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Research Article

Empirical Assessment of African Oil Bean Husk as a Fluid-Loss Control Agent in Oil-Based Drilling Mud

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Abstract

Efficiency of drilling mud is partly determined by filtrate loss. In this article, research on suitability of African oil bean husk (AOBH), as a fluid loss control additive for oil-based drilling mud (OBM) is presented. Dry AOBH of particle sizes 63 μm, 125 μm and 250 μm were used. Fourier Transform Infrared Spectrophotometer (FTIR) and Phenom Prox model of the Scanning Electron Microscope energy dispersive X-ray spectroscopy (SEM-EDS) were used to determine morphology and chemical properties of AOBH. OBM samples were prepared using the various sizes of AOBH as fluid-loss control additives and Grel Alphatex as industrial grade additives. Power Law Model and Herschel-Bulkley Models were used to model rheology of samples. Results show that AOBH contains mainly asphaltic compounds, is eco-friendly and biodegradable. Results from mud tests show close values in performances of AOBH and industrial grade. Filter cake thickness was 2.1mm – 2.8mm for AOBH-additives mud, but 2.3mm for industrial-additives mud. Filtrate loss was 2.0ml – 3.4ml for AOBH-additives mud, but 2.3ml for industrial-additives mud. Apparent viscosity for AOBH-additives mud was 77.5 -92.0cp, but 99.0cp for industrial–additives mud. Plastic viscosity for AOBH-additives mud was 73.0 - 81.0cp, but 87.0cp for industrial-additives mud. Yield point for AOBH-additives mud was 9.0 – 22.0, but 24.0 for industrial-additives mud. Both models show that efficiency of the mud containing AOBH in cleaning hole increased as grain size of AOBH reduced.

Keywords

Fluid-Loss, Control-Agent, Oil-Based-Drilling-Mud, Oil-Bean-Husk

1. Introduction

Existing literature have shown that the contribution of drilling fluid in terms of the overall cost of drilling may be between 15% but may cause 100% of the drilling problems [43] Drilling fluid has gone through technological evolution from simple mixture of water and clays to complex mixtures of various organic and inorganic materials. However, these complex mixtures can be categorized into three types of drilling fluids: oil-based drilling fluid (OBDF), water-based drilling fluid (WBDF) and synthetic-based drilling fluid (SBDF).

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The choice of type to use is determined by technical requirements, nature of formation, characteristics of the fluid, cost and environmental consideration. For instance, research has shown that WBDF is biodegradable, improves soil fertility, increase organic matter and preserve environment [9]. Also, WBDF is easy to prepare, economical, and most efficient compared to other drilling fluids [8, 38]. Hence, approximately 80% of wells were drilled using WBDF [8, 9, 38]. However, WBDF is not preferred in shale formation as it is known to cause wellbore instability due to reaction of shale and water; formation damage, etc [32]. OBDF is preferred in situation where WBDF cannot be used such as deviated well, horizontal and multilateral wells, high temperature and high pressure formation, shale formation, etc. Although, OBDF poses danger to the environment and treating waste derived from OBDF is very expensive [6, 29, 39]. Oil-based drilling fluid is preferred for its superior temperature stability, lubricity, and hole stabilizing [29]. It is mainly composed of a reverse emulsion of saltwater in a continuous oil phase which is stabilized by surfactants [31]. Surfactant is used for oil-wetting and can also act as a thinner. The oil-based fluid customarily contains lime to sustain a high pH, enhance emulsion stability and to resist the harmful effect of acidic gases. A major benefit of using an oil-based fluid is to avoid occurrence of shale inhibition. However, oil-based mud has some disadvantages such as bonding between the cement and the formation to oil-wet surfaces, poor filter cake clean-up, and possible environmental hazards like seepage into aquifers and causing pollution [41]. Therefore, oil base mud is used in cases where water-based mud is considered inadequate.

Drilling fluids consist of two phases water/oil and organophilic clays [23, 25]. Water/oil is stabilized by surfactants which act as wetting agents and emulsifiers. Organophilic clays viscosify the drilling fluid. Other agent are added to drilling fluid to provide some functional requirements, such as appropriate rheology, density, fluid loss control property, and pH [10]. Fluid lost from the drilling fluid carry solid particles into the formation, thus, reduce its porosity and permeability [22]. Fluid loss is minimized by the creation of a low permeable filter cake at the wellbore surface. Desired filtration rate as well as the mud cake can be achieved by using various types of materials called fluid loss control agent. The damaging effect of mud filtration on well productivity necessitates crucial research effort to find effective ways to reduce the volume of mud filtration and solid invasion [20]. Various materials such as natural starch and synthetic starch like carboxymethyl cellulose (CMC) are used to control fluid loss and viscosity of drilling fluids [36]. Majority of the fluid loss control additives used for drilling in the petroleum industry are polymers containing traces of salts that are not environmentally friendly. Such additives are not suitable for all conditions of well and for all geological formations.

