EDIBLE CLAY INGESTION ALTERS THE RENAL FUNCTION OF NON-PREGNANT FEMALE WISTAR RATS

*D. O. EDEHA, J. O. NZOPUTAM & O. V. ONUZULIKE

**D. O. E.: Department of Physiology, Faculty of Basic Medical Sciences, College of Medical Sciences, Benson Idahosa University, Nigeria.; D. O. E., J. O. N. & O. V. O.: Department of Physiology, School of Basic Medical Sciences, College of Medical Sciences, University of Benin, Nigeria.*

**Corresponding Author's email: daniel.edeha@yahoo.com, daniel.edeha@uniben.edu, dedeha@biu.edu.ng*

ABSTRACT

Edible clay is mainly consumed by women and children in specific regions of the world. However, studies have shown that its consumption tends to expose consumers to heavy metal toxicity. This study aimed to investigate the effect of edible clay ingestion on the renal function of Female Wistar rats. Forty (40) female Wistar rats (150–200 g) were assigned to four groups, each split into two subgroups (day 14 and day 28) with five rats (n = 5). Group 1 received distilled water (control), while Groups 2–4 were given edible clay suspensions at 400 mg/kg (low dose), 800 mg/kg (medium dose), and 1600 mg/kg (high dose). On days 14 and 28, rats were sacrificed for blood serum and kidney collection to assess renal function markers and histology. On day 14, high-dose edible clay significantly reduced serum potassium, while bicarbonate levels increased across all doses, and creatinine rose in the low and medium groups. By day 28, serum urea and bicarbonate levels were significantly elevated across all doses, with creatinine also increased in the medium-dose group. Histology revealed normal kidney architecture with dose-dependent interstitial congestion due to increased blood flow. This study has shown that prolonged ingestion of edible clay may have deleterious effect on renal functions.

Keywords: Edible clay, Renal function, Renal histology, Heavy metals, Non-pregnant Wistar rats

Introduction

Food must meet specific requirements, such as being devoid of harmful microorganisms and metals, and must also include nutrients like vitamins and minerals that are thought to be necessary for life and growth. Eating clay, often known as earth, is one of the habits, employed by man in search of food that may or may not contain harmful substances (Sturney & Hersen, 2012). Edible clay is the portion of the earth that humans consume, whether it is prepared or not.

They occur as pellets or large blocks predominantly found in West Africa, especially in Nigeria where they are known by local names such as nzu (Igbo), eko (Benin), ndom (Efik/Ibibio) (Edeha *et al*., 2023). They are also known as mabele, shilè and umcako in the Congo, Ghana and South Africa respectively (Owhorji *et al.,* 2019).

In many regions of Africa and the world, edible clay is regularly consumed by children,

and both pregnant and non-pregnant women. Some expectant mothers cannot live without it and think that it helps their unborn children grow better and gives them fair skin, others use the same clay as lotion on their newborns after giving birth. There are many uses for clay, as well as a plethora of myths and superstitions around it (Belluco, 2013). Generally, people consume clay for many reasons such as to provide relief from a number of illnesses including nausea, diarrhea, and vomiting (Ekosse & Ngole, 2012). It has also been reported that consuming clay or other earthy materials may help with toxin elimination and appetite relief (Brand *et al*., 2010). However, edible clay intake carries health hazards, such as alimentary canal damage and heavy metal toxicity, particularly lead (Ekosse *et al*., 2010). In addition, consuming geophagic clay increases the risk of parasite transmission, including whip worms (Trichuris triciura), roundworms (Ascaris lumbricoides), and other nematodes (Nabuuma, 2021). Furthermore, it has been claimed that clay may clog the intestines, resulting in situations that affect the fetus. Additionally, some soils might interfere with absorption by mixing with minerals in food (Jakari, 2015).

Given that clay is often created by the weathering and sedimentation of rocks, it is possible that some more metals will get lodged in the clay and be consumed. Some of these metals, in moderation, may be beneficial to the diet, at higher concentrations, others may be detrimental, and the cumulative impact might pose health risks (Belluco, 2013). According to Nurnadia *et al*. (2013), the majority of these edible clays include trace amounts of lead (Pb), chromium (Cr), mercury (Hg), and cadium (cd), all of which are physiologically hazardous (Nurnadia *et al*., 2013). Trace minerals are present in clays in certain amounts. In addition to heavy metals, radioactive gases and organic compounds have also been found in clay (Gomes *et al*., 2021). Most of the time, pollution causes minerals like copper (Cu), sodium (Na), iron (Fe), phosphorus (Ph), zinc (Zn), potassium (K), and manganese (Mn) to increase in concentration. When ingested, edible clay may release mineral nutrients upon contact with digestive secretions. However, due to their low nutritional value and potential toxicity, caution should be exercised in their sourcing and excessive consumption.

