ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 13 No. 1
January 2013
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

GEOPHAGIA CLAY SOIL AS A SOURCE OF MINERAL NUTRIENTS AND TOXICANTS

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ABSTRACT

Geophagia, which involves ingestion of non-food lithospheric substances, is the major form of pica in many African cultures. A common lithospheric pica substance ingested in the Cape Three Point region of West Africa, particularly Ghana and Togo, is a white loamy clay soil. This clay soil is usually ingested by women of reproductive age. Some of the reasons assigned to clay geophagia include appealing flavour, to alleviate nausea during pregnancy, and for absorption of toxins in the gastrointestinal tract. Some speculation indicates that geophagia may be an attempt to replenish mineral nutrients in undernourished persons. The study of the acid extractable mineral contents of this white clay soil was done to provide information on the mineral contents that could potentially be absorbed in the gastrointestinal tract. Results showed that the clay soil was very dry with mean moisture content of 0.19±0.01%. On dry weight basis, the geophagia clay soil contained (mg/100 g) aluminium, 1,239.6; iron, 962.9; lead, 2.4; magnesium, 64.3; and zinc, 54.6. The extractable mineral contents of this clay soil, on dry weight basis, were (mg/100 g): zinc, 1.40±0.05; iron, 14.19±0.13; magnesium, 23.83±0.31; and aluminium, 37.91±2.94. Compared to the total minerals contents of the clay soil, the acid extractable fractions represented 2.6% of zinc, 1.5% of iron, 36.4% of magnesium, and 3.2% of aluminium. Even though lead was not detected in the acid extracts, a small amount was detected in the dry clay soil. Arsenic was not detected in any clay sample or extracts. It was concluded that the main mineral nutrient potentially contributed by this clay pica substance was iron. The clay soil liberated a substantial amount of iron (14.2 mg/100g), which constituted 78.9% of the 18 mg/d iron RDA for women of reproductive age and 53.0% of the 27 mg/day iron RDA for pregnant women. The potentially undesirable effect of ingesting this clay soil is the high level of aluminium (37.9 mg/100g).

Key words: Geophagia, pica, pregnancy, clay, iron

INTRODUCTION

Pica is defined as the craving for non-food substances or food items that are unusual in kind or quantity [1-3]. The most common form of pica globally is geophagia which is the ingestion of lithospheric substances, notably clay soil [4-8]. The clay soil commonly consumed by geophagic persons contains several mineral nutrients including magnesium, zinc, copper, manganese, silicon, and iron, as well as some toxic mineral elements such as lead and aluminium [4].

Several different types of clay soil are ingested by geophagic persons around the world and vary in colour from whitish, creamy, greyish, yellowish, to reddish [1,4,6,9]. In West Africa, particularly Ghana and Togo, geophagia involves ingestion of a creamy-white loamy clay soil locally known as *ayelo* in Accra, Ghana. Some of this clay product is mined from a clay mining town called *Anfoega* in the Volta Region of Ghana close to the borders of Togo. The freshly mined wet semi-solid clay soil is moulded into lumps ranging from about 20 g to over 200 g a piece, oven baked, and sold in markets for ceramic, traditional and cultural applications, and to a small extent, for ingestion.

General pica and geophagia prevalence of 48% and 28%, respectively, have been reported in Ghana among women of reproductive age [1,10]. Other African countries where geophagia has been reported include Malawi, Nigeria, Swaziland, South Africa, Togo, Zambia, and Zimbabwe [3,5]. Geophagia is not limited to Africa and has been reported in India, China, Haiti, Australia, Turkey, Germany, Mexico, Middle East, Latin America, and in rural South of the United States of America [4,11]. In an earlier study, the average daily clay soil ingestion among women in Accra was reported as 70 g, range 3-488 g which was higher than the 50 g average reported among women in rural Holmes County, Mississippi [11-13]. The clay soil ingested in Ghana and Togo is the shale type composed of 67% silicate, 15.9% aluminium oxide, 3.4% iron oxide, 3.64% potassium oxide, 3.61% sodium oxide, 3.0% calcium oxide, 1.0% magnesium oxide, 0.6 titanium oxide, and trace amounts of other oxides [14].