Some examples of fluid loss control additives are polyacrylamide, polyethyleneimine, carboxymethyl cellulose (CMC) and hydroxyethyl cellulose (HEC). The latter is sometimes employed but has high forming during mixing with slurry and is expensive [14]. Owing to their chemical composition most of these existing fluid loss control additives are costly and toxic to the environment [27]. Hence, use of local additives was suggested [5, 40].

Various materials have been used as fluid loss materials examples and their functions are listed:

1. Nutshell: Granular lost circulation material
2. Mica: Flake for seepage losses and prevention
3. Shredded Cedar Fibre: For sealing fractures in water-based mud
4. Cellulose: For lost circulation and sweep in oil-based mud
5. Sawdust: Applied as a filter loss additive in water-based mud

(Source: [37]).

Various researchers have also used various locally sourced materials as fluid loss additives in OBM namely:

1. Sawdust [2, 3]
2. Rice husk plus Sawdust [12]
3. Rice husk [12, 15]

Results obtained from the listed studies show that the locally sourced materials are organic materials derived mainly from plants. The results of their mud tests show comparable performance of local materials with the contemporary industrial grade materials. Nevertheless, suitability of these materials as fluid-loss control additives is limited because they are not easily affordable, not readily available and they have highly competitive alternative use.

Therefore, in this article research on African Oil Bean Husk (AOBH) as a fluid loss control agent for oil base mud is presented. The research was necessitated by the need to formulate an environmentally friendly fluid-loss additives mud, need for cheaper additives, need to maintain a healthy environment and need for locally sourced materials, which is in line with initiative of the federal government to encourage high local content. This research is also significant because of its contribution towards the drive to conserve foreign exchange according to the government initiative, to create employment, develop local materials, to actualize sustainable development goal and to increase per capital income for Nigeria. Africa oil bean (*Pentaclethra Macophylla-Benth*) plant is a perennial, tropical tree in the family – Leguminosae Mimosoideae. In Nigeria it is locally called “Ugba” by the Igbos, “Apara” by the Yorubas and “Ukana” by the Efik. It is a The tree flourishes in the Eastern and Southern parts of Nigeria [4, 24].

It has pods (husk) containing up to 10 seeds. Africa oil bean is eaten for its high nutritional content [1, 19]. However, demand for the husk is low since it very few usages. In rural areas, dry husk is used as fuel. Use of the husk as fuel is discouraged because it causes air pollution. Also, the heating value of the husk is very low compared to other alternative fuels. Therefore, creating a more profitable use for AOBH will be highly valued. Thus AOBH having no competitive alternative use promises to be a good example of profitable locally-sourced fluid-loss control additive.

2. Materials and Method

Various materials and equipment were used for the experiment.

2.1. Materials

The materials used for formulating OBM and their function are presented in Table 1.

Table 1. Materials for formulating OBM.

Materials	Function
De Ionized water	Continuous phase
Barite	Weighing material
Lime	pH enhancer
Xanthan gum (XG)	Fluid loss control/viscosifier for OBM
Organophilic clay	Primary viscosifier for OBM
Soltex	Industrial fluid loss control agent for HPHT drilling
AOBH	Locally-sourced fluid loss control additive
$CaCO_3$	Soluble weighing material for OBM
$CaCl_2$	Shale inhibitor for OBM

The equipment used in carrying out the experimental investigation is presented in Table 2.

Table 2. Equipment used in testing OBM.

Equipment	Function
HPHT filter press machine	Filtration property at HPHT drilling condition for OBM
Baroid Mud balance	Mud density
Ofite HPHT Rheometer	Mud viscosity of OBM
Marsh funnel viscosity	Quick viscosity measurement
FTIR Spectrophotometer- FTIR 8400 S	For functional group and bond type identification
SEM-EDS	Morphology and elemental composition of AOBH

Property of the diesel used as base fluid for OBM is presented in Table 3.

Table 3. Property of the diesel used as base fluid for OBM.

