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Understanding Geophagic Practice as a Source of Mineral Nutrients and Toxicants

T Kamau, HN Nyambaka and MP Nawiri*

Chemistry Department, Kenyatta University, P.O Box 43844, Nairobi, Kenya

Abstract: Geophagy, a type of pica where particularly soil and clay deposits are consumed is hypothesized to be motivated by among other factors that of nutritional benefit. The practice cuts across socio-economic, ethnic, religious and racial divides worldwide. In Africa, Kenya has the highest prevalence rate of geophagy at 65%. In Kiambu County, Kenya, geophagic individuals have numerous sources of geophagic materials. While the variations in the levels of essential and toxic minerals ingested is largely unknown, the materials contain minerals which may have both positive and negative effects to human health as would be referenced to the recommended daily allowances (RDA) and WHO/EFSA limits. Levels of Ca, Mg, Fe, Mn, Al, Si, Zn and Pb in geophagic materials from quarry mines, supermarkets and open-air markets in Kiambu County, Kenya were analysed using flame AAS. Where detected, Ca, Mg, Fe, Si, Mn and Al ranged from 0.60±0.00-3.91±0.00, 0.02±0.00–0.16±0.02, 0.06±0.01-0.69±0.02, 39.45±0.14-62.53±0.34, 0.01±0.00-0.03±0.00, and 12.20±0.00-31.58±0.19 while Zn and Pb ranged from 10.89±0.89-161.67±0.19 and 1.09±0.03-79.67±0.04 ppm respectively. Significant differences ($p<0.05$) observed are explained to be due to their sources. Levels however do not point to the geophagic materials being good nutritional boosters for minerals as hypothesized. The geophagic practice should infact be discouraged as cumulative intake of the minerals and especially the toxic ones have detrimental effects on human health.

Keywords: Pica, geophagy, geophagic materials, quarry mines

*Corresponding author email:-nawiri.mildred@ku.ac.ke

1. Introduction

Pica is the craving and subsequent consumption of non-food substances including earth, charcoal, ice and uncooked rice. Geophagy is a type of pica where particularly soil and clay deposits are consumed [1]. The practice of pica is hypothesized to be motivated by micronutrient deficiency, cultural, medicinal and physiological factors and it cuts across socio-economic, ethnic, religious and racial divides worldwide [2,3,4]. In sub-Saharan Africa, the popularity of the geophagic practice has been increasing overtime especially among pregnant women and children aged below five years [6]. Kenya has the highest prevalence rate of geophagy at 65% as compared to other African countries[7].Geophagic individuals living in Kiambu County, Kenya (the study area) obtain soil and clay from walls of mud houses, termite moulds, quarry mines, supermarkets and open-air markets. As such, there has been an upward trend in sales made from selling geophagic materials in the County [8].

The concern about geophagic practice is the differences in mineralogy and chemical composition of geophagic materials as this result in variations in the levels of essential and toxic minerals ingested. Geophagy posits contain minerals which have both positive and negative effects to the internal support structure of the body [9.10’11]. While magnesium, zinc, iron and silicon are critical in the proper functioning of the body if correct limits are maintained, toxic minerals such as lead and aluminum lead to metal toxicity even at low levels [12,13,14]. There are recommended dietary allowances as well WHO/EFSA limits set for various minerals. Studies however are called to ascertain the extent of exposure to the minerals from geophagic materials. Take for instance the concern on geophagic materials that were sold in open-air markets in Eastern, Nairobi and Nyanza provinces of Kenya reported to contain levels of lead and cadmium beyond the WHO recommended levels therefore posing risk of heavy metal poisoning [8].

It is in light of the aforementioned that levels of calcium, magnesium, iron, manganese aluminum and silicon as well as zinc and lead in geophagic materials from quarry mines, supermarkets and open-air markets in Kiambu County, Kenya were determined.

2. Materials and Methods

2.1 Study Area and Sample Collection

The study was carried out in Kiambu County, Kenya where samples were obtained from eight quarry mines (coded QM_1, QM_2, QM_3, QM_4, QM_5, QM_6, QM_7 and QM_8), four brands from supermarkets (coded SM_1, SM_2, SM_3 and SM_4) and two colored samples from open-air markets (yellow and white in colour).

2.2 Reagents and equipment

All chemicals and reagents used in this study were of analar grade, manufactured by Sigma Aldrich Company and supplied by Kobian Laboratory supplies, Nairobi. Buck. These were Al, Fe and Si standards, Mg, Mn, Zn and Pb metals (99.99% purity) calcium carbonate, nitric acid, hydrochloric acid (HCl), hydrofluoric acid (HF), boric acid and cesium chloride Scientific.

The AAS model used was 10VGP flame and the operating parameters set according to the manufacturer's specifications.

