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# EVALUATION OF THE EFFECTIVENESS OF LOCAL CLAY FOR USE AS WATER-BASED DRILLING MUD (A CASE STUDY OF AMAI IN UKWUANI L.G.A, DELTA STATE)

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**ABSTRACT**

This study evaluates the effectiveness of clay deposits from Amai-Nge and Umubu communities in Ukwuani Local Government Area, Delta State, Nigeria, for application in water-based drilling mud systems as potential alternatives to imported bentonite. Clay samples were processed and formulated into drilling fluids, while rheological and filtration properties were determined according to API recommended practice (API RP-13B). Initial characterization of raw clays showed inferior performance relative to commercial bentonite, with Amai and Umubu samples exhibiting low plastic viscosity (1–2 cP), low apparent viscosity (4.5–5.0 cP), and acidic pH values of 5.77–6.14 compared with bentonite values of 8 cP, 13 cP, and pH 10.0, respectively. Following beneficiation using sodium carbonate ($Na_2CO_3$) and barite ($BaSO_4$), significant improvements were observed. Beneficiated Umubu clay demonstrated plastic viscosity of 5 cP (150% increase), apparent viscosity of 15 cP (200% increase), and yield point of 20 lb/100 ft² (233% increase), surpassing commercial bentonite by approximately 15.4% in apparent viscosity and 81.8% in yield point. pH increased from 6.14 to 10.05, achieving API-compliant alkaline conditions, while filter cake thickness (1.05 mm) remained within acceptable API limits. The Amai clay showed moderate enhancement but remained below commercial performance levels. The results demonstrate that with proper beneficiation, Umubu clay can serve as a cost-effective substitute for imported bentonite in water-based drilling fluid systems.

**Keywords**: Plastic Viscosity (PV); Apparent Viscosity (AV); Yield Point; Fann viscometer

## INTRODUCTION

Drilling muds are an essential component of rotary drilling operations, providing functions such as cooling and lubricating the drill bit, removal of cuttings from the borehole, wellbore stability, and control of formation pressures. The choice of drilling mud significantly influences drilling efficiency, cost, and safety. The most widely used mud additive for viscosity and filtration control is bentonite clay, a naturally occurring smectite-rich material. However, the high cost and import dependency of bentonite in Nigeria have created a need to explore local clay alternatives that are abundant, affordable, and environmentally sustainable.

Clay minerals are hydrous aluminosilicates with layered structures capable of swelling, ion exchange, and water absorption. Among the various clay types, montmorillonite (smectite) is the most desirable for drilling mud because of its high surface area and swelling characteristics. Bentonite, particularly Wyoming bentonite, is the industry standard. Aigbedion (2007), Olatunde et al. (2011), Igbalajobi (2013), Okon & Samuel (2014), and Amadi et al. (2020) have investigated local clays from various regions (Akwa Ibom, Edo, Delta, Anambra) for drilling mud applications. Findings consistently show that local clays often require beneficiation, usually by adding sodium carbonate (soda ash) to enhance swelling and barite to increase density. Prior studies indicate that raw local clays tend to have lower pH, lower plastic and apparent viscosity, reduced yield strength and poor filtration control. But after beneficiation, their performance improves significantly, often approaching API standards.

Delta State, particularly the Amai and Umubu areas of Ukwuani Local Government Area, is known for extensive clay deposits. These clays have historically been used for pottery, construction, and minor industrial applications. Their suitability for drilling mud formulation, however, has not been fully evaluated. This study therefore examines the physicochemical and rheological properties of raw Amai clay, determine the overall viability of Amai clay for drilling mud formulation, compares them with imported bentonite, and evaluates the impact of beneficiation using barite and soda ash. This study contributes to growing Nigerian research by focusing on clay from Amai and Umubu, areas with limited documented geological evaluation.

