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Evaluating the effect of unmodified and modified starch (EDTA-DSD) as fluid-loss control additives in locally-sourced bentonite water-based drilling mud

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Abstract

Drilling oil and gas wells for hydrocarbon exploration involve high fluid loss costs. Minimizing the fluid loss is crucial to the drilling process to preserve the mud's qualities and to avoid formation impairment. Research has shown positive use of carboxymethylcellulose (CMC) and imported bentonite in the formulation of water-based mud to minimize fluid loss, however, increases the operating cost while the local bentonite has shown increased filtration losses. The aim of this study is to evaluate the rheological and filtration properties of water-based muds formulated using unmodified and modified starch with ethylenediaminetetraacetic acid (EDTA-DSD), a locally sourced material as a fluid loss additive and hyperdrill as a viscosifier at low-pressure low temperature (LPLT) and high-pressure high temperature (HPHT) conditions, and their performances were compared with CMC as reference fluid loss additives. Thermogravimetric Analysis (TGA), Scanning Electron Microscope (SEM) were harnessed to study the properties of these starches while the starch modification was achieved through acetylation and carboxymethylation. Full-set measurements of laboratory tests were conducted to evaluate the influence of adding 0.5-2g of CMC, unmodified and modified starch to the mud samples respectively, and measurements were taken using mud balance, viscometer, low-pressure and low-temperature filter press, chemical titration, and other standard drilling fluid laboratory equipment as recommended by API. Result showed that Plastic viscosity, PV for unmodified starches ranged from 14-17cP, Yield point, YP ranged from 25-31lb. /100ft^2,filtrate volume ranges from 18-31ml at LPLT and 30-43ml at HPHT while PV for modified starches ranged from 14-15cp, YP ranged from 27-31lb. /100ft^2, filtrate volume ranges from 17-31ml at 100psi and 19-43ml at 500psi of pressure. Experimental results indicate that the filtrate volume and cake thickness compare favorably with CMC, has the capacity to withstand HPHT conditions and are within the American Petroleum Institute specification for water-based mud. Thus, demonstrate its suitability for current and future exploration and exploitation of oil and gas resources.

Keywords: Soursop, Modified starch (EDTA-DSD), Fluid-loss control additives, Bentonite, Water-based drilling mud, ethylenediaminetetraacetic acid disodium salt dihydrate (EDTA-DSD)

Introduction

One of the key to a successful well drilling operation is drilling mud, which comprises complex fluid mixtures with various additives dissolved into a continuous fluid phase to optimize their functions. Based on the kind of continuous fluid phase, they are typically categorized as water-based mud (WBM), oil-based mud (OBM), and synthetic-based mud (SBM) (Okon et al., 2020). The main responsibilities of the mud include stabilizing the borehole wall, removing cuttings from the hole and transporting them to the surface, lubricating and cooling the drilling bit, managing pressure and reducing filtration loss (Dias et al., 2015). Due to its affordability and environmental benefits, WBM is the most widely utilized drilling fluid in the industry. A variety of additives, including clays, polymers, and salts, are combined with water to formulate it. According to Al-Hameedi et al., 2020, fluid loss control additives are crucial part of drilling mud systems that let them fulfill requirements while strictly adhering to environmental, health, and safety laws.

Recently, there have been a number of challenges in the formulation and application of drilling muds. These include the rising cost of additives and their importation, the use of synthetic chemicals as additives that are unable to meet the toxicity and green level biodegradability requirements of oilfield chemicals, and the growing importance of environmental concerns in drilling operations (Amanullah et al., 2016). In drilling mud compositions, biodegradable and non-toxic filtration control agents are recommended (Okoro et al., 2019; Dike et al., 2019). Drilling and completion fluids are formulated with fluid loss additives to limit fluid loss to adjacent formations within an acceptable range, which is less than 15 cc/30 min under standard API test conditions thereby maintaining drilling fluid consistency near wellbore formation stability and preventing pay zone damage (Dankwa et al., 2018). Some commercial fluid loss additives, including lignosulfonates, polyanionic cellulose (PAC), carboxymethyl cellulose (CMC), and synthetic polymers like polyacrylamides and polyalphaoleins, are used as drilling fluid additives to help control fluid loss and viscosity, although they have drawbacks and affect the overall drilling cost (Mojeed et al., 2018). Fortunately, this issue has been solved by utilizing a naturally occurring material. Starch, glycogen, and other polysaccharides, which are naturally found in plants, make up the majority of sugar. Starch is a key form of carbohydrate that is found in most common plants and is used in the oil and gas industry as well as other sectors (Dankwa et al., 2018). Corn starch is the first and most widely used source of starch when making a drilling fluid additive with bentonite. In addition to aiding in filtration procedures, corn starch is used to boost viscosity because it behaves just as well as colloidal substances (Novrianti et al., 2019). Taiwo, (2011) confirmed that viscosity and fluid loss in water-based drilling muds could be controlled by substituting local starch for imported sample. According to Dankwa et al., 2018, freshly dug cassava can be used to manufacture starch flour, which could improve WBM's viscosity and lessen fluid loss. The findings demonstrated that because cassava flour has the ability to swell, adding more of it to the WBM also enhanced the viscosity of the mud samples. (Akintola et al., 2017) showed that lowering the starch size produces improved filter cake thickness which can assist eliminate downhole difficulties. The particle size distribution of drilling fluids is one of the main factors influencing the effectiveness of fluid loss additives (Popoola et al., 2023). However, there are some drawbacks to normal starch, such as syneresis, rapid retrogradation, heat degradation, and low resilience to shear stress etc. Consequently, strategies to overcome these limitations have been devised, by starch modification such as acetylation and carboxymethylation of starch (Akintola et al., 2022). Modified starches are starch-based compounds that have undergone chemical alteration to make them more resistant and withstand temperatures of 130°C or greater, which qualifies them for use in more drilling applications in the petroleum industry. Given that modified starch-added muds can withstand HPHT conditions and that mud samples with acetylated cassava or maize starch added showed the smallest filtrate volumes and filtrate losses within the API specification (Sulaimon et al., 2021). Another compound that has shown positive impact on the rheological properties of drilling muds is hyperdrill.

