ± 0.02	3.26 ± 0.09	0.02 ± 0.01
Mean ± SD	2.22 ± 0.01	0.12 ± 0.01	0.22 ± 0.03	1.65 ± 0.16	3.64 ± 1.98	0.19 ± 0.02	2.13 ± 0.03	0.02 ± 0.01

All the values are in mg/L

Table 2. Mean (± SD) heavy metals contents in tea aqueous extract.

Samples	As	Cd	Cu	Fe	Mg	Pb	Se	Zn
Lip	1.65 ± 1.60	0.37 ± 0.01	4.15 ± 0.09	1716.6 ± 186.15*	244.56 ± 10.07	00 ± 0.07	0.00 ± 0.32	0.80 ± 0.4
Tia	2.3 ± 0.20	7.92 ± 0.73	5.69 ± 0.09	442.95 ± 8.25	123.54 ± 10.92	0.06 ± 0.08	0.00 ± 0.95	0.03 ± 0.04
Top	1.20 ± 0.00	0.31 ± 0.01	2.33 ± 0.71	1551.20 ± 159.15*	221.59 ± 10.36	0.11 ± 0	10.39 ± 0.16	0.12 ± 0.01
Gin	0.30 ± 0	2.41 ± 0.02	3.95 ± 0.54	591.95 ± 27.15	41.10 ± 0.72	00 ± 0.02	11.09 ± 0.29	0.12 ± 0.01
Mean ± SD	1.36 ± 0.83	2.75 ± 0.19	4.03 ± 0.36	975.68 ± 95.16	157.77 ± 8.10	0.09 ± 0.57	10.74 ± 0.43	0.28 ± 0.23

*Significantly different from the rest tea $p < 0.001$; All the values are in mg/L

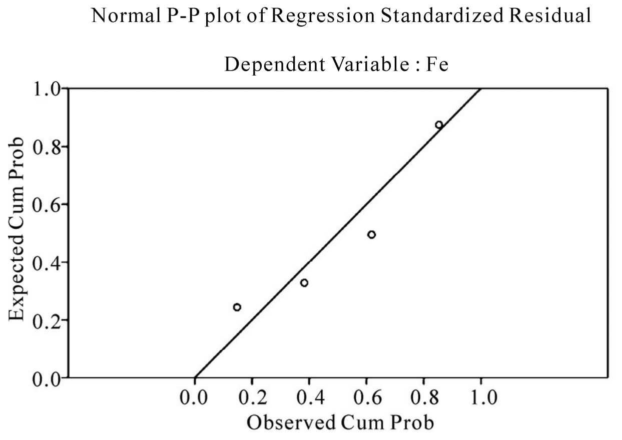

Figure 1. Showing regression table of Mg as constant and Fe as dependent variable.

in variety of tea brand may be due to their geographical origin [21], due in part to leachate characteristic of soil. Long-term plantation of tea can cause soil acidification and elevated concentrations of bioavailable heavy metals in the soil, therefore, enhance the risk of heavy metals accumulation in tea leaves. The variations in the present study might be due to different agro-climatic origins of the imported tea. Although toxic effects of heavy metals have sufficiently being described by WHO 1998a [24], however, the beneficial effects of tea is in a fairly narrow concentration range between the essential and the toxic level [12]. The tea aqueous extracts have considerable amounts of metals ions that could contribute towards daily intake, but these values are lower than the daily requirements of human being (WHO 1998b) [25]. The determination of these elements in beverages, water, food, plant and soil is thus of outermost important tasks. One of the major food sources of these metals is green leafy vegetable [26]. It is equally recommended that aqueous extracts be routinely consumed for the essential nutrients. Routine check and frequent analysis of tea in Nigeria and elsewhere is required to avoid the risk of exceeding the daily in-take beyond the tolerance limits standards.

In conclusion, the geographical variations in heavy metal concentrations among the tea samples were evident in all the brands. At the same time, we found significant differences in the percent solubility of Fe and Mg in all water soluble complexes. Some authors have noted some differences between the metal concentrations in other tea brands. The wide variations of metal concentrations observed could be due to seasonal changes and to the chemical-physical characteristics of the growing regions.

The authors herewith state that there are no conflicts of interest and the present study was not funded nor receive any grant from funding agency.

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