### Geology of the Study Area

Niger Delta is located on the continental margin of Southern Nigeria and covers an area of 70km. It lies between longitude $5^0$E and $8^0$E and latitudes $30^0$ and $60^0$ Short and Stable (1997). Stable mega tectonic framework such as the Benin and Calabar flank mark the northwest and eastern boundaries. The Anambra basin and the Abakaliki high mark the northern boundary and it is bounded to the south by the west of guinea (Chinyem et al., 2026). The stratigraphic fill of the Niger Delta basin is composed primarily of three lithostratigraphic units that extend across the whole delta (Igili, & Ndubueze, 2024).These include basal marine pro-delta Akata Formation, the middle shallow-marine delta front Agbada Formation and, the overlying youngest continental, delta plain Benin Formation (Doust and Omatsola 1990; Adojoh et al., 2020). The Akata Formation, a prodeltaic lithofacies of Paleocene to Recent in age is composed primarily of marine shales with turbidite sands and continental slope channel fills. It is estimated to be up to 7 km thick and generally considered as the source rock of the Niger Delta. The middle paralic Agbada Formation, estimated to be over 3.7km thick and ranges in age from Eocene to Recent (Tuttle et al., 1999) is primarily composed of delta-front lithofacies and characterized by intercalations of sand and shale. The sandstone reservoirs facies within this formation are mostly shoreface and channel sands with minor shales in the upper part, and alternation of sands and shales in the lower part (Doust & Omatsola 1990). This unit serves as the hydrocarbon reservoir within the basin with sand percentage ranging from 30 to 70% (Doust and Omatsola 1990; Igili, and Ndubueze (2024). The deltaic sequence is capped by the topmost Benin Formation that is Oligocene to Recent in age, about 2km thick and is made up of continental fluvial sands (Avbovbo 1978; Doust & Omatsola 1990; Owolabi et al., 2019). Adegoke et al. (2017) described the formation as friable, white, fine to coarse and pebbly, poorly sorted sands, with lignites occurring as thin streaks or as finely dispersed fragments.

The Amai-Nge and Umubu clay deposits are located within the Niger Delta Basin of southern Nigeria (Fig. 1). The deposits occur within sediments associated predominantly with the continental Benin Formation and adjacent deltaic units characterized by alternating sands, silts, and clay-rich intervals. Clay accumulation within these environments is largely controlled by fluvial and deltaic depositional processes (Igili, & Ndubueze, 2024). Niger Delta clays are generally composed of aluminosilicate minerals dominated by kaolinite, illite, and varying proportions of smectitic components (Ogala, 2012). The rheological behavior of drilling mud largely depends on the abundance of expandable clay minerals, particularly montmorillonite-rich smectite (Igbalajobi, 2013).

The Amai and Umubu deposits investigated in this study are likely derived from weathering and transport of continental sediments deposited under deltaic conditions. Variations in rheological behavior observed between both samples may reflect differences in clay mineral composition, cation exchange capacity, and degree of mineral alteration. Understanding such mineralogical controls is important in explaining the differing responses of the two clay types to sodium activation and beneficiation (Igbalajobi, 2013; Olatunde, 2011; Okon & Samuel, 2014).

