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Essential Minerals, Heavy Metals, and Consumption Prevalence of Edible Clay sold in some North-Western States of Nigeria

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Abstract
Clay is consumed to satisfy cravings or to depress vomiting and other discomforts associated with pregnancy which is becoming alarming among pregnant women. This study aimed to identify the chemical composition of bentonite (Ulo) and kaolin (Nzu) and the prevalence of their consumption by women in Northern Nigeria. The edible clays were ground to powdered and sieved for analysis. The AOAC method was used for the proximate analysis. The samples were digested and analyzed for macrominerals and heavy metals using Atomic Absorption Spectrophotometer. A standardized questionnaire was designed and validated to determine the consumption prevalence and Microsoft Excel and the Statistical Package for Social Sciences (SPSS) were used to analyze the data. According to the proximate analysis results, both 'Ulo' and 'Nzu' samples had a high ash content (above 85%). While bentonite had a significantly ($P<0.05$) higher calcium content whereas kaolin had a significantly ($P<0.05$) higher sodium and magnesium content. For the heavy metals, the levels of lead, arsenic, and aluminum in kaolin were significantly ($P<0.05$) higher. 64% of the respondents acknowledged consuming both edible clays during and after pregnancy. Both clays contain essential micronutrients and some heavy metals, therefore they ought to be consumed with caution, especially during pregnancy
Keywords: Edible clays, bentonite, geophagy, kaolin, nzu, ulo

Introduction

Consumption of edible clay is termed Geophagy which means deliberate consumption of soil or any earth material (Odimegwu et al., 2021; Omoniyi et al., 2018). Clay consumption can also be attributed to Pica; an eating disorder/medical condition that makes someone crave and/or become addicted to soil eating or other non-food materials (C. de S. F. Gomes, 2018; Kikouama et al., 2009). In Nigeria, calabash chalk is a common name for edible clay. One of these geographical elements that is widely used in Nigeria and other West African nations is calabash chalk. According to Abraham et al. (2013), it is also referred to as "Argile," "Calabar stone," "Calabash clay," "Poto" in English, "La craie" in French, and "Mabele" in Lingala of the Congo. It is known as "Nzu" and "Ulo" in Igbo and "Ndom" in Efik/Ibibio in South-East Nigeria. The primary component of naturally occurring chalks is fossilized seashells, although clay and mud can be combined with sand, wood ash, and occasionally salt to create an artificial form. The resulting product is moulded and then heated to produce the final product (Food Standard Agency, 2008). 'Nzu', a local white clay, is typically the most consumed in Nigeria. According to some reports, it contains kaolin, which is layered silicate soft clay that is often white but can also be red, pink, or brown at times. The benefits of this clay include inducing and speeding up blood clothing (Kelvin, 2012; Chen et al., 2014).

Clay has been used by man since antiquity as a dietary supplement, a remedy for diseases (Ferrell, 2008; C. de S. F. Gomes, 2018; C. F. Gomes *et al*., 2017) and for reflection of culture and religious beliefs (Ferrell, 2008; C. de S. F. Gomes, 2018). Clay eating is more common among Africans, particularly among the female gender (Odimegwu *et al*., 2021). The use of edible clay as an anti-emetic by pregnant women is a popular norm in Nigeria and other African countries (Odilon and Balde, 2010).

In Nigeria, edible clay eaters mostly buy from the market with the sole intention of either satisfying their craving for being addicted to its earthy smell or depressing vomiting and other discomfort associated with early pregnancy (Kelle *et al*., 2022). In addition to these, Aleruchi *et al*. (2022) also mention weight loss and appetite suppression as additional reasons for consuming edible clay. The results of a literature search conducted by Kelle *et al*. (2022) show that pregnancy is the foremost reason for consuming edible clay, data obtained from South Africa, Ghana, Tanzania, Kenya and Nigeria linked pregnant women with edible clay consumption.

