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Full Length Research

Suitability assessment of indigenous clay deposits for drilling fluid application: A case study of Egbeta clay

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ABSTRACT: The reliance on imported bentonite for drilling fluid formulation in Nigeria poses significant economic challenges and limits local content development. This study evaluates the suitability of indigenous clay deposits from the Egbeta community, Edo State, for water-based drilling fluid applications. Clay samples were collected and subjected to laboratory analyses, including moisture content, pH, mud weight, rheological properties, sand content, and cation exchange capacity (CEC). Local additives such as lime and starch were incorporated to assess their influence on mud performance. Results indicated that Egbeta clay exhibits low moisture content (2.3–5.0%), acidic pH (4.17–4.51), poor viscosity, weak gel strength (1–3 lb/100 ft²), and low yield point, reflecting limited hydration and suspension capacity. Moderate CEC values (3.0–4.0 meq/100 g) suggested some ion exchange potential, but overall rheological behaviour remained below standard drilling fluid requirements. Additive incorporation produced slight improvements in viscosity and gel strength, yet performance was insufficient for direct industrial application. High sand content (2.5–3.0%) further highlighted the presence of impurities requiring beneficiation. The findings demonstrate that untreated Egbeta clay is unsuitable for direct drilling fluid use. However, with beneficiation, chemical activation, and incorporation of polymers or nanomaterials, its properties could be enhanced to meet industrial standards. This study provides baseline data on Egbeta clay and underscores its potential as a local substitute for imported bentonite, supporting Nigeria's petroleum sector and local content initiative.

Keywords: Cation exchange capacity, pH, lime, moisture content, mud weight, rheological properties, sand content, starch.

INTRODUCTION

Drilling fluids, commonly referred to as drilling muds, are essential materials used during oil and gas well drilling operations because they perform several critical functions necessary for efficient and safe drilling activities. These functions include cooling and lubricating the drill bit, transporting drilled cuttings from the bottom of the well to the surface, maintaining hydrostatic pressure to prevent formation fluid influx, stabilising the wellbore walls, minimising formation damage, and reducing friction within the drilling system (Zhang *et al*., 2020; Panikarovskiy *et al*., 2021). The effectiveness of any drilling operation is therefore closely linked to the quality and performance of the drilling fluid employed. Poor drilling fluid performance can lead to operational problems such as pipe sticking, wellbore instability, excessive fluid loss, formation damage, poor hole cleaning, and increased drilling cost.

Drilling fluids are broadly classified into water-based, oil-based, and synthetic-based mud systems. Among these categories, water-based drilling fluids remain the most widely used because of their relatively low cost, environmental friendliness, ease of preparation, and adaptability to different drilling conditions (Akpan *et al*., 2019). The performance of water-based drilling muds is highly dependent on the materials used in their formulation, particularly clay minerals, which serve as the primary viscosifying and filtration control agents. Clay minerals are valued in drilling fluid systems because of their hydration characteristics, colloidal behaviour, swelling capacity, and ability to form stable suspensions in aqueous media (Zhuang *et al*., 2024). These characteristics enable drilling fluids to effectively transport drill cuttings and maintain desirable rheological properties during drilling operations.

Among the various clay minerals used in drilling fluid formulation, bentonite, especially sodium bentonite, is the most preferred because of its high swelling ability, large surface area, and excellent rheological properties (Afolabi *et al*., 2017). Bentonite contributes significantly to mud viscosity, gel strength, filtration control, and suspension stability. According to Zhang *et al*. (2020), clay minerals play an indispensable role in determining the performance characteristics of drilling fluids, while Zhuang *et al*. (2024) emphasised that the physicochemical properties of clay minerals directly influence drilling fluid behaviour under different operational conditions. The growing complexity of modern drilling operations, including deep and horizontal drilling, has further increased the demand for drilling fluids with enhanced rheological and thermal stability properties.