Previous study by Edeha *et al.,* (2023) shows that uzalla geophagic clay contains high deposits of heavy metals like Indium, Beryllium and lead. Also, from a mineralogical standpoint, the consumed clay, uteh-uzalla geophagic clay (Eko), is mostly composed of quartz and kaolin, with small amounts of smectite. Those who regularly consume clay may be at risk of health problems due to the presence of quartz in the clay. This is due to the fact that quartz is much harder than tooth enamel in the human body and has been shown to be so, on a hardness scale. This might indirectly have a negative impact on the internal system. As previously noted by Jahanshahee *et al*., (2004), when quartz in the clay goes through the gastrointestinal system, it may collect in the colon and potentially cause a colon rupture.

Stemming from the large consumption of edible clay by both pregnant and non-pregnant women, and children, and the scarcity of literature on its effect on the renal system, it is the aim of this study to evaluate the effect of edible clay ingestion on the renal system of normal female wistar rats, in order to provide timely information to consumers on possible

health benefits or hazards to the major system of filtration in the body.

Experimental

Sources of Edible clay

Five blocks of edible clay, each weighing between 100 and 150 grams, were obtained from Ogiso Market in Benin City, Nigeria. According to the vendors, the clay was sourced from Uzalla, a nearby village. To avoid contamination, after cleaning the samples were securely sealed in zip-lock bags.

Preparation of Edible Clay Suspension

The edible clay blocks were crushed into a powdery form using a mortar and pestle. Subsequently, 40 g of the powdered clay were mixed with 440 milliliters of distilled water, with continuous stirring to create a thoroughly dispersed suspension. This suspension was then stored and stirred before each subsequent administration (Ikewuchi *et al.,* 2019).

Dose Ranges

The selected dosage ranges were based on previous studies, including the use of 200 mg/kg by Ekanem *et al.* (2015), and findings by Ekong *et al.* (2015), which reported no fatalities even at a dose of 5,000 mg/kg.

Experimental Animals and Design

A total of forty (40) female Wistar rats, each weighing between 150 and 250 grams, were sourced from the Animal House of the Department of Pharmacology at the University of Benin, where they were also housed throughout the duration of study. After sorting into different experimental groups, the animals were allowed two weeks to acclimatize. The animals were divided into four groups of 10 rats each (n = 10). The groups were further split into two subgroups and tagged day 14 and day 28, with five rats (n = 5) in each subgroup (Ikewuchi *et al.,* 2019; Edeha *et al.,* 2024). Group 1 was control group and received distilled water daily. While groups 2 to 4 were the treatment group and received different dosages of the edible clay suspension ranging, respectively, from 400, 800, and 1600 mg/kg through oral route using the gavage (Ikewuchi *et al.,* 2019). The animals were given unlimited access to water and rat chow food, and maintained under standard environmental conditions throughout the duration of study. On the fourteenth (14th) and twenty-eight (28th) day of the experimental period, five rats from each subgroup were sacrificed; collection of blood samples was through cardiac puncture (Ikewuchi *et al.,* 2019) into plain bottles for biochemical determination of serum proteins, urea, creatinine, sodium, potassium, and chloride levels in order to evaluate renal kidney function. Serum proteins, urea and creatinine were determined by spectrophotometry (Olisah & Meludu, 2021). The ion-selective electrode method was used to measure serum levels of sodium, chloride and potassium (Olisah & Meludu, 2021). Kidney tissues were harvested, fixed in 10% formaldehyde, paraffin embedded, sectioned and stained with Hematoxylin and Eosin (H&E) for histological evaluation at x400 magnification using a light microscope (Maghsoudi *et al.,* 2011).

Statistical Analysis

The data obtained from the study were analyzed statistically using GraphPad Prism version 8.1. Analysis of variance (ANOVA) was performed, and results were expressed as mean ± standard error of the mean (SEM). A post-hoc test using the Least Significant Difference (LSD) method was applied. Statistical significance was set at p-values lesser than 0.05 ($P < 0.05$).

The resulting statistical values were illustrated using bar charts for visual representation.

Results

Renal Function Test

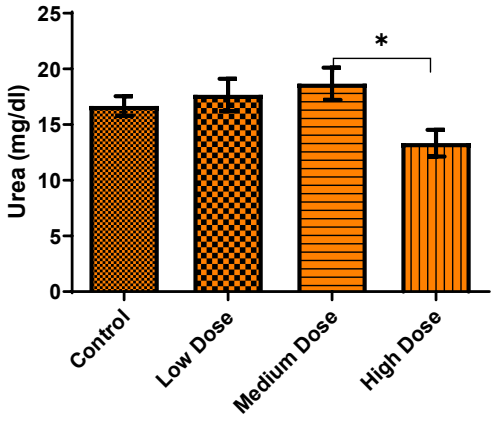


Fig. 1: Showing the effect of acute edible clay consumption for two weeks on urea concentration of female Wistar rats

No significant changes were observed between the treatment groups and the control. The high dose group had significantly lower urea compared to the medium dose, but not with low dose and control ($P < 0.05$).

P < 0.05 indicates statistically significant differences among treated groups and in comparison, with the control group.