Several motivating factors for geophagia have been reported. Clay ingestion has been used as a remedy for diarrhoea and stomach discomfort supposedly to absorb bacterial toxins associated with gastro-intestinal distress, as well as to alleviate nausea and the toxaemia of pregnancy [5,9,10,15]. On the other hand, geophagia has been associated with lead poisoning, hyperkalemia, phosphorous intoxication, dental injury and other undesirable effects including low bone mineralization [7,16]. Several studies have reported associations between geophagia and anaemia, and between geophagia and deficient ferritin levels [1,17-19]. Zinc deficiency has been observed to promote pica in young children [20].

Despite conflicting views, several evidence point to some nutritional benefits of geophagia. Whereas other researchers have speculated that geophagia during pregnancy may induce iron deficiency anaemia, others have indicated that geophagia may, in fact, be an adaptation to iron deficiency [1,3,18,21]. The high prevalence of geophagia among anaemic pregnant women sparks a quest for knowledge of the

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ISSN 1684 5374

potentially available mineral contents of the lithospheric substances ingested. This necessitates mineral analysis of the soil types usually ingested. The creamy white clay soil ingested in the Cape Three Point region of West Africa as a potential source of iron and other mineral nutrients has not been studied. This study seeks to bridge this knowledge gap.

The hydrochloric acid (HCl) extraction applied in this study is based on the premise that the acid soluble fraction of the minerals in the clay soil is the component that is potentially available for absorption in the gastrointestinal tract [22,23]. Similar methods have earlier been employed by others to test lithospheric pica substances ingested by pregnant women in Kenya, Uganda, Tanzania, Turkey, Australia, and India [5,23]. The extraction process aimed to simulate the acidic conditions in the stomach using 0.1 M HCl, pH 1.0, and the gentle mixing movement that occurs in the stomach for a transit of about 3 hours [24].

METHODS

Clay soil samples

A rapid market survey was conducted at the two major markets, Madina and Makola markets in Accra to locate the spots where clay soils were sold. Five representative clay soil lumps were then obtained through a systematic random sampling technique from each of 5 spots from each market [25]. These clay soil samples are known to come from a single source, *Anfoega,* a town in the Volta Region of Ghana popular for mining the clay soil as a major commercial activity. The clay soil lumps from each market were crushed and ground in a mortar into a fine composite powdered sample. The composite powdered sample from each market was mixed thoroughly and then partitioned into laboratory samples in several clean 100 g size polythene bags, sealed and then stored in a cold room till needed. Analytical samples were taken from these bags for analyses. Market samples were not combined but kept separate for analysis.

Hydrochloric acid extraction of minerals

Approximately 0.5 g of the clay sample was extracted with 100 ml 0.1 M HCl (Analar grade) solution in a conical flask [5,23]. The extraction was achieved by slow agitation of the mixture in the conical flask for 3 hours on a Gallenkamp waterbath (model WF220, General Scientific Instruments Inc., Ontario, Canada) at 37 °C on a shaker at 180 rev/min. The crude extract was then filtered through a No. 1 ashless 11.0 µm Whatman grade filter paper. Five analytical samples from each of the two markets were extracted along with 3 blanks.

Wet ashing of extracts and powdered clay samples

The five sample extracts and the 3 blanks were wet-ashed to eliminate organic compounds and to free all minerals into solution using the method described by Osborne and Voogt [26]. Quantitative amounts of about 0.5 g each of the 5 analytical samples, comprising the powdered clay samples, were also wet-ashed for analysis of the total mineral content in the clay soil. Each wet-ashed solution was topped up to 100 ml with distilled deionised water in a 100 ml volumetric flask.

