World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

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The effect of calabash chalk on the gastrointestinal motility and transit time of male albino Wistar rat

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World Journal of Advanced Research and Reviews, 2024, 24(02), 425–434

Publication history: Received on 14 September 2024; revised on 01 November 2024; accepted on 04 November 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.2.3243

Abstract

Background*:* Calabash chalk, a naturally occurring mineral, is widely consumed in many African countries for various purposes, including pleasure, medicinal use, and regular diet. Pregnant women commonly use it to alleviate nausea. However, research has shown that consuming this geophagic material poses several health risks. This study aimed to investigate the effects of Calabash chalk on gastrointestinal motility and transit time.

Method*:* 10 male albino Wistar rats weighing between 150 and 170 g were randomly assigned to two groups. Group A served as the control and received standard animal feed and water, while Group B received animal feed, water, and 1.3 g/kg body weight of Calabash chalk orally. Both groups were treated for 21 days before being sacrificed. The intestinal motility and transit time were then assessed.

Result*:* The results showed a significant increase ($p < 0.01$) in ileal smooth muscle contraction in the test group following the administration of graded doses of acetylcholine (10^-8, 10^-7, and 10^-6) compared to the control group. Additionally, a significant increase ($p < 0.001$) was observed in the test group with acetylcholine at 10^-5, although there was a significant decrease ($p < 0.05$) at higher concentrations. The administration of atropine also resulted in a significant increase ($p < 0.05$) in intestinal motility in the test group. Furthermore, there was a significant decrease ($p < 0.05$) in transit time in the test group compared to the control group. In contrast, no significant difference ($p > 0.05$) was observed in the total length of the small intestine between the two groups.

Conclusion*:* The administration of Calabash chalk significantly increased small intestinal motility and decreased transit time. These effects may lead to gastrointestinal irritation, malabsorption of nutrients, and digestive inefficiency. Given the potential health risks associated with Calabash chalk, it is not advisable for regular consumption mainly due to its adverse effects on the gastrointestinal system.

Keywords: Calabash chalk; Gastrointestinal motility; Transit time; Gastrointestinal system; Health risks

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1. Introduction

Calabash chalk is found predominantly in Nigeria and northern West African countries [1]. It can also be found in the ethnic stores in Canada, the United Kingdom and the United States of America. Calabash chalk is also known as calabash stone (English), Nzu by the Igbos, Ndom by the Efiks and Ibibios, Eko by the Edo's of Nigeria as well as Argile in French and mable by the lingalas of Congo [2]. It is commercially available and may be sold in blocks as large as pellets or in powder form. Geophagia is defined as the practice of eating earth, including soil and chalk [3]. People engage in geophagia for a variety of reasons including religious beliefs, medicinal purposes, or as part of a regular diet [4]. One geophagic material is Calabash chalk, which is popularly consumed by members of Nigerian and West African communities for pleasure [4,5]. Geophagia occurs with animals as well as humans, by both sexes and in all races [6,7]. It may also be prepared from clay and mud which maybe mix with other ingredients including sand, wood ash, and sometimes salt. The resulting product is molded and then heated to provide final product, the prevalence of chalk consumption is greater among women, especially during pregnancy [8].

Multi-elemental analysis using energy dispersive X-ray fluorescence spectroscopy identified 22 elements in Calabash chalk, including lead and aluminium and persistent organic pollutants [9]. Lead and other toxic elements present in the chalk have been reported to be associated with numerous gastrointestinal disorders including nausea, ulcers, and gastritis [1]. This geophagic material is consumed by the oral route, and several pollutants have been reported to be present in Calabash chalk. *Calabash chalk* is a naturally occurring material mainly composed of fossilized sea shells. However, it can also be artificially prepared using clay, wood ash, and sometimes salt. The process involves molding and heating the mixture to form the chalk-like substance [10].

