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Availability of some inorganic micronutrients and effects of grading on their levels in East African black teas and infusions.

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Abstract

Inadequate micronutrients in diets cause health complications. Tea beverages are widely consumed fluids but it is not known if they could supply adequate micronutrients to overcome hidden hunger. East Africa supplies substantial amounts of tea to the world markets whose levels of micronutrients are unknown. Micronutrients levels in East Africa were assessed. Wide ranges and deviations were observed. Large particle size grades and local market teas had higher contents. About 41% and 82% Mn and Cu were extracted in hot water infusion. A 2g cup of tea contributed 57% of the daily minimum requirements of Mn, but low levels of other micronutrients. Consumption of more than two cups of tea per day can supply enough daily Mn requirements.

INTRODUCTION

Micronutrients play vital roles in metabolic processes and are essential for the general well being of humans. The deficiency or excess of the micronutrients can cause diseases and/or be deleterious to human health [1]. Although the world now understands the nature, magnitude and problems caused by micronutrient deficiency often called 'hidden hunger', the situation is still prevalent. Hidden hunger is a situation where quantities of foods are adequate but lack vital micronutrients [2]. The determination of inorganic micronutrients levels in foods and related products is essential to understand their possible roles in alleviating the hidden hunger problem. Tea beverages, infusions of dried young tender shoots of *Camellia sinensis L. O. Kuntze* [3,4], are the most popular, non- alcoholic beverages in the world [5], and most widely consumed fluids after water [6,7]. The beverages may contribute to solutions of the hidden hunger problem if they contain appropriate levels of micronutrients. The tea bush is known to accumulate trace elements [8,9]. The chemical composition of tea leaves and manufactured tea consists of tannins, flavonols, proteins, amino acids, enzymes, aroma forming substances, vitamins, minerals and trace elements [10]. Some of the beneficial effects of drinking tea are prevention of chronic and cardiovascular disease, cancer, anti-oxidative *detoxification* thus slowing progression of diseases [11]. Although most of these activities have been attributed to tea polyphenols, some micronutrients are also known to manage the ailments.

Several studies have reported the presence of some nutrients in tea from various countries [4, 10, 12]. Ca, Na, Mg, K and Mn were present in tea at mg/g level, Cr, Fe, Co, Ni, Cu, Zn and Cd occurred at low level of a few µg/g scale [13]. However the level of micronutrients in teas changed with locations in India [10]. In other studies, tea quality parameters [14,15,16], quality precursors [17] and yields [15, 18] changed with geographical area of production within East Africa. The levels and variations of micronutrients in East African teas with area of production have not been documented.

The tea drinking habits vary worldwide and consumers prefer different brands and grades of tea [12]. East Africa produces mainly CTC black tea for export and domestic consumption. The grades range from broken pekoe, pekoe fannings and dust samples [19], the pekoe fannings being the grade produced in largest quantities in East African tea factories [20]. It is not known if the inorganic micronutrients levels in black tea vary with grading. Tea beverages are a cheap part of daily dietary intake and frequent consumption may increase nutritional health if it has substantial amounts of the necessary nutrients. Herein, we report the levels of some essential elements in black tea from different factories in East Africa, the Kenyan local market, their variations in the different grades of black tea and levels in hot water infusions.

MATERIALS AND METHODS

Sample collection and chemicals

Samples were obtained from 42 factories collected from two tea brokerage firms in Mombasa, Kenya. From each factory, 200g of the PF1 grade replicated three times was obtained. From another 8 factories, 200g each of grades BP1, PF1, PD and D1 grades of black tea were obtained in triplicate from each factory. Tea samples from the local market were obtained from Tuskys, Nakummatt and Ukwala supermarkets in Kisumu City, Kenya in triplicate for each brand.

Micronutrients analyses

The standard procedure described in AOAC [21] was followed with slight modifications for the preparation of the tea samples for analysis of the micronutrients. Prior to analysis, samples were oven dried at 80^0 C overnight then cooled in a desiccant before weighing. Accurately weighed 1.0000g of the black tea was transferred in a silica crucible and ashed in a muffle furnace at 460^0C under a gradual increase ($\leq 50^0$C/h) for 12 hours for analysis of Mn, Fe, Zn and Cu while for Se analysis 2.0000g of black tea was used. The ashed samples were cooled and removed from the furnace, then digested using a double acid (concentrated hydrochloric acid and nitric acids) and hydrogen peroxide in the ratio of 2:3. Care was taken to ensure that all ash came into contact with the acid. Further the crucible containing the acid solution was kept on a hot plate and evaporated to dryness. The final residue was dissolved in 0.05 M hydrochloric acid solution for extraction and made up to 25 mL for Mn, Fe, Zn and Cu analysis and to 10 mL for Se analysis. Working standards solutions were prepared by diluting the stock solution with 0.05 M hydrochloric acid. The blanks were treated in the same way as the samples and the analysis of the Mn, Fe, Zn, Cu and Se determined by Atomic Absorption Spectrometer, (Shimadzu AA 6200 model, Japan).