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ISSN 1684 5374

Mineral Analysis

Each wet-ashed solution was analysed for the minerals: zinc, iron, magnesium, arsenic, aluminium, and lead, using an Atomic Absorption Spectrophotometer (Model 250, PerkinElmer Inc., Waltham, Massachusetts) with wavelength and lamp settings specific for each mineral element. Five wet-ashed solutions each from the acid extract and the powdered samples were analysed in duplicate for the above minerals.

Moisture Determination

To enable expression of the mineral content on dry weight basis, the moisture content of the clay samples were determined using the air-drought oven method [27]. Approximately 0.5g each of the clay sample was quantitatively weighed into each of clean dried moisture dishes and placed in a forced convection oven (Model 28, Thelco Precision Scientific Inc., Toronto, Canada) at 105 ºC for about 12 hours [27]. The moisture dishes were cooled in a desiccator and weighed using an electronic digital weighing scale (Model G160, Ohaus analytical balance, Parsippany, NJ). The moisture determination was done in triplicate.

RESULTS

The clay soil lumps ingested by geophagic persons were found to be very dry with mean moisture content of 0.19 ± 0.01 % despite being obtained from the open market. The total mineral contents of the clay soil categorised by source are shown in Table 1. The selected minerals in decreasing order of abundance were aluminium, iron, magnesium, zinc, and lead. The toxic mineral arsenic was not detected in any sample. Results from the acid extracts did not follow this sequence of abundance (Table 2). The concentrations of the minerals in the acid extract in decreasing order of abundance were aluminium, magnesium, iron, and zinc. Even though lead was detected in the powdered samples, it was not detected in the acid extracts. Arsenic was not detected in the powdered samples and not in the acid extracts. The percentage acid extractable fractions ranged from 1 - 37% (Table 2). Based on the percentage extractable, magnesium was the most extractable. However, in terms of quantity, the mineral that was of highest concentration was aluminium. Figure 1 relates the acid extractable amounts of minerals based on 100 g of clay soil to their respective recommended dietary allowance (RDA). Based on the RDA, the clay soil liberated a substantial amount of iron.

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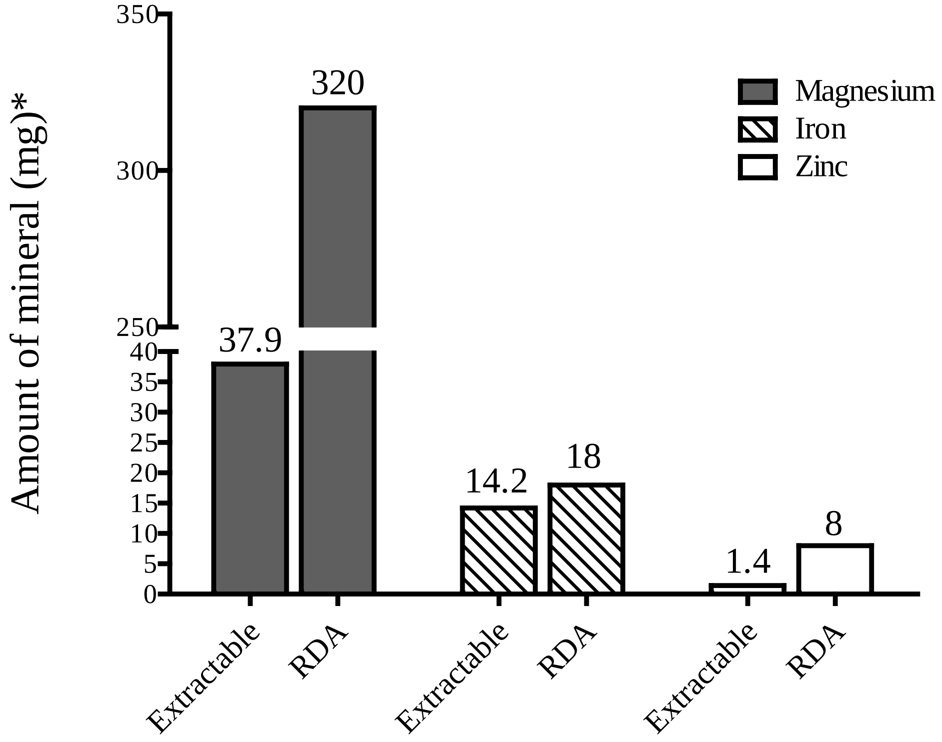