Hyperdrill AF 251 are anionic polyacrylamides which are water soluble synthetic linear polymers with different molecular weight and varying charge densities. They are synthesized from acrylamide or the combination of acrylamide and acrylic acid. The presence of the amine and carbonyl functional groups (-NH2 and C=O) enable it to form hydrogen bonds thus increasing its hydrophilicity characteristics. It is mostly used as flocculants in many industrial applications such as water treatment, water-based fluids where it increases the flocculation of particles thus increasing viscosity (Voronova et al., 2020). The physical properties responsible for its action is high hydrophilicity, high crystallinity and low molecular weight.

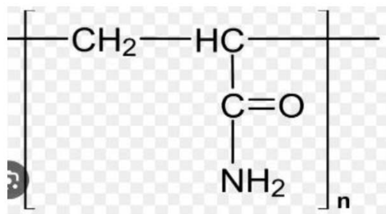

Figure 1—Chemical structure of polyacrylamide.

The unique molecular structure of hyperdrill enable them to absorb five times the weight of water and swell to a volume of 12-16 times their dry bulk (Voronova et al., 2020). Therefore, the study is set out to determine the potential impact of EDTA-DSD modified starch and hyperdrill on the efficacy of domestic bentonite in the drilling fluid application process. This study aims to quantify the parameters of fluid loss and assess the performance of EDTA-DSD modified starch, unmodified starch, and hyperdrill potential modification on mud rheology and fluid loss when compared with CMC standard.

Materials and Methods

All the chemicals - Local Bentonite obtained from Adamawa State, Nigeria, deionized water, sodium hydroxide, Hyperdrill AF 251 polymer (HD), CMC are of analytical grade, and obtained from the Covenant University Ota Drilling Fluid Engineering Laboratory. While Ethylenediaminetetraacetic acid disodium salt dihydrate (EDTA-DSD) was obtained from Sigma Aldrich (Germany). Soursop fruit was purchased from Zuba market in Abuja.

Starch Extraction

The extraction of starch from the soursop was carried out using the procedures described by Adewumi et al. (2019). The unripe soursop was carefully washed in water, peeled and the seeds were removed. The unripe pulp was cut into small pieces and soaked in sodium metabisulphite (1%) solution at room temperature for 24 h. Thereafter, the soursop pieces were grinded into slurry form. The paste was filtered using a Muslim cloth. It was left to settle for some time then the supernatant was carefully decanted and the mucilage was discarded. The resulting starch was air dried, crushed, weighed and stored in the sample bottle for further analysis.

Starch Modification

Modification with ethylenediaminetetraacetic acid disodium salt dihydrate (EDTA-DSD). The modification of the starch was carried out using (Matthew et. al., 2015) method with slight modification. 25 g of the starch sample was dispersed in 125ml of distilled water and stirred magnetically for 20 mins. The pH of the slurry obtained was adjusted to 8.0 using 1.0 M NaOH. Powdered EDTA-DSD (2.55 g) was added bit by bit to the mixture while maintaining a pH range of 8.0 to 8.5 by adding the adding the 1 M of

NaOH simultaneously. The reaction was allowed to proceed for 5 min after the addition of acetic anhydride. The pH of the slurry was finally adjusted to 4.5 using 0.5 M HCl. It was then filtered, washed four times with distilled water and air dried for 48 h.

Figure 2—Unmodified and modified starches

Starch Characterisation

The thermal stability of the unmodified soursop starch (NSS), modified EDTA-DSD and CMC was analyzed via thermogravimetric (TGA) analysis using WW. MCE TA instrument TGA Q50. The surface morphology was evaluated with Scanning Electron Microscopy (SEM) (S-3400N; Hitachi, Tokyo, Japan).