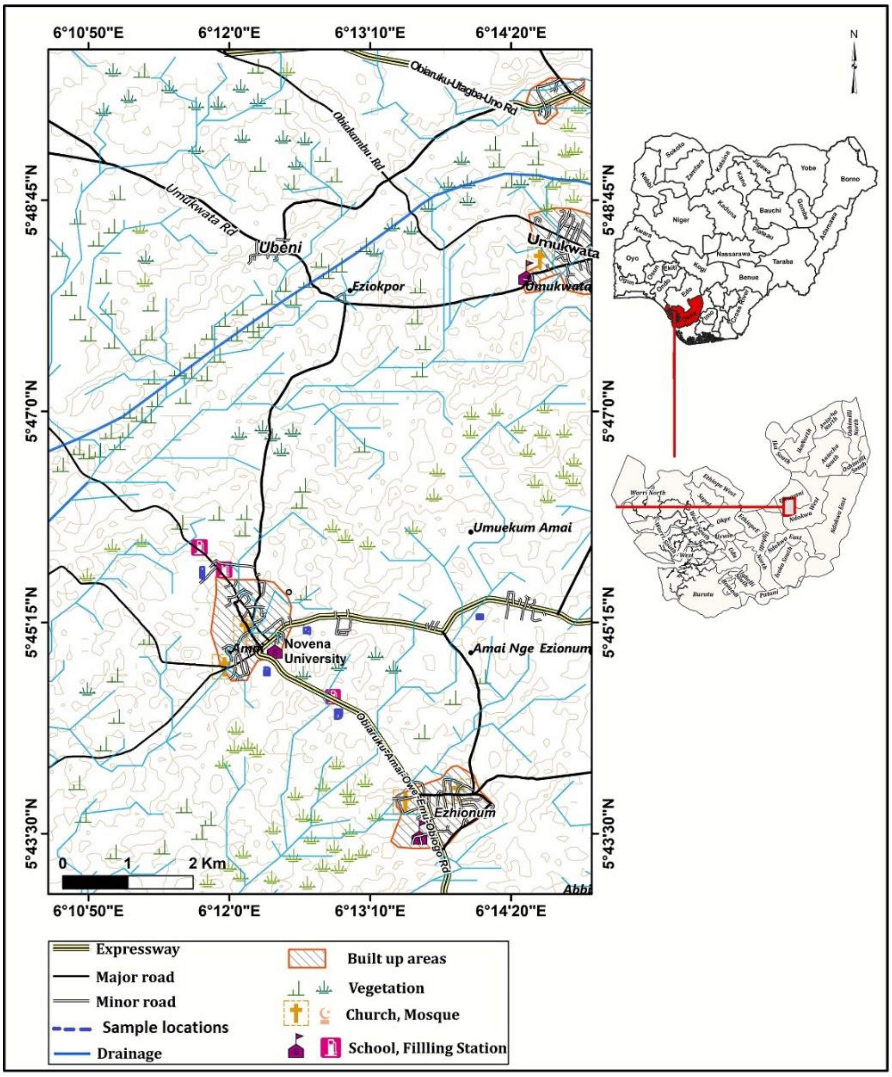


Figure 1: showing map of the study area and sampling points

## MATERIALS AND METHODS

### Sample Collection

Clay samples were collected from Amai-Nge and Umubu communities using a GPS-guided sampling procedure. Samples were wrapped in aluminum foil, sealed, and transported to the laboratory.

### Sample Processing

Samples were air-dried for seven days, mixed with water to form slurry, and sieved to remove coarse debris. The filtrates were allowed to settle for 3–5 days, decanted, sun-dried for four days, crushed, and sieved through 125-micron mesh to obtain fine clay powder.

**Mud Formulation**

24.5g of clay and 350mL (per API RP 13B) of fresh water were mixed using a high-speed mixer to form homogeneous muds. Additional beneficiation reagents included barite ($BaSO_4$) and soda ash ($Na_2CO_3$) of 10g and 5g were used respectively with 24.5g of the local clay. Laboratory tests conducted are;

i. Density: Mud balance g/cm$^3$
ii. pH: pH meter
iii. Plastic Viscosity (PV): θ600 – θ300 (cP)
iv. Apparent Viscosity (AV): θ600/2 (cP)
v. Yield Point (YP): YP = θ300 – PV 1b/100ft$^2$
vi. Cake Thickness: Filter press (for Sample B beneficiated)

**Density Measurement**

Density was measured using a mud balance following API procedures.

*Rheological Measurements*

Apparent viscosity (AV) and plastic viscosity (PV) were measured using a rotational viscometer at 600 and 300 rpm.

$$\text{Apparent Viscosity (AV)} = \frac{\text{Reading at 600rpm}}{2} \quad (1)$$

It has the SI derived unit Pa·s (Pascal-second), but the centipoise is frequently used in practice: (1 mPa·s = 1 cP).