1.1. Chemistry of Calabash Chalk

Calabash chalk, a naturally occurring substance, is primarily composed of aluminum silicate hydroxide derived from kaolinite, a mineral in the kaolin clay group. The chemical composition of kaolinite is $Al_2Si_2O_5(OH)_4$, characterized by a layered structure. It consists of one tetrahedral sheet of silica (SiO_4) linked to an octahedral alumina (AlO_6) sheet. This arrangement forms a robust lattice contributing to the material's physical properties.

Upon heating (endothermic dehydration) at 550–600 °C, kaolinite begins to lose hydroxyl groups, leading to the formation of disordered metakaolin. Continuous heating up to 900°C results in further hydroxyl loss, which plays a critical role in modifying the structure.

At temperatures between 925–950 °C, metakaolin transitions to an aluminum-silicon spinel. This transformation can be represented by the reaction: $2Al_2Si_2O_7 \rightarrow Si_3Al_4O_{12} + SiO_2$

When subjected to calcination temperatures above 1050°C, the spinel phase nucleates and transforms into platelet mullite and highly crystalline cristobalite, with the reaction: $3Si_3Al_4O_{12} \rightarrow 2(3Al_2O_3{\cdot}2SiO_2) + 5SiO_2$

Finally, heating beyond 1400 °C produces needle-shaped mullite, which significantly enhances the material's structural strength. This phase change, particularly mullite formation, is crucial in applications requiring high mechanical integrity.

1.2. General uses of Calabash Chalk

It is locally used during pregnancy to prevent vomiting, over-salivation, and nausea, remedy for morning sickness, and nullify the elemental balance like iron (Fe), potassium (K), and magnesium (Mg) within the body [11,12]. Calabash chalk is also used in facial masks and soaps. It has been proven that Kaolin clay may be useful in decolonizing dye waste water via electrification [13]. When applied topically, it serves as an emollient and drying agent. When ingested, it acts as an absorbent that binds gastrointestinal toxins and controls diarrhea.

It is used in the production of paper [14]. Kaolin is also known for its capabilities to induce and accelerate clotting. In Africa, kaolin is used topically on the skin for rashes such as those caused by measles and is eaten for pleasure or to suppress hunger, especially among women [15].

1.3. Adverse Effect of Calabash Chalk

There are several reports regarding the health risks of consuming calabash chalk, including the alteration of a normal concentration of hemoglobin, red blood cell counts, and erythrocyte sedimentation rate. Another possible side effect of eating this geophagia is the alteration of growth rate and demineralization in the femur bone [2,16]. Other reports suggest that continuous ingestion can cause constipation and stomach pains, could be a source of severe toxicity, and can also cause numerous gastrointestinal disorders such as nausea, ulcers, and gastritis [17]. Lead, one of the constituents of calabash chalk lowers the intelligence quotient in children and damages brain cells in albino rats [18].

1.4. General Overview of the Gastrointestinal Tract

The gastrointestinal tract is a specialized system in the human body that is majorly responsible for digestion. Other functions are the passage of food from one segment to another, secretion of digestive juice and digesting of food, absorption of water, various electrolytes, digestive products, etc. [19]. These functions are carried out by the principal components which are the mouth, the pharynx, esophagus, stomach, small and large intestine. The enteric nervous system (neural control of motility) in the GIT controls the gastrointestinal movements and secretions and is composed of two plexuses: myenteric plexus or Auerbach's plexus and an inner plexus called the sub-mucosal plexus or Meissner's plexus that lies in the sub-mucosal.

The myenteric plexus controls motility mainly, while the sub-mucosal plexus controls secretions and local blood flow. The myenteric plexus increases motility by increasing tonic contractions of the intestinal wall's 'tone', increasing the intensity of the rhythmical contractions, and increasing the velocity of excitatory wave conduction along the intestinal wall.

1.5. Significance of Intestinal Transit

The time it takes for food to travel through the colon is called the colonic transit time. A transit test is used to evaluate constipation. A much longer transit time indicates slowed bowel function. Intestinal transit time may be affected by certain medications and medical conditions. Very long transit time may be caused by narrowing in the intestine, an inactive thyroid gland (hypothyroid sin), and complications of diabetes [20]. Short transit time may be caused by inflammatory bowel disease, intestinal infection, lactose intolerance, or irritable bowel syndrome.