Clay eating can cause damage to teeth enamel, expose consumers to biological and chemical contaminants (Amelia and Brandon, 2019) and interfere with the absorption of some drugs and nutrients (Eraga *et al*., 2017; C. de S. F. Gomes, 2018; Iwuagwu and Jideonwo, 1990). As a geological material, edible clay can contain heavy metals that can be released into the body upon consumption and trigger health problems when present in large amounts (Kelle *et al*., 2022). The results of a literature review conducted by Gomes (2018) show that edible clay can be contaminated by microorganisms and heavy metals such as Pb, Cd, Hg, Al, and As. Accumulation of copper, nickel, and manganese was observed in the brain, heart, kidney, liver, lungs, skeletal muscle, and blood of rabbits fed with edible clay (S. P. I. Ogah and Emetumah, 2019).

Consumption of clay is becoming alarming among young age and pregnant women in North-Western Nigeria despite the weighty uncertainty regarding its safety. The pervasive retail of the clay in most markets in the region is an indication of its large volume consumption. A significant amount is recklessly consumed by many either as anti-nausea or because of its petrichor (earthy smell) nature. Looking at its origin, the clay can fortunately serve as a cheap source of essential minerals or unfortunately serve as a source of toxic contaminants including dangerous heavy metals. There is a greater tendency to have both the essential minerals and the heavy metals in the clay since it is a mildly modified geological material.

There is scarce information on the mineral and heavy metal contents of the edible clay consumed in the North-West. The research intends to disclose the cons and pros associated with the consumption of edible clay sold in the North-West market by investigating their mineral and heavy metal contents.

Materials and Methods

Sample Collection

Samples were purchased from Kurmi Market in Kano State and brought to the Department of Food Science and Technology at Federal University Dutsin-Ma in Katsina State. The edible clays were ground in a mortar and pestle, sieved with a 115 µm mesh, and sealed in airtight containers for chemical analysis.

Sample Digestion

The acid digestion method described by Kelle *et al*. (2022) and Umudi (2017) were adopted. Two grams (2 g) of the clay samples were mixed with 20 ml of aqua regia (HNO_3/HCl in the ratio of 1:3 v/v). The mixture was then heated in a fume chamber until all solids were completely dissolved. The solution was allowed to cold down to room temperature and filtered with

Whatman 110mm filter paper into 120 ml plastic bottles that are thoroughly clean. The volume of the filtrate was increased to 100 ml using deionized water.

Proximate Analysis

AOAC standard method was used to determine the edible clays' proximate composition. The nitrogen-free extract (NFE), a technique described by James (1995), was used to determine the carbohydrate content. The mean protein, fat, and carbohydrate values were multiplied by their corresponding Atwater factors (4, 9, and 4, respectively), and the product was then calculated to determine the samples' caloric value.

Macro minerals and heavy metals determination

A 500 ml volumetric flask was filled with 0.5 g of the sample, 15 ml of HNO_3, and 5 ml of 70% perchloric acid ($HClO_4$). To achieve clarity, the flask was set on a hot plate in the fume cupboard. After being moved to a 100 ml volumetric flask, the solution was diluted with water to volume. To ascertain the elements, aliquots or dilutions of this sample were subsequently aspirated into the air-acetylene flame of the WFX 320 (AAS) Atomic Absorption spectrometer. The elements were reported using graphic extrapolations with standard pure metals and visuals. The Official Methods of AOAC International were used for the determination of macro minerals Mg, Ca, Na, K, and heavy metals Pb, Cd, As, and Al.

Study area

A convenience sample of 200 pregnant women who visited antenatal clinics at Federal Medical Center Katsina State and Murtala Muhammad General Hospital Kano State participated in a cross-sectional study. An anonymous, closed-ended, structured questionnaire created exclusively for the study based on objectives and literature review was used to conduct the interview. The questionnaire which included background information to collect data on respondents' knowledge, attitudes, and perceptions of geophagy as well as their health state, was verified by experts in the field. Following their reading and signing of the consent form, the participants were enlisted into the study, and each one received a token worth 1,000 Naira. Copies of the questionnaires that the 100 participants duly filled out and returned were statistically examined.