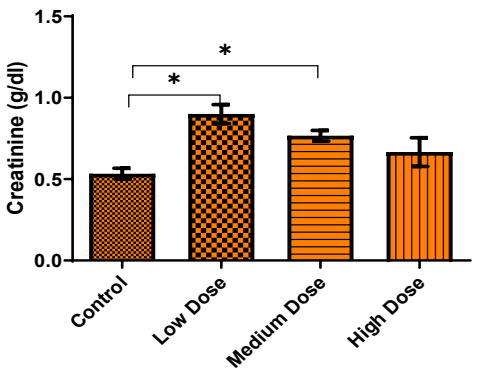


Fig. 2: Showing the effect of acute edible clay consumption for two weeks on creatinine concentration of female Wistar rats

The low and medium dose groups had significantly increased creatinine compared to control ($P < 0.05$). The high dose group showed no significant increase compared to control ($P < 0.05$).

**P < 0.05 indicates statistically significant differences among treated groups and in comparison, with the control group.*

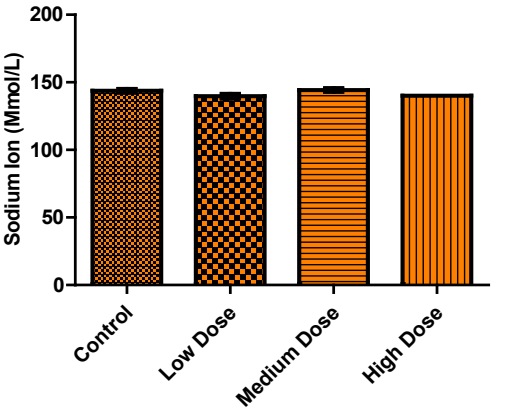


Fig. 3: Showing the effect of acute edible clay consumption for two weeks on sodium ion concentration of female Wistar rats

No significant differences among all treatment groups and when compared to control ($P < 0.05$).

**P < 0.05 indicates statistically significant differences among treated groups and in comparison, with the control group.*

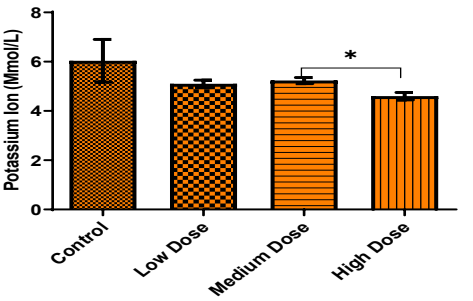


Fig. 4: Showing the effect of acute edible clay consumption for two weeks on potassium ion concentration of female Wistar rats

No group differed significantly from control. However,

the high dose group showed a significant decrease compared to the medium dose.

**P < 0.05 indicates statistically significant differences among treated groups and in comparison, with the control group.*

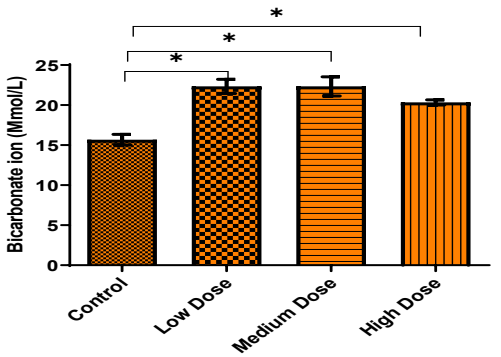


Fig .5: Showing the effect of acute edible clay consumption for two weeks on bicarbonate ion concentration of female Wistar rats

All treatment groups showed significant increases in bicarbonate compared to control (P < 0.05).

**P < 0.05 indicates statistically significant differences among treated groups and in comparison, with the control group.*

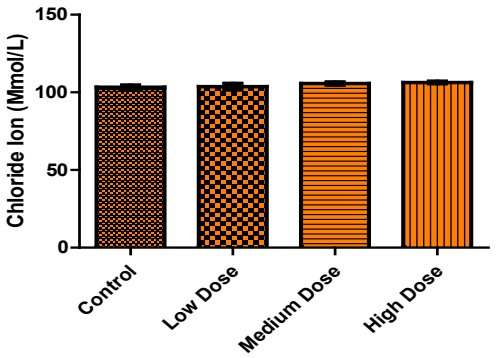


Fig. 6: Showing the effect of acute edible clay consumption for two weeks on chloride concentration of female Wistar rats

No significant change in any group, and when compared to control (P < 0.05).

**P < 0.05 indicates statistically significant differences among treated groups and in comparison, with the control group.*

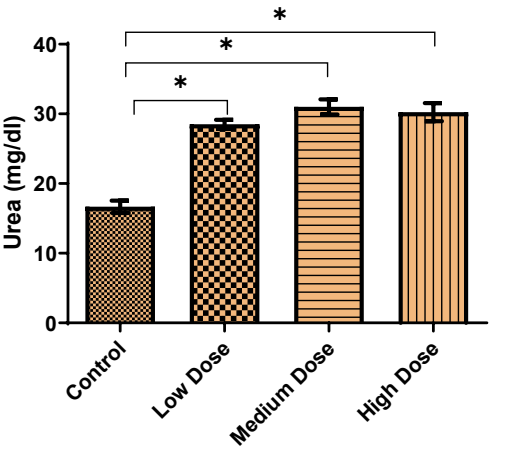


Fig. 7: Showing the effect of edible clay consumption for four weeks on Urea concentration of female Wistar rats

All treatment groups showed a significant increase in serum urea when compared to control (P < 0.05).