System	Versadril
Base Oil	Diesel
Density (S.G)	0.86
Viscosity (cp at ℉)	3.44

System	Versadril
Flash point (℉)	150 (130min)
Pour point (℉)	14
Analine point (℉)	149 (135min)
Aromatics (normal reporting unit)	18-30
Aromatics PAH (as phenanthrene)	~3%

2.1.1. Preparation and Characterization of AOBH

The standard procedures as stipulated by API for preparation of drilling fluid were used. Also, the standard procedures as stipulated in API recommended practice code (API RP 13B-2) for characterizing OBM was followed. [11, 16-18] AOBH was air-dried for six (6) days, and ground with grinder to smooth powder. The ground husks were further air-dried for four (4) days. Using sieve, particle sizes of 63 μm, 125 μm and 250 μm were recovered. Shimadzu Fourier Transform Infrared (FTIR) Spectrophotometer- FTIR 8400 S was used to determine the functional group and bond type identification of the AOBH sample. The samples were made to pass through an infrared detector connected to a computer. With an adsorption range of 600 to 400cm^{-1}, the sample was scanned and the reflectance of the sample was interpreted to obtain the dominant functional group and its bond structure/type. Phenom Prox model of the Scanning Electron Microscope energy dispersive X-ray spectroscopy (SEM-EDS) was used to determine the morphology and elemental composition of the AOBH was examined.

2.1.2. Mud Formulation and Preparation

Oil-based drilling mud Sample A was formulated without fluid loss material as blank mud. Sample B of OBM was formulated with 1.0wt% of Soltex as fluid-loss control additives. Other samples (Samples C, D, E, F, G and H) of OBM were formulated with either 1.0wt% or 2.0wt% AOBH material made from the various particle sizes (63 μm, 125 μm and 250 μm) respectively. The weight percent is based on the density of the base fluid, for WBM, 350g of the 350mL of the continuous phase. The composition of samples is presented in Table 4.

Table 4. *Composition of OBM sample.*

Sample	Base Oil (ml)	Org. Clay (g)	Pri Emul. (g)	Barite (g)	CaOH (g)	Sec Emul. (g)	$CaCO_3$ (g)	$CaCl_2$ (g)	XG (g)	Fluid-loss additive (g)
A	350	30.0	11.0	18.0	5.0	8.0	8.0	3.50	7.50	Nil
B	350	30.0	11.0	18.0	5.0	8.0	8.0	3.50	7.50	1.0wt% Soltex
C	350	30.0	11.0	18.0	5.0	8.0	8.0	3.50	7.50	1.0wt% 63 μm AOBH
D	350	30.0	11.0	18.0	5.0	8.0	8.0	3.50	7.50	2.0wt% 63 μm AOBH
E	350	30.0	11.0	18.0	5.0	8.0	8.0	3.50	7.50	1.0wt% 125 μm AOBH
F	350	30.0	11.0	18.0	5.0	8.0	8.0	3.50	7.50	2.0wt% 125 μm AOBH
G	350	30.0	11.0	18.0	5.0	8.0	8.0	3.50	7.50	1.0wt% 250 μm AOBH
H	350	30.0	11.0	18.0	5.0	8.0	8.0	3.50	7.50	2.0wt% 250 μm AOBH

2.2. Measurement of Mud Properties

Less filtrate volume suggests greater wellbore formation preservation and less formation mud contamination of the drilling mud [33].

The filtration properties tested at elevated temperature and pressure (above 212 ℉ and above 100psi). During the measurement of HPHT rheology of OBM the computer accessories were connected to the viscometer for the purpose of viewing the viscometer readings during the test. The viscometer and the computer sets were connected to the power socket. The speed of the rotor (rpm), pressure and temperature were adjusted using the manual control mode on the screen. The effective viscosity which is also the plasticity of the mud in centipoise (cp) was determined with marsh funnel. The density of a drilling fluid was determined with mud balance.

Digital pH meter was calibrated and used to determine the pH of the mud.

3. Results and Discussion

Results of experiments and tests conducted are presented as follows:

