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Evaluation of Fluid Loss Control Performance of Local Biopolymer

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ABSTRACT

Drilling mud is recognized as the life-wire of drilling operations in the oil and gas industry, and is essential for the exploration and production of subsurface hydrocarbon resources. Drilling mud is plagued by fluid loss, which reduces the volume of the continuous phase while increasing the thickness of the mud cake. This problem has led to the introduction of additives that enhance the mud filter cake features and reduce the filtration rate. Several conventional fluid loss control additives, such as polyanionic cellulose (PAC) and carboxymethyl cellulose (CMC), have been utilized for fluid loss control; however, these additives are expensive and environmentally harmful. These have led to continued research for more suitable local alternatives, which, if successful, could replace these conventional materials. In this study, the performance of locally sourced materials, Afzelia Africana (AA) and Maranta Arundinacea Root (MAR), was compared to that of the conventional material, carboxymethyl cellulose (CMC). Fourier Transform Infrared Spectroscopy (FTIR), rheology, and filtration tests were carried out in this study. From the FTIR results, AA and MA exhibited similar functional groups, including amines, aromatics, carboxylic acids, and alcohols, as indicated by the CMC. From the rheology results, AA exhibited a similar viscosity-increasing attribute observed in CMC, while MAR showed to be a poor viscosifier. According to the filtration loss results, MA recorded a 21 mL fluid volume at 9 g, AA recorded a 66 mL fluid volume at 9 g, while CMC recorded 10 mL at 9 g. MAR demonstrated potential to substitute for CMC as a fluid loss control additive when modified.

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Introduction

In drilling engineering studies, liquid-based drilling fluid, also known as drilling mud (DM), is referred to as the lifeblood of all drilling activities in the oil and gas industry [1]. They are widely utilized to aid drilling activities for the exploration and exploitation of subsurface hydrocarbon resources [2]. The DM can be water-based, oil-based, or synthetic-based, but water-based DM is the most commonly utilized due to cost and environmental considerations [3]. The drilling mud consists of several additives, and must be properly engineered to match a well's requirements [4] effectively. Thus, some of the functions expected from a DM include subsurface pressure control [5], maintaining borehole stability [6], bottom-hole cleaning, and transporting cutting to the surface [7]. Among the highlighted functions, DM is designed to close wellbore walls that have been drilled to avert fluid loss. This is achieved by developing a filter cake of low permeability in the borehole [8]. As a result, DM are engineered to prevent undesired continuous loss of fluid to the formation [9]. These engineering techniques are done to prepare DM that promotes borehole stability, forms a thin filter cake, and reduces fluid loss [10]. The engineering of DM to achieve set objectives is what is referred to as fluid-loss or filtrate-loss control. The fluid-loss control entails introducing chemicals to the drilling mud to enhance its cake features and reduce its filtration rate [11]. The static and dynamic filtration mechanisms are the mechanisms that influence the buildup of filter cake, with static filtration corresponding to non-circulation time. In contrast, dynamic filtration corresponds to the circulation period. To handle this drilling mud function, commercial chemicals such as polyanionic cellulose (PAC), carboxymethyl cellulose (CMC), and other polymers have been utilized as fluid loss control additives [12]. These commercial polymers, however, are expensive and, in some cases, not eco-friendly, which has led to a shift in the utilization of locally sourced materials as a filtrate loss control agent in water-based mud (WBM) [13].

