

Bioaccumulation of Aluminum in Dry Tea Leaves and Health Risks Associated with its Consumption by an Urban Populace in Port Harcourt Metropolis, Rivers State, Nigeria

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Abstract

The concentration of aluminum in two brands of dry tea leaves and health risk assessment associated with its consumption was determined using standard methods. The dry tea leaves was Purchased from livinchu supermarket along Adageorge road in the heart of Port Harcourt metropolis, Rivers State, Nigeria, and brought to the laboratory of School of Pharmaceutical Technology, Department of Pharmacy Technician. The leaves were removed from their pouches and transferred into sample bottles, followed by acid digestion and an aspiration of an aliquot of the digested solution into an Agilent 42100 MP-AES machine to determine the residual aluminum content of the various teas, which was subsequently used to estimate the health risk associated with its consumption. Results showed that all the teas studied contained aluminum at varied concentrations with green tea containing moringa and strong black tea for men having values above 1000mg/kg while the rest had values less than 1000mg/kg. The result has clearly shown that green tea with moringa and black strong tea for men are hyperaccumulators of aluminum from soils than others, which can used for phytoremediation of aluminum contaminated soil. It also suggests that consumption of dry tea leaves is a major source of dietary exposed to aluminum in humans. Health risks assessment indicators depicted that all ADIs and HQs were less than unity ($ADD < 1$ and HRI or $HQ < 1$), and implies that there is no possibility of contracting non-cancerous disease that would have caused undue health issues of public health interest via consumption.

Keywords: bioaccumulation, aluminum, dry tea leaves, health risks, consumption

Introduction

Tea is produced from dry leaves of the shrub called *Camellia Sinensis*. The tea plant is perennial and once planted can last over 100 years under good agronomic and cultural practices (Owuor et al., 2008). Its cultivation is restricted to certain areas like tropical regions and mountainous areas of the tropics, where altitudes are in the range of 1200-1800 m above sea level with temperature regimes of 10-27°C without frost. This explains why tea plants can only thrive well at very few locations in West Africa, China, Iran etc. (Asogwa, 2007).

In Nigeria, tea is only grown in Mambilla Plateau which was introduced to Nigeria from Kenya in 1972 by the Nigerian Beverage Production Company (NBPC). Ten years later, breeding started with the acquisition of 33 clones by the Cocoa Research Institute of Nigeria from NBPC. Today, tea production is a great contributor to the national economies of some African countries like Cameroon, Kenya, Malawi, Tanzania and most Asian countries like China and Iran (Omolaja & Esan, 2005).

Currently, global tea production comprises about 78% black tea, 20% green tea and 2% Oolong tea (FAO, 2008). Most of these teas are very popular alcohol-free and caffeinated beverages consumed all over the world (Cacera et al., 2001; Saud & Al-oud, 2003; Chen et al., 2007; Yao et al., 2008). However, in Nigeria, tea production has not been sufficient to meet up the demand from processing companies. Tea has both pharmaceutical and numerous health benefits when taken at the prescribed quantity because of its intrinsic properties. Despite these health benefits from tea consumption, research has shown that tea also carries some potential health risks factors which may pose a threat to the health of tea consumers, due to the accumulation of high levels of certain heavy metals and other metals like aluminum (Dogru et al., 2011; Ma et al., 2016). This idea was supported by various researchers who reported that aluminum is involved in certain diseases like Alzheimer's disease, Parkinson's disease, dialysis encephalopathy etc (Qin & Chen, 2007; Dogra et al., 2011; Kolachi et al., 2011; Deghesele et al., 2013).

Furthermore, aluminum is very toxic and has a direct effect on living organisms and there is a paucity of information regarding aluminum levels in tea leaves consumed as beverages. It is, therefore, pertinent to investigate aluminum levels in some selected tea leaves consumed in Port Harcourt metropolis since there is a paucity of information in this regard.