**P < 0.05 indicates statistically significant differences among treated groups, and in comparison, with the control group.*

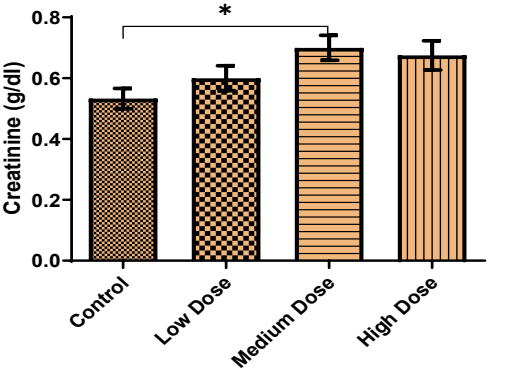


Fig. 8: Showing the effect of edible clay consumption for four weeks on creatinine concentration of female Wistar rats

The medium dose group showed significantly elevated creatinine compared to the control ($P < 0.05$). The low and high dose groups did not show significant increases compared to the control ($P < 0.05$).

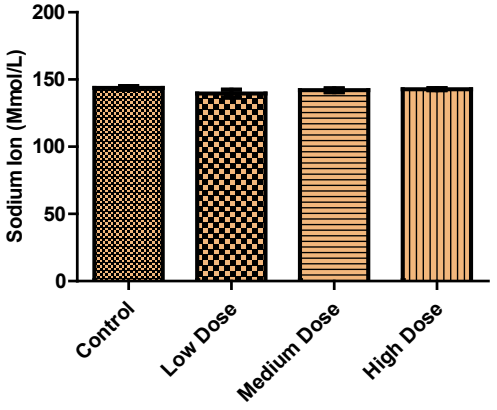


Fig. 9: Showing the effect of edible clay consumption for four weeks on sodium concentration of female Wistar rats

No significant difference in serum sodium across all groups ($P < 0.05$).

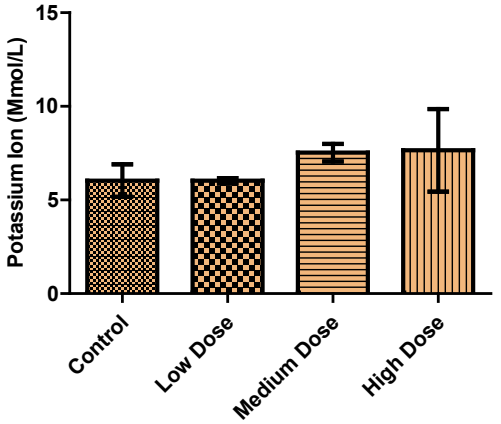


Fig. 10: Showing the effect of edible clay consumption for four weeks on potassium concentration of female Wistar rats

No significant changes were noted with the different doses compared to control respectively ($P < 0.05$).

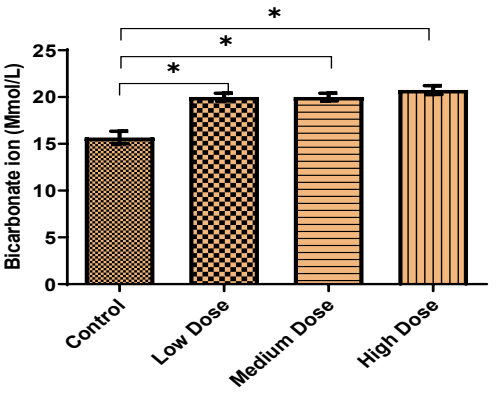


Fig. 11: Showing the effect of edible clay consumption for four weeks on bicarbonate concentration of female Wistar rats

There were significant increases in low, medium and high doses compared with control respectively ($P < 0.05$).

**P < 0.05 indicates statistically significant differences among treated groups and in comparison, with the control group.*

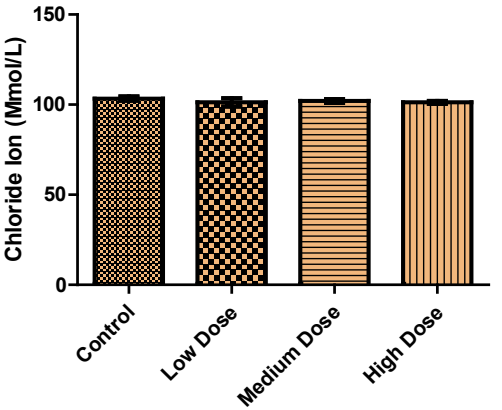


Fig. 12: Showing the effect of edible clay consumption for four weeks on chloride concentration of female Wistar rats

There were no significant changes with the different doses compared to control respectively ($P < 0.05$).