Mud Formulation to evaluate unmodified and modified (EDTA-DSD). 12 samples of water-based mud and standard mud (CMC) were prepared according to the API standard procedure to evaluate the impact of unmodified and modified EDTA-DSD starch on mud rheology and fluid loss. Table 1 shows the mud composition. The composition of WBM is based on the API standard specification for water-based drilling fluid (American Petroleum Institute, 2020). The components shown in the formulation were mixed adequately by using a high-speed mixer (HMO200-CE) to prepare the mud systems. The ingredients were added slowly to the fluid phase to provide adequate time for proper mixing and homogenization of system. The pH of the mud was improved on by adding 0.3g of NaOH to make the drilling fluid more alkaline (Amanullah et al., 2016).

Table 1—Composition of Water-based muds

S/N	Parameters	Samples											
		LBM+CMC				LBM+HD+NSS				LBM+HD+EDTA-DSD			
		A	B	C	D	E	F	G	H	I	J	K	L
1	Bentonite (g)	25	25	25	25	25	25	25	25	25	25	25	25
2	De-ionized water (ml)	400	400	400	400	400	400	400	400	400	400	400	400
3	Barite (g)	10	10	10	10	10	10	10	10	10	10	10	10
4	NaOH (g)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
5	CMC (g)	0.5	1.0	1.5	2.0	-	-	-	-	-	-	-	-
6	Hyperdrill, HD (g)	-	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
7	NSS (g)	-	-	-	-	0.5	1.0	1.5	2.0	-	-	-	-
8	EDTA-DSD (g)	-	-	-	-	-	-	-	-	0.5	1.0	1.5	2.0

Mud Tests

Mud pH, density, rheological and filtration properties were all tested on the mud samples in accordance with API recommended practices (AP1-13B-2).

Mud Rheology. The rheological properties of these mud systems were investigated (API RP 13B-1 2009) and Rheometer (Model 286) was used to measure the viscosities of the mud samples. The power switch was turned on and the speed selector was manually turned to stir on top of the motor. The stir was turned to a speed of 600 rpm, and measurements or dial readings were recorded (Sulaimon et al., 2021). This procedure was repeated for each of the mud samples and the measurement were recorded. Plastic viscosity, PV, Yield point, YP, Apparent viscosity, AV, Shear stress and shear rate were then evaluated and calculated using equations I - V.

$$\text{Shear Rate}\left(s^{-1}\right) = 1.7\times\ \text{RPM}\ldots \quad \text{(I)}$$

$$\text{PV(cP)} = 600\text{rpm} - 300\text{rpm} \quad \text{(II)}$$

$$\text{YP}\left(\text{lb.}/100\text{ft}^2\right) = 300\text{RPM} - \text{PV} \quad \text{(III)}$$

$$\text{Apparent Viscosity (AV)} = 600\text{RPM}/2 \quad \text{(IV)}$$

$$\text{Shear Stress (dyne)} = 5.1\times\ \text{Dial reading} \quad \text{(V)}$$

Gel Strength. The thixotropic behavior was evaluated and the progress in the samples' strength obtained. The mud was stirred at 600 rpm and then allowed to gel for 10 seconds and 10 minutes before readings were taken. This procedure was repeated for 300rpm, 200rpm, 100rpm etc. (Olaniyan et al., 2024).

Filtration Properties. Upon preparation of mud samples, each sample was left to stand for 30 minutes and the filtration test of these mud systems were conducted. The API filter press (171-00-C) was used for conducting the filtration experiments from which the filtrate volume and filter cake thickness were determined (API RP 13B-1, 2017). About 300 ml of the mud samples A – L were poured into a standard API filter press facilitated with a strengthened filter paper of 10 mm diameter and 2.5 µm pore size. Mud samples were exposed to 100 psi pressure for a period of 5 min. Fluid loss volumes were recorded at 5 min interval for 30 minutes for LPLT and 500psi for HPHT (Popoola et. al., 2023).

Results and Discussion

Water-based muds formulated with locally-source bentonite muds was beneficiated with 0.5g of hyperdrill and 0.5-2g of unmodified and modified starches, their performances were compared with CMC formulated muds.

Starch Characterization

The thermal stabilities of unmodified (NSS) and modified (EDTA-DSD) starches were evaluated to determine their decomposition characteristics when compared to CMC and the results are presented in Figure 3. The thermogram of all analyzes samples shows comparable trend, signifying thermal breakdown and mass loss for the samples. The first degradation for modified occurred at a lower temperature of 96 °C with 2.3% weight loss when compared to NSS and CMC decomposition at 99 °C with 0.3 % weight loss which results in mass loss due to water fragments elimination by evaporation. Modifying the native soursop displayed diverse effects on the thermal stability of the starches in comparison with standard CMC. At 70.5 % degradation which occurs as a result of depolymerization of the carbon chain, modification with ethylenediaminetetraacetic salt showed similar stability with CMC while unmodified NSS produced the best thermal stability {EDS (332 °C) = CMC (332 °C) < NSS (395 °C)}.