In recent years, researchers have explored several approaches to improve the performance of clay-based drilling fluids. These approaches include beneficiation, chemical activation, polymer modification, and nano-particle incorporation. Ratkievicius *et al*. (2017) modified bentonite clay using cationic surfactants and observed significant improvement in viscosity enhancement for vegetable-oil-based drilling fluids. Cheraghian *et al*. (2018) also reported that clay/silica nanocomposites improved both rheological and filtration properties of water-based drilling fluids. Similarly, Song *et al*. (2016) demonstrated that the incorporation of biopolymers into bentonite drilling fluids effectively minimised fluid loss and formation damage. These advancements indicate that the properties of clay materials can be significantly enhanced to meet modern drilling requirements.

The increasing global demand for energy resources has intensified drilling activities, thereby increasing the consumption of drilling mud materials. However, the importation of bentonite and other drilling fluid additives remains a major economic challenge for many developing countries, including Nigeria. The dependence on imported drilling mud materials contributes substantially to drilling costs and negatively affects local content development within the petroleum sector (Agwu *et al*., 2016). As a result, considerable research attention has been directed toward the exploration and evaluation of indigenous clay deposits as potential substitutes for imported bentonite in drilling fluid applications (Afolabi *et al*., 2017). Nigeria is endowed with abundant clay mineral deposits distributed across various geological formations, many of which possess industrial potential for drilling fluid formulation.

Several Nigerian clay deposits have been investigated for their suitability in drilling mud applications. Agwu *et al*. (2016) studied the activation of local bentonitic clays and observed that beneficiation processes improved viscosity and gel strength properties. Arabi *et al*. (2018) evaluated clays obtained from the Pindiga Formation in Northeastern Nigeria and reported that locally beneficiated clays exhibited acceptable morphology, rheology, and thermal stability for drilling operations. Jimoh *et al*. (2021) investigated the rheological behaviour of drilling mud formulated with Ubakala clay in the presence of natural polymers and found that the formulated mud possessed improved rheological properties suitable for drilling applications.

Lawrence *et al*. (2025) further investigated the enhancement of Nteje clay using wet and thermal beneficiation methods and concluded that beneficiation significantly improved the clay's drilling fluid properties. Similarly, Ituen *et al*. (2026) successfully formulated and evaluated water-based drilling mud from locally sourced materials in Akwa Ibom State, demonstrating the viability of indigenous resources for drilling fluid production. John (2025) also evaluated Iyi-Ogene clay as a potential material for drilling mud formulation and reported that local clay deposits possess promising industrial applications when properly processed and characterised. These studies collectively indicate that indigenous clay deposits in Nigeria have significant potential for drilling fluid applications and could reduce dependence on imported bentonite if adequately developed.

The suitability of clay materials for drilling fluid application is determined by several important physicochemical and rheological properties, including plastic viscosity, apparent viscosity, yield point, gel strength, filtration loss, pH, density, thermal stability, and mineralogical composition (Deng *et al*., 2020). Rheological properties are particularly important because they determine the ability of drilling fluids to transport drilled cuttings, suspend weighting materials, and maintain wellbore stability. Deng *et al*. (2020) emphasised that effective hole cleaning during drilling operations depends largely on the rheological behaviour of the drilling fluid. In addition, fluid loss control is essential for minimising formation damage and maintaining drilling efficiency. Fattah and Lashin (2016) reported that drilling fluid density and weighting materials significantly affect filter cake properties and formation damage characteristics.

Recent developments in drilling fluid technology have also focused on the use of nanoparticles and environmentally friendly additives to improve drilling fluid performance under challenging drilling conditions. Aramendiz and Imqam (2019) formulated water-based drilling fluids using silica and graphene nanoparticles and reported enhanced rheological and filtration properties suitable for unconventional shale drilling applications. Al-Shargabi *et al*. (2022) observed that nanoparticle additives improve drilling fluid performance under high-temperature and high-pressure conditions, while Ikram *et al*. (2021) highlighted the growing relevance of carbon-based nanomaterials in modern drilling fluid systems. Furthermore, environmentally sustainable drilling practices have gained increasing attention due to concerns regarding the environmental impact of drilling fluid waste disposal.