2.0: Materials and Methods

2.1: Collection of Materials

Two types of tea leaves namely, green and black tea which are mostly consumed and sold in Port-Harcourt metropolis were chosen and bought at livinchu supermarket along Ada George road and brought to the school of pharmaceutical technology, Rivers State College of Health Science and Management Technology, Port Harcourt Rivers State Nigeria. The tea brands consisted of three brands of green tea namely, green tea with moringa (GM), green tea with mint (G+M), green tea with lemon lime (G+Li+Le) and two brands of black tea namely, strong black tea for men and black tea Chinese respectively. Port-Harcourt is located at ..

2.2: Preparation of Dry Tea Leaves Materials

The tea leaves were prepared in two batches using single and composite samples (four pouches). To prepare the composite sample, four pouches of each brand of tea were bulked together and homogenized to form a representative sample and transferred into separate sample bottles for both green and black tea leaves. For the single batch, a single pouch of all the brands of tea leaves was torn open and the dry leave was transferred into a sample bottle for each. All the obtained samples were then stored for analytical purposes.

2.3: Acid Digestion Method

The method of Patrick-Iwuanyanwu and Chioma (2017) was used. A total of 100mL of H₂SO₄, HNO₃ and HClO₄ in the ratio of 40%:40%:20% were mixed. A portion of 1g of each sample of tea leaves was weighed and accurately digested with 2mL of the mixed acid on each sample in a Kjeldahl flask. Each sample was then digested in a fume cupboard with a hot plate until white fumes appeared. After that, the solution was then allowed to cool, filtered and transferred into a 100mL volumetric flask and made up to mark with distilled water, and an aliquot aspirated into the MP-AES Agilent 42100 machine to determine the amount of residual aluminum present in the sample at 319nm wave length.

2.4: Calculation of Health Risks Assessment

To assess the possible health risk that may be associated with the consumption of dry tea leaves, the average daily intake dose (ADI) and the health risks index or hazard quotient was determined using the appropriate formula:

$$ADD = \frac{C_{\text{metal}} \times C_{\text{factor}} \times IR}{BW} \dots \text{Equation 1 (Qaiyum et al., 2011; Peng et al., 2016).}$$

Where, C_{metal} = Al concentration in dry tea leaves (mg/kg, DW), C_{Factor} = the conversion factor, and IR = the daily intake of dry tea leaves which is 11.4g/person/day (Peng et al., 2016), and BW is the average body weight for Nigerian consumer which is 60kg for adult (Tsafé et al., 2012). The conversion factor of 0.085 was used to convert fresh tea leaves for adults.

$$HRI \text{ or } HQ = \frac{ADI}{RfD} \dots \text{Equation 2 (Charry et al., 2008; Jan et al., 2010; USEPA, 2013; Peng et al., 2016)}$$

This parameter was estimated as the ratio of the average daily intake dose (ADI) of aluminum (Al) to the daily intake oral reference dose (RfD) for aluminum (Al). The daily intake reference dose for Al was taken as 7mg/kg/day (FAO/WHO, 1989). Furthermore, the level or extent of health hazard or risk was determined as a ratio of HRI to RfD where if $\frac{HRI}{RfD} =$ or $<$

RfD: minimum risk; $\frac{HRI}{RfD} > 1$ to 5 times RfD: Low risk, $\frac{HRI}{RfD} > 5$ to 10 times RfD: Moderate risk; $\frac{HRI}{RfD} > 10$ times $>$ RfD: High risk (NYSDOH, 2007).

3.0: Results and Discussion

3.1: Results

The summary of the result of aluminum concentrations in all the dry tea leaves and their composite is displayed in Table 1 and Table 2 respectively. The result shows that the aluminum concentration in the various tea leaves differed and ranged between 22.918 mg/kg (green tea with mint) as the least and 3580.400mg/kg (Green tea with moringa) as the highest, while green tea with lemon and lime which contained ascorbic acid has an intermediate concentration of 24.903mg/kg respectively. Again, in black tea leaves, the aluminum concentration ranged between 15.394mg/kg as the least and 5231.544mg/kg as the highest in strong black tea for men.