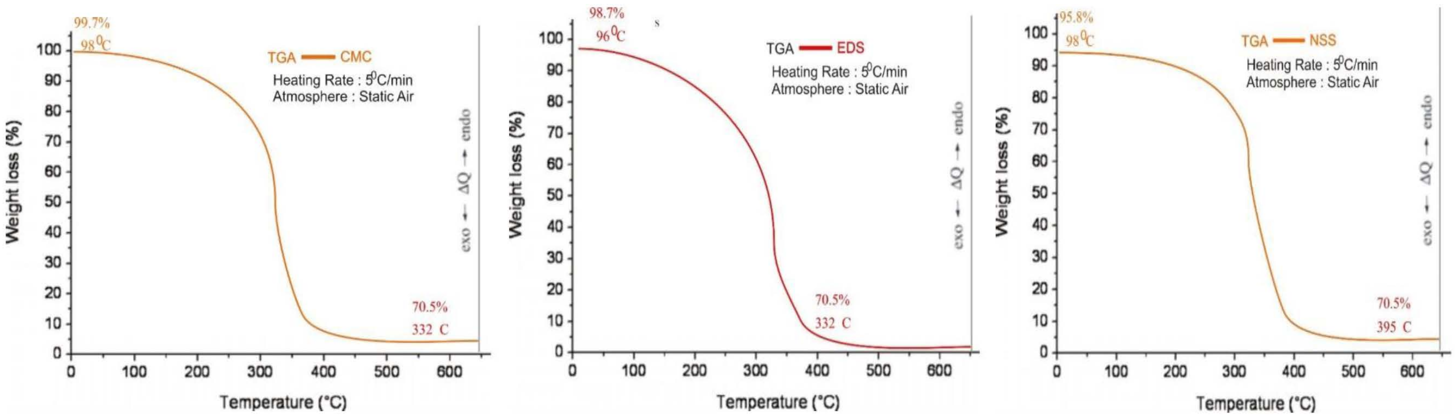

Figure 3—The stability of (a) CMC (b) modified EDTA-DSD (c) unmodified soursop starch

The final degradation temperature shows the temperature at which the carbon chains are totally broken leaving the residues. At this stage it was observed that native soursop (NSS) produced the best stability while CMC produced the least stability. Thus the trend in the stability of the starches in comparison with CMC are; NSS (415 ^{o}C; 12.46 % residue) > EDS (395^{o}C; 8.60 % residue) > CMC (380 ^{o}C; 10.40 % residue). Since stability of starches (Viscosifiers) is an important parameter required in the formulation of drilling muds especially in drilling of high temperature and high-pressure wells, the results obtained in this study showed that native soursop starch and its modified form especially with EDS has the potential and will be useful additive in drilling fluid formulation.

Starch morphology (Figure 4) was imagined by scanning electron microscopy (SEM). The micrograph demonstrated variations in granular size, size distribution, and shape. The native soursop (NSS) irregularities in its granule size and more interstitial pores. While the modified soursop starch, EDTA-DSD shows a smooth surface without pores and more clustered particles forming greater networks, whereas CMC had a smooth, small particle size and clustered granules.

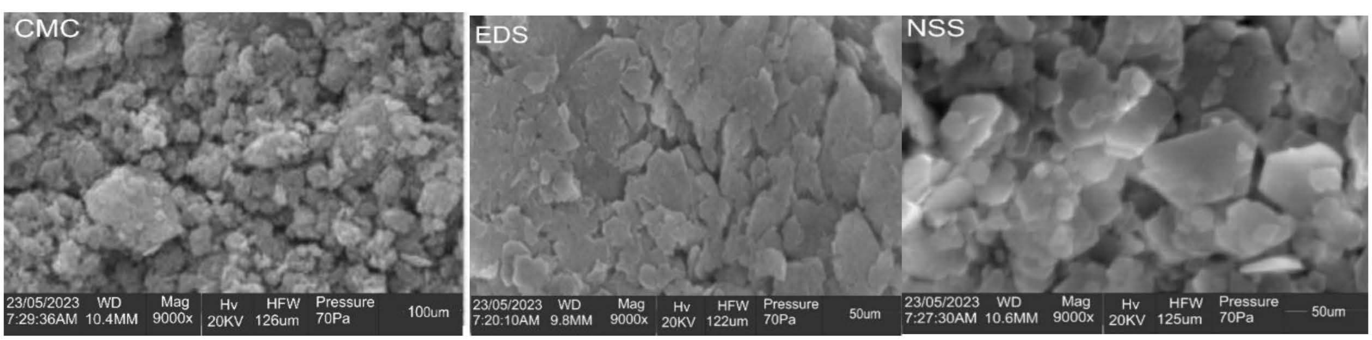

Figure 4—The SEM morphology of (a) CMC (b) modified EDTA-DSD (c) unmodified soursop starch at 9,000 magnifications.