1.6. Statement of Problem

The widespread consumption of calabash chalk, particularly among individuals of different backgrounds, including pregnant women and breastfeeding mothers, has raised concerns regarding its potential health implications. Calabash chalk is commonly used in West Africa and the sub-Saharan region, particularly in Nigeria, as a remedy for nausea and morning sickness. However, its consumption, especially during pregnancy, has prompted the need for further investigation into its effects on health. This research seeks to address the gaps in understanding the impact of calabash chalk on gastrointestinal motility and transit time in male albino Wistar rats. Given its popularity, particularly among vulnerable populations such as pregnant and breastfeeding women, there is a critical need to explore the potential adverse effects this chalk may have, explicitly concerning gastrointestinal function and its influence on lipid profiles. Thus, this study aims to compare and assess the effects of calabash chalk consumption on these parameters in a controlled experimental setting.

2. Materials and methods

2.1. Materials

The following materials were used in the study:

- Wooden cages
- Syringes (2 ml, 1 ml, and 3 ml)
- Calibrated water bottle
- Distilled water
- Sample bottles
- Cannula
- Timing watch
- Normal saline
- Saw dust
- Feeder and rat chow
- Calabash chalk (powdered)
- Digital weighing balance
- Dissecting set

2.2. Methods

2.2.1. Preparation and Storage of Experimental Diet

The Calabash chalk block was procured from a local market in Akpabuyo in Calabar and was grounded into powder. The powdered calabash chalk was kept in a dry, airtight container, from which the stock solution was prepared. It was then administered to the experimental rats at the doses of 1.3 g/kg i.e. 0.13 mg/ml.

2.2.2. Experimental Animals

Ten (10) male albino Wistar rats weighing between 150-170 g at the time of purchase were procured from the Department of Physiology, University of Calabar, Nigeria. The animals were housed in the Faculty of Basic Medical Sciences Animal House, University of Calabar, and allowed to acclimatize for three weeks (21 days) before the commencement of the experiment. During this period, the rats were provided with standard rat chow and water ad libitum and housed under controlled environmental conditions with a 12-hour light/dark cycle. The bedding was changed twice weekly to maintain hygiene.

At the start of the experiment, the rats were randomly assigned to two groups (n=5 per group):

- **Group 1 (Control group)**: Received standard rat chow and water only.
- **Group 2 (Experimental group)**: Received standard rat chow, water, and calabash chalk supplementation at 1.3 g/kg body weight.

Both groups were monitored and treated for 21 days. Throughout the study, the animals had free access to food and water. The research was conducted following internationally accepted principles for the care and use of laboratory animals and ethical guidelines for the use of experimental animals.

This design ensured appropriate animal welfare and ethical practices, providing controlled conditions for reliable experimental outcomes.

2.2.3. Collection of Edible Clay and Preparation of Edible Clay Suspension

Blocks of edible clay were procured from a local market in Akpabuyo, Cross River State, Nigeria. The clay was ground into a fine powder using a manually operated grinder to ensure uniform particle size. For the preparation of the edible clay suspension, 1.3 g of the powdered clay was dissolved in 32 mL of distilled water. The mixture was stirred continuously to achieve a well-dispersed solution. Due to its solubility in water, the edible clay formed a stable suspension.

The prepared suspension was stored in a sealed container and gently stirred prior to each administration to maintain homogeneity. This method ensured accurate dosing and consistency in administering the edible clay to the experimental subjects.

2.2.4. Preparation of Rat Tissue and Intestinal Motility Studies

The day before the experiment, the rats fasted for twelve (12) hours and were allowed ad libitum access to drinking water to facilitate digestion. Following fasting, the rats were sacrificed via cervical dislocation. A midline incision was made along the linea alba to expose the abdominal cavity and reveal the small intestine. The distal ileum was identified, isolated, and quickly removed for further analysis.