**P < 0.05 indicates statistically significant differences among treated groups and in comparison, with the control group.*

Renal Histology

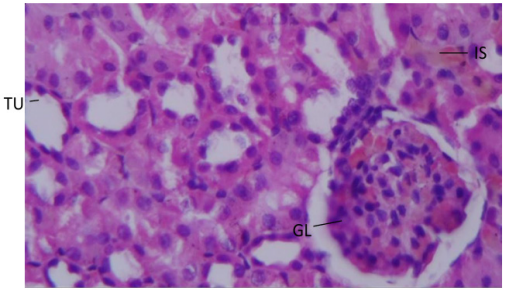


Plate 1: Rat kidney of control group following treatment with distilled water only for 2 weeks. Composed of normal tissue: tubules (TU), interstitial space (IS), glomeruli (GL): H&E x 400. The kidney shows normal histological architecture. Tubules (TU), interstitial space (IS), and glomeruli (GL) are intact, with no evidence of damage, inflammation, or congestion. This serves as a reference baseline for what healthy renal tissue looks like.

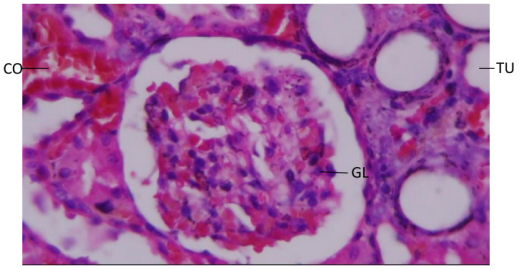


Plate 2: Rat kidney given low dose of edible clay for 2 weeks showing normal architecture: Tubules and glomeruli appear structurally intact. However, there is active interstitial congestion (CO), indicating the presence of increased blood or fluid within the interstitial capillaries or tissues. This may reflect an early vascular response to the clay exposure at low dose. H&E x 400.

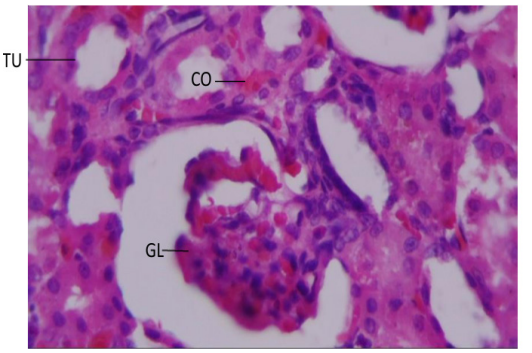


Plate 3: Rat kidney given medium dose of edible clay (Eko) for 2 weeks, showing normal architecture: glomeruli (GL), active interstitial congestion (CO), tubules (TU): H&E x 400. Similar to the low dose, there is active interstitial congestion, which may imply a dose-dependent vascular response. No signs of tubular necrosis, glomerular atrophy, or inflammation were observed, suggesting that structural integrity is still maintained.

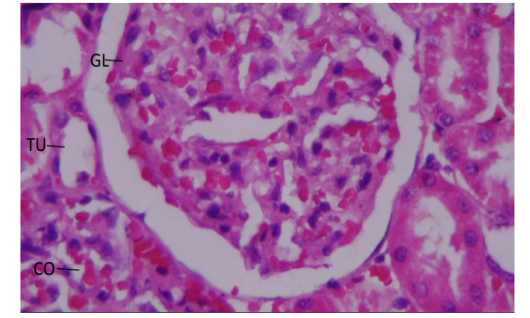


Plate 4: Rat kidney treated with high dose of edible clay (Eko) for 2 weeks, showing normal architecture: tubules (TU), active interstitial congestion (CO) and glomeruli (GL): H&E x 400. The structure of the kidney remains grossly normal. There is prominent interstitial congestion, more apparent than at the lower doses. The persistence of congestion with increasing dosage indicates that vascular alterations are present even in the absence of overt cellular damage.

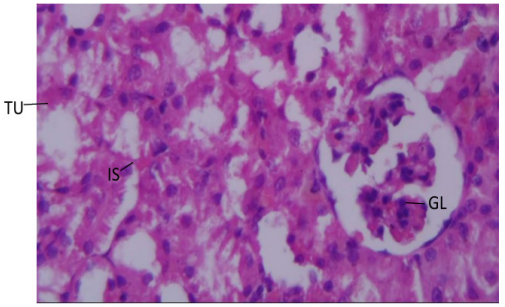


Plate 5: Rat kidney of control group following treatment with distilled water only for 4 weeks. Composed of normal tissue: tubules (TU), interstitial space (IS), glomeruli (GL): H&E x 400. The renal structure remains normal, with tubules, interstitial space, and glomeruli clearly visible and well-organized. No congestion or degenerative changes are seen, consistent with healthy, untreated tissue.

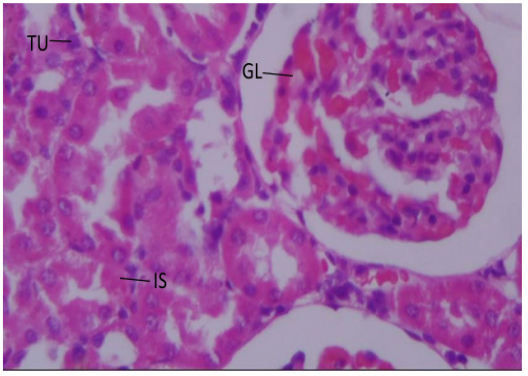


Plate 6. Rat kidney given low dose Edible clay for 4 weeks showing normal architecture: tubule (TU), interstitial space (IS), glomeruli (GL): H&E x 400. The kidney tissue remains structurally intact. Tubules and glomeruli are preserved, and the interstitial space appears unaffected.