Pereira *et al*. (2022) emphasised the need for sustainable drilling fluid treatment methods, while Al-Hameedi *et al*. (2019) explored the application of eco-friendly additives for improving water-based drilling fluid properties.

Despite the numerous investigations carried out on Nigerian clay deposits for drilling fluid applications, most studies have focused on clays from regions such as Pindiga, Ubakala, Nteje, Akwa Ibom, and Iyi-Ogene (Arabi *et al*., 2018; Jimoh *et al*., 2021; Lawrence *et al*., 2025; Ituen *et al*., 2026; John, 2025). However, there is limited or no documented information regarding the physicochemical, rheological, and filtration properties of Egbeta clay and its suitability for drilling fluid formulation. This represents a significant knowledge gap concerning the industrial potential of the clay deposit for oil and gas drilling applications. In addition, the continued dependence on imported bentonite increases drilling costs and limits local content development within Nigeria's petroleum industry (Afolabi *et al*., 2017). Although previous studies have shown that local clays can be improved through beneficiation and modification processes, the performance behaviour of Egbeta clay under drilling conditions remains largely unexplored. Therefore, there is a need to evaluate the suitability of Egbeta clay as a potential local material for drilling fluid application and to provide scientific data that could support its possible industrial utilisation in drilling operations.

METHODOLOGY

Apparatus and materials used

The experimental investigation was conducted using a range of laboratory apparatus designed to measure and analyse the properties of drilling fluids. The equipment included a mud balance for density determination, viscometers (specifically the Marsh funnel viscometer and the six-speed gear viscometer) for rheological measurements, a sand content apparatus for evaluating solid impurities, and a pH meter for assessing fluid acidity or alkalinity. Additional instruments such as Erlenmeyer flasks, a weighing balance, and a slurry mixer were employed to facilitate sample preparation and accurate measurement. The materials utilised in the study comprised locally sourced clay samples from Okada, barite as a weighting agent, lime for pH adjustment, calcium methyl cellulose (CMC) and Q-Broxin as viscosifiers, as well as starch for fluid loss control. These additives were systematically incorporated to investigate their influence on the rheological and chemical properties of the formulated drilling fluids.

Sample collection

Clay samples were collected from the Egbeta community, one of the villages surrounding Okada town in Ovia North East Local Government Area (LGA) of Edo State, Nigeria. Egbeta lies approximately 16 km from Okada and is geographically positioned at latitude 6.7891°N and longitude 5.5142°E, with an elevation ranging between 76 and 145 meters above sea level. Sampling was carried out at three distinct locations within the community, designated as Samples A, B, and C, to ensure representative coverage of the study area.

Test description

Moisture content determination

4g of clay samples were poured into the crucible and kept in an oven at a temperature of 90 ± 0.5°C. After 1 hour of ageing, the crucible was cooled in the desiccator and weighed. It was placed in the oven for further ageing for 15 minutes and then cooled in the desiccators and weighed. The 15 minutes ageing, cooling and weighing continue until a constant weight is achieved. The percentage moisture content (%) was therefore calculated and recorded.

$$\%\text{Moisture Content} = \frac{\text{W1} - \text{W2}}{\text{W2}} x100$$

Where: W1= Weight of wet clay sample (g), and W2 = Weight of oven-dried clay sample (g)

Hydrogen ion determination

The pH meter was first standardised with the proper buffer solution of 6.8 and 7.2 pH. 4g of clay samples were poured into 250 ml of water and stirred. The tip of the probe of the pH meter was then placed on the slurry, and the reading of the pH was read directly from the meter and recorded.

Mud weight (density) determination

Using the mud balance, 15 g of the clay sample to be tested was poured into 250 ml of water and stirred vigorously for 30 minutes. The mud cup of the mud balance was filled to the brim with the mud to be tested, and the weight of the mud was then determined. Weight was read and recorded in pounds per gal (lb/gal) and pounds per square inch per thousand feet (Ib/in^2/1000ft), respectively.