Preparation of infusions

The 12 brands of locally consumed tea and 12 randomly sampled black teas from the tea brokers were used in this study. The method of Lasheen *et al* [22] was used in the preparation of black tea infusions. One hundred (100) ml of hot (75°C 85°C) distilled water was added to 2 g of black tea particles. The mixture left to infuse for 4 minutes then filtered through a Whatman grade number 42 qualitative filter paper ashless, Whatman 1442-055. The residues were oven dried at 105°C, re-weighed and then subjected to analysis of the micronutrients by the Atomic Absorption Spectrophotometer. Analysis of each sample was repeated three times. The amount of micronutrients infused was calculated as difference between micronutrients in tea leaves before and after infusion.

Statistical analysis

The data from the East African tea samples were subjected to statistical analysis using MSTATC statistical programme. The effects of grading on micronutrient content of the black teas were analyzed using a two factor completely randomized design. Micronutrient levels in teas from different factories and teas from the local market were analyzed using a completely randomized design. Microsoft Excel was used to calculate the means, standard deviation and percentage infusions for the tea infusions.

RESULTS AND DISCUSSION

Concentration of essential elements in black teas from East Africa

The variation in the essential micronutrients with factory of production is presented in Table 1. The order of concentration was Mn > Fe > Zn > Cu > Se. For each micronutrient, the ranges were large, demonstrating that there are large variations in factors affecting the distribution of these micronutrients in different regions. The levels of selenium were very low while Mn was reasonably high.

There was significant ($p \leq 0.001$) differences in levels of the micronutrients in the 42 different factories in East Africa (Table 2). Thus, the East African black teas supply the micronutrients and the level of supply varies from factory to factory or region to region. It is therefore important that in the use of tea to supply the micronutrients, assessments are done first to establish the ability of individual the factory/region as adequate. Mn was the most abundant micronutrient in East African black teas, similar to studies on tea from other regions like India [10], Iran [23] and Pakistan [24].

The comparisons of micronutrient levels from East African teas to teas from other regions are given in Table 3. The levels of micronutrients in East Africa were similar to the levels in Indian[10], Japan[25], Saudi Arabia[27] and Turkey[28] black teas but the levels in Spain[26] tea were very high while the levels of Iranian teas were relatively lower. The levels of the micronutrients in Pakistan tea [24] were however lower than the levels of the micronutrients in East African teas except for copper. The large variations compared to teas from other regions [10, 23] are attributed to different agro-climatic conditions and possible differences in the varieties of teas and agronomic inputs used. However, the differences demonstrate that teas produced and sold in different regions have varying abilities to supply the micronutrients making it necessary to test the teas before providing recommendations for the purposes of hidden hunger alleviation.

The variations of the micronutrients in black tea from different factories in East Africa in the present study can be attributed to differences in agronomic, agro-climatic, soils, cultural factors and varieties. Indeed the nitrogenous fertilizer application rates [29], plucking standards [30], plucking intervals [31] and cultivars [32] have been demonstrated to cause large yield and/or quality differences. Similar differences were recorded in the micronutrients herein.

Effect of grading on micronutrient content of black tea.

Different grades of black tea from different factories showed significant ($p \leq 0.05$) differences in micronutrients content (Table 4). All the micronutrients significantly ($p \leq 0.05$) varied with factories of production. Again Mn had the highest concentration while Se had the least concentration in all the studied black tea grades. The concentrations of Mn, Fe, Zn, Cu and Se followed the BP1>PF1>D1>PD pattern in all the grades but Zn was higher in PD grade than in D1 grade of black tea. The variations in Zn recorded, need further experimentation to confirm. The variation in the distribution of the micronutrients in various grades is not strange although the grades originated from the same leaves. In a

Table 1. Concentrations (µg/g) of micronutrients in East African black teas

Statistical analysis*	Mn	Fe	Zn	Cu	Se
Min	341.00	81.67	33.67	2.33	0.27
Max	814.67	536.00	76.67	23.00	6.23
Mean	666.28	169.33	46.47	8.69	2.25
SD	121.44	129.71	13.46	4.62	1.28
Median	677.84	137.5	44.67	8.17	2.13

*No. of factories sampled=42

Table 2: Analyses of variances for the changes in micronutrients in tea from different factories