Olatunde et al. [14] conducted a fluid loss control test on WBM with 32 g of gum arabic. According to their experimental study, gum Arabic resulted in 17ml of fluid loss. Adebayo and Chinonyere [15] carried out a fluid loss control study of sawdust (0.5-1 mm-sized) in WBM. According to the results of their study, sawdust recorded fluid losses of 12-59 mL at 5-30 g, respectively. Egun and Abah [16] experimented on the fluid loss control performance of cassava starch on WBM. According to the results of their study, cassava starch records a fluid loss volume of 4-8 ml at 2-4 g, respectively. Azizi et al [17] conducted a fluid loss control test on WBM using Agarwood waste (45 and 90 μm). According to the experiment's results, 6 g of Agarwood waste yielded a fluid loss volume of 13-16 mL. Dagde and Nmegbu [18] carried out a fluid loss control evaluation on groundnut husk. According to their experimental study, 2-4 g of groundnut husk yielded 7.6 mL and 6.5 mL, respectively. Okon et al. [19] experimented on the fluid loss performance of Rice Husk (125 μm) on WBM. According to their experimental study, 5-20 g of rice husk yielded 16-42.5 mL of fluid loss. Nmegbu and Bari-Agara [20] experimented on the fluid loss performance of corn cob cellulose. From their experimental evaluation, 2-3 g of corn cob cellulose yielded 5.8 mL and 5.8 mL of fluid loss volume, respectively. Chinwuba et al. [21] experimented on the performance of Pleurotus tuber-regium. According to their experimental study, Pleurotus tuber yielded 8-10.8 mL at 5-6 g of dry weight. Okon et al. [22] conducted a fluid loss control study using local materials, namely rice husk (RH), Detarium microcarpum (DM), and Brachystegia eurycoma (BE), as well as conventional materials, including carboxymethyl cellulose (CMC). According to their experimental study, RH yielded the best fluid loss control performance, recording 2.8 mL, while DM, BE, and CMC recorded 4.5 mL, 7.3 mL, and 4.2 mL, respectively. Chinwuba et al. [23] evaluated the fluid loss potential of local bentonite in combination with periwinkle shell and Mucuna solannie. According to their experimental study, 5g-5g of periwinkle shell and Mucuna solannie improved its fluid loss control performance, as it recorded 12 filtrate volumes. Ikram et al. [24] investigated the fluid loss control performance of okra and starch. According to their study, okro yielded 20.8 mL, 17.6 mL, and 17 mL at 0.25%, 0.5%, and 1% wt concentrations, respectively, while starch recorded 18.8 mL of fluid loss at a 0.25% wt concentration. Kerunwa et al [25] evaluated the performance of coconut fiber (CF) and corn cobs (CC) as fluid loss control additives, as an alternative to carboxymethyl cellulose (CMC). According to the results of their experimental study, the CF-CC blend exhibited the best fluid loss control performance, yielding a fluid volume of 8ml. In comparison, CMC, CF, and CC yielded fluid volumes of 8.6 mL, 14 mL, and 10.2 mL, respectively. As shown in the review, studies have recorded positive signs in substituting materials, such as carboxymethyl cellulose (CMC), for fluid loss control.

In this work, the fluid loss control performance of Afzelia Africana (AA) and Maranta Arundinacea Root (MAR) was compared with carboxymethyl cellulose (CMC) in water-based drilling mud. Afzelia Africana is primarily grown in the savannah region, the drier parts of the rainforest zones, and fringing forests within the African continent. Their seeds are used as soup thickeners, similar to those of Irvingia gabonensis and Citrullus lanatus. Maranta Arundinacea Root is a white, flavorless starch extracted from tropical tubers and used as a gluten-free thickener for soups and sauces. FTIR characterization was employed to identify the functional groups present in AA, MAR, and CMC, before rheology and fluid loss studies, which were used to compare their performance in a water-based mud (WBM) system.

Materials and Methods

The following are materials used for this study: locally sourced fluid loss control additive such as Afzelia Africana (AA) and Maranta Arundinacea Root (MAR), conventional fluid loss control additive (Carboxymethyl Cellulose (CMC)), Barite (weighting agent/density control agent), Bentonite (Viscosifier/lubricant agent), Calcium carbonate, Water(Base fluid), Sodium hydroxide (pH control agent), Hamilton Beach mixer, Buck 530 IR-spectrophotometer, pH meter, Low Pressure-Low Temperature API Filter Press (LPLT) in Fig. 2, Baroid Mud Balance, Rotary Viscometer (Ofite Model 800s) in Fig. 1, Weighing Balance (Ohaus) and Stopwatch.

Fig. 1. Ofite rotary viscometer

Fig. 2. API filter press

Sourcing of Material

Afzelia Africana (AA) was sourced from Enugu State, South-Eastern Nigeria. Maranta Arundinacea Root (MAR) was sourced from Imo State, South-Eastern Nigeria. Bentonite, Barite, Distilled Water, Calcium Carbonate, Sodium Hydroxide, and CarboxyMethyl Cellulose (CMC) were sourced from ChemScience Store.

Preparation of the Locally Sourced Bio-polymer

The local bio-polymers, namely Afzelia Africana (AA) and Maranta Arundinacea (MA), were sourced from a local market in the Southeastern Part of Nigeria. The pods of AA were placed in an oven for 30 minutes at 60°C to reduce their moisture content. The pods were then broken to recover the seeds. The recovered seeds were further oven-dried for 2 hours at 75°C, and thereafter crushed into fine particles using an industrial blender. The crushed particles were sieved using a 0.062 mm sieve to obtain powdered particles, which were stored in an airtight container. The MA roots were sliced into smaller pieces and ground in a water mixture. The MA-water solution was allowed to stabilize for 2 hours before the water content was reduced. The process was repeated twice until a transparent top water layer was achieved.