Measurement of rheological properties

Properties like funnel viscosity, rotatory viscosity, plastic viscosity, apparent viscosity and gel strength were carried out in turn using the Marsh funnel and six-speed gear viscometers. 120 g of clay samples was dissolved in 2000 mL of fresh water. The mud slurry prepared was poured through the screen of the marsh funnel to get to the underside of the screen; almost immediately, the outlet of the funnel is left open so as to allow the flow of the mud to reach exactly 1 quartz (946 ml). The timing starts as soon as the flow begins; funnel viscosity is noted as sec. API.

To measure the rotator viscosity and gel strength of the mud, the mud slurry prepared as stated above was poured into the slurry cup of the viscometer and stirred with the rotor of the viscometer. Readings for 600 rpm and 300 rpm were read directly from the viscometer and recorded in cp.

Sand content measurement

The mud slurry prepared was poured into the sand content tube to the mark "mud to here", and water was added to the mark "water to here", and the mixture was shaken for proper mixing. Thereafter, the sand content test was carried out, and the results were read directly from the tube and recorded as sand content %.

Cation exchange capacity (CEC)

2 ml of the mud sample was added into 10 ml of water in the Erlenmeyer flask, and 15ml of 3% H_2O_2 and 0.5ml of H_2SO_4 solution were added to the constituents in the flask and mixed by swirling. After mixing, the solution was gently boiled for 10 minutes, and then diluted to about 50 ml of water; 0.5ml methylenblue solution was added in drops to the flask and shaken for 305 seconds. While the solids are suspended, a drop is removed on filter paper; the endpoint is reached as the eye appears as a greenish-blue ring surrounding the dye solid. The cation exchange capacity is calculated and corrected to the Bentonite value of CEC.

Data analysis

The data obtained from the laboratory experiments were analysed using descriptive and comparative analytical methods. Measured parameters such as moisture content, pH, mud weight, viscosity, gel strength, sand content, cation exchange capacity, plastic viscosity, apparent viscosity, and yield point were presented in tables and evaluated to determine the suitability of the Egbeta clay for drilling fluid application. The effects of different additives on the rheological properties of the clay samples were also compared, while the results were interpreted against standard drilling fluid performance requirements and findings from previous studies.

RESULTS AND DISCUSSION

Moisture content

The moisture content values presented in Table 1 showed that Samples A, B, and C recorded moisture contents of 2.5%, 5.0%, and 2.3%, respectively. Sample B exhibited the highest moisture content, while Sample C had the lowest value. The generally low moisture content values indicate that the Egbeta clay possesses low water retention and hydration characteristics in its natural state. Moisture content is an important parameter in drilling fluid applications because it influences clay swelling behaviour, dispersion, and rheological performance.

The low moisture values obtained suggest limited hydration ability, which may adversely affect the swelling and viscosifying properties required for efficient drilling mud performance. Similar observations were reported by Afolabi *et al*. (2017), who noted that many Nigerian indigenous clays exhibit low hydration characteristics compared with commercial bentonite. Zhang *et al*. (2020) also explained that clay minerals suitable for drilling fluid applications should possess appreciable hydration and swelling capacities to ensure effective rheological performance. Therefore, the low moisture content observed for the Egbeta clay may partly explain the poor rheological properties recorded in subsequent tests.

pH characteristics

The pH values shown in Table 2 were 4.46, 4.17, and 4.51 for Samples A, B, and C, respectively, indicating acidic conditions for all the clay samples. Sample B was the most acidic among the tested samples. In drilling fluid systems, pH significantly affects clay dispersion, additive performance, corrosion tendency, and mud stability.

The acidic nature of the Egbeta clay suggests that mud formulated from the clay may promote corrosion of drilling equipment if used without proper treatment. Water-based drilling muds generally require alkaline conditions for optimum performance and thermal stability. Akpan *et al*. (2019) reported that drilling fluids with low pH values often exhibit reduced thermal stability and increased corrosion potential under high-temperature drilling conditions. Similarly, Chang *et al*. (2019) emphasised that alkaline environments improve the performance of drilling fluid additives and enhance mud stability. Consequently, the acidic pH values obtained for the Egbeta clay indicate that pH adjustment through chemical conditioning would be necessary before practical drilling applications.

Mud weight

The mud weight results presented in Table 3 showed a gradual increase with increasing clay concentration and barite addition. Sample A increased from 8.5 to 8.70 ppg, Sample B from 8.45 to 8.65 ppg, while Sample C increased from 8.5 to 8.80 ppg. The corresponding pressure gradients also increased with increasing mud concentration.

Mud density is essential for maintaining wellbore stability and controlling formation pressure during drilling operations. The increase in mud weight observed in this study is attributed to the incorporation of barite, which serves as a weighting material in drilling fluids. Similar observations

Table 1. Moisture content table.

Parameters	Weight of clay sample in grams		
	Sample A	Sample B	Sample C
Initial weight of the sample	4.0	4.0	4.0
Weight after 1hr. aging	3.94	3.81	3.93
Weight after 15 minutes of ageing	3.90	3.81	3.91
Final/constant weight	3.90	3.80	3.91
Moisture content %	2.5	5.0	2.3

Table 2. pH level at room temperature

Samples	Wt. of sample in grams	pH
Sample A	4.0	4.46
Sample B	4.0	4.17
Sample C	4.0	4.51

Table 3. Mud weight at varying quantities of mud at room temperature.

Parameters	Sample A	60g sample A + 20g barite	70g sample A + 20g barite	80g sample A + 20g barite	Sample B	60g sample B + 20g barite	70g sample B + 20g barite	80g sample B + 20g barite	Sample C	60g sample C + 20g barite	70g sample C + 20g barite	80g sample C + 20g barite
Pounds per gallon (il.gal)	8.5	8.6	8.70	8.70	8.45	8.60	8.65	8.65	8.5	8.70	8.72	8.80
Pounds per square in^2 per thousand feet (Il/in^2/1000ft)	440	450	460	460	435	450	455	455	440	460	460	470

were reported by Fattah and Lashin (2016), who noted that mud density increases with the addition of weighting agents, although excessive solids concentration may negatively affect rheological and filtration properties. The relatively moderate mud weight values obtained indicate that the Egbeta clay can support density enhancement when combined with barite; however, excessive solids loading may adversely affect drilling efficiency.

Marsh funnel viscosity

The marsh funnel viscosity values shown in Table 4 revealed that the untreated clay samples recorded viscosities of 26 s/API, 32 s/API, and 30 s/API for Samples A, B, and C, respectively. The addition of additives such as CMC, starch, Q-broxin, and lime resulted in slight viscosity improvements, with the highest value of 34 s/API recorded for Sample B treated with 3 g CMC.

Despite these improvements, the viscosity values remained relatively low compared with standard drilling mud requirements. Viscosity is a critical drilling fluid property because it determines the carrying capacity of drilled cuttings and influences hole-cleaning efficiency. Deng *et al*. (2020) reported that drilling fluids with low viscosity often exhibit inadequate hole-cleaning performance and poorsuspension capability. Similarly, Agwu *et al*. (2016) observed that many Nigerian local clays

Table 4. Viscosity in sec in API using the Marsh funnel viscometer at varying quantities of additives at room temperature.

Parameters	Sample A	Sample A + 2g Q-broxin	Sample A + 3g CMC	Sample A + 3g lime	Sample A + 15g starch	Sample A + 20g starch	Sample A + 30g starch	Sample A + 40g starch	Sample A + 50g starch
Viscosity	26	25	32	24	26	27	28	28	28

Parameters	Sample B	Sample B + 2g Q-broxin	Sample B + 3g CMC	Sample B + 3g lime	Sample B + 15g starch	Sample B + 20g starch	Sample B + 30g starch	Sample B + 40g starch	Sample B + 50g starch
Viscosity	32	28	34	29	33	32	32	30	30

Parameters	Sample C	Sample C + 2g Q-broxin	Sample C + 3g CMC	Sample C + 3g lime	Sample C + 15g starch	Sample C + 20g starch	Sample C + 30g starch	Sample C + 40g starch	Sample C + 50g starch
Viscosity	30	29	31	29	30	30	30	31	30

Table 5. Rotary viscosity in cp using the Fann GV viscometer, at varying quantities of additives at room temperature

Speed (rpm)	Sample A	Sample A + 2g Q-broxin	Sample A + 3g CMC	Sample A + 3g lime	Sample A + 15g starch	Sample A + 20g starch	Sample A + 30g starch	Sample A + 40g starch	Sample A + 50g starch
600	4	3	6	3	4	5	6	6	6
300	2	1	3	1	2	2	3	2	2

Speed (rpm)	Sample B	Sample B + 2g Q-broxin	Sample B + 3g CMC	Sample B + 3g lime	Sample B + 15g starch	Sample B + 20g starch	Sample B + 30g starch	Sample B + 40g starch	Sample B + 50g starch
600	3	3	4	3	3	4	5	4	4
300	2	1	2	1	2	2	3	1	1

Speed (rpm)	Sample C	Sample C + 2g Q-broxin	Sample C + 3g CMC	Sample C + 3g lime	Sample C + 15g starch	Sample C + 20g starch	Sample C + 30g starch	Sample C + 40g starch	Sample C + 50g starch
600	4	3	5	4	5	7	6	6	6
300	2	1	2	1	2	3	4	4	4

require beneficiation and chemical activation to achieve a viscosity comparable to API-grade bentonite.

The slight improvement observed after the addition of CMC and starch confirms the effectiveness of polymers as viscosifying agents in water-based drilling fluids. Similar improvements in rheological performance after polymer modification were reported by Song *et al*. (2016) and Jimoh *et al*. (2021). Nevertheless, the viscosity values obtained indicate that the Egbeta clay possesses limited natural viscosifying capacity.

Rotary viscosity

The rotary viscosity values presented in Table 5 ranged from 3 to 7 cP at 600 rpm and from 1 to 4 cP at 300 rpm across all samples and additive concentrations. Sample C treated with 20 g starch produced the highest viscosity value of 7 cP at 600 rpm.

The low rotary viscosity values indicate weak shear resistance and poor carrying capacity of the formulated mud systems. Rotary viscosity is directly related to the ability of drilling fluids to transport drilled cuttings from the bottom of the well to the surface. Srungavarapu *et al*. (2018) noted that adequate rheological strength is necessary for efficient hole cleaning and suspension of solids during drilling operations. Therefore, the low viscosity values recorded suggest that untreated Egbeta clay may not provide sufficient suspension performance under field drilling conditions.

The improvements observed after starch and CMC additions are consistent with the findings of Cheraghian *et al*. (2018), who reported that polymeric and nano-enhanced additives significantly improve the rheological properties of clay-based drilling fluids. However, despite additive incorporation, the rheological performance remained relatively poor compared with conventional drilling mud standards.

Table 6. Gel strength in Ib/100ft at varying quantities of additives at room temperature.

Time	Sample A	Sample A + 2g Q-broxin	Sample A + 3g CMC	Sample A + 3g lime	Sample A + 15g starch	Sample A + 20g starch	Sample A + 30g starch	Sample A + 40g starch	Sample A + 50g starch
10 sec.	1	1	2	1	2	2	2	1	1
10 min.	1	1	1	1	1	0	0	0	0

Time	Sample B	Sample B + 2g Q-broxin	Sample B + 3g CMC	Sample B + 3g lime	Sample B + 15g starch	Sample B + 20g starch	Sample B + 30g starch	Sample B + 40g starch	Sample B + 50g starch
10 sec.	1	1	1	1	1	1	2	1	1
10 min.	1	1	1	1	1	0	0	0	0

Time	Sample C	Sample C + 2g Q-broxin	Sample C + 3g CMC	Sample C + 3g lime	Sample C + 15g starch	Sample C + 20g starch	Sample C + 30g starch	Sample C + 40g starch	Sample C + 50g starch
10 sec.	1	1	1	1	1	2	2	2	1
10 min.	1	1	1	1	2	2	3	2	2

Gel strength

The gel strength values presented in Table 6 were generally low, ranging from 1 to 3 lb/100 ft² for both the 10-second and 10-minute measurements. Sample C showed relatively better gel strength development after starch addition, reaching 3 lb/100 ft² at 10 minutes.

Gel strength determines the ability of drilling mud to suspend cuttings and weighting materials when circulation stops. Low gel strength values imply poor suspension capability and a tendency for solids to settle at the bottom of the wellbore. Arabi *et al*. (2018) reported that local clays with inadequate gel strength may lead to inefficient cuttings suspension and operational challenges during drilling activities. Similarly, Zhuang *et al*. (2024) explained that enhanced colloidal interaction among clay particles is necessary to achieve stable gel structures in drilling fluids.

The slight increase in gel strength after starch and CMC addition demonstrates the beneficial effect of polymers on mud structure development. However, the generally low gel strength values indicate that substantial beneficiation and additive optimisation would be required before the Egbeta clay can satisfy industrial drilling fluid specifications.

Plastic viscosity, apparent viscosity, and yield point

The plastic viscosity, apparent viscosity, and yield point results shown in Table 7 revealed generally poor rheological properties for the formulated mud systems. Plastic viscosity values ranged from 1 to 4 cP, while apparent viscosity values ranged from 1.5 to 3.5 cP. Yield point values were mostly low and, in several cases, negative. Sample C treated with starch exhibited relatively better yield point values of 2 lb/100 ft².

Plastic viscosity reflects the internal resistance to flow caused by suspended solids, whereas yield point measures the electrochemical attractive forces between particles and the carrying capacity of the drilling fluid. The low plastic and apparent viscosity values obtained indicate insufficient particle interaction and weak rheological structure formation. Negative yield point values further suggest instability within the mud system and poor particle suspension behaviour.

Deng *et al*. (2020) observed that drilling fluids with low yield point values exhibit inadequate cuttings transport efficiency, especially in deviated wells. Similarly, Ratkievicius *et al*. (2017) reported that untreated bentonite systems often require polymer or surfactant modification to improve rheological stability and yield performance. The modest improvements obtained after starch and CMC addition in this study agree with previous findings by Jimoh *et al*. (2021) and Song *et al*. (2016), who reported enhanced rheological properties following polymer treatment of local clays.

Sand content

The sand content values shown in Table 8 were 2.5%, 2.6%, and 3.0% for Samples A, B, and C, respectively, with Sample C recording the highest value. High sand content in drilling mud is undesirable because it increases abrasive wear on drilling equipment and may contribute to stuck pipe incidents and poor mud performance. Vipulanandan and Mohammed (2020) reported that excessive solid particles in drilling fluids adversely affect filter cake quality and drilling efficiency. The relatively high sand content values obtained in this study indicate the presence of coarse particles and impurities within the Egbeta clay

Table 7. Plastic viscosity (cp), apparent viscosity (cp) and yield point (Ib/100ft^2) at varying quantities of additives at room temperature.

Parameters	**Sample A**	**Sample A + 2g Q-broxin**	**Sample A + 3g CMC**	**Sample A + 3g lime**	**Sample A + 15g starch**	**Sample A + 20g starch**	**Sample A + 30g starch**	**Sample A + 40g starch**	**Sample A + 50g starch**
Plastics viscosity	2	2	3	2	2	3	3	4	4
Apparent iscosity	2	1.5	3	1.5	2	2.5	3	3	3
Yield point	0	-1	0	-1	0	-1	0	-2	-2

Parameters	**Sample B**	**Sample B + 2g Q-broxin**	**Sample B + 3g CMC**	**Sample B + 3g lime**	**Sample B + 15g starch**	**Sample B + 20g starch**	**Sample B + 30g starch**	**Sample B + 40g starch**	**Sample B + 50g starch**
Plastics viscosity	1	2	2	2	2	3	3	4	4
Apparent iscosity	1.5	1.5	2	1.5	1.5	2	2.5	2	2
Yield point	1	-1	0	-1	0	-1	0	-3	-3

Parameters	**Sample C**	**Sample C + 2g Q-broxin**	**Sample C + 3g CMC**	**Sample C + 3g lime**	**Sample C + 15g starch**	**Sample C + 20g starch**	**Sample C + 30g starch**	**Sample C + 40g starch**	**Sample C + 50g starch**
Plastics viscosity	2	2	3	3	3	4	2	2	2
Apparent iscosity	2	1.5	2.5	2	2.5	3.5	3	3	3
Yield point	0	-1	-1	-2	-1	-1	2	2	2

Table 8. Sand content results in % volume at room temperature

Sample A (%)	**Sample B** (%)	**Sample C** (%)
2.5	2.6	3.0

Table 9. Cation exchange capacity (CEC) results at room temperature.

Sample A		**Sample B**		**Sample C**	
MEq/100g	**Ib/bbl**	**MEq/100g**	**Ib/bbl**	**MEq/100g**	**Ib/bbl**
3.5	17.5	4.0	20	3.0	15

deposits. This suggests that beneficiation and particle-size refinement would be necessary before the clay can be effectively utilised for drilling fluid formulation.

Cation Exchange Capacity (CEC)

The cation exchange capacity values presented in Table 9 were 3.5, 4.0, and 3.0 meq/100 g for Samples A, B, and C, corresponding to 17.5, 20, and 15 lb/bbl, respectively. Sample B recorded the highest CEC value.

CEC is an important indicator of the clay’s ability to adsorb and exchange ions, which significantly influences hydration, swelling, and rheological behaviour. Moderate CEC values are beneficial for drilling mud functionality; however, excessive ion exchange activity may destabilise mud systems under varying formation conditions. Afolabi *et al*. (2017) explained that the performance of local Nigerian clays depends largely on their mineralogical composition and ion exchange characteristics. Similarly, Zubkova *et al*. (2024) emphasised that clay minerals with balanced cation exchange properties exhibit improved drilling fluid stability and rheological behaviour.

Although the Egbeta clay exhibited moderate CEC values, the overall rheological performance remained poor. This suggests that factors such as mineral composition, particle-size distribution, and low swelling capacity may have limited the clay's drilling-fluid performance despite its moderate ion-exchange characteristics.

Conclusion

This study assessed the suitability of Egbeta clay for drilling fluid application using its physicochemical and rheological properties. The results showed that the clay samples possessed low moisture content, acidic pH, low viscosity, poor gel strength, and low yield point, indicating weak hydration and poor suspension capacity. Although the addition of additives such as CMC and starch slightly improved the mud properties, the overall drilling fluid performance remained below standard requirements. The relatively high sand content also suggests the presence of impurities that may negatively affect drilling operations. Therefore, Egbeta clay in its natural state is not suitable for direct drilling fluid application, but it has potential for use after proper beneficiation and chemical treatment.

Recommendations

1. The Egbeta clay should be beneficiated and chemically activated to improve its viscosity, swelling, and rheological properties.
2. Suitable additives such as polymers and nanomaterials should be incorporated to enhance gel strength and mud stability.
3. Further mineralogical and chemical characterisation studies should be conducted to better understand the clay composition and behaviour.
4. Additional investigations under high-pressure and high-temperature drilling conditions should be carried out to evaluate the clay's field applicability.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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