The variation identified in granule size with SEM was comparable with the measured granule size distribution. Moreover, all the starches showed to have small sizes that are aggregated together thereby forming larger networks (Afolayan et al., 2012) which is suitable for industrial application such as drilling fluid formulation.

Effect of unmodified and EDTA modified Starch on Mud pH

The pH of the samples investigated ranged from 9.1 - 9.7 for samples A to D and 8.5 – 9.1 for E to L. However, the addition of constant concentration 0.3g of the NaOH used as pH control additive further boosted the pH of all the muds samples from the range of 10.1 – 10.6 for samples A to D and 8.8 – 10.1 for E to L showing that the pH values for all the samples are in alkaline medium before and after the

NaOH addition as shown in Table 2. This result is in conformity with the API recommended standard for a water based mud and (Sulaimon et al., 2021) findings that modified starch keeps the mud in an alkaline medium mitigating against the corrosion of the bottom hole assembly equipment during drilling operations and fronting a balanced medium for drilling operations. It therefore means that the addition of NaOH in starch formulated muds may not be needed as this might lead to extra cost.

Table 2—Physicochemical properties of NSS, EDTA-DSD and CMC muds

Properties	Samples											
	A	B	C	D	E	F	G	H	I	J	K	L
Density (ppg)	8.6	8.5	8.4	8.4	8.4	8.3	8.1	7.8	8.7	8.7	8.6	8.5
Specific Gravity	1.03	1.03	1.02	1.03	1.0	1.00	0.97	0.94	1.04	1.04	1.03	1.02
pH without NaOH	9.7	9.2	9.8	9.1	8.8	8.9	8.5	8.6	8.6	8.6	8.6	9.1
pH with NaOH	10.6	10.7	10.3	10.1	9.0	10.1	8.8	9.0	9.6	8.8	8.8	9.0

Effect of unmodified and EDTA modified Starch on Mud Density

The effect of the increasing composition of unmodified and EDTA modified starch on mud density of the mud samples revealed a density range of 7.8 – 8.4lb/gal for UM muds and 8.5 – 8.7lb/gal for EDTA muds respectively. In table 2, the density value for CMC formulated mud ranged from 8.4-8.6lb/gal for varying concentration. The modified samples shows a comparable values with the density of muds formulated with CMC. These may be link to the molecular structure of the EDTA after modification. The density of the mud experienced a sustained trend as the concentration of starches increased as reported by the work of (Sunday et al., 2015). This will eliminate well complications such as underbalanced drilling, lost circulation, differential pipe sticking, decrease in ROP, formation damage, etc. (Talukdar et al., 2018).

Rheological Properties

Table 3 shows detailed properties of the plastic viscosity, apparent viscosity and Gel strength of the mud samples and the impact of hyper-drill, unmodified and modified starches on the locally-sourced bentonite and was graphically represented in Figure 5 to 8. The study's findings and results are discussed in this section.

Table 3—Rheological data of unmodified and modified muds

S/N	Parameters	Samples											
		LBM+CMC				LBM+HD+NSS				LBM+HD+EDTA-DSD			
		A	B	C	D	E	F	G	H	I	J	K	L
1	θ_{600} (cP)	6	9	8	10	57	65	59	56	59	52	57	40
	θ_{300} (cP)	4	6	6	7	41	48	45	42	45	38	42	29
	θ_{200} (cP)	2	3	4	4	34	40	38	32	38	33	35	26
	θ_{100} (cP)	3	2	4	4	26	30	27	27	28	23	27	18
	θ_{60} (cP)	2	2	4	5	21	24	23	21	24	20	22	14
	θ_{30} (cP)	2	1	4	4	17	19	16	15	17	16	18	11
	θ_{6} (cP)	2	1	4	4	9	11	10	8	11	9	10	5
2	Plastic Viscosity (cP)	2	3	2	3	16	17	14	14	14	14	15	11

S/N	Parameters		Samples											
			LBM+CMC				LBM+HD+NSS				LBM+HD+EDTA-DSD			
			A	B	C	D	E	F	G	H	I	J	K	L
3	Yield Point (lb/100sqft^2)		2	3	2	4	25	31	31	28	31	24	27	18
4	Apparent Viscosity (cP)		1.5	1.5	1.3	1.4	28.5	32.5	29.5	28	29.5	26	28.5	20
5	Gel Strength (lb/100sqft)	10secs	7	6	5	3	7	6	7	6	8	7	7	5
		10mins	8	6	7	2	7	10	8	8	10	8	3	7