(a) (b)

Fig. 3. (a) Afzelia Africana (AA), and (b) Maranta Arundinacea root (MAR)

(a) (b)

Fig. 4. (a) Ground AA, and (b) ground MAR

FTIR Evaluation

Fourier Transform Infrared (FTIR) evaluation was done using the Buck 530 IR-spectrophotometer. The local materials are Afzelia Africana (AA) and Maranta Arundinacea root (MAR), while Carboxymethyl cellulose (CMC) was used as a conventional material. The FTIR test produces a graph in the form of absorbance spectra, which shows the unique molecular structure and chemical bonds of the sample materials. The absorption spectrum exhibits peaks that correspond to the components present in the materials. The absorbance peaks indicate the presence of functional groups (e.g., alkanes, acid chlorides, and ketones). The various bond types and corresponding active groups absorb infrared radiation of varying wavelengths. Then, the analytical spectrum is checked in a reference library catalogue to determine the range of values used in identifying present functional groups.

Mud Formulation

In the fluid loss experimental study, three different mud samples, namely CMC Mud sample, AA Mud sample, and MAR Mud sample, were formulated with concentrations of fluid loss control additives varied at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively. CMC-Mud Sample is the mud sample with CMC as a filtrate loss control additive, AA-Mud Sample is the mud sample with AA as a fluid loss control additive, while MAR-Mud Sample is the mud sample with MAR as a fluid loss control additive.

Mixing Procedure of Mud Sample Formulation

The defined quantity of the additives utilized was weighed using a weighing balance. 350 ml of Distilled water was measured using a cylinder with defined graduations. The distilled water was introduced into the mud cup, and agitation commenced using the Hamilton Beach Mixer. Thereafter, 15 g of Bentonite was introduced to the agitated water and stabilized for five minutes. 0.5 g of NaOH and 0.25 g of $CaCO_3$ were introduced to the slurry and agitated for two minutes. 1 g of CMC was introduced to the resultant solution and mixed for three minutes. 10 g of Barite was introduced to the resultant solution and mixed for 15 minutes. The approach was conducted for 3 g, 5 g, 7 g, and 9 g of CMC. The Hamilton Beach mixer was used to mix the mud slurry at medium speed, with a total mixing time requirement of thirty minutes. The same formulation approach for CMC mud was utilized for the AA mud sample and the MAR mud sample, respectively. Table 1 depicts the composition of water-based mud (WBM) with 1 g of Fluid Loss Control Additive. This composition was repeated for 3 g, 5 g, 7 g, and 9 g of fluid loss control additives.

Table 1. Composition of Water-Based Mud (WBM) with 1 g of Fluid Loss Control Additive

Additives	CMC Mud Sample	AA Mud Sample	MAR Mud Sample
Water (ml)	350	350	350
Barite (g)	10	10	10
Bentonite (g)	15	15	15
Calcium Carbonate (g)	0.25	0.25	0.25
Sodium Hydroxide (g)	0.5	0.5	0.5
CMC (g)	1	Nil	Nil
Ground AA (g)	Nil	1	Nil
Ground MAR (g)	Nil	Nil	1

Mud Rheology

The formulated mud was introduced into the cup of the viscometer (Fig. 1) up to the graduated point, fixed on the viscometer stand, and elevated to the graduated point to ensure sufficient immersion by the rotating sleeve. Rotor speeds of 3 rpm, 6 rpm, 30 rpm, 60 rpm, 100 rpm, 200 rpm, 300 rpm, and 600 rpm were used to obtain dial readings for the mud sample. Using the dial readings, the plastic viscosity (PV), apparent viscosity (AV), and yield point (YP) were derived using the following equations.

$$\text{Plastic Viscosity (cp)} = \theta_{600} - \theta_{300} \tag{1}$$

$$\text{Yield Point (lb/100ft}^2\text{)} = \theta_{300} - \text{PV} \tag{2}$$

$$\text{Apparent Viscosity (cp)} = \frac{\theta 600}{2} \tag{3}$$

WBM especially with local bio-polymer fits Herschel-Buckley equation perfectly than Power Law or Bingham Plastic Model [26] and is expressed as

$$\tau = \tau_0 + ky^n \tag{4}$$

where: τ, n, y, k, and τ_0 represent shear stress, flow behavior index, shear rate, yield stress, and consistency index of the fluid. Fluid is Newtonian when the flow behavior index is zero, Dilant when the flow behavior index is less than one, and Pseudo-plastic when the flow behavior index is greater than one [27]. The yield stress of the fluid can be derived as recommended by API for the rheological parameters of the Buckley model using R6/R3 [28]

$$\tau_0 = 2\tau_3 - \tau_6 \quad (5)$$

where τ_3 and τ_6 are the shear stresses at 3 rpm and 6 rpm, respectively.