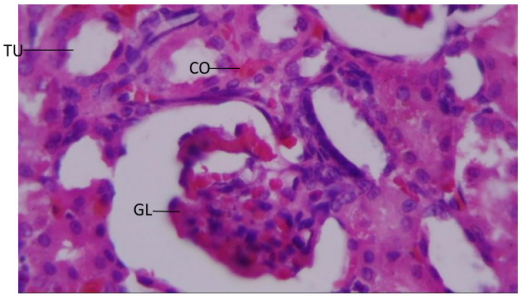


Plate 7: Rat kidney given medium dose of edible clay (Eko) for 4 weeks, showing normal architecture: glomeruli (GL), active interstitial congestion (CO), tubules (TU): H&E x 400. Normal architecture is preserved. Active interstitial congestion is again present, indicating that vascular changes persist or reappear at this dose over extended exposure. No visible signs of cellular degeneration, but the congestion may affect perfusion if sustained.

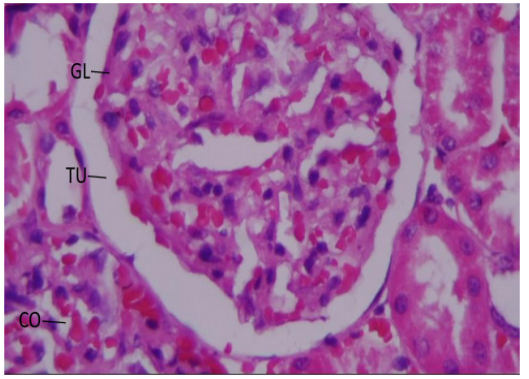


Plate 8: Rat kidney treated with high dose of edible clay (Eko) for 4 weeks, showing normal architecture: tubules (TU), active interstitial congestion (CO) and glomeruli (GL): H&E x 400. Despite high-dose, long-term exposure, the kidney shows normal architecture. However, there is marked interstitial congestion, similar to or more pronounced than at 2 weeks. This suggests that while the renal parenchyma remains intact, vascular stress is sustained with prolonged high-dose exposure.

Discussion

Due to its high blood flow and ability to filter a significant quantity of toxins, which may accumulate in the renal tubules, the kidney is very vulnerable to toxicants (Cooksey, 2012). Nephrotoxicity may cause systemic toxicity, which may impair one's capacity to eliminate bodily wastes, maintain electrolyte balance, and synthesize vital hormones at reduced levels. This study's result shows that the urea concentration in the high does group significantly decreased in the second week of ingestion of edible clay, as shown in Figure I. The byproduct of the production of proteins and nitrogen is urea, a volatile chemical molecule (Almeras & Argiles, 2009). Due to a dilution effect from either slower reabsorption or greater blood volume, being overhydrated may lower the content of urea. However, Figure VII shows that on the 28th day of ingestion of edible clay, the urea concentrations of low, medium, and high dosages had significantly increased when compared to the control. This rise may have been the consequence of elevated urea synthesis, reduced urea elimination, or both biological processes combined. Lead, a heavy metal and a major constituent of edible clay (Nkansah, 2016) has been linked to elevated urea concentrations (Alasia *et al.,* 2010; Nakhaee *et al.,* 2019). The glomerular filterate rate, may be lowered by lead exposure (Fadrowski *et al.,* 2013). This reduction can result in a decrease in urea clearance, which raises urea levels. Figure II shows a significant increase in the serum creatine concentration of the low and medium group, compared to control after 14 days of edible clay consumption. But figure VIII shows that only the medium dose group had a significantly higher creatinine concentration than the control, while there was no significant difference in the low and high dose groups compared to the control. Creatinine is a breakdown product of creatine phosphate in muscle and its serum content is an important indicator of renal health as it is excreted by the kidneys (Moosavi, 2017). According to a certain study, there is a correlation between lead exposure and decreased renal function, such as elevated creatinine levels (Harari, *et al*., 2018). The glomerulus, which is involved in filtration in the kidney may be damaged by lead exposure. These organs are in charge of collecting and eliminating blood particles in the urine. Lead-induced renal impairment may impair the ability of the kidney to eliminate creatinine from the blood. The serum sodium concentration in Figure III and Figure IX following the ingestion of edible clay on the 14th and 28th days respectively did not alter with varying doses with respect to control, a finding that is consistent with the works of Zeigbo *et al.,* (2020) who didn't observe any significant change in serum sodium in the first trimester of pregnancy following ingestion of edible clay, but reduced significantly in the second trimester of pregnancy. However, they attributed the low sodium concentration in the 2nd trimester to increased plasma volume associated with pregnancy (Blaustein *et al.,* 2006; Zeigbo *et al.* 2020). On the 14th day of edible clay consumption, there was a significant decrease in the potassium ion serum concentration of the high dose group in comparison to control, as shown in figure IV. Whereas at the 28th day, although there was a slight increase in the potassium concentration, especially in the medium and high dose groups compared to control, this change did not vary significantly when compared to the control. This slight difference in potassium ion from being significantly low at day 14, to becoming slightly elevated could be as a result of the kidneys' adaptability. The kidneys' ability