*Filtration and Fluid Loss Test*

A filter press operated at 100 psi for 30 minutes was used to determine fluid loss and filter cake thickness.

**pH Measurement**

Colorimetric pH paper was used to measure the aqueous mud pH.

*Plastic Viscosity (PV):* Plastic Viscosity (PV) is a resistance of fluid to flow. According to the Bingham plastic model, the PV is the slope of shear stress and shear rate. Typically, the viscometer is utilized to measure shear rates at 600, 300, 200, 100, 6, and 3 revolutions per minute (rpm). In the field, the plastic viscosity can be calculated by a simple calculation shown below. Plastic Viscosity (PV) = Reading at 600 rpm – Reading at 300 rpm. The unit of PV is Centi Poise (cP).

*Rate of Penetration (ROP):* The ROP will be directly affected by the plastic viscosity. Thicker mud will have bigger hold down effect than thinner mud. Therefore, it causes in reduction in ROP (Dhiman, 2012).

**RESULTS AND DISCUSSION**

This work aimed at evaluating the effectiveness of local clay within Amai Delta State, Nigeria to substitute for imported bentonite in water based drilling mud and also look for additives that will improve the rheological properties of clay. Table 1 below presents the results of the mud prepared with local clay as well as the bentonite control.

**Table 1: Raw Local Clay vs Bentonite**

| Property | Bentonite | Sample A | Sample B |
|---|---|---|---|
| Density | 9.0 | 7.5 | 8.10 |
| pH | 10.00 | 5.77 | 6.14 |
| PV | 8.00 | 1.00 | 2.00 |
| AV | 13.00 | 4.50 | 5.00 |
| YP | 11.00 | 7.00 | 6.00 |

**Raw Clay Performance vs Bentonite**

Results from local clay table 1, fig 2 and 3 were found to be out of the API standard compared to foreign bentonite mud. Though the density of the local clay match the API specification as they were almost the same especially that of Umubu. Both Amai and Umubu clays show much lower PV, AV, and pH than bentonite. This indicates poor swelling capacity and weak viscosity, confirming they are mainly calcium-based clays, typical of Nigerian clay deposits. The significant difference in their rheological properties such as density, pH, plastic viscosity, apparent viscosity and yield strength of the local clay necessitated the benefaction of the local clay, i.e. addition of chemicals to low quality clay to improve its performance. The local clay was beneficiated with barite ($BaSO_4$) and soda ash ($Na_2CO_3$) to improve the mud density, viscosity and pH with their results shown in table 2, fig 4 below.