The isolated ileum was placed in a petri dish containing aerated Tyrode solution, which was continuously bubbled with air and maintained at a temperature of 37 °C. The ileum was then cut into segments approximately 2 cm in length and mounted vertically in a 10 mL organ bath (Searle Instruments, England) filled with Tyrode solution. One end of each ileum segment was securely attached to a fixed support connected to an oxygen tube within the bath. In contrast, the other end was tied with thread to a lever arm tangential to a kymograph drum (Searle Instruments, England), which was set to exert a load of 0.5 g for recording isotonic contractions.

The tissue segments were allowed to equilibrate for 45 minutes before data collection. During this equilibration period, the bathing fluid was replaced with fresh Tyrode solution at 15-minute intervals to prevent the accumulation of metabolites. The composition of the Tyrode solution is detailed in the Appendix. This combined methodology ensured optimal conditions for studying intestinal motility and provided reliable data on transit time.

2.2.5. Intestinal Transit

The intestinal transit experiment was conducted using a modified method based on Perez (1996). A marker was freshly prepared by suspending 10% charcoal in 1 g of gum Arabic. Before administration, the rats were deprived of food for 24 hours but were allowed free access to water.

Subsequently, each rat was administered 1.5 mL of the charcoal marker and maintained without food or water for one hour to facilitate the determination of intestinal transit. At the end of this period, the rats were sacrificed via cervical dislocation, and the intestines were rapidly isolated. The distance (in centimeters) traveled by the charcoal meal from the pylorus was measured.

This distance was expressed as a percentage of the total length of the intestine, measured from the gastro-pyloric junction to the ileocecal junction, as described by Gonçalves et al., [21]. The intestinal transit was calculated using the following formula:

$$\textbf{Intestinal Transit} = (\frac{\text{(Total length of the small intestine (cm)}}{\text{Length traveled by the charcoal marker (cm)} \times 100}$$

2.3. Statistical Analysis

Data obtained from the study are presented as mean ± SEM (Standard Error of the Mean). Statistical analysis was performed using a one-way analysis of variance (ANOVA), followed by a post hoc test (Tukey's HSD). Data analysis was conducted using statistical software, including SPSS (Statistical Package for the Social Sciences) and Microsoft Excel (2010 version, Microsoft Corporation, Washington). A p-value of less than 0.05 ($p < 0.05$) was considered statistically significant.

3. Result

3.1. Comparison of Percentage Maximum Contraction of Ileal Smooth Muscle to Graded Concentrations of Acetylcholine in Control and Calabash Chalk-Treated Rats

The effect of graded concentrations of acetylcholine (ACh) on the percentage maximum contraction of ileal smooth muscle in control and calabash chalk-treated rats is shown in Figure 1. The test group, treated with calabash chalk, demonstrated a significant increase ($p < 0.05$) in ileal smooth muscle contraction compared to the control group across a range of ACh concentrations.

At lower ACh concentrations of 10^{-9}, 10^{-7}, and 10^{-5} M, the mean ± SEM values for maximum contraction in the control group were 4.88 ± 0.13, 7.75 ± 0.25, and 16.50 ± 0.50%, respectively. In contrast, the calabash chalk-treated group exhibited significantly higher contractile responses of 25.00 ± 1.00, 27.00 ± 1.00, and 29.25 ± 1.25%, respectively. This demonstrates a pronounced sensitivity of the test group to ACh at these concentrations.

Furthermore, at an ACh concentration of 10^{-5} M, the percentage contraction in the test group (30.75 ± 1.75%) was significantly higher ($p < 0.01$) compared to the control group (20.25 ± 0.75%). This indicates a more robust contractile response in the test group at this concentration.

However, at a higher ACh concentration of 10^{-4} M, the test group exhibited a significant decrease ($p < 0.001$) in contraction compared to the control group, with the mean ± SEM values being 22.00 ± 0.00% for both groups. This suggests a reduced contractile efficiency or possible desensitization to ACh at higher concentrations in the calabash chalk-treated group.