Table 1: Summary of Aluminum Content in the Selected Tea Leaves Consumed in Port-Harcourt Metropolis

Tea Name	Code	Method	Wave Length (nm)	Aluminum Content per Pouch of Tea Leave (Mg/kg)
Green Tea with Moringa	GT+MO	EPA 3030B	319	3580.400
Green Tea With Mint	GT+MT	EPA 3030B	319	22.918
Green Tea with Lemon and Lime (Slimming Tea).	G+Le+Li	EPA 3030B	319	24.904
Strong Black Tea for Men	SBT	EPA 3030B	319	5231.544
Black Tea Chines	BT	EPA 3030B	319	15.394

Source: Researcher’s Field Work, 2023

Furthermore, a comparison of the aluminum concentration of single and composite pouches revealed that the aluminum concentration increased from 3580.400mg/kg (single pouch) to 4946.638mg/kg (composite pouches) in the dry leaves of green tea, while that of black tea increased from 5231.544mg/kg (single pouch) to 5826.851mg/kg (4 pouches). This trend was applicable to all the brands studied as depicted by Table 2, thus, suggesting that taking more than 2g (single pouch of dry tea leaves) increases the amount of Al to be ingested.

Table 2: Comparison of Aluminum Content in Single and Composite Samples of Dry Leaves of Green Tea with Moringa and Strong Black Tea for Men

Tea Name	Method	Wave Length (nm)	Aluminum Content per Pouch of Tea Leave (Mg/kg)	Aluminum Content 4 Pouches of Tea Leave (Mg/kg)
Green Tea with Moringa	EPA 3030B	319	3580.400	4946.638
Green Tea + Lemon + Lime	EPA 3030B	319	24.904	49.26
Green tea + Mint	EPA 3030B	319	22.918	46.99
Strong Black Tea for Men	EPA 3030B	319	5231.544	5826.851
Black ChineseTea	EPA 3030B	319	15.934	24.42

Source: Researcher's Field Work, 2023

3.2: Discussion

3.2.1: Bioaccumulation of Aluminum by Dry Tea Leaves

The result of this study (Table 1) is in agreement and has also confirmed the result of several independent researchers that most dry tea leaves contained aluminum in their matrix (Ruan & Wong, 2001; Moghaddan et al., 2008; Barcena – Padilla, 2010; Barcena – padilla et al., 2011). This is in agreement with literature data reported by the aforementioned researchers and implies that tea consumption is a potential source of bioavailable aluminum in the diet (Steinhausen et al., 2004; Yokel & Florence, 2008). Furthermore, the aluminum concentration in green and black tea leaves is at variance with the result obtained by Ruan and Wong (2001) who reported concentrations between 468mg/kg and 930mg/kg in their study. However, their values are not higher than that in green tea with moringa and strong black tea for men and their composites (Table 2). In another study, Moghaddan et al., (2008) have shown aluminum concentrations between 10,000mg/kg and 30,000mg/kg which are several times higher than all the results obtained in this study.

Again, the result of aluminum concentrations in green tea with moringa and strong black tea for men shows that these tea leaves are hyperaccumulators of aluminum and could be called metallophytes since they bioaccumulated Al over 1000mg/kg. This idea was

supported by Ozdemir et al. (2002), Jansen et al. (2003), Peng et al. (2018), who claimed that tea leaves are hyperaccumulators of aluminum.

The aluminum concentration in our present study could be attributed to the dry tea leaves being a metallophyte or having the potential to bioaccumulate aluminum to a great extent into their matrices. This idea was buttressed independently by Flaten (2002) and Jansen et al. (2003). However, metallophytic or hyperaccumulating potentials of tea leaves were only found in green tea with moringa and strong black tea for men. It could also be attributed to the presence of a large amount of water-soluble or bioavailable fraction of aluminum in the soil, and its mobility. In this mobile form, plants' roots can absorb or abstract it and subsequently sequester it into other parts of the plant (leave or stem). This idea was buttressed by Radulescu et al (2013). However, green tea with mint and green tea with lime and lemon does not exhibit hyper accumulating properties as their accumulation of aluminum was less than 1000mg/kg. This could be attributed to the existence of a strong affinity for root exchange sites where aluminum could precipitate as hydroxides to form plaque, thus reducing the total amount of aluminum that would have been sequestered to other parts of the plant, hence the lower concentration of aluminum in green tea with mint, green tea with lemon and lime and black Chinese tea respectively as a result of poor or reduced translocation factor (Ghosh & Singh, 2005; Bhattacharya et al., 2010). This implies that the sequestering capacity of the plant could account for the varied concentration of aluminum in the various tea leaves. Also, the presence of reduced or low polyphenols in their matrix could be implicated.