The 10-minute and 10-second gel strength was also determined from the mud sample during the measurement of thixotropic properties. The rotary sleeve speed of the viscometer was set above 600 rpm, and the mud was stirred for 60 seconds before the process was abruptly stopped. The stirred mud was left undisturbed for 10 seconds, after which the flip toggle was shifted to the gel speed, and the maximum dial reading was recorded. The same procedures were repeated for 10 minutes, and the corresponding result was recorded.

Mud Filtration

The mud filtration study was conducted under LPLT conditions using an API Filter Press. The filter press is used for filtration tests. The API filter press is utilized for filtration evaluation. It consists of six independent filter cells with one inert gas source, as shown in Fig. 2. The test procedure for the filtration study was conducted at ambient temperature and 100 psi to simulate overbalance pressure, using the following sets of procedures.

(1) The cells were cleaned, dried, and the rubber gaskets were inspected.
(2) The cells were coupled up in the following sequence: base-cap, rubber gasket after base-cap, screen, filter paper, rubber gasket after filter paper, and cell body.
(3) 130 ml of the formulated drilling mud using additives from Table 1 was introduced to the cell before being fixed into the base and tightened to ensure enclosure.
(4) A 50 ml graduated cylinder was placed at the base of the cell to recover filtrate.
(5) The cell was pressurized with 100psi of inert gas.
(6) The filtrate volume was recorded at different intervals of 30 minutes.
(7) The additional thickness of the formulated mud on the filter paper was derived using a caliper and documented in x/32-in unit.

Results and Discussion

FTIR Evaluation

FTIR Evaluation was conducted in this study for the various fluid loss control additives. Figs. 5-7 depict the FTIR Spectra of Afzeila Africana (AA), Maranta Arundinacea Root (MAR), and CarboxyMethyl Cellulose CMC respectively. As shown in Fig. 5, the absorption spectra of 974.27 cm^{-3}, 1054.7 cm^{-3}, 1152.47 cm^{-3},1299.45 cm^{-3},1388.29 cm^{-3},1895.61 cm^{3},2056.19 cm^{-3}, 2344.13 cm^{-3}, 2530.76 cm^{-3}, 2665.05 cm^{-3}, 2775.74 cm^{-3}, 2855.76 cm^{-3}, 3038.27 cm^{-3}, 3172.8 cm^{-3}, 3366.16 cm^{-3}, shows the presence of functional groups such as alkenes, aliphatic amines, alkyl halides, phenol, aromatic, isothiocyanate, carbon dioxide, carboxylic acid, aldehyde, alkanes, aromatics, alcohol, 1,2 amines, amides. From Fig. 6, the absorption spectra of 755.77 cm^{-3}, 865.84 cm^{-3}, 1171.58 cm^{-3}, 1306.89 cm^{-3}, 1400.19 cm^{3}, 1605.85 cm^{-3}, 1880.14 cm^{-3}, 2038.05 cm^{-3}, 2204.19 cm^{-3}, 2450.73 cm^{-3}, 2557.1 cm^{-3}, 2665.25 cm^{-3}, 2789.39 cm^{-3}, 2970.86 cm^{-3}, 3080.35 cm^{-3}, 3298.3 cm^{-3}, 3492.17 cm^{-3}, shows the presence of functional groups such as alkyl halides, aromatics, aromatics amines, one amines, aromatic compound, isothiocyanate, alkyne, carboxylic acid, thiol, aldehyde, alkane, alkenes, 1,2 amines, amides, alcohol. As shown in Fig. 7, the adsorption spectra of 675.12 cm^{-3}, 864.52 cm^{3}, 985.29 cm^{-3}, 1307.57 cm^{-3}, 1427.46 cm^{-3}, 1622.11

cm^{-3}, 1864.6 cm^{-3}, 1956.37 cm^{-3}, 2091.39 cm^{-3}, 2199.42 cm^{-3}, 2447.38 cm^{-3}, 2551.8 cm^{-3}, 2694.77 cm^{-3}, 2896.42 cm^{-3}, 3062 cm^{-3}, 3167.72 cm^{-3}, 3282.35 cm^{-3}, 3697.27 cm^{-3}, 3826.71cm^{-3}, shows the presence of functional groups such as alkynes, aromatics, alkenes, alcohols, carboxylic acid, ethers, one amines, aromatic compound, isothiocyanate, isocyanate, alkane, alkynes(terminal). As observed from Figs. 5-7, Alcohol, Aromatics, Carboxylic Acid, and Isothiocyanate compounds present in CMC were also present in AA and MAR. The phenol compound present in CMC was absent in the AA and MAR. Alkene present in CMC and MAR was absent in AA. The results indicate that the local materials are composed of polysaccharides.