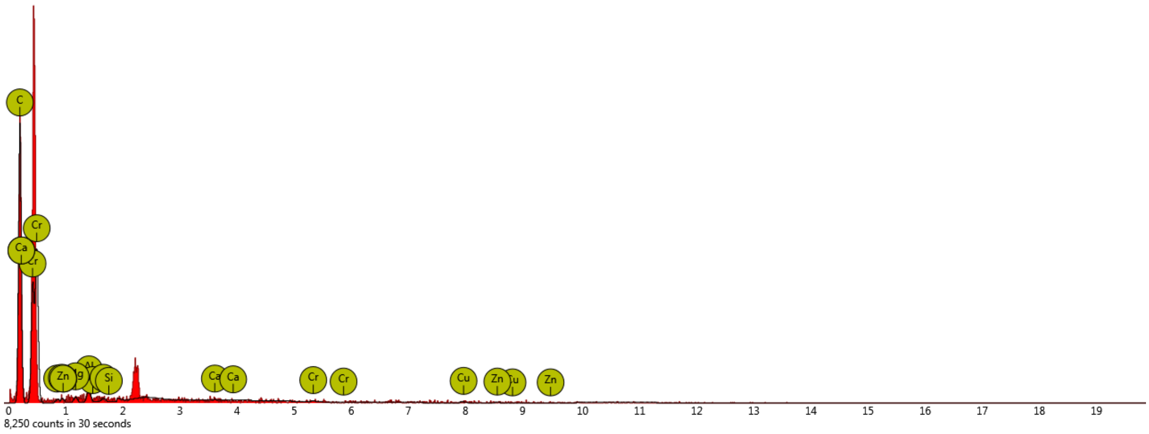
3.1. Characterization of AOBH

1. Results from Fourier Transform Infrared (FTIR) Test

The functional group compositions present in the AOBH samples as recorded from FTIR spectrum analysis revealed a wavelengths range of 4000 to 750cm^{-1}. The leading functional groups present are C-H and N-H groups with wavelengths of 2924.18cm^{-1} and 3340.82cm^{-1} respectively. Other functional groups are carboxylic acid, alcohols, alkene and thiol. The N-H is found also in primary amine. The major functional groups, composition and compounds present in AOBH are listed in Appendix II.

2. Scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM-EDS) of AOB

The results obtained from SEM-EDS are presented in Figure 1.



FOV: 950 µm, Mode: 15kV - Map, Detector: BSD Full, Time: SEPT 26 2022 7: 32

Figure 1. *Energy dispersive X-ray spectroscopy (SEM-EDS) of AOBH.*

As shown in Figure 1, The material tends to possess high amount of carbon with a weight concentration of 93.96%, other elements in the material include, copper, potassium, zinc, sodium, silicon, magnesium and calcium. Elements present and their concentration are shown in Table 5.

Table 5. *Elements contained in AOBH and their concentrations.*

Element	Symbol	Atomic Number	Atomic Conc. (%)	Weight Conc. (%)
Carbon	C	6	96.56	93.96
Potassium	K	19	1.84	1.73
Copper	Cu	29	0.73	3.55
Zinc	Zn	30	0.64	3.19
Sodium	Na	11	1.44	1.77
Magnesium	Mg	12	0.41	0.76
Silicon	Si	14	0.21	0.45
Calcium	Ca	20	0.06	0.18

As shown in Table 5, alkali metals are the main elements present in AOBH. These alkali metals impact alkalinity to the drilling muds thus the pH value of mud containing AOBH will be higher than that of the mud without AOBH.

Characterization of AOBH show that it does not contain toxic chemical, since it organic material, it is biodegradable, and does not harbour toxins. Therefore, it can be inferred that AOBH is does not pose harmful threat to the environment.

3.2. Characterization of Drilling Mud

3.2.1. Filtration Property

Figure 2 and (Appendix I) show the filtration property of OBM samples: filter cake thickness (FCT) and fluid loss (FL).

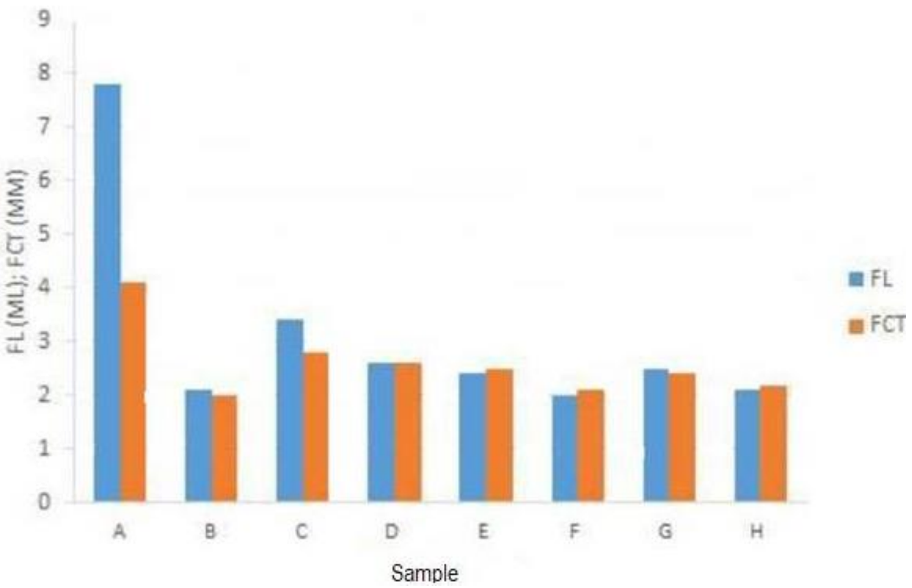


Figure 2. *Filtration property of OBM: filter cake thickness (FCT) and fluid loss (FL).*