Again, the type or variety of tea leaves could be implicated (Table 1). In our present result, the concentration of aluminum is different depending on the type or blend. For example, aluminum concentration in green tea leaves is lower than that of black tea leaves even in its composite. This view was corroborated by Fung et al (2009) who reported that the quantity of aluminum in young leaves from a Kenyan variety had a significantly higher aluminum concentration (2152mg/kg) than a Chinese variety (381mg/kg). Furthermore, Chen et al (2009) have also shown that the aluminum concentration in leaves of eight tea cultivars grown on the same plantation varied. This is in accord with Flaten (2002) and Street et al. (2007) who attributed the difference in aluminum in the different tea leaves to the presence of phenolic groups in teas. They argued that black tea leaves have more polyphenolic groups than green tea leaves and can form complexes or chelates more than green tea leaves. This is in good agreement with previous studies by Ruan & Wong (2001) and Liu et al (2003). Hence, the observed result of black tea leaves having more aluminum concentrations than green tea leaves.

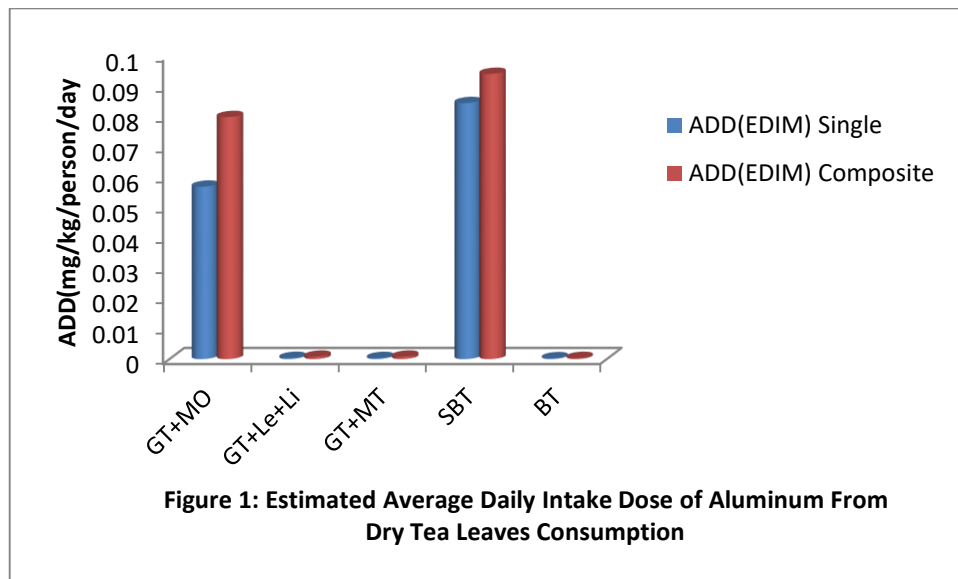
Furthermore, the location or source of the tea leaves is another factor. Several authors have independently reported that dry tea leaves obtained from different countries have different concentrations of aluminum in their dry leaves (Ansari et al., 2007; Mehra & Baker, 2007; Lech & Lachowicz, 2009). They reported that the aluminum concentration in dry tea leaves from Turkey, Czech Republic, Hong Kong and Italy showed strong variation. In addition, soil conditions such as pH, organic matter, cation exchange capacity and available phosphorous play a great role in how much aluminum can be absorbed by the tea plant and sequestered in other parts of the plant (Jin et al., 2005; Cai et al., 2010; Cai et al., 2016). This idea was supported by Peng et al (2018) who argued that aluminum concentration in dry tea leaves may be influenced by soil condition, tea variety, harvest season and leave maturity.