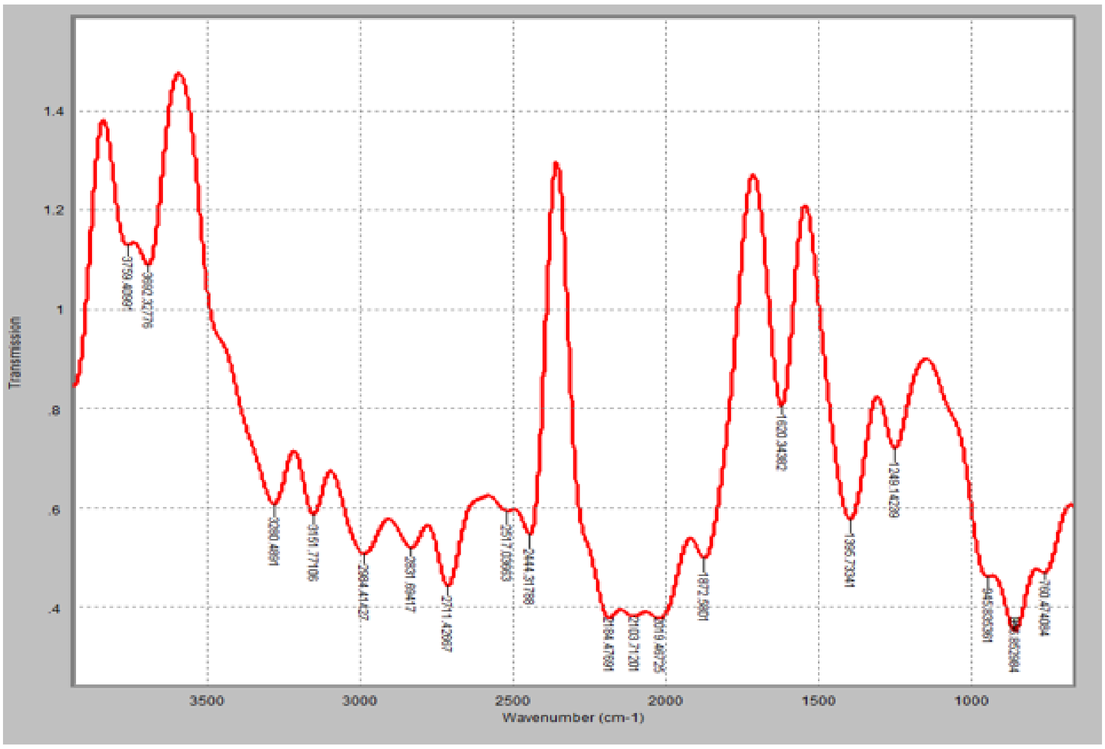

Fig. 5. FTIR spectra of Afzelia Africana (AA)