2.3 Sample Preparation

Balcerzak's procedure[15] of sample preparation was followed where samples were dried in an oven at 110^{o}c for 8 hours and then allowed to cool to room temperature in a desiccator. They were crushed to obtain fine particles and ground into a finer powder of 5μm size for 6 hours in a ball mill. They were then weighed and stored in labeled sample plastic bottles.

Cold digestion was employed for determination of the oxides of Si, Al, Fe, Mg and Ca while for Zn and Pb, hot digestion was employed. In cold digestion, a 0.100 g of the powdered sample was carefully weighed into a 100 ml plastic bottle and using a plastic tipped automatic pipette, 3 ml of HCl and 1 ml of HNO_3 were added and the solution allowed to stand were added and the solution allowed to stand overnight. An amount of 3 ml of HF was added followed by 50 ml of boric acid solution and filled to the mark using distilled-deionized. The solution was allowed to stand for three hours before aspiration into the AAS machine. In hot digestion, a 1.500 g of the sample in a 50 ml volumetric flask was dissolved with distilled-deionized water to form a slurry before adding 15 ml of conc. HCl and 5 ml of conc. HNO_3. After the reaction had ceased, the solution was slowly heated in a sand bath to near boiling point for 1 hour with frequent agitation and allowed to cool. After cooling, the solution was filled to the mark with distilled-deionized water before aspiration into the AAS machine.

3. Data analysis

Data were analyzed with SPSS 17.0 for windows. The mean and standard deviation of means were calculated. The data were analyzed by one-way analysis of variance (ANOVA) and Duncan's multiple range tests was used to separate means ($P < 0.05$).

4. Results and Discussion

The levels of the minerals Ca, Mg, Fe, Mn, Al, Si, Zn and Pb in geophagic materials sampled from quarries, supermarkets and open air markets in Kiambu County, Kenya are presented in Table 1.

Table 1: Levels of minerals in geophagic materials sourced in Kiambu County, Kenya

Mean levels (Mean ±SE, n=14)									
Soil source in Kiambu County		% weight CaO	% weight MgO	% weight Fe_2O_3	% weight MnO	Zn (ppm)[1]	Al_2O_3 % weight	SiO_2 % weight	Pb(ppm)[1]
Quarry mines	QM_1	ND	0.02 ± 0.00^{a}	0.51 ± 0.03^{abc}	0.01 ± 0.00^{b}	159.00 ± 0.06^{d}	23.88 ± 0.15^{b}	42.51 ± 0.14^{c}	38.67 ± 0.01^{a}
	QM_2	0.63 ± 0.00^{a}	0.03 ± 0.00^{b}	0.69 ± 0.02^{e}	0.03 ± 0.03^{f}	161.67 ± 0.03^{f}	31.39 ± 0.45^{g}	40.95 ± 0.06^{b}	78.67 ± 0.02^{g}
	QM_3	0.61 ± 0.00^{a}	ND	0.54 ± 0.03^{bc}	0.02 ± 0.01^{d}	160.00 ± 0.03^{e}	31.39 ± 0.35^{c}	47.04 ± 0.12^{f}	69.33 ± 0.01^{e}
	QM_4	ND	0.02 ± 0.00^{a}	0.49 ± 0.03^{ab}	0.03 ± 0.01^{e}	132.67 ± 0.09^{b}	26.44 ± 0.26^{d}	44.00 ± 0.10^{d}	74.33 ± 0.02^{f}
	QM_5	1.80 ± 0.00^{b}	ND	0.60 ± 0.03^{d}	0.02 ± 0.02^{c}	127.67 ± 0.03^{a}	22.93 ± 0.35^{a}	40.01 ± 0.12^{a}	54.00 ± 0.57^{c}
	QM_6	0.60 ± 0.00^{a}	ND	0.51 ± 0.02^{abc}	0.03 ± 0.01^{e}	133.67 ± 0.03^{c}	30.17 ± 0.15^{f}	43.78 ± 0.05^{d}	57.68 ± 0.01^{d}
	QM_7	0.61 ± 0.00^{a}	0.03 ± 0.00^{b}	0.57 ± 0.02^{cd}	0.01 ± 0.01^{a}	159.98 ± 0.09^{e}	31.58 ± 0.19^{g}	45.17 ± 0.46^{e}	79.67 ± 0.04^{h}
	QM_8	ND	0.03 ± 0.00^{b}	0.46 ± 0.03^{a}	0.01 ± 0.01^{b}	133.67 ± 0.03^{c}	29.50 ± 0.76^{c}	41.34 ± 0.14^{b}	48.97 ± 0.04^{b}
p-value		0.238	0.398	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Supermarkets	SM_1	1.80 ± 0.00^{a}	0.04 ± 0.00^{a}	0.09 ± 0.01^{b}	0.03 ± 0.00	11.22 ± 0.33	44.01 ± 0.89^{d}	40.87 ± 0.46^{a}	11.00 ± 0.02^{a}
	SM_2	0.61 ± 0.00^{b}	0.16 ± 0.00^{c}	0.06 ± 0.00^{a}	ND	ND	21.12 ± 0.98^{b}	39.45 ± 0.14^{a}	17.33 ± 0.01^{b}
	SM_3	0.60 ± 0.00^{b}	0.06 ± 0.00^{b}	0.09 ± 0.00^{b}	ND	10.89 ± 0.32	37.51 ± 0.08^{c}	40.61 ± 0.07^{a}	17.34 ± 0.02^{b}
	SM_4	0.63 ± 0.00^{b}	0.06 ± 0.00^{b}	0.23 ± 0.01^{c}	ND	ND	12.88 ± 0.23^{a}	62.53 ± 0.34^{b}	39.00 ± 0.01^{c}
p-value		0.310	<0.01	0.260		0.984	<0.05	<0.05	0.984
Open-air markets	White	3.91 ± 0.02	0.33 ± 0.01	0.37 ± 0.01	ND	78.66 ± 0.01	12.20 ± 0.00	58.40 ± 0.08	1.10 ± 0.02
	Yellow	2.10 ± 0.01	0.19 ± 0.01	0.38 ± 0.01	ND	70.32 ± 0.01	14.17 ± 0.00	56.60 ± 0.12	1.09 ± 0.03
***p-value*[2]**		0.002	<0.05	0.018		<0.05	<0.05	0.01	0.656