Another contribution to the observed aluminum concentration in the different tea leaves is the effect of the harvesting season on the bioaccumulation of aluminum. This assertion was put forward by Peng et al (2018) who reported that harvest season or seasonal variation greatly affected the levels of aluminum in dry tea leaves. Their result showed that seasonal variation gave different hyperaccumulation of aluminum with summer having the

highest, followed by autumn and springtime as the lowest. This could be attributed to higher plant metabolism or increase transpiration in autumn and summer compared to spring which would bring more aluminum into the plant. It could therefore be inferred that the blended teas were harvested in spring during which low levels of aluminum are observed, while green tea with moringa and strong black tea for men were harvested during summer and autumn respectively.

3.2.2: Health Risks Assessment of Human Exposure to Aluminum via Consumption of Dry Tea Leaves of Green and Black Teas

The estimated average daily intake (ADI) dose or average daily intake dose of Al from consuming dry tea leaves is presented in Figure 1 for both single and composite tea pouches of all the types of tea investigated. The result depicted that the ADI varied between 0.0003mg/kg/person/day and 0.0845mg/kg/person/day in the dry tea leaves from a single pouch, while in the composite pouches, it varied between 0.0004mg/kg/person/day and 0.0941mg/kg/person/day. It was also revealed that the ADI for the composite dry tea leaves was generally greater than that of the single pouch. Furthermore, strong black tea for men has the highest ADI in both single and composite pouches of dry tea leaves. However, all the ADIs were lower than unity (ADI < 1).



The HRI or HQ in dry tea leaves varies between 4.2857×10^{-5} and 1.2071×10^{-2} for a single pouch, while in the composite, it varied between 5.6340×10^{-5} and 1.3443×10^{-2} . Furthermore, the HRIs of the composites are greater than that of the single pouch. However, all the HRIs are generally less than unity (HRI < 1).

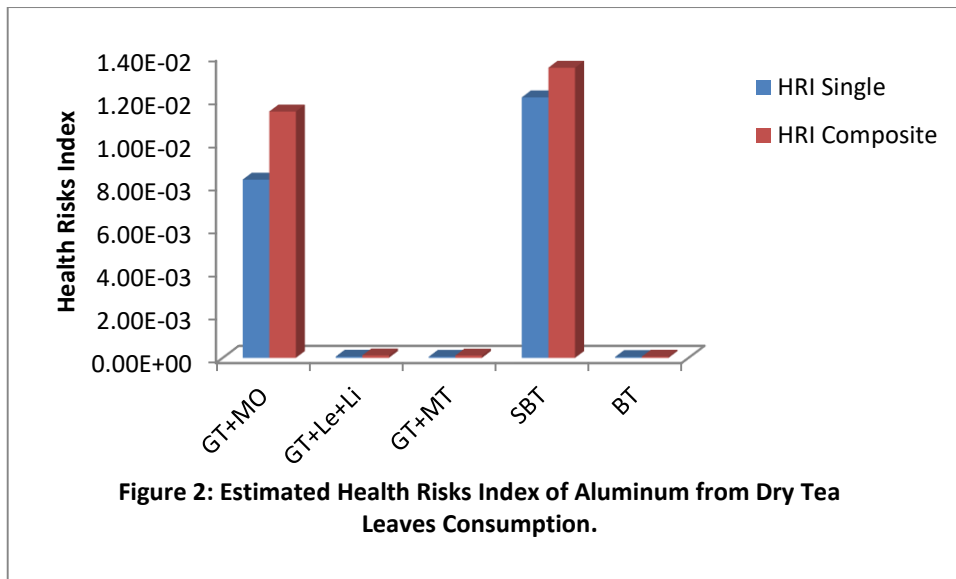


Figure 2: Estimated Health Risks Index of Aluminum from Dry Tea Leaves Consumption.