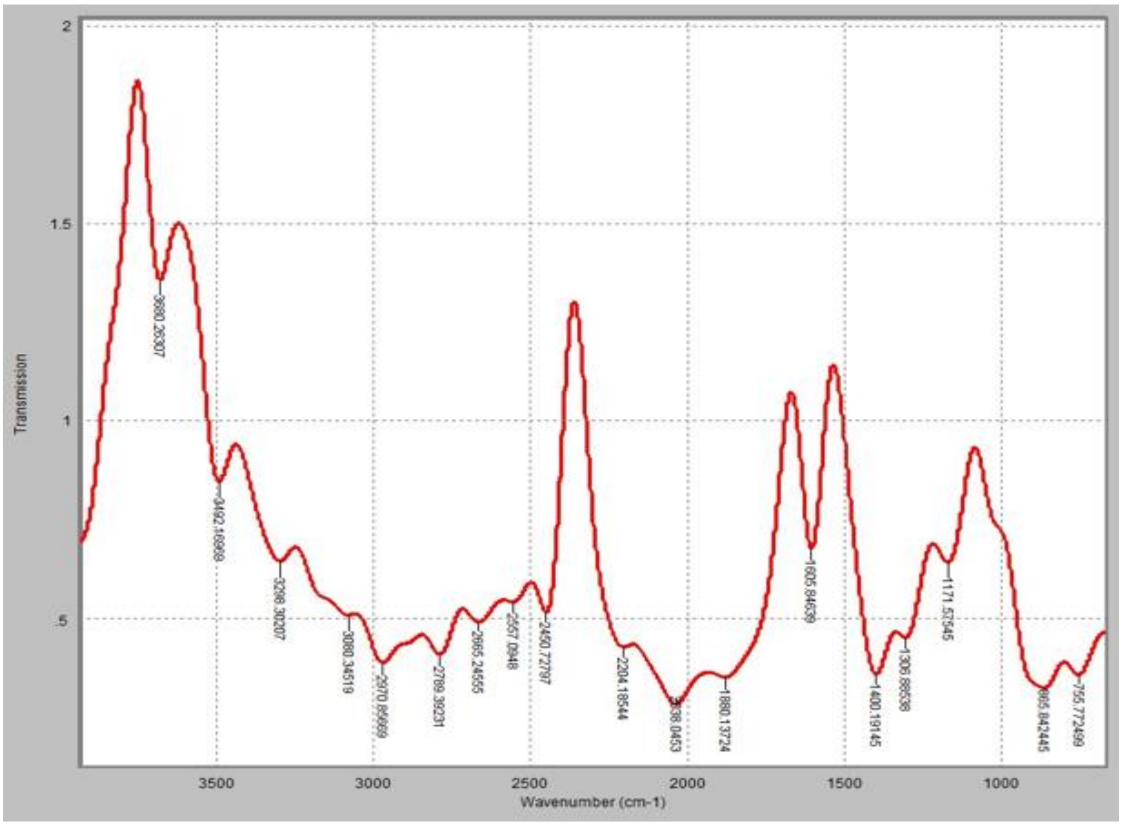

Fig. 6. FTIR spectra of Maranta Arundinacea root (MAR)

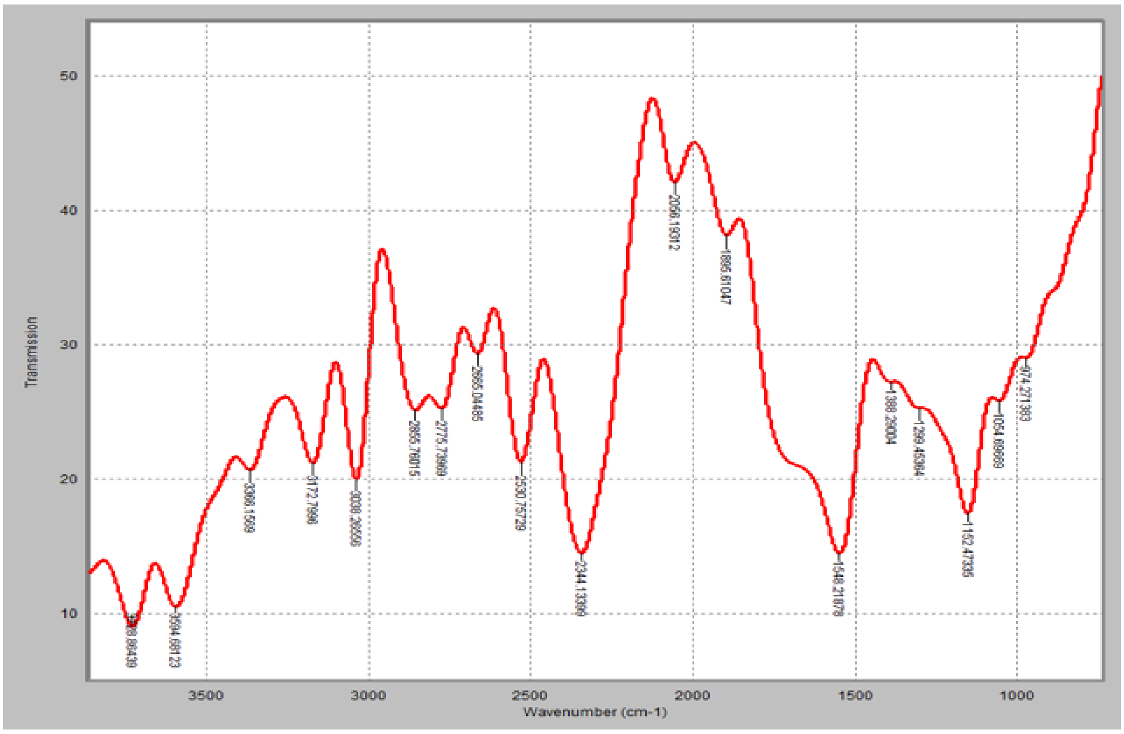

Fig. 7. FTIR spectra of carboxyl methyl cellulose (CMC)