These results suggest that calabash chalk treatment enhances the sensitivity of ileal smooth muscle to ACh at lower concentrations but leads to reduced contraction at higher concentrations, potentially indicating a biphasic response.

Figure 1 Illustrates the percentage maximum contraction of ileal smooth muscle in response to graded concentrations of acetylcholine (ACh) in control and calabash chalk-treated rats

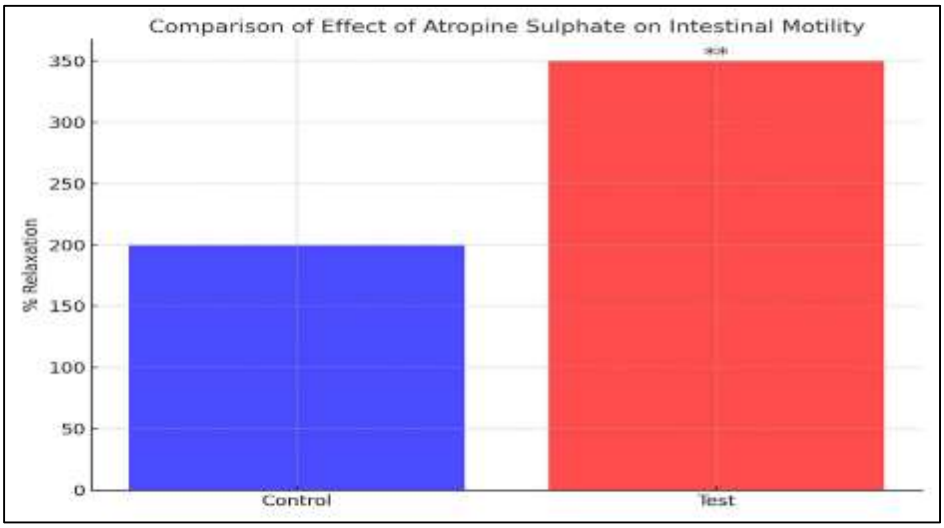

Figure 2 Compares the effect of atropine sulfate on intestinal motility in control and calabash chalk-treated rats. The figure shows that the test group treated with calabash chalk exhibited significantly higher intestinal relaxation ($p < 0.01$) compared to the control group. This suggests that atropine's relaxing effect on the intestine is enhanced in the calabash chalk-treated group. Values are expressed as mean ± SEM, n = 4

3.2. Comparison of Basal Height of Contraction of the Intestinal Smooth Muscle in Control and Calabash Chalk-Treated Rats

The basal height of the intestinal smooth muscle contraction was measured in the control and calabash chalk-treated groups. The mean ± SEM values were 2.88 ± 0.13 for the control group and 2.13 ± 0.13 for the test group. Although the test group exhibited a lower basal contraction than the control group, this difference was not statistically significant. These findings suggest that calabash chalk treatment does not significantly alter the basal contractile activity of the intestinal smooth muscle.