Mud Sample A lost 7.8ml of fluid to the formation and a filter cake whose thickness was 4.1mm was formed. The results indicate that mud Sample B lost 2.1ml of fluid to the formation and a filter cake whose thickness was 2.0mm was formed. Also, had a reduced filter cake thickness 2.0mm (51.2% reduction). As observed results agree with literature on water-based mud, where amount of fluid-loss control agent increased as mud cake thickness reduced [26]. Also in agreement with literature on oil-based mud, filtration rate decreased with increased solids concentration [30]. AOBH recorded average reduction of 2.43mm (40.7% reduction) in filter cake thickness for the OBM. Sample F had closest cake thickness to cake thickness of Sample B but Sample H had closest fluid loss value to fluid loss value of Sample B.

The amount of fluid loss from the whole mud represents invasion of clear filtrate into the formation and causes formation damage [35]. The results showed there was a 73% reduction of fluid loss (2.1ml) with the commercial material for fluid loss control whereas the AOBH had a reduction in average mud loss into the formation at 2.5ml (67.9% reduction) for the OBM. The filtration property of AOBH material is acceptable because the fluid loss from all the samples were within the acceptable range for drilling operation (below or equal to 5ml) [28].

3.2.2. Mud Density

As shown in Table 6, AOBH caused little or no reduction in the density of the drilling mud. The results are satisfactory because high or low reduction in mud density, caused by adding mud additive, would require alteration in the drilling design. For most drilling operations the mud density values are within the range of 8.65ppg and 9.6ppg [7].

Table 6. *Mud Density and Marsh Funnel Time of samples.*

Samples (OBMs)	A	B	C	D	E	F	G	H
Mud Density (ppg)	14.90	14.55	14.20	14.20	14.00	13.95	13.90	13.90

Samples (OBMs)	A	B	C	D	E	F	G	H
Marsh Funnel Time	78.45	78.18	75.87	75.43	73.89	73.50	73.67	73.09

3.2.3. Marsh Funnel Viscosity (MFV)

As shown in Table 6, there were slight reduction in marsh funnel viscosity under the influence of AOBH. This reduction in viscosity as well in density agrees with literature asserting a direct relationship between viscosity and hydrostatic pressure [21]. The effect of the reductions in viscosity is a slight reduction in the wellbore cleaning and cutting-carrying capacity of the drilling muds, thus, leading to a slight reduced rate of penetration (ROP).

4. Rheological Properties of the Drilling Fluids

Average Viscosity (AV), Plastic Viscosity (PV) and Yield Point (YP) of WBM are displayed in Figure 3.

(a) Plastic viscosity, PV

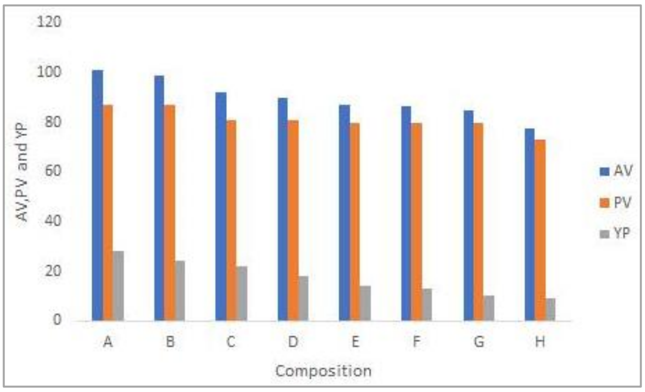


***Figure 3**. Average Viscosity, Plastic Viscosity and Yield Point of OBM Samples.*

The plastic viscosity of samples is presented in Figure 3 and Appendix III. The results showed a reduction in plastic viscosity in the presence of a fluid-loss control agent. The AOBH possesses similar values with the commercial grade, this performance signified that the AOBH acted as a reliable solid control agent in the OBM with excellent plastic viscosity. The reduction in plastic viscosity is within the API range (less than 35cp) this is in agreement with [42]. The drop in PV of the mud enhances the efficiency of pumping the mud.