Rheology

Table 2 depicts the rheological features of the AA-WBM, CMC-WBM, and MAR-WBM. As shown from the result of PV, CMC's initial PV of 11 cp at 1 g increased to 13 cp, 16 cp, and 18 cp when the concentration increased to 3 g, 5 g, and 7 g, respectively, while further concentration to 9 g did not improve PV. For MAR, the initial PV of 4 cp at 1 g decreased to 2 cp when the concentration was increased to 3 g, then returned to 4 cp at 5 g, before experiencing a continuous decline with further increases in concentration. For AA, its initial PV of 5 cp at a 1 g concentration increased to 9 cp, 11 cp, and 14 cp at 3 g, 5 g, and 7 g concentrations, respectively. Further concentration had no impact on the PV. As observed from the results, AA and CMC recorded their highest PV at 7 g, while MAR recorded its highest at 1 g. As shown from YP result, CMC recorded 10, 17, 23, 29, and 38 lb/100ft^2 at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively, MAR recorded 4, 3, 4, 3 and 2 lb/100ft^2 at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively, while AA recorded YP of 4, 11, 21, 21 and 39 lb/100ft^2 at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively. As observed from the YP result, AA recorded a higher YP than CMC at 9 g, while at other concentrations, CMC recorded a higher YP than AA. As shown from AV result, CMC recorded 16 cp, 21.5 cp, 27.5 cp, 325 cp, and 37 cp at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively, MAR recorded six cp, 3.5 cp, six cp, 3.5 cp and four cp at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively. In comparison, AA recorded concentrations of 7.0 cp, 14.5 cp, 21.5 cp, 24.5 cp, and 29.5 cp at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively. As observed from the AV result, CMC recorded a higher viscosity value than AA, while MAR did poorly. As shown in the YS result, CMC recorded values of 32.6, 44.6, 57.3, 68.4, and 80.0 at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively. MAR recorded 12.3, 7.3, 12.3, 7.3, and 8.1 at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively, while AA recorded 14.2, 29.9, 46.0, 51.2, and 70.4 at 1 g, 3 g, 5 g, 7 g, and 9 g, respectively. As observed from the result, the YS of AA and CMC increased with an increase in concentration. Combining PV, YP, AV, and YS results, AA exhibited a similar rheological pattern to CMC, which can be attributed to the number of substituent chains in its chemical composition, enabling it to increase its viscosity with concentration [29, 30]. MAR-based WBM exhibited poor rheological values, indicating that it is not effective in improving mud rheology. According to the gel strength results, AA performed favorably in comparison to CMC. AA and CMC recorded constant gel strength values at 9 g concentration, respectively. Gamal et al. [31] reported that flat rheology is needed for mud where the gel strength values are constant over time. A mud formulation with this concentration will require a flat rheology.

Table 2: Rheological properties of the formulated water-based drilling muds

S/N	Material	Conc. (g)	Plastic Viscosity (cp)	Yield Point ($lb/100ft^2$)	Apparent Viscosity (cp)	Yield Stress ($lb/100ft^2$)	Gel Strength	
							10 S	10 Min
1	CMC	1	11	10	16	32.6	20	30
		3	13	17	21.5	44.6	32	38
		5	16	23	27.5	57.3	45	47
		7	18	29	32.5	68.4	52	53
		9	18	38	37	80.0	56	56
2	MAR	1	4	4	6	12.3	8	17
		3	2	3	3.5	7.3	4	8
		5	4	4	6	12.3	5	11
		7	2	3	3.5	7.3	4	7
		9	3	2	4	8.1	5	10
3	AA	1	5	4	7	14.2	10	15
		3	9	11	14.5	29.9	25	34
		5	11	21	21.5	46.0	38	46
		7	14	21	24.5	51.2	40	48
		9	10	39	29.5	70.4	50	50

Fluid Loss

Fig. 8 shows the fluid loss volumes of MAR, AA, and CMC WBMs. From Fig. 8, 1 g of AA resulted in a fluid loss of 35 ml, while further increases in concentration to 3 g, 5 g, 7 g, and 9 g resulted in corresponding increases in fluid loss of 46 ml, 54 ml, 60 ml, and 66 ml, respectively. 1 g of MA recorded a fluid loss of 24 ml, while a further increase in concentration to 3 g, 5 g, 7 g, and 9 g gradually reduced the fluid loss volume to 23 ml, 23 ml, 22 ml, and 21 ml, respectively. 1 g of CMC resulted in a fluid loss of 15 ml, while further increases in concentration to 3 g, 5 g, 7 g, and 9 g gradually reduced the fluid loss volume to 13 ml, 12 ml, 10 ml, and 10 ml, respectively. As observed, MAR performed better than AA, as it recorded the least fluid loss volume at 9 g with a filtrate volume of 21 ml, while AA recorded the least fluid loss volume at 1 g with a filtrate volume of 35 ml. The fluid loss control performance of MAR over AA can be attributed to the finer particle sizes of MAR, which are nanoparticulate, compared to AA, which has a particle size of 250 mesh. Although MAR performed better than AA, CMC recorded the least fluid loss among the materials utilized, with a filtrate loss of 10 ml at 7 g and 9 g, respectively. The performance of CMC over MAR and AA could be attributed to its ability to yield increased cellulose content in the DF as a result of increased additive concentration [32]. Comparing Fig. 6 with Table 2, AA can be considered as a viscosity-increasing additive, while MAR can be viewed as a fluid-loss control additive.