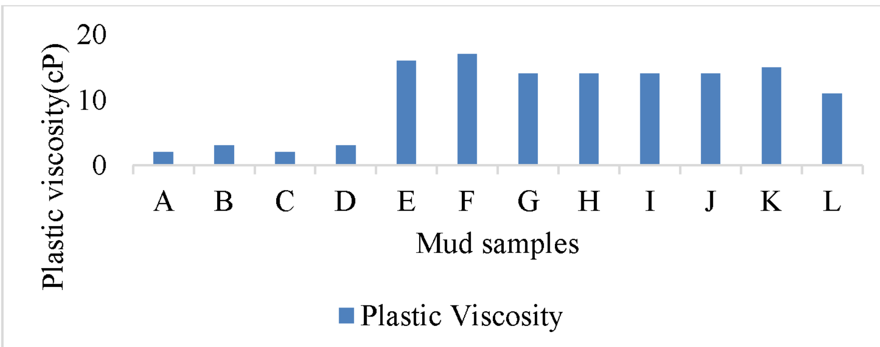

Figure 5—Plastic Viscosity of unmodified and EDTA-DSD modified starch muds.

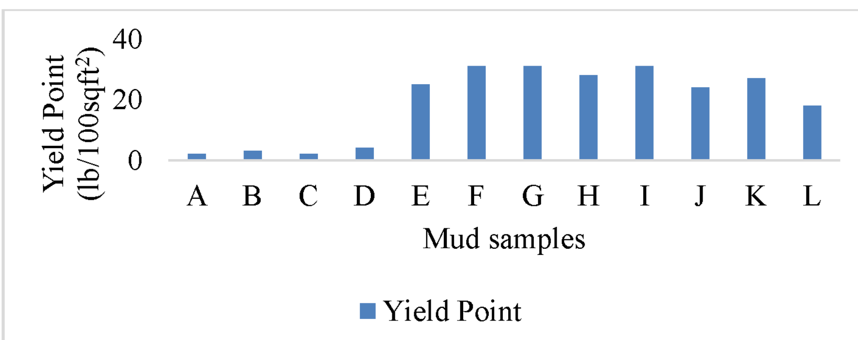

Figure 6—Yield point of unmodified and EDTA-DSD modified starch muds.

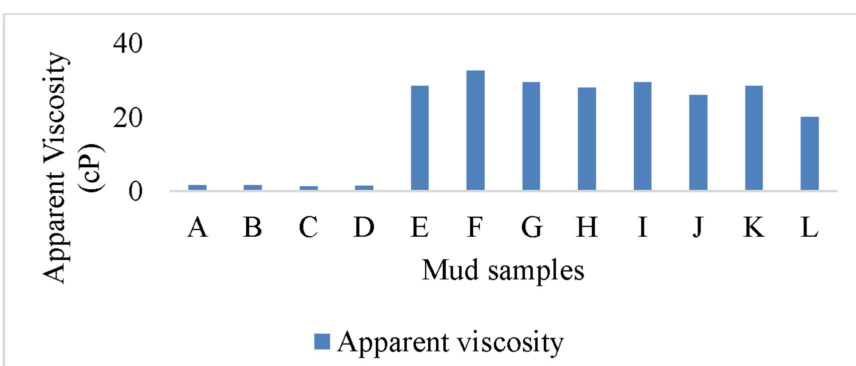

Figure 7—Apparent Viscosity of unmodified and EDTA-DSD modified starch muds.

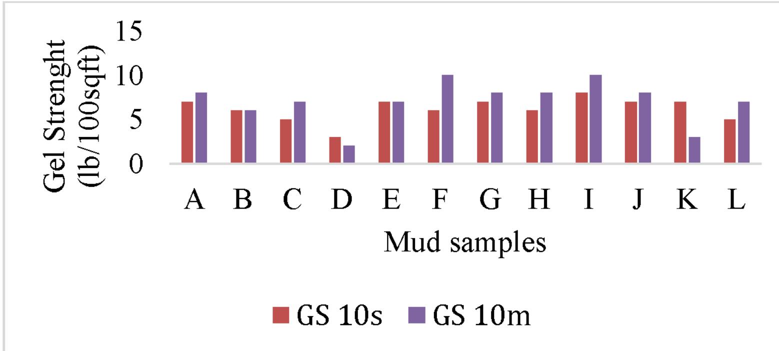

Figure 8—shows the Gel Strength of unmodified and EDTA-DSD modified starch muds.

Effect of unmodified and EDTA-DSD modified Starch on Mud Rheology. The effect of the unmodified (NSS) and EDTA-DSD modified starches on the rheological properties of the mud samples at varying concentration were further presented graphically in figure 5 - 8. In figure 5, PV of the NSS samples showed an increasing trend as the concentration of the starch increased from 0.5 to 1.0 gram, and later decreased as the NSS starch concentration increased from 1.5g to 2.0g, while the PV of EDTA-DSD starch showed an increasing trend as the concentration of the starch increases. All the beneficiated samples showed greater PV values than CWBM muds. This is attributed to the colloid properties of the starch and the tendency of improving the viscosity (Al-Hameedi et al., 2020; Sulaimon et al., 2021). Fig. 6 represent the yield point of the mud samples. The unmodified muds showed a greater yield strength behaviour than the EDTA-DSD muds at concentration of 0.5, 1.0, 1.5 and 2grams respectively. The yield point of the muds formulated with starch grew significantly as the concentration of the starch additives increases from 0.5 to 2g. The behavior of the EDTA-DSD muds were almost comparable as the starch concentration increases (Akintola et al., 2023). The same performance was observed in the plot of mud samples versus AV (cp) in (Figure 7).