(b) Apparent viscosity, AV

The results presented in Appendix III, and in Figure 3 showed that the AV values tend to reduce under with presence of fluid-loss control additives. The value of AV was shown to vary directly as the grain size of AOBH. This trend is in agreement with observations of literature [34].

(c) Gel strength

Drilling muds with higher gel strengths require more pressure to initiate its pumping. Gel strength was characterized as initial gel strength (10 seconds) and final gel strength (10 minutes). From Figure 3 and Appendix III it was shown that at the initial gel strength (10 seconds gel) of the OBM reduced with the application of the AOBH. The final gel strength (10 minutes gel) of OBM possesses reduced slightly due to presence of AOBH. The gel strength varies directly as the particle size for both initial and final gel strength test.

5. Modelling the Rheology of the Drilling Fluids

The model for hydraulic property of a drilling fluid mimics the behaviour of the mud in relation to its ability to clean cutting out of the well at certain shear rates. The power law model presented in equation (1) and the Herschel-Bulkley model presented in Equation (5) were used in this study.

5.1. Power Law Model

When the shearing characteristic of a non-Newtonian fluid is a transition between Newtonian fluid model and Bingham plastic model, the power law model is applicable. Such fluid is a pseudo plastic fluid. Example is such pseudo plastic fluid is drilling mud. In using the power law model for the drilling mud, the thickness of the mud referred to as consistency index (K) and the fluid behaviour index (n) are calculated from the rheometer readings. These constants are used for plotting shear rate of the fluids against shear stress. As n reduces below 1.0, the fluid becomes more shear thinned and provides better hole cleaning ability. As K increases, cleaning ability of the mud increases. The behavior index, n, and consistency factor, K, were computed using 2 and 4 respectively.

$$\tau = K(\gamma)^n \tag{1}$$

Given that:

τ = shear stress (Ib/100ft^2)

$$n = 3.32\log\left(\frac{\emptyset_{600}}{\emptyset_{300}}\right) \tag{2}$$

$$\gamma = 1.703\times\text{rpm setting} \tag{3}$$

$$K = \frac{510\phi_{300}}{511^n} \quad (4)$$

5.2. Herschel-Bulkley Model

At very high shear rate (at the bit) or low shear rates (in the annulus) the power law model does not accurately describe the behaviour of the drilling fluid [13]. Rather, the Herschel-Bulkley model gives a better description of the performance of the fluids.

The yield shear stress, τ_y, consistency factor, K, and behavior index, n, were computed using 6, 7 and 8 respectively.

$$\tau = \tau_y + K(\gamma)^n \quad (5)$$

Given that:
τ = shear stress (Ib/100ft^2)
τ_y = yield shear stress

$$\tau_y = 2\theta_3 - \theta_6 \quad (6)$$

$$K = 500\, \frac{\phi_{300} - \tau_y}{511^n} \quad (7)$$

γ = shear rate (s^{-1})

$$n = 3.32\log\left(\frac{\phi_{600} - \tau_y}{\phi_{300} - \tau_y}\right) \quad (8)$$

5.3. The Power Law Mode Plots

The power law model plots (PLMP) of the drilling OBM samples are presented in Figure 4, generated from the data in Appendix III.

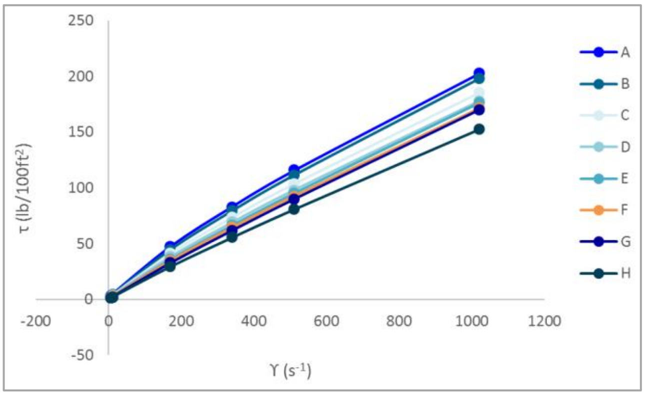


Figure 4. *Power Law model plot OBM samples.*

The PLMP for all the drilling fluids revealed that all the mud samples are non-Newtonian even under a blend of the AOBH material into the muds.