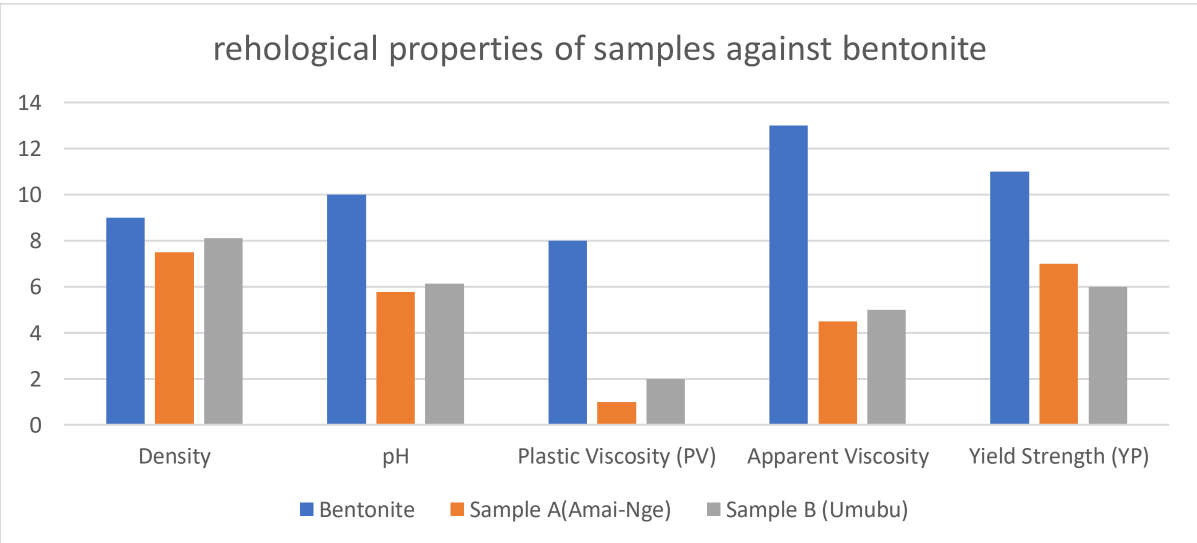


Figure 2: Showing the rheological differences between raw clay and bentonite

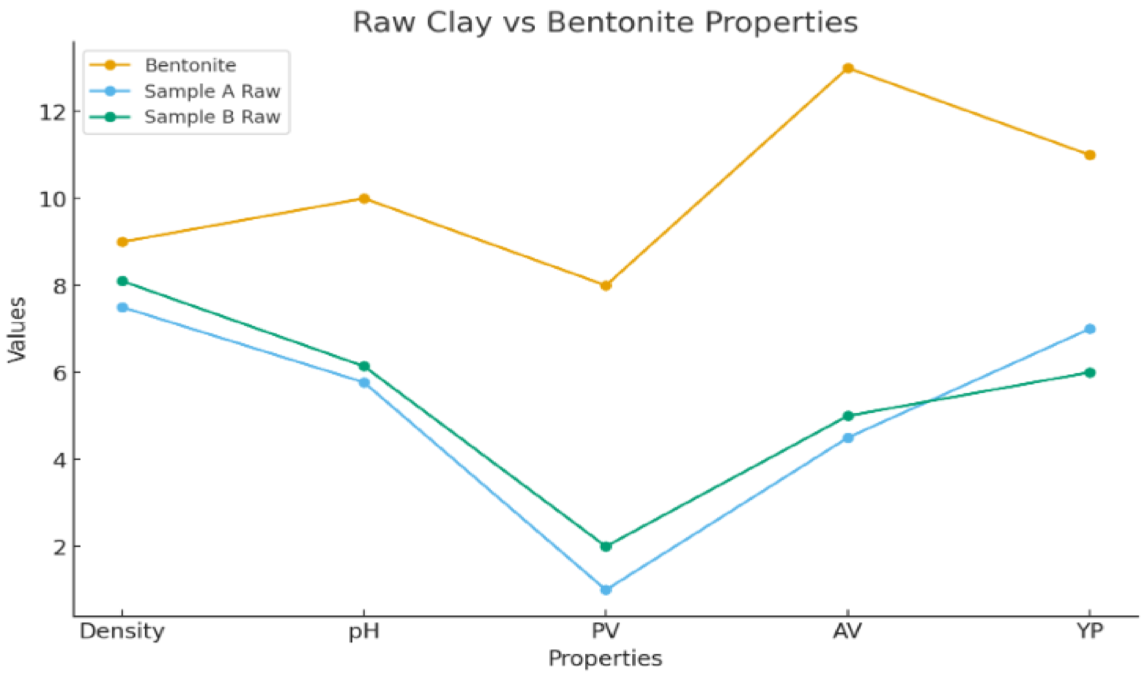


Figure 3: Showing the rheological differences between raw clay and bentonite

**Table 2: Beneficiated Sample A**

| Property | Bentonite | Sample A Raw | Sample A Beneficiated |
|---|---|---|---|
| Density | 9.0 | 7.5 | 7.9 |
| pH | 10.00 | 5.77 | 10.47 |
| PV | 8.00 | 1.00 | 2.0 |
| AV | 13.00 | 4.50 | 5.5 |
| YP | 11.00 | 7.00 | 7.0 |
| Cake Thickness | — | — | 1.05 mm |