The gel strength carries the solids produced by the drill bit and keeps them suspended in the fluid. Although the GS increased when the muds with the starches were measured in comparison to the CMC muds, the initial gel (IG) and final gel (FG) properties measured for the gel strength (GS) results demonstrate that the investigated muds do not have a progressive tendency to form gels (Akintola et al., 2023). Consequently, utilization of these muds will require no additional hydraulic-horse power or pressure increase when drilling operation resumes after an operational shut-down and no risk to the drilling operation. The characteristics of Gel strength of CWBM and the unmodified and modified muds starches are therefore almost comparable in properties. Result presented shows that the unmodified and modified starch mud samples had improved properties when compared to that of the CWBM muds as seen in the rheological properties of drilling mud obtained which is comparable with the API specification 13-A for drilling grade bentonite as shown in Figure 8.

Effect of unmodified and EDTA-DSD modified Starch on Fluid behavior of the muds. The amount of fluid lost over the period of 30 minutes, as demonstrated by the results, provides information on the efficacy of the starches in preventing fluid loss. The value of the filtrate volume decreased with increasing starch concentration, as shown in Table 4. Drilling mud's filtration volume is being reduced due to water absorption by unmodified and EDTA starch. This is may be attributed to the morphological structure of the starches. The native soursop (NSS) showed irregularities in its granule size and more interstitial pores. While the modified soursop starch, EDTA-DSD shows a smooth surface without pores and more clustered particles forming greater networks, thereby, causing an increase in fluid's absorption capacity with increasing starch concentration, leading to a lowered filtrate volume. Whereas the CMC had a smooth, small particle size and clustered granules. All of the muds used to make the filter cakes were fairly dense, well-formed, and had thicknesses ranging from 0.1 to 0.4 cm as shown in figure 7. The thin filter cake demonstrates that differential sticking is not possible and that the hole diameter is unaffected (Dankwa et al., 2018).

Table 4—Filtration properties of the mud samples

		Mud samples											
		LBM+CMC				LBM+HD+NSS				LBM+HD+EDTA-DSD			
		A	B	C	D	E	F	G	H	I	J	K	L
LPLT	Filtrate volume (ml)	33	29	30	31	19	18	21	19	19	17	20	20
	Filter cake (cm)	0.2	0.2	0.3	0.2	0.3	0.3	0.1	0.2	0.2	0.2	0.1	0.1
HPHT	Filtrate volume (ml)	50	40	33	43	33	31	30	32	20	19	20	18
	Filter cake (cm)	0.3	0.3	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.4	0.3	0.4

Shear stress–shear rate behaviour of unmodified and EDTA-DSD modified Starch on Fluid behavior of the muds. Figure 9-11 show the shear stress and shear rate behavior of the mud formulated with modified and unmodified starches. The plots demonstrated a non-Newtonian behaviour of the fluids (Sulaimon et al., 2021; Talukdar et al., 2018). However, a trend of high viscosity at reduced shear rates was observed in all the formulation. Drilling cuttings may be effectively suspended and transported from the wellbore to the surface using the mud systems developed (Okoro et al., 2019).