From the results it was shown that the fluid behaviour index reduced under the influence of the fluid loss control agents. Value the fluid behaviour index varies inversely as particle sizes of the AOBH. Also, the mud consistency index reduced with the addition of the fluid loss control materials. The mud consistency index varies directly as particle size.

Sample A exhibited a very low shear stress at low shear rate. This was due to the fact that the fluid behaviour index is higher resulting in lower cutting removal from wellbore. At low rate of shear of the mud Sample B, the shear stress was high, this was attributed to the introduction of a fluid loss control material with a lower fluid behaviour index. This composition will offer a better hole cleaning. The introduction of finest particles (63 µm) of AOBH in mud Sample C resulted in a drop of over 50% of the needed shear stress at higher shear rates (600rpm). This implies that the force acting on the flowing fluid becomes reduced under the presence of the additive. For the increase in the concentration of particle size 63 µm AOBH in Sample D, there was a moderate increase in shear stress when the shearing rate of the mud was low. This was due to an increase in the fluid behaviour index and a slight drop in yield point. The power law plot of mud sample containing 125 µm of AOBH in Sample E portrays similar behaviour with 63 µm size at low shear rates and at high shear rates. Variation of grain sizes and concentrations of AOBH in Sample F, G and H, exhibited similar behaviour of shear stress at low and high shear rates. This was because, the YP, n and K had similar values.

5.4. Herschel-Bulkley Model Plots

The Herschel-Bulkley Model Plots (HBMP) of the drilling fluids is presented in Figure 4, revealed that all the mud samples are non-Newtonian even when AOBH material was added into the muds. Yield shear stress increased as the particle size of AOBH increased. Plot of shear stress (lb/100ft^2) versus shear rate (s^{-1}), there is an intercept (yield point) along the axis of the shear stress. It was observed that the fluid behaviour index reduced due to the effect of the fluid loss control agents. As the particle sizes of the AOBH decreased, the hole cleaning ability of the drilling mud increased. The mud consistency index reduced due to effect of adding the fluid loss control materials. From the ongoing, it can be deduced, the AOBH reduced the hole cleaning ability of the drilling muds.

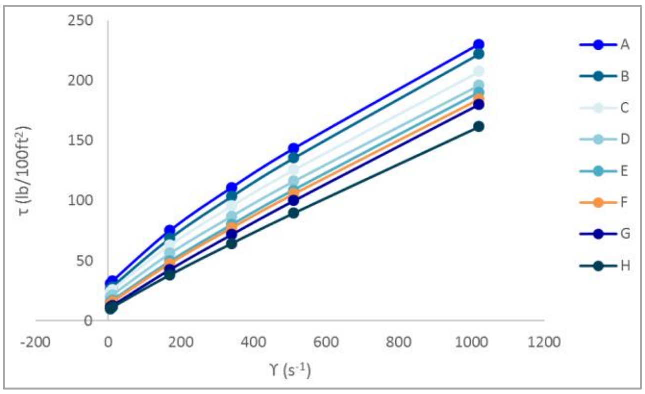


Figure 5. *Herschel-Bulkley Model Plot for OBMs.*

It was observed from Figure 4 that all the mud samples exhibited a very low shear stress at low shear rate. Lower values when a fluid loss control agent was added were always exhibited. Lower shear stress at lower shear stress was observed as particles size of AOBH was reduced.

Trends shown by both models suggested that the newly formulated drilling muds exhibited similar characteristics with the existing industrial drilling muds, which further suggests that ABOH can effectively function as fluid-loss control additive in drilling mud.

6. Conclusion

The following conclusions are made from observations of the experimental investigation of this study.

1. The locally sourced material (AOBH) is biodegradable; it is not toxic and does not pose environmental threat.
2. AOBH is cheap because it is easily available, it is affordable, does not have competitive alternative use and it is locally sourced material.
3. The AOBH is suitable for drilling all formation types based on its filtration properties. It possesses similar performance with the imported fluid-loss control agent as added in OBM.
4. Reduction in the mud density and marsh funnel viscosity in the presence of AOBH was observed. However, all observed values fell within the API approved range.
5. There was a small reduction in the rheology of all the mud samples containing AOBH. All the samples were non-Newtonian based on rheology modelling and the rheological data obtained from rheometer. The utilization of AOBH tends to reduce the shear stresses in all mud samples at low and high shear rates. The wellbore cleaning ability of the samples reduces as the particle sizes of AOBH increases.
6. Based on the observed performance from these experimental investigations, the AOBH can be applied in OBM while drilling wellbore.