Figure 1: Acid extractable mineral nutrients of clay soil ingested in Ghana and Togo compared with dietary requirements for women of reproductive age

*Extractable mineral contents are based on 100 g of clay soil, dry weight basis. The recommended dietary allowance (RDA) for each mineral is based on current Institute of Medicine, National Research Council, recommendations [28].

DISCUSSION

This study presents first-hand information on mineral contents of the clay soil ingested by geophagic persons around the Cape Three Point region of West Africa, particularly Ghana and Togo, and the acid extractable fractions which are potentially available for absorption. The small fraction of iron that was acid extractable from 100 g of clay soil constituted 78.9% of the iron RDA (18 mg/day) for the female of reproductive age, and 53% of the iron RDA (27 mg/day) for the pregnant female [28]. This relative value reported for geophagic pregnant women in this region is higher than the 14% reported for geophagic pregnant persons in Kenya [14]. The extractable iron content is lower than the 48 mg per 100 g reported by Hunter for the copper belt zone of South Africa [9]. The relationship of pica with iron status has received conflicting reports. Whereas some reports have associated geophagia with anaemia and low iron status [14,19,29], others suggest geophagia may help meet iron and other essential minerals need [9,30,31]. In terms of a nutritional hypothesis for geophagia, several questions still remain unanswered. Even though most geophagic pregnant women tend to be anaemic, it is still unclear whether it is the anaemic condition that induced geophagia or vice versa. Physiological adaptations occur during pregnancy including significantly enhanced absorption of essential minerals such as iron to meet the increased need of about 27 mg/day, which cannot be met by the normal diet [28,32-34]. When the extractable mineral contents are determined at low pH of 1.0-3.0, as exists in the stomach environment, significant amounts of minerals such as iron, calcium and magnesium are liberated which indicate some availability from the clay soils ingested [5,23,30]. Results of this study lend further evidence that the clay soil ingested in the Cape Three Point of West Africa, particularly Ghana and Togo, liberates significant amount of iron during simulated stomach conditions. It is worth noting that absorption from non-heme iron is usually low under normal conditions but could increase substantially under anaemic conditions [33,35].

A significant finding of this study is that the toxic minerals, arsenic and lead, were not detected in the acid extracts. Even though some amount of lead was present in the powdered sample, it was not detected in the acid extract. Whereas lead poisoning in children eating contaminated soil has been reported, the type of clay soil in this study is not a potential source of arsenic or lead [36]. Thus the interference of lead with iron absorption under anaemic conditions is alleviated.

A worrisome finding of this study is that the clay soil contained about 1.2 g of aluminium per 100 g, of which a small but significant fraction was acid extractable. Normal dietary intake of aluminium is reported to be between 3-20 mg/day of which only about 15 μg is usually absorbed and then eliminated through the kidneys [16,37,38]. The observed acid extractable fraction of aluminium in this study was above this range. Thus clay geophagia in this region may constitute significant risk to aluminium toxicity. Excessive ingestion of aluminium could lead to bone mineralisation problems and intestinal malfunction [16,39]. Some associations between aluminium ingestion and age-related Alzheimer's disease have been reported [40]. Notwithstanding this, geophagia is reported to enhance the secretory and immune system of female monkeys because aluminium-rich clay soils are reported to have beneficial immunological properties [12,42].

The magnesium content of the clay soil, even though not as high as aluminium, was the most acid extractable. Compared to the RDA, the acid extractable fraction of the magnesium content, which is the amount potentially available for absorption, was low (Figure 1). In light of the results, this type of clay soil is an insignificant source of magnesium for geophagic persons.