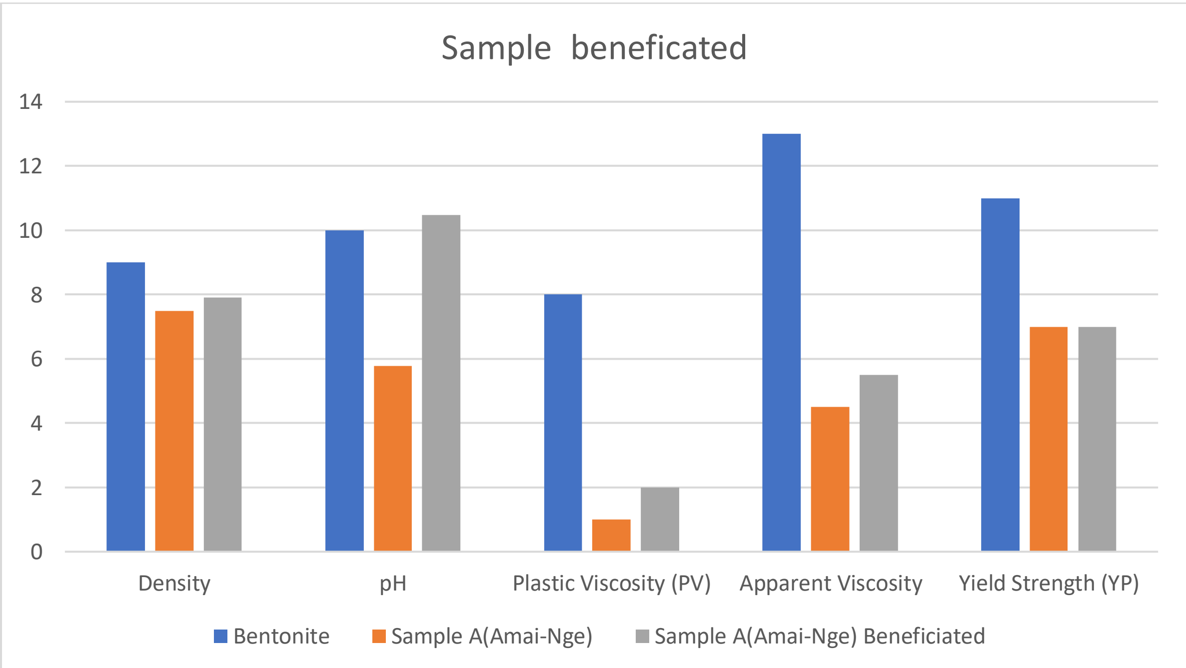


Figure 4: Showing the rheological differences between raw clay (Sample A), bentonite and beneficiation with barite (BaSO4) and soda ash ($Na_2CO_3$)

**Beneficiated Sample A**

pH increased from 5.77 → 10.47, indicating successful sodium activation. AV improved from 4.5 → 5.5. YP remained moderate (7.0), suggesting limited structural improvement. Density improved to 7.9 but still below bentonite Fig 4.

**Table 3: Beneficiated Sample B**

| Property | Bentonite | Sample B Raw | Sample B Beneficiated |
|---|---|---|---|
| Density | 9.0 | 8.10 | 8.30 |
| pH | 10.00 | 6.14 | 10.05 |
| PV | 8.00 | 2.00 | 5.0 |
| AV | 13.00 | 5.00 | 15.00 |
| YP | 11.00 | 6.00 | 20.00 |
| Cake Thickness | — | — | 1.05 mm |