to modify secretion and reabsorption rates allows them to react to variations in salt and electrolyte levels, and also adjust how it handles fluctuations of electrolytes back to normal over time (Edeha *et al.,* 2023). Another reason for this change could have been because of the high presence of potassium in ingested edible clay. Many studies have shown that potassium is a major constituent of edible clay (Umudi, 2017; Edeha *et al.,* 2023). On the 14th and 28th days of edible clay administration, no significant difference was seen in the chloride ion concentration between the various dosages and the control group, as shown in Figure VI and XII respectively. The bicarbonate ion concentration increased significantly on the 14th and 28th day for low, medium, and high doses respectively when compared to the control group, as seen in Figures V and XI. Bicarbonate ion concentration in the body is usually regulated by the respiratory system through the excretion of carbon dioxide and by the renal system through the excretion of hydrogen ions (Brinkman & Sharma, 2023). With respect to the renal system, an increase in serum bicarbonates could arise from reduced glomerular filtration rate, which result in a failure to excrete bicarbonates leading to a build-up of serum concentration of the ion, a condition called metabolic Alkalosis. Again, lead has been implicated to have a negative correlation with the glomerular filtration rate, through mechanisms that may involve increases in blood pressure and arteriosclerosis (Fadrowski *et al.,* 2013).

Histologically, the kidney's cortex may be determined by looking for both glomeruli and tubules together. A mast of tissues limits the white area that encircles the tuft of capillaries. Additionally visible is the nucleus of mesangial cells, which encircle capillaries. Bowman's space, which encircles the glomerulus, is constrained or restricted by the Bowman's capsule, which is made up of tubular epithelial cells (Murray *et al.,* 2023). There is enhanced blood flow since the blood is clearly seen in the tissues of experimental groups 2 to 4 (slides 2 to 4), at both the 14th day and 28th day of edible clay ingestion. Low dosage edible clay stimulates the kidneys' blood flow, which the kidneys employ to control blood pressure. Plates 2, 3, 4, 7 and 8 clearly demonstrates elevated blood flow in the interstitial region and vasodilation-related congestion, which may have been the result of a vigorous pumping of the heart. It might be assumed that edible clay caused the blood vessels to dilate and the heart to pump more blood. Plate 4 shows that the tubules around the glomerulus seem patent, the lumen is open, and there is also an increase in blood flow. Although it has been demonstrated that lead causes constriction of blood vessels through a direct effect on increasing the secretion of endothelin and inhibition of nitric oxide, thus reducing blood flow to tissues (Reza *et al.,* 2008), perharps the vasodilation and increased blood flow seen in this study may be the function of another constituent of edible clay. Potassium ion has been reported to play a central role in the control of blood pressure, and its vasodilatory effect on blood vessels causes blood flow to increases to various tissues in the body including the kidney (Manger *et al.,* 2003). The mechanism of action of potassium induced increased blood flow involves the hyperpolarization of the vascular smooth muscle cells of blood vessels subsequent to potassium stimulation by the ion of the electrogenic Na^+ - K^+ and/or activating the inwardly rectifying Kir channels (Haddy *et al.,* 2006). Thus, dietary supplementation of potassium may be able to counter the toxic effect of lead on the cardiovascular system,

thereby lowering the blood pressure and preventing vasoconstriction of blood vessels.

Conclusion

Findings from this study shows that edible clay may negatively alter the normal function of the kidneys, elevating serum urea, creatinine and bicarbonate concentration. This effect of edible clay may be induced by lead, a heavy metal contained in edible clay, which has been linked to its toxic effect on the kidney. The study also indicates that edible clay may have an impact on the structure of renal tissues, causing vasodilation and increased blood flow in the form of active congestion. Potassium, another constituent of edible clay may be responsible for the action.

References

ALASIA, D., EMEM-CHIOMA, P., & WOKOMA, F. (2010). Association of lead exposure, serum uric acid and parameters of renal function in Nigeria lead-exposed workers. *Int. J. Occup. Environ. Med,* **1** (4), 182-190.

ALMERAS, C., & ARGILES, A. (2009). The general picture of uremia. *Seminars in Dialysis.* **22** (4), 329-333.

BELLUCO, S., LOSASSO, C., MAGGIOLETTI, M., ALONZI, C. C., PAOLETTI, M. G., & RICCI, A. (2013). Edible insects in a food safety and nutritional perspective: A critical review. *Comprehensive reviews in food science and food safety,* **12** (3), 296-313.

BLAUSTEIN, M. P., ZHANG, J., CHEN, L. & HAMILTON, B. P. (2006) How Does Salt Retention Raise Blood Pressure? *American Journal of Physiology Regulation and Integral Compound Physiology*, **290**, 514-523.