Micro-Nutrient	K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Mn							
	2	Factor A	41	1816072.86	44294.46	436.92	0.0000
	-3	Error	82	8313.10			
		Total	125	1824622.86			
Coefficient of Variation%:			1.51				
Fe							
	2	Factor A	41	2068996.71	50463.33	4180.26	0.0000
	-3	Error	82	989.88	12.07		
		Total	125	2070077.37			
Coefficient of Variation%:			1.92				
Zn							
	2	Factor A	41	14767.96	360.19	44.04	0.0000
	-3	Error	82	670.55	8.17		
		Total	125	15445.30			
Coefficient of Variation%:			5.89				
Cu							
	2	Factor A	41	3234.38	78.88	39.51	0.0000
	-3	Error	82	163.71	1.99		
		Total	125	3401.71			
Coefficient of Variation%:			14.69				
Se							
	2	Factor A	41	199.32	4.86	227.23	0.0000
	-3	Error	82	1.75	0.02		
		Total	125	201.45			
Coefficient of Variation%:			6.50				

Table 3. Comparison of micronutrient levels (µg/g) in East African teas with those from other regions in the world.

	East African Tea[g]	Iran[a]	India[b]	Japan[c]	Spain[d]	Saudi Arabia[e]	Turkey[f]
Mn	666.3±121.67	182.9±123.40	575±112.78	503±7	1004.1	750.9±185.34	806.0±34.2
Fe	169.3±129.33	92.6±89.68	NA	134±48	946.2	250.5±199.23	NA
Zn	46.5±13.47	40.3±13.89	NA	36.6±0.7	43.2	65.7±31.30	140.9±9.1
Cu	8.7±4.67	29.3±6.37	14.8±3.43	27.7±0.7	31.5	18.1±6.94	24.8±1.4
Se	2.3±1.23	NA	NA	NA	NA	NA	NA

a[23]; b10]; c[25]; d[26]; e[27]; f[28]; gThis study, NA- Not analysed

Table 4. Levels (µg/g) of micronutrients from different black tea grades from East Africa

Element	Grade	Factory of production								
		1	2	3	4	5	6	7	8	Mean grade
Mn	BP1	696.67	691.33	694.33	672.33	718.67	734.00	710.67	715.33	704.17
	PF1	692.00	693.00	678.67	660.33	674.67	681.00	682.00	708.67	683.79
	D1	680.67	644.67	667.67	643.67	665.00	655.33	659.00	705.33	665.17
	PD	623.33	650.00	624.67	623.67	635.00	624.33	641.67	618.33	630.13
	Mean factory	673.17	669.75	666.33	650.00	673.33	673.67	673.33	686.92	
	C.V %				1.69					
	LSD(P=0.05)				10.96					10.43
	Interactions				19.28					
Fe	BP1	170.00	119.67	91.33	163.67	101.00	85.33	124.67	78.00	116.71
	PF1	116.67	81.67	114.67	82.33	115.67	75.33	115.00	75.67	97.13
	D1	100.33	73.33	74.33	99.33	86.33	75.67	74.00	70.67	81.75
	PD	46.33	45.33	45.00	91.33	83.00	36.00	18.67	42.67	51.04
	Mean factory	108.33	80.00	81.33	109.17	96.50	68.08	83.08	66.75	
	C.V %				3.02					
	LSD(P=0.05)				2.53					2.40
	Interactions				4.44					
Zn	BP1	41.00	45.67	33.00	44.00	42.67	46.33	42.33	46.00	42.63
	PF1	40.00	43.00	42.67	46.00	42.33	39.00	36.67	39.33	41.13
	D1	32.33	26.00	27.00	43.00	38.33	38.00	31.00	21.33	32.13
	PD	42.00	56.33	26.33	43.67	48.67	34.33	22.67	33.33	38.42
	Mean factory	38.83	42.75	32.25	44.17	43.00	93.42	33.17	35.00	
	C.V %				5.92					
	LSD(P=0.05)				2.20					1.82
	Interactions				3.88					
Cu	BP1	15.00	17.00	19.67	17.33	16.67	20.33	17.33	13.67	17.13
	PF1	18.67	14.00	16.00	12.00	15.33	15.33	13.00	17.00	15.17
	D1	7.67	11.33	10.33	15.00	12.00	15.00	15.33	13.00	12.46
	PD	7.67	11.67	9.00	12.33	11.67	7.00	11.67	5.33	9.54
	Mean factory	12.25	13.50	13.75	14.17	13.92	14.42	14.33	12.25	
	C.V %				12.30					
	LSD(P=0.05)				1.61					1.53
	Interactions				2.84					
Se	BP1	2.40	13.97	10.30	10.23	8.57	1.08	4.37	2.53	6.68
	PF1	3.11	3.93	3.63	4.17	3.43	4.23	3.97	4.53	3.88
	D1	3.43	2.40	1.40	4.43	2.43	3.67	1.50	2.67	2.74
	PD	3.20	0.50	2.43	2.37	3.10	1.63	1.43	3.13	2.22
	Mean factory	3.04	5.20	4.44	5.30	4.38	2.65	2.82	3.22	
	C.V %				14.47					
	LSD(P=0.05)				0.54					0.52
	Interactions				0.95					

