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Research Paper

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Improving Properties of Water-Based Drilling Mud using Hamburger Bean and African Oil Bean Shell Powders as Eco-friendly Fluid Loss Retardant Additive

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Abstract

The processing of hamburger bean (HB) and African oil bean (AF) seeds for local consumption generates large amounts of waste (shells) that are considered an environmental nuisance. This manuscript presents the experimental result from the study on the utilization of HB and AF shell powders as fluid loss control additives in drilling mud. The mud filtration test was conducted at 25°C and 100 psi following with the American Petroleum Institute (API) guidelines for polymer-based mud. From the study, the HB-based mud sample showed a progressive decrease in the volume of fluid loss as the content of the HB additive increased. Furthermore, the fluid loss from mud samples with AF increased with an increase in its concentration, producing mud cake thickness between 2.2 and 2.8 mm. ultimately, the results demonstrate that HB is a cost-effective and sustainable green additive that can serve as a local alternative to the imported and expensive conventional filtrate control additives.

Keywords: Fluid Loss Control Additive, Hamburger Bean Shell, African Oil Bean, Cost Efficiency, Sustainability.

Introduction

Drilling of the wellbore remains a fundamental and expensive stage in the exploration and production of petroleum from its natural deposit [1]. Drilling fluid is utilised while drilling an oil well to enhance drilling efficiency and well productivity. The optimisation of drilling mud properties such as filtration and rheological properties is essential to forestall challenges such as lost circulation, differential pipe stuck, and equipment damage caused by excess fluid loss to the permeable formation when the fluid is circulated in the wellbore during drilling operations [2].

Drilling fluid, also known as drilling mud, contains a base fluid and a plethora of additives to enhance the efficiency of the mud to perform functions such as cooling and lubricating the drill strings [3], cleaning of the wellbore [4], and reduction in erosion of the borehole [5].

Drilling fluids are classified as water-based, oil-based, and synthetic-based. The application of each type of drilling fluid is subject to the drilling condition and nature of the formation [6]. Meanwhile, most mud engineers in the drilling industry recommend water-based drilling mud due to its acceptable cost efficiency, eco-friendliness, and wide availability. During the circulation of drilling mud in a well bore, certain volumes of the fluids are lost into permeable formation. Continuous fluid loss can result in formation damage, differential pipe stock, lost circulation, and equipment damage [7]. These consequences informed the need for effective mitigation strategies and precision in designing the mud composition about the formation's requirements [8]. In recent years, different researchers have employed agricultural wastes as additives in drilling mud. Oseh et al. [9] reported that agricultural materials used in drilling mud are advantageous owing to their cost-effectiveness, eco-friendliness, and ease of handling. Some of the literature-reported additives include, but are not limited to, cocoyam peels [10], corn cobs and coconut shell powder [