Table 3 illustrates the thickness of the mud cake formed by the formulated mud samples. As can be observed from Table 3, CMC recorded a mud cake thickness of 2/32 of an inch at concentrations of 1-5 g, respectively. At concentrations of 7-9 g, the mud cake thickness increased to 3/32 of an inch, respectively. MAR recorded 2.5/32 of an inch mud cake thickness from 1-3 g concentration, respectively, while from 5-9 g concentration, mud cake thickness reduced to 2/32 of an inch, respectively. AA recorded a mud cake thickness of 3/32 of an inch at 1 g, and this increased to 7/32, 8/32, 11/32, and 17/32 of an inch, respectively. When compared to others, MAR recorded a closer mud cake thickness to CMC, while the mud cake thickness of AA continued to increase with an increase in concentration. Comparing Table 3 with Fig. 6, the thickness of mud cake for CMC slightly increased with a reduction in fluid loss volume, the thickness of mud cake for MAR reduced with a decrease in fluid loss volume, while the thickness of the mud cake for AA increased with an increase in fluid loss volume. The slight increase in mud cake thickness for CMC could be attributed to the deposition or sedimentation effect of the material. The increase in mud cake thickness for AA is attributed to the loss of fluid volume. If untreated, it gives rise to differential sticking of the drill pipe and possible non-productive time (loss time), which negatively impacts drilling operations (incurring extra costs) and formation damage (skin). MAR recorded a drop in filter cake thickness and filtrate volume with increasing concentration. This is due to MAR's ability to form a thin, low-permeability filter cake, thereby reducing the volume of fluid lost to the formation. Comparing the fluid loss result of MAR with the works of Olatunde et al. [14], Azizi et al. [17], and Ikram et al. [24], which recorded 5%, 4%-5%, and 6%- 5% fluid losses, respectively, MAR can be considered as a possible substitute for CMC.

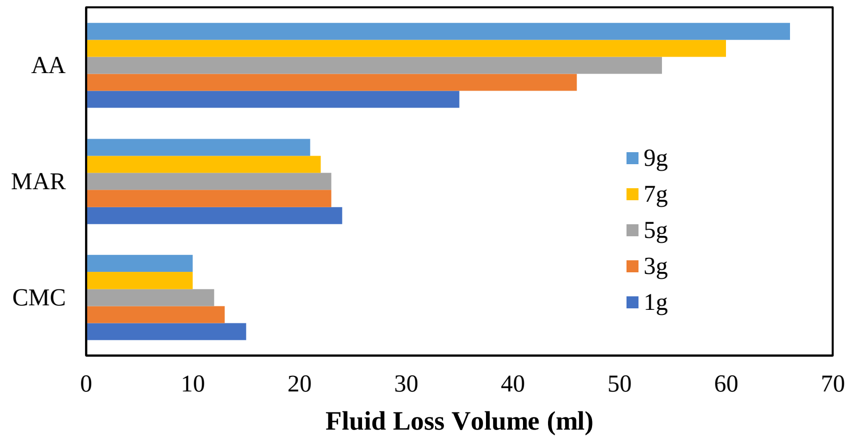

Fig. 8. Fluid loss volumes of the formulated mud samples

Table 3: Mud cake thickness formed by the formulated mud samples

S/N	Material	Formulation (g)	Mud cake thickness (x/32) inch
1	CMC-WBM	1	2
		3	2
		5	2
		7	3
		9	3
2	MAR-WBM	1	2.5
		3	2.5
		5	2
		7	2
		9	2
3	AA-WBM	1	3
		3	7
		5	8
		7	11
		9	17

Conclusion

Based on the experimental study conducted and the results obtained, the following conclusions can be drawn.

(1) From the FTIR characterization study conducted, the locally sourced bio-materials recorded similar functional groups such as carboxylic acid, amines, aromatic, and alcohol, which were present in carboxymethyl cellulose (CMC).
(2) From the rheology study carried out, AA, which competed with CMC, can be utilized as a viscosifier based on its rheological behavior.
(3) From the fluid loss control study carried out, MAR recorded better fluid loss control performance than AA, as 9 g of MAR yielded a filtrate loss volume of 21 ml at 30 minutes, respectively, while 9 g of AA yielded a filtrate loss volume of 66 ml at 30 minutes.
(4) MAR competed favorably with CMC in fluid loss control and can be utilized as an alternative fluid loss control additive
(5) An increase in fluid loss of water-based mud (WBM) increases the thickness of its filter cake.

Further Research Area

(1) Performance Study of MAR and AA as partial replacement additives for CMC in WBM.
(2) The impact of temperature, salinity, and oil contamination on the performance of MAR and AA in WBM.
(3) Improvement on the rheological Performance of MAR using a heat reformulation approach, and improvement on the fluid loss control performance of AA using locally sourced nanoparticles.

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