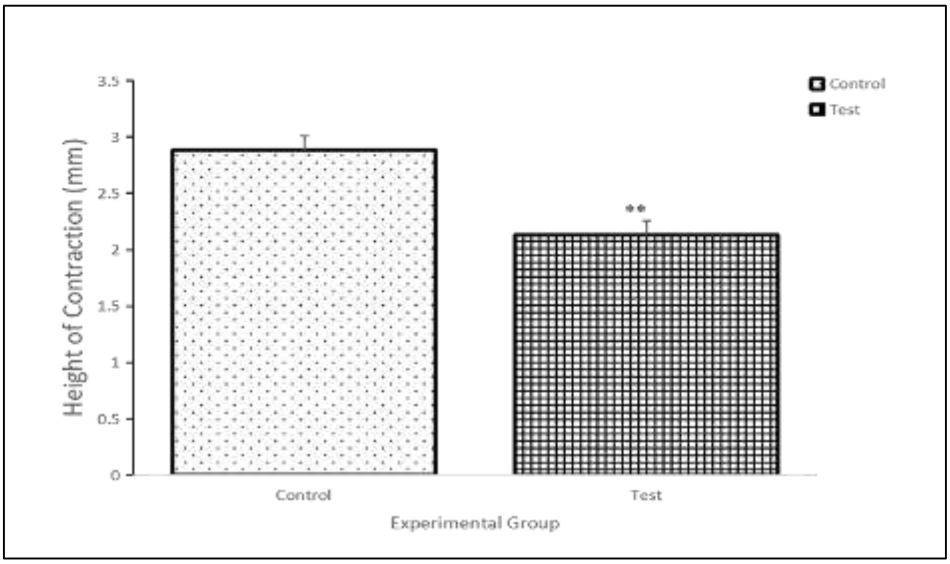

Figure 3 Compares the basal height of the intestinal smooth muscle contraction between control and calabash chalk-treated rats. Values are expressed as mean ± SEM, with n=4, and statistical significance is noted at p<0.01 versus the control

3.3. Comparison of Small Intestinal Transit Between the Control and Test Groups

The small intestinal transit was significantly reduced in the test group compared to the control group. The mean ± SEM values for intestinal transit were 57.6 ± 1.06% for the control group and 41.9 ± 2.71% for the calabash chalk-treated group. Statistical analysis revealed a significant decrease in intestinal transit in the test group compared to the control group ($p < 0.001$).

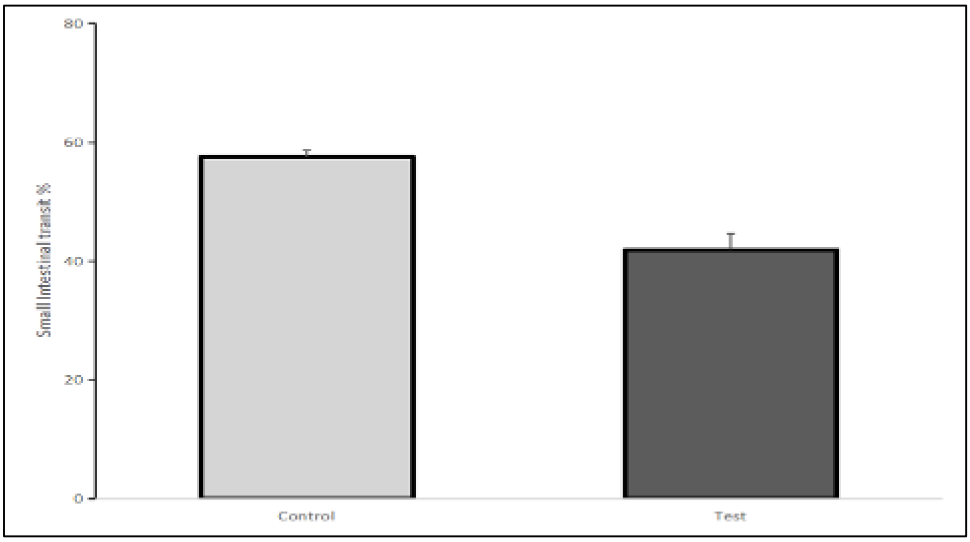

Figure 4 Comparison of small intestinal transit between the control and test groups. Values are presented as mean ± SEM, n = 5. ***p < 0.001 vs. control

3.4. Comparison of Small Intestinal Total Length Between Control and Test Groups

The mean ± SEM values for the total length of the small intestine were 104.7 ± 3.29 cm for the test group and 103.0 ± 4.60 cm for the control group. The results showed no significant difference ($p > 0.05$) between the test and control groups.