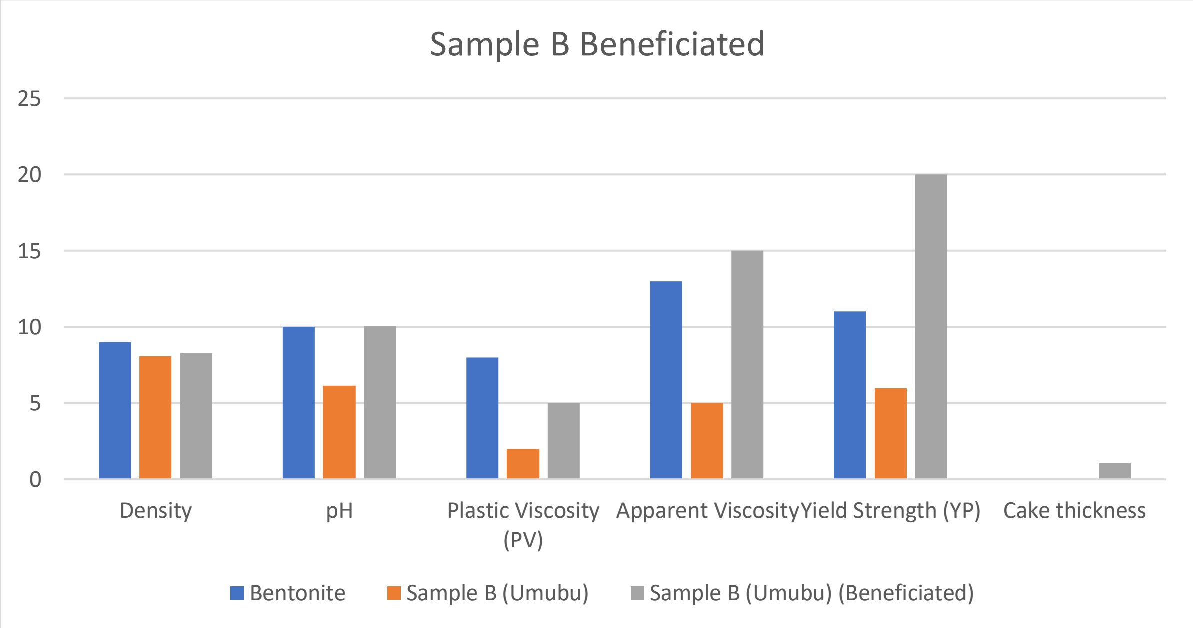


Figure 5: Showing the rheological differences between raw clay (Sample A), bentonite and beneficiation with barite (BaSO4) and soda ash ($Na_2CO_3$)

**Beneficiated Sample B**

PV increased significantly (2.0 → 5.0), AV showed a major jump (5.0 → 15.00), indicating excellent viscosity response, YP increased sharply (6.0 → 20.0), showing strong gel strength, pH improved to 10.05. Cake thickness of 1.05 mm indicates acceptable filtration property fig. 5.

Sample B (Umubu) performed significantly better and approached or exceeded bentonite performance after beneficiation, while Sample A showed improvement but remains inferior to bentonite.

**CONCLUSION**

Local clays from Ukwuani LGA especially Sample B from Umubu have strong potential as substitutes for imported bentonite after beneficiation. This study evaluated Amai and Umubu clays for use in water-based drilling mud systems. Raw clay results showed insufficient rheological performance compared to bentonite. Beneficiation with soda ash and barite significantly improved properties. Sample B showed the most promising rheological characteristics, achieving viscosities and yield points suitable for drilling operations. The results demonstrate that rheological and pH characteristics can be adjusted to meet drilling mud requirements, reducing import dependency and lowering drilling costs in Nigeria. However, the study was restricted to samples from two locations, and no mineralogical characterization using techniques such as XRD, SEM/EDS, or XRF was conducted. Furthermore, contamination studies and economic feasibility assessments were not performed. Future investigations should address these limitations to establish industrial-scale applicability.

*Declaration of Conflict of Interest:* Authors have declared that no competing interests exist. Data *Availability Statement:* Data are available upon request from the first author

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