BRAND, C. E., DE JAGER, L., & EKOSSE, G. E. (2010). Possible health effects associated with human geophagic pratice. An overview. *South African Medical Technology,* **23** (1), 11-13.

BRINKMAN, J. E., & SHARMA, S. (2023). Physiology, Metabolic Alkalosis. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; from: https://www.ncbi.nlm.nih.gov/books/NBK482291/.

COOKSEY, C. (2012). Health concerns of heavy metals and metalloids. *Science Progress,* **95**, 73–88.

EDEHA, D. O., OMIGIE, M. I., FAYORIJU, O. D., & AGOREYO, F. O. (2023). Effects of High Fat Ketogenic Diet on Renal Functions of Wistar Rats. *Journal of Basic and Applied Medical Sciences,* **3** (1), 19-28.

EDEHA, D. O., OMIGIE, M. I. & AGOREYO, F. O. (2024). The Effect of Edible Clay Suspension on Some Hematological Indices and Histology of The Lungs of Female Wistar Rats. Abstracts of The Proceedings of The XLIst Annual Scientific Conference of The Physiological Society of Nigeria. *Niger. J. Physiol. Sci,* **39** (2), 5.

EDEHA, D.O., OMIGIE, M.I., & OBARISIAGON, S. (2023). The Effect of Edible Clay (Eko) Suspension on Serum Lipid Profile of Normal Female Wistar Rats. *African Scientist,* **24** (4), 548 – 553.

EKANEM, T.B., EKONG, M.B., ELUWA, M.A., IGIRI, A.O., & OSIM, E.E. (2015). Maternal geophagy of calabash chalk on foetal cerebral cortex histomorphology. *The Malaysian Journal of Medical Sciences,* **22** (4), 17.

EKONG, M.B., PETER, A.I., EKANEM, T.B., & OSIM, E.E. (2015). Determination of elemental composition and median lethal dose of calabash chalk. *Int. J. Biol. Med. Res*, **6** (2), 4902 - 4906.

EKOSSE G. E., & NGOLE, V. M. (2012). Mineralogy, geochemistry and provenance of geophagic soils from Swaziland. *Applied clay science*, **57**, 25-31.

FADROWSKI, J.J., ABRAHAM, A.G., NAVAS-ACIEN, A., GUALLAR, E., WEAVER, V.M., & FURTH. S.L. (2013). Blood lead level and measured glomerular filtration rate in children with chronic kidney disease. *Environ Health Perspect*, **121** (8), 965-70.

GOMES, C., RAUTUREAU, M., & POUSTIS, J. (2021). Benefits and Risks of Clays and Clay Minerals To Human Health From Ancestral To Current Times: A Synoptic Overview. *Clays and Clay Mineral,* **69**, 612–632.

HADDY, F. J., VANHOUTTE, P. M., & FELETOU, M. (2006). Role of potassium in regulating blood flow and blood pressure. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, **290** (3), R546-R552.

HARARI, F. SALLSTEN, G., CHRISTENSSON, A., PETKOVIC, M., HEDBLAD, B., FORSGARD, N., MELANDER, O., NILSSON, P.M., BORNE, Y., ENGSTROM, G., & BARREGARD, L. (2018). Blood Lead Levels and Decreased Kidney Function in a Population-Based Cohort. *Am J Kidney Dis,* **72** (3), 381-389.

IKEWUCHI, C. C., IKEWUCHI, J. C., EZEKA, U. K., & IFEANACHO, M. O. (2019). Effect of "edible clay" (takere) suspension on serum lipid profiles and atherogenic indices of normal Wistar rats. *Food science and nutrition,* **7** (3), 977–986.

JAHANSHAHEE, A., PIPELZADEH, M.H., & AHMADINEJAD, M. (2004). A case report of colon and rectum obstruction because of sand in a three-year-old boy. *Arch. Iran Med,* **7** (1), 66 – 67.

JAKARI, M. (2015). Geophagia and Its Health Implications in Nigeria: A Case Study of Urban Dwellers in Kano. *Journal of African Studies,* **8** (3), 45 - 56.

MAGHSOUDI, S., GOL, A., DABIRI, S. & JAVADI, A. (2011). Preventive Effect of Ginger (Zingiber officinale) Pretreatment on Renal Ischemia-Reperfusion in Rats. *Eur. Surg. Res*, **46**, 45–51.

MANGER, W.**,** SIMCHON, S., STIER, C. JR, LOSCALZO, J., JAN, K., JAN, R., & HADDY, F. (2023). Protective effects of dietary potassium chloride on hemodynamics of Dahl salt-sensitive rats in response to chronic administration of sodium chloride. *J Hypertens,* **1**, 2305–2313.

MOOSAVI, M. (2017). Bentonite Clay as a Natural Remedy: A Brief Review. *Iran J Public Health,* **46** (9), 1176-1183.

MURRAY, I.V., & PAOLINI, M.A. (2023). Histology, Kidney and Glomerulus. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; Available from: https://www.ncbi.nlm.nih.gov/books/NBK554544/

NABUUMA, J. (2021). Health risks associated with heavy metal exposure in geophagic products (Emumbwa) consumed during pregnancy (Doctoral dissertation, Kyambogo University).