Only a small fraction of the small amount of zinc in the clay was acid extractable. The acid extractable content could potentially contribute 18% of the RDA of 8 mg/day for women of reproductive age [28]. Daily zinc loss is between 2-3 mg which implies that the small amount of acid extractable zinc from the clay soil could be of value especially in zinc deficiency prone communities where geophagia is practiced [37,38]. There are significant differences in the types of clay soil ingested around the globe [1,4,6,9]. In a similar study, Hunter [9] had observed that 100 g of white clay in the copper belt of South Africa could contribute about 15 mg of calcium, 48 mg of iron,

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and 42 mg of zinc, which may make significant contribution in those who have deficient intakes in this population. Other researchers have reasoned similarly [9, 21,30,31].

Strengths and limitations

This study presents the first reports on the mineral contents of the clay soil ingested in the Cape Three Point region of West Africa, determined using a very sensitive instrument, atomic absorption spectrophotometry. This study does not only report the total mineral contents but also the acid extractable fractions to provide information on potentially available contents. A limitation of this study is that even though some mineral contents were acid extractable, it does not prove that all the liberated minerals may be bioavailable in the gastrointestinal tract. Despite this limitation, this study provides credible information on the mineral contents of the clay soil ingested by geophagic persons in West Africa.

CONCLUSIONS

The minerals in the geophagia clay soil found in the Cape Three Point region of West Africa were only sparingly acid extractable. Compared to the respective RDA's, the mineral nutrient contributed significantly by this clay soil was iron, and the potentially undesirable effect of ingesting this clay soil is excessive aluminium intake. The deleterious health effects of geophagia may overshadow any nutritional benefits. Consequently, prenatal counselling should include education on pica, particularly against geophagia during pregnancy.

ACKNOWLEDGEMENT

Our sincerest gratitude goes to Mr. Hesse, Mr. Achampong and Mr. Frimpong all of the Ghana Standards Board, Mr. Kissi-Adu of the Center for Scientific and Industrial Research and Mr. Kumah of the Nutrition and Food Science Department, University of Ghana, for their invaluable contributions to the success of this study.

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Table 1: Mineral contents of clay soil ingested by geophagic persons in Ghana and Togo

Type of mineral*	Makola sample (mg/100g, ± SD)	Madina sample (mg/100g, ± SD)	Overall mean (mg/100g, ± SD)
Aluminium	1,254.55 ± 14.00	1,224.70 ± 12.21	1,239.63 ± 13.07
Arsenic	ND†	ND†	-
Iron	959.40 ± 5.280	965.35 ± 5.326	962.88 ± 5.30
Lead	2.30 ± 0.07	2.41 ± 0.01	2.36 ± 0.08
Magnesium	63.86 ± 1.24	64.70 ± 1.34	64.34 ± 1.28
Zinc	54.27 ± 1.05	54.88 ± 1.33	54.58 ± 1.16

*Contents are on dry weight basis. †ND is none detected.

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Table 2: Acid extractable mineral contents of clay soil ingested by geophagic persons in Ghana and Togo

Type of Mineral*	Makola sample (mg/100g ± SD)	Madina sample (mg/100g ± SD)	Overall mean (mg/100g ± SD)	% acid extractable‡
Aluminium	39.05 ± 3.10	39.78 ± 2.83	37.91 ± 2.94	3.18
Arsenic	ND†	ND†	-	-
Iron	14.10 ± 0.10	14.27 ± 0.13	14.19 ± 0.13	1.51
Lead	ND†	ND†	-	-
Magnesium	23.35 ± 0.29	24.55±0.10	23.85 ± 0.31	36.44
Zinc	1.32 ± 0.05	1.47 ± 0.04	1.40± 0.05	2.57

*Contents are on dry weight basis.
‡Percentage acid extractable per 100 g of clay soil
†ND is none detected.

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