To describe the level of health risks that may be associated with dry tea leaves consumption, the ratio of HRI to RfD was calculated and compared with RfD alone and the result is presented in Figure 3. The result showed that the HRI/RfD in all the dry tea leaves were extremely less than the RfD, thus suggesting and confirming the previous health risks parameters to agree with HRI/RfD, since $HRI/RfD < RfD$. It means the minimum risk of undue health-related problems or public health concerns may arise from the consumption of dry tea leaves.

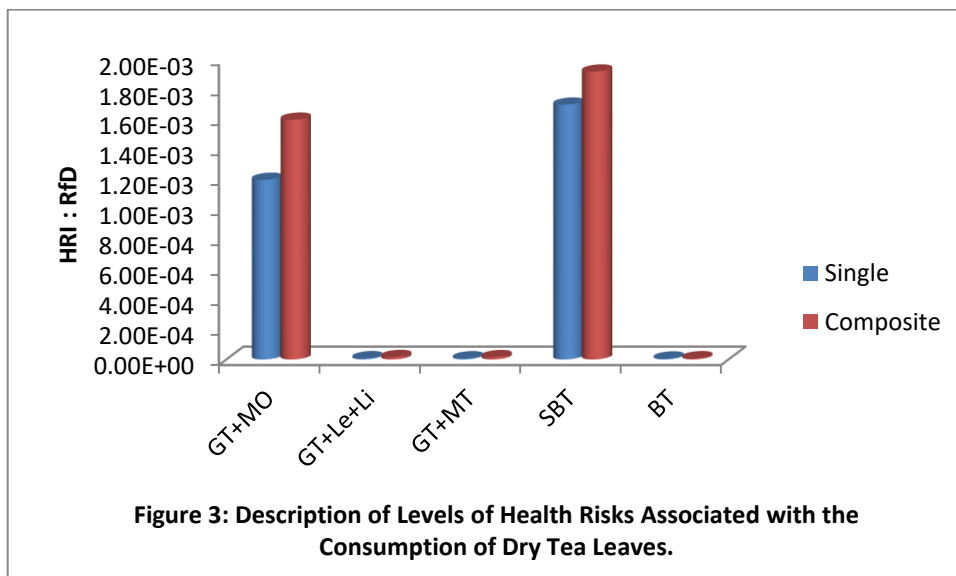


Figure 3: Description of Levels of Health Risks Associated with the Consumption of Dry Tea Leaves.

In this study, the ADI in green tea leaves and black tea leaves were observed to be low and lower than unity ($ADI < 1$). Similarly, the ADI in both the single pouch and composite

pouches were low and lower than unity. Furthermore, their values were even lower than the RfD and permissible limit of Al in water (0.2mg/L). The obtained ADI implies that consumers are not likely to have any undue health issues of public health concern.

Health risks index or hazard quotient (HRI or HQ) results have shown that all the HRIs were low and lower than unity (HRI or HQ < 1) but were higher in the composite than in the single pouch. Our present result is at variance with other researchers who did a similar study using the vegetable to assess arsenic (As) exposure via consumption. They reported independently that the HRIs obtained were greater than that unity (HRI or HQ > 1). This idea was corroborated by Ikeda et al (2000) and Zhuang et al (2007). The overall results of risk assessment depicted that currently and in the nearest future, no undue health issues of public health interest will arise or is expected.

Conclusion

The result has shown that Al concentrations in dry tea leave differ according to type and brand (green and black tea) with green tea containing moringa and strong black tea for men, having higher concentration above 1000mg/kg, while other brands in this study had concentrations far below 1000mg/kg. Thus, suggesting that both green tea with moringa and strong black tea for men are hyperaccumulator of Al. In addition, the plant could be classified as a metallophyte which could be used as a phytoremediating agent in Al polluted or contaminated soil or environment to remove Al. Furthermore, health risks assessment results showed absence of any possible undue non-cancerous diseases currently, or in the near future, since all the risks indices were lower than unity (ADI < 1; HRI or HQ < 1) in all the tea samples studied. It could therefore be inferred that the dry leaves of the various teas could be consumed since they pose no health threat to consumers.

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