Data Analysis

Using a Microsoft Excel 2013 spreadsheet, laboratory analytical results were collated, input into the computer, and analyzed before being reported as mean ± SEM. Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS version 20.0) and included Analysis of Variance (ANOVA) and T-tests. A significance level of $p<0.05$ was considered.

Results and Discussion

3.1 Results

Table 1 presents the results of the proximate analysis which reveals that there is a significant difference between the moisture content (3.21 ± 0.02%; 3.84 ± 0.01%), of bentonite and kaolin clay respectively. No significant difference was recorded between the ash content of bentonite and kaolin clays (about 85%). Whereas the fat content was found to be 0.52 ±0.002 for bentonite and 0.50 ±0.00 for kaolin clays. The fibre contents of bentonite (0.00 ±0.00) were significantly lower than that of Kaolin (2.3 ±0.01). The protein content of bentonite clay (3.74 ± 0.03%) was significantly higher than that of kaolin clay (2.78 ± 0.06%). Similarly, the bentonite's carbohydrate content (8.21±0.17) and energy value (48.97 ± 0.62Kcal) were also significantly higher than that of kaolin clay with 6.92 ± 0.19% and 38.91 ± 0.37Kcal respectively

Table 1: Proximate composition of bentonite (Ulo) and kaolin (Nzu)

	Moisture (%)	Ash (%)	Fat (%)	Fibre (%)	Protein (%)	CHO (%)	Energy (Kcal)
Bentonite	3.21±0.02[b]	85.39±0.16[a]	0.52±0.02[a]	0.00±0.00[b]	3.74±0.03[a]	8.21±0.17[a]	48.97±0.62[a]
Kaolin	3.83±0.01[a]	85.30±0.12[a]	0.50±0.00[a]	2.3±0.01[a]	2.78±0.06[b]	6.92±0.19[b]	38.91±0.37[b]

Values with the same letter [a-b] in each column are not significantly different (P < 0.05) for the proximate composition of bentonite (Ulo) and kaolin (Nzu)

The results of the macro mineral analysis in mg are shown in Table 2, which indicates that the potassium (K) content of both bentonite (0.18±0.02) and Kaolin (0.21±0.01) was not significantly different, but the sodium (Na) content of kaolin clay (0.20 ± 0.01) was significantly higher than that of bentonite clay (0.13 ± 0.01), the calcium (Ca) content of bentonite clay (2.20±0.01) was significantly higher than that of kaolin clay (1.21 ± 0.01), and the magnesium (Mg) content of kaolin clay (2.18±0.01) was significantly higher than that of bentonite clay (1.71 ± 0.01). Whereas there was no significant difference in potassium (K) contents of both bentonite and Kaolin. In terms of heavy metals, bentonite clay was found to contain no lead (Pb), although both clays had the same amount of cadmium (Cd). Kaolin clay had considerably higher levels of arsenic (As) and aluminum (Al) than bentonite clay (P=0.001).

Table 2: Mineral composition and heavy metals of bentonite (Ulo) and kaolin (Nzu) in mg

	K	Na	Ca	Mg	Pb	Cd	As	Al
Bentonite	0.18±0.02[a]	0.13±0.01[b]	2.20±0.01[a]	1.71±0.001[b]	0.00±0.00[b]	0.03±0.00[a]	0.01±0.01	0.20±0.01
Kaolin	0.21±0.01[a]	0.20±0.01[a]	1.21±0.00[b]	2.18±0.01[a]	0.08±0.01[a]	0.03±0.00[a]	0.02±0.00	0.30±0.01

Values with the same letter [a-b] in each column are not significantly different (P < 0.05) for the mineral composition and heavy metals of bentonite (Ulo) and kaolin (Nzu)

Table 3 shows a higher proportion of the respondents (more than 70 %) acknowledged occasionally consuming "Nzu" and "Ulo." Some claimed to have only consumed during pregnancy, while others did so at other times. 64.0 % of the respondents, reported consuming both "Nzu" and "Ulo" up to three times per week, while just 6 % acknowledged consuming both clays every day. 57.5 % of those who consumed the edible clays reported consuming tiny amounts of the substances, making "neighborhood" and "their hometown" the primary sources of these compounds.