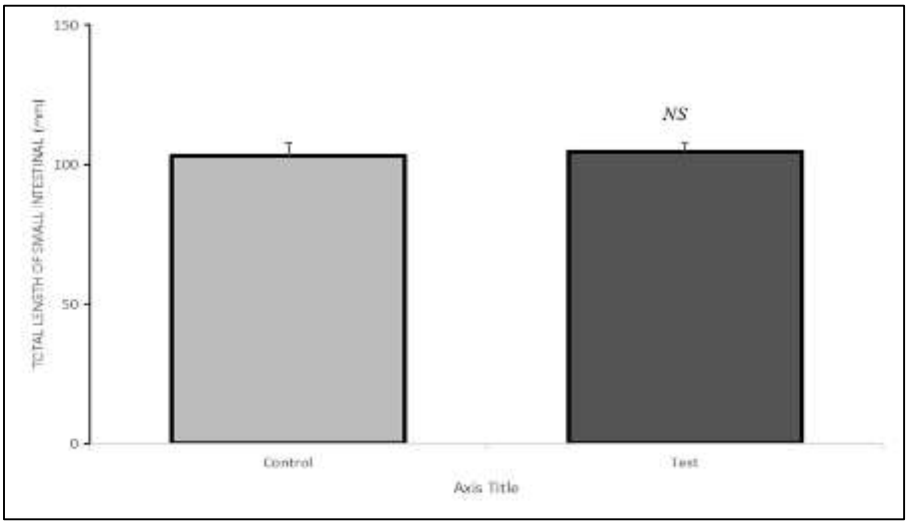

Figure 5 Comparison of Small Intestinal Total Length Between the Control and Test Groups. Values are expressed as mean ± SEM, n = 5. NS: $p > 0.05$ vs. control (not significant)

4. Discussion

This study investigated the effect of Calabash Chalk on small intestinal motility and transit time. The electrical activity of gastrointestinal smooth muscle is modulated by spike potentials, which are preceded by slow waves. Spike potentials result from the rapid entry of calcium ions and small quantities of sodium ions through calcium-sodium channels [22].

This study revealed significant alterations in ileal smooth muscle contraction and intestinal transit. Comparison of the percentage maximum contraction of the ileal smooth muscle showed a significant increase ($p < 0.001$) in the test group compared to the control group following the addition of graded doses of acetylcholine (ACh). Furthermore, the test group demonstrated a significant increase ($p < 0.01$) in contraction compared to the control. However, a significant decrease ($p < 0.05$) was observed in the test group at higher ACh concentrations.

The administration of atropine sulfate, an antagonist of ACh, also resulted in a significant increase ($p < 0.01$) in motility in the test group compared to the control group, indicating that the calabash chalk modulated the cholinergic pathways influencing intestinal motility.

The comparison of intestinal transit time showed a significant decrease ($p < 0.001$) in the test group compared to the control group, indicating faster transit. However, no significant difference ($p > 0.05$) was observed between the test and control groups concerning the total length of the small intestine.

Calabash Chalk contains toxic substances such as lead, arsenic, aluminum, and alpha-lindane [23]. Lead has been linked to gastrointestinal issues such as gastritis, nausea, vomiting, and constipation [24] and can cause ulcers when consumed in large quantities [25]. Arsenic has been implicated in causing gastric distress [26], and aluminum has been associated with constipation, pain, anorexia, nausea, and gastrointestinal irritation [27].

In addition to these toxic substances, Calabash Chalk contains kaolin, which coats the gastrointestinal tract. Kaolin has absorptive properties, reducing the bio-availability of drugs and other substances, including toxins, and has been linked to diarrhea by preventing the formation of bulky stool [28]. The increased intestinal motility observed in this study could be attributed to these toxic substances in Calabash Chalk.

5. Conclusion

This study concludes that consuming Calabash Chalk increases intestinal motility and decreases transit time, possibly resulting from its toxic components, including lead, arsenic, and kaolin. Caution is advised regarding using Calabash Chalk due to its potential adverse gastrointestinal effect.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest related to the research, authorship, and publication of this article.

Statement of ethical approval

All procedures performed in studies involving animals were in accordance with the institution's ethical standards and national guidelines for the care and use of laboratory animals. The Institutional Animal Care and Use Committee (IACUC) of the University of Calabar approved the study protocol, ensuring compliance with ethical guidelines for animal research.

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