Abbreviations

AOBH	African Oil Bean Husk
API	American Petroleum Institute
AV	Average Viscosity
CMC	Carboxymethyl Cellulose
FCT	Filter Cake Thickness
FL	Fluid Loss
FTIR	Fourier Transform Infrared Spectrophotometer
HBMP	Herschel-Bulkley Model Plots
HEC	Hydroxyethyl Cellulose
HPHT	High Pressure, High Temperature
MFV	Marsh Funnel Viscosity
OBM	Oil-based Drilling Mud
PLMP	Power Law Model Plots
PV	Plastic Viscosity
ROP	Rate of Penetration
SDG	Sustainable Development Goals
SEM-EDS	Scanning Electron Microscope Energy Dispersive X-ray Spectroscopy
WBM	Water-Base Mud
YP	Yield Point

Authors' Contributions

Sunday Chukwuyem Ikpeseni: Conceptualization, Data curation, Methodology, Formal Analysis, Investigation, Correspondence

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Ifeanyi Eddy Okoh: Conceptualization, Resources, Data curation, Methodology

Mathias Ekpu: Data curation, Methodology

Lawrence Chukwuka Edomwonyi-Otu: Editing

Hilary Ijeoma Owamah: Formal Analysis, Investigation, Editing

Statements and Declarations

This is to inform you that this manuscript titled "Empirical Assessment of African Oil Bean Husk as a Fluid-Loss Control Agent in Oil-Based Drilling Mud" contains original work done by the authors. The authors have no conflict of interest with any other and have submitted this manuscript to your journal house for possible publication. The manuscript has neither been submitted to this journal before nor any other journal.

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

Appendix I. Filtration Properties of the WBM

Table A1. *Filtration Properties of the WBM.*

Sample	WBM FL (mL)	FCT (mm)
A	14.2	6.4
B	2.3	2.3
C	3.3	2.9
D	2.5	2.6
E	3.0	2.7
F	2.6	2.6
G	2.6	2.5
H	2.3	2.3

Appendix II. Compositional Framework of AOBH

Table A2. *Compositional framework of AOBH.*

Group	Molecular motion	Type of vibration	Intensity	Band (cm-1)	Area
Benzene	$C-C$	bending	strong	709.83	16.04
Anhydride	$CO-O-CO$	stretching	strong	1018.45	5.404
primary alcohol	$C-O$	stretching	strong	1087.89	2.794
aromatic ester	$C-O$	stretching	strong	1373.36	4.09
carboxylic group	$-OH$	bending	medium	1458.23	4.709
Alkene	$C=C$	stretching	strong	1643.41	4.601
Azide	$N=N=N$	`stretching	strong	2160.35	2.336
Thiol	$S-H$	stretching	weak	2522.98	1.477
Alkane	$C-H$	stretching	medium	2924.18	29.244
aliphatic primary amine	$N-H$	stretching	medium	3340.82	29.076
aliphatic primary amine	$N-H$	stretching	medium	3441.12	22.478
Alcohol	$-OH$	stretching	medium	3780.6	2.892
Alcohol	$-OH$	stretching	medium	3896.34	2.929
Alcohol	$-OH$	stretching	medium	3958.06	1.235

Appendix III. Rheological Properties of the WBM

Table A3. Rheological properties of the WBM.

Sample (WBMs)	A	B	C	D	E	F	G	H
ϴ600	59.0	58.0	59.0	58.0	57.0	58.0	56.0	56.0
ϴ300	35.0	36.0	37.0	36.0	35.0	35.0	34.0	34.0
ϴ200	24.0	23.0	24.0	23.0	24.5	24.0	23.5	23.0
ϴ100	14.0	15.0	15.5	14.5	14.0	13.5	13.0	13.0
ϴ6	9.0	10.0	10.0	10.5	10.0	9.0	9.5	9.0
ϴ3	3.0	3.5	4.0	3.0	3.5	3.0	3.0	2.8
10sec Gel	2.0	2.3	2.5	3.0	2.5	2.5	2.7	2.5
10 min Gel	6.0	6.0	5.0	6.0	5.7	5.6	5.8	6.0
AV	29.5	29.0	29.5	29.0	28.5	29.0	28.0	28.0
PV	24.0	22.0	22.0	22.0	22.0	23.0	22.0	22.0
YP	11.0	14.0	15.0	14.0	13.0	12.0	12.0	12.0
n	0.75	0.69	0.67	0.69	0.70	0.73	0.72	0.72
K	0.33	0.49	0.57	0.47	0.44	0.37	0.38	0.38

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