Discussion

Consumption of edible clay is known among diverse groups of people, it's particularly common among many African descent (Odimegwu et al., 2021). Besides Nigeria, edible clay is also consumed in Guinea, Ivory Coast and Senegal (Kikouama et al., 2009). In addition to Africa, history shows that clay was also consumed in Iran, India, China, the Mediterranean, Western Europe, Oceania, and Indonesia (Odilon and Balde, 2010). The compounds found in edible clay are kaolinite, illite, muscovite, quartz, feldspars (Kikouama et al., 2009), monomineralic, smectite, chlorite, and vermiculite (Ferrell, 2008). It is consumed by many pregnant women to alleviate excessive salivation and vomiting mostly during the first 12 weeks of pregnancy (Odilon and Balde, 2010).

Table 3. Consumption of edible bentonite (Ulo) and kaolin (Nzu) by respondents

Variable	Sub variable	N	%
Do you consume bentonite (Ulo)?	Never	50	25
	Sometimes	144	72
	Only during pregnancy	58	29
Do you consume kaolin (Nzu)?	Never	70	35
	Sometimes	134	67
	Only during pregnancy	62	31
	Don't consume	54	27
How often do you consume Ulo and Nzu?	Less than 3 times a week	128	64
	4-6 times a week	56	28
	Daily	34	17
How do you obtain the Ulo and Nzu	Neighborhood	154	77
	Shops	102	51
	My home town	156	78
	Market	104	52
	Others	98	49
	Small	124	62
What size of Ulo and Nzu do you consume?	Medium	96	48
	Large	18	9

Microbial contamination was also reported by Omoniyi et al. (2018) in edible kaolin. Aleruchi et al. (2022) isolated pathogenic microorganisms that are extremely resistant to famous and legendary broad-spectrum antibiotics such as Augmentin, Ceftriaxone, Cefuroxime, and Ceftazidime in edible clay samples collected from Port Harcourt, Rivers State. Nevertheless, certain types of edible clay were reported to possess excellent antimicrobial properties (Williams et al., 2009). Willey et al. (2008) state that moisture content above 15% is considered favourable for microbial growth. The low moisture content of both clays (less than 4%) may explain why they can be stored for a longer time without spoiling, as some women carry them around in handbags and purses for weeks without any deterioration. Therefore, the pathogens reported by Aleruchi et al. (2022) may not be the natural flora of the clay but contaminants that have their way either through handling or processing. Metals and microbial contamination of edible clay can be minimized by subjecting the clay to various soil-washing techniques as demonstrated by Omoniyi et al. (2018).

Clay can serve as a good and cheap source of essential minerals and also a reckless source of dangerous heavy metals, both were reported by Ogah et al. (2015) in edible clay samples obtained from Abakaliki, Ebonyi State. Edible clay can contain vital electrolytes such as magnesium and potassium (Aleruchi et al., 2022). Substantial amounts of iron, copper, and zinc can be found in clay (Aleruchi et al., 2022; Odilon and Balde, 2010). Barium, cobalt, chromium, copper, manganese, nickel, lead, strontium, vanadium, zinc and zirconium were detected in edible clay samples collected from Ivory Coast, Guinea and Senegal (Kikouama et al., 2009). Ferrell (2008) reported the presence of aluminium, silicon, potassium, sodium, calcium, magnesium, iron, manganese, titanium, phosphorous, sulphur, barium, strontium, lead, zinc, cadmium, cobalt, copper, chromium, nickel, vanadium, zirconium, selenium, molybdenum, beryllium, antimony and arsenic in edible clay samples gathered from different parts of the globe. Edible clay samples obtained from Ozanagogo, Delta State, Nigeria are rich in iron and magnesium (Umudi, 2017). The ash content is a measure of a food or substance's mineral content as reported by Ndife et al. (2019) and therefore, the ash content of both edible clays was found to be high (85%), which was in line with the previous report of Ejike and Ogugua (2017) who revealed a high ash content in 'Nzu' and 'Ulo'. Thus, both edible clays exhibited a significant amount of ash content indicating high inorganic composition (mineral content). The macrominerals including magnesium were present in significant quantities in both samples, but given the adult required daily allowance (RDA) of 250 mg/day (FNB/IOM, 2002), it cannot be considered a rich source of magnesium to the body. Sodium, potassium, and calcium were present in moderate concentrations and were consistent with previous reports of Umudi (2017) and Ejike and Ogugua (2017). Calcium is an essential mineral needed for bone formation and neurological function. The calcium content was low in both samples compared to the WHO/FAO recommended intake of 400 – 500 mg per day for adults and 1200 mg per day for children. Both samples' potassium and sodium contents were below WHO recommendations, with potassium being a little higher than sodium.