previous study similar variations had been shown in the black tea chemical quality parameters [33]. The difference in the chemical quality parameters [33] and micronutrients concentrations in the black tea grades can be attributed to the different parts of the leaf the grade originated from. Grading is based on the size of the particles which is determined by their ability to fall through the screens of mesh after tea drying. Broken pekoe is a medium particle size grade that consists of small leaf particles of leaves, the fannings are smaller particle grade and consisting mainly smaller pieces while the dust is the smallest particle size grade and consists tiny remnants created in sorting and crushing processes [34] and when further refined it gives the pekoe dust with slightly larger particle sizes [35]. Generally the grade distribution varies from factory to factory even when plucking standards

Table 5. Levels (µg/g) of micronutrients in various brands of tea from the Kenyan local market.

	Micronutrients				
Tea Brands	Mn	Fe	Zn	Cu	Se
Sachets					
Baraka chai	2784.67	290. 00	41.33	21. 00	3. 20
Sasini tea	2844. 00	332. 00	34. 00	8. 00	3. 90
Fahari ya Kenya tea	3066.67	351.33	36.33	11. 00	3. 20
Aberdare tea	2463.33	273.67	37.33	10. 00	2. 30
All time kenya tea	2557.33	310. 00	44.33	8. 00	2.57
Melvins Tangawizi tea	2640.33	471.33	44.33	20. 00	2. 30
Eden tea	2358.33	222.33	45.33	11.33	3. 40
Kericho Gold tea	2558.33	244. 00	43.67	8.67	2.97
Instant teas					
Alitea instant tea	216. 00	36.33	14. 00	2.33	0. 60
Finlays instant tea	165.67	27. 00	12. 00	2.67	0.37
Tea bags					
All time Kenya tea	2368.33	214.33	35. 00	5. 00	2.57
Ketepa pride	2658.67	342. 00	45.67	3.67	2.43
C.V (%)	1.25	4.28	9.68	13.15	10.02
L.S.D (P=0.05)	49.99	19.96	6.28	2. 20	0.45

and/or leaf age is the same. This is due the setting of the CTC maceration machines. When the CTC rollers are set very tightly, there is usually more extensive leaf cell matrix destruction leading to more dust of finer particle sizes than when the CTC rollers are more loosely set. Thus the significant variations observed may be due to the differences in CTC roller settings during the black tea processing and differences caused by other growth factors. However, the extent of change in concentrations varied from factory to factory leading to significant ($p \leq 0.05$) interaction effect between grades and factory. It may not therefore be possible to predict the pattern of distribution of the micronutrients in the different factories, unless the CTC settings are standardized.

Levels of the micronutrients in teas from the Kenyan local market

The levels of the micronutrients in several brands of tea in the local market are presented in Table 5. The levels followed the same pattern observed earlier (Table 1 and 4). However, the levels of micronutrients observed in the local market black teas (Table 5) were higher than those obtained from the auctioneers (Table 1 and 4) intended for foreign export market. It had been speculated that the quality of tea offered for the local market could be lower than those offered for export market. The teas offered in local market are often from coarser plucking standards, consequently being of low black tea quality [33] and high Zn and Fe contents [36]. The observation indicates that the quality of teas offered in the local market could be different from those offered in the export market. Instant teas had significantly ($p \leq 0.05$) lower levels of the micronutrients than the teas in sachets and tea bags which were comparable. Instant teas are made from concentrates of liquor infusions. The result demonstrates that a lot of micronutrients were left in the residues. Thus, instant teas could be poorer suppliers of the micronutrients than the leaf teas. Tea quality [37] and levels of tea leaf nutrients [38] are known to vary with several agronomic practices. Generally, high Zn and Fe levels are associated with mature leaf [38]. The significant ($p \leq 0.05$) differences in the micronutrients imply that the ability of the brands to supply the micronutrients varies. It is therefore important to determine the levels of the nutrients in tea before using specific brands to supply micronutrients. However in all the brands, the levels of the micronutrients were high suggesting that irrespective of the brand, all the teas were better sources of the micronutrients than exported teas.