[1] level expressed in ppm ND – Not Detected [2] Student t-test

[abc] Mean values followed by the same letter in the same source are not significantly different ($\alpha=0.05$)

The mineral levels in the geophagic materials from the quarries, supermarkets and open air markets ranged as follows: In the quarries, CaO (0.60 ± 0.00-1.80 ± 0.00 %wt), MgO (0.02 ± 0.00-0.03 ± 0.00%wt), Fe_2O_3 (0.49 ± 0.03-0.69 ± 0.02 %wt), Mn (0.01 ± 0.00-0.03 ± 0.00 %wt), Zn (127.67 ± 0.03-161.67 ± 0.03 ppm), Al_2O_3 (22.93 ± 0.35-31.58 ± 0.19 %wt), SiO_2 (40.01 ± 0.12-47.04 ± 0.12 %wt) and Pb (38.67 ± 0.01-79.67 ± 0.04 ppm).

In supermarkets, CaO (0.60 ± 0.00-1.80 ± 0.00 %wt), MgO (0.06 ± 0.00-0.16 ± 0.00 %wt), Fe_2O_3 (0.06 ± 0.00-0.23 ± 0.01 %wt), MnO (0.03 ± 0.00 %wt), Zn (10.89±0.32-11.22±0.33 ppm), Al_2O_3 (12.88±0.23-44.01±0.89 %wt), SiO_2 (39.45±0.14-62.53±0.34 %wt) and Pb (11.00±0.02-39.00±0.01 ppm) and in the open air markets, CaO (2.10±0.01-3.91±0.02 %wt), MgO (0.19±0.01-0.33±0.01 %wt), Fe_2O_3 (0.37±0.01-0.38±0.01 %wt), Zn (70.32±0.01-78.66±0.01 ppm) Al_2O_3 (12.20±0.00-14.17±0.00 %wt), SiO_2 (56.60±0.12-58.40±0.08 %wt) and Pb (1.09±0.03-1.10±0.02 ppm).

While the detection of these minerals in the samples was expected as soils contain these minerals, it was observed that samples from different sources contained significantly different amounts of the minerals ($p<0.05$). These differences could be explained due to underlying soil profiles [9,10,11]. Samples in supermarkets and open air markets were different from those of quarries as they are not necessarily obtained from the quarries in the region.

Comparison of the levels of minerals to the respective documented RDI showed that other than Fe, in the quarry mines and in the open-air markets, the rest contributed less than 10.0% of the RDI. These results therefore contradict the hypothesis that geophagic materials play a role in boosting the nutritional status of the individuals. This is in agreement to conclusions reported by other researchers, that individuals consuming soils are supplied with less than 1% of RDI [10,16]. It is worth-noting that in comparison to WHO/EFSA limits, Si and Pb levels exceeded the limits. This points to potential risks associated with the toxicity of these minerals [9,16,17,18].

5. Conclusion

The findings demystify the hypothesis of geophagic materials being of nutritional benefit as levels of Ca, Mg, Mn, Al, Si, Zn and Pb were found to contribute less than 10.0% of the RDI. Further the consumption of geophagic materials pose risk of dangers associated with Si and Pb poisoning as shown by their levels exceeding those set by WHO/EFSA. The authors recommend a sensitization campaign against geophagy.

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