Consumption of edible clay can cause heavy metal poisoning and bowel blockage (C. F. Gomes et al., 2017). The findings of Odimegwu et al. (2021) revealed that consumption of edible clay above 500 mg/kg of body weight can be harmful to the digestive tract. According to the results of the heavy metal analysis, both clays contained lead (Pb), cadmium (Cd), arsenic (As), and aluminum (Al), while bentonite clay did not. Kaolin clay had the highest mean concentrations of all the heavy metals, which is consistent with the findings of Ejike and Ogugua (2017). The mean concentrations of the metals were within the safe limits recommended by the FAO and WHO. Lead (Pb) poisoning is the most often reported hazardous side effect of pica (Ali, 2001). In mineralizing tissues, lead tends to replace calcium. There is also a chance of congenital toxicity with lead poisoning. High levels of lead exposure can harm the kidney, gastrointestinal tract, joints, reproductive system, and brain system in addition to impairing hemoglobin synthesis (Zhuk and Kist, 1993). This has serious public health consequences as lead poisoning is excreted through the placenta and breast milk, and it can have a significant impact on both the fetus and newborns. Mothers who have been exposed to lead poisoning have experienced difficulties such as early birth, stillbirth, and miscarriage. According to the survey's findings, the participants consumed both kaolin and bentonite clay up to three times per week, suggesting that women in Kano and Katsina States, Nigeria, frequently consume both edible clays. This research raises concern regarding the health repercussions of the practice (geophagy) as have been revealed by specialists. Various forms of geophagic materials are accessible, and people opt for a specific time (particularly pregnant women as a result of pica). This study found that "Nzu" (kaolin clay) was consumed at a higher rate than "Ulo" (bentonite clay). This is consistent with the findings of Ekenedo and Okereke (2018), who found that "Nzu" was consumed at a higher rate than other clay varieties. Reasons behind such preferences may include hunger, taste, cultural practices as well as nutritional value (Arikan-Saltik et al, 2013). Similarly, Simelane (2008) discovered that in South Africa, soil is preferable to other geophagic materials. The largest consumers of geophagia materials were respondents under forty (40) years. This is comparable to the results of Njiru et al. (2011), who revealed that pregnant women and schoolchildren in Africa had a greater prevalence of geophagy. Although the practice is now most prevalent among the world's poorer or more tribally oriented people (Abrahams et al., 2013), it was suggested that intrusive treatment approaches are necessary when an individual's pica is considered life-threatening. This practice is unaffected by age, race, economic status, or physiological state (Stiegler, 2005).

Conclusion

Regardless of age, educational attainment, or place of residence, women in Kano and Katsina States especially those who are pregnant consume both bentonite and kaolin clay. Chemical analysis of the edible clay samples revealed that both clays had relatively high ash contents and low levels of other nutrients, with bentonite clay having a far greater energy value. Examining the edible clays' non-nutritive composition later revealed that both had notable concentrations of heavy metals which could have an impact on the bioavailability of the less concentrated nutrients. This suggests that they contain hazardous compounds which could be deemed to be relatively harmful for intake at certain quantities. Hence, excessive intake of these clays could be a risk factor for several diet-related deficiency disorders and may be detrimental to both pregnant mothers and babies. As a result, eating edible clay should be done carefully, especially during pregnancy period

Conflict of interest

The authors declare no conflict of interest

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