Table 6. Contribution of East African tea to the requirements micronutrients for humans.

Levels (µg/g) of one cup of local market teas (2g of black tea infused)					
Element	Mn	Fe	Zn	Cu	Se
Amount in black tea	5222.16±180.32	602.16±64.80	82.84±4.67	26.58±8.08	6.30±1.63
Amount in infused tea residue	3081.08±123.34	499.80±45.89	43.79±3.37	4.78±1.67	4.25±0.45
Amount extracted during infusion	2141.08±46.56	102.36±12.54	48.05±4.33	21.80±0.21	2.05±0.13
% mean Extraction	41.00±5.33	17.00±7.67	58.00±4.67	82.00±3.47	32.00±2.67
Comparisons (% Extractions)					
Chen, 1990	33-36	< 10	36-56	70-80	8-24
Lasheen *et al.*, (2008).	36	24	50	75	-
Powell *et al.*, (1998)	45.8	<0.02	0.44	0.91	-
Minimum requirements (NAS, 1980)	2300	8000	8000	900	55
Contribution to hidden hunger (%)	87.00	1.20	0.60	2.40	3.73
Comparison (% of required amount)					
Chen 1990)	60-100	<1-1.6	1.3-4.0	10-30	1.0-8.0
Levels (µg/g) of one cup of Export market teas (2g of black tea infused)					
Amount in black tea	1412.32±123.67	233.34±24.80	78.84±4.67	25.58±8.08	6.87±1.63
Amount in infused tea residue	833.27±67.34	193.67±5.89	33.12±3.37	4.58±1.67	4.68±0.45
Amount extracted during infusion	579.05±46.56	39.67±6.54	45.72±4.33	21.00±0.21	2.19±0.13
% mean Extraction	41.00±5.33	17.00±7.67	58.00±4.67	82.00±3.47	32.00±2.67
Contribution to hidden hunger (%)	25.18	0.50	0.57	2.33	3.98

*No. of samples = 12 different brands of local teas and 12 samples from export market.

Contribution of black tea to the requirements of micronutrients for humans

The black teas from East Africa had varying amounts of micronutrients (Table 1, 4, 5). Tea is consumed as liquor infusion. Thus unlike foods wholly consumed, critical levels of nutrients should be based on the amounts infused into the tea liquor. Despite the levels of micronutrients observed in Tables 1, 4 and 5, the amounts that are infused could be variable. The changes in the amounts of micronutrients infused in tea liquors are presented in Table 6. Some elements were well extracted into the infusion such as Mn, Cu and Zn but Fe and Se were only partly extracted (Table 6). Chen, [39] reported complete extraction into the tea infusion of Br, K, good extraction of Cu, F, Ni, Zn, Cr, Mn, Mg, S and Co while Fe, Se, Pb and Ca could only be partly extracted in Chinese tea brands. These findings are similar to the findings reported herein. The micronutrients levels in black tea were more than what is infused, as also observed by Lasheen *et al* [22] and Gezgin *et al* [40]. It is therefore not possible to predict from the total micronutrients in whole tea, the actual contribution of tea beverages to the alleviation of hidden hunger. However, it can be concluded that black tea from East Africa can be a significant source of Mn to alleviate/reduce hidden hunger related to Mn deficiency. The contribution of tea to alleviating/reducing human health hidden hunger of the other micronutrients was minimal.

In the preparation of a cup of tea 2g of black tea particles or one tea bag is used which is approximately 2g [22] in 100 mL of hot water. Thus the extent of contribution of tea to partial alleviation of shortage of the micronutrients depends on the actual number of cups consumed per day (Table 6). Consumption of about two cups per day of the local teas and at least four cups of export tea will supply adequate Mn. Very many cups of tea would be required to alleviate other micronutrient deficiencies. Tea is therefore not a suitable nutrient supply for these micronutrients and can only supplement other sources.

CONCLUSION

The teas from East Africa contain varying amounts of micronumtrients, possibly caused by differences in agronomic, agro-climatic, soils, cultural factors and varieties. Such variations are further exuberated by grading in the order BP1>PF1>D1>PD. Despite the levels of the micronutrients in the tea leaf, the amounts extracted were also variable. Some elements e.g Mn, Cu, and Zn were well extracted but Fe and Se were only partially extracted. The East African teas can be a good supplier of Mn to alleviate hidden hunger related to Mn deficiency, while other micronutrients require consumption of many cups of tea for any significant contribution to the hidden hunger alleviation. Consumption of about two cups per day of local teas supplies adequate amounts of Mn.

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