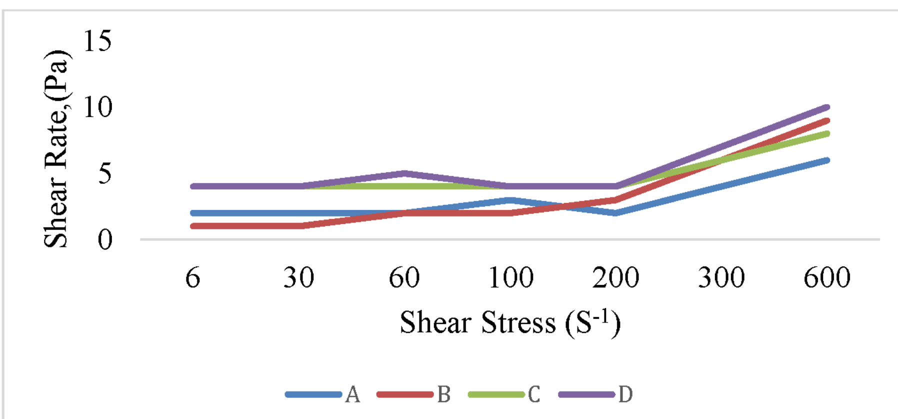

Figure 9—Shear rate- shear stress diagram for CWB muds

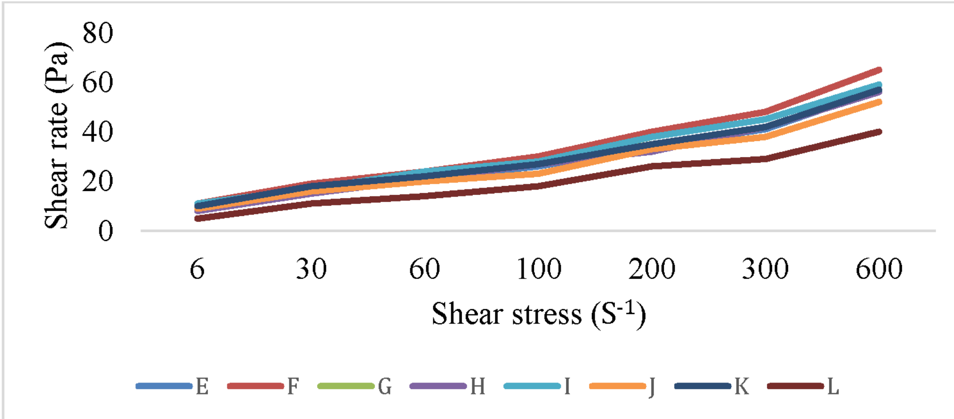

Figure 10—Shear rate- shear stress diagram for unmodified and modified muds

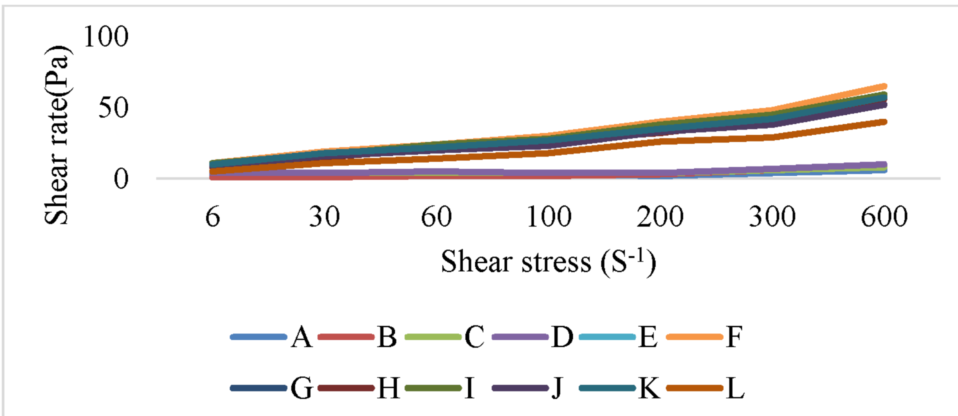

Figure 11—Plot of the shear rate against shear stress of the formulated mud samples.

Plastic Viscosity. Figure 5 displays the Plastic Viscosity of unmodified and EDTA-DSD modified starch muds.

Yield point. Figure 6 shows the Yield point diagram of unmodified and EDTA-DSD modified starch muds.

Apparent Viscosity. Figure 7 shows the Apparent Viscosity plot of unmodified and EDTA-DSD modified starch muds.

Gel Strength. Figure 8 shows the Gel Strength plot of unmodified and EDTA-DSD modified starch muds.

Filtration properties

Table 4 displays the filtration properties of mud samples that were formulated.

Rheogram of Mud samples

Figures 9 displays the shear stress and shear rate diagram of mud samples formulated with CMC as filtrate additives, Figure 10 displays the Shear stress and Shear rate diagram of unmodified and EDTA-DSD modified mud samples and figure 11 shows the combined plots for the mud samples.

Conclusion

The findings in this study demonstrate that unmodified and EDTA-DSD modified starch can be effectively employed as an affordable biodegradable substitute for industrial-grade CMC, which lowers API filtration losses. The following summarizes the main findings from the laboratory analysis and data interpretation:

1. Both modified starch (EDTA-DSD) and unmodified starch, have good potentials to help aid fluid loss and can act as alternatives for CMC in the industry as fluid loss additives. This is may be attributed to the morphological structure of the starches.
2. The thermal stabilities of the NSS and EDTA-DSD is comparable to that of CMC. The trend in the stability of the starches in comparison with CMC are; NSS (415 ^{o}C; 12.46 % residue) > EDS (395^{o}C; 8.60 % residue) > CMC (380 ^{o}C; 10.40 % residue).
3. Study showed that Plastic viscosity, PV for unmodified starches ranged from 14-17cP, Yield point, YP ranged from 25-31lb. /100ft^2,filtrate volume ranges from 18-31ml at LPLT and 30-43ml at HPHT while PV for modified starches ranged from 14-15cp, YP ranged from 27-31lb. /100ft^2, filtrate volume ranges from 17-31ml at 100psi and 19-43ml at 500psi of pressure.
4. Thus, demonstrate its suitability for current and future exploration and exploitation of oil and gas resources.
5. It is therefore recommended that the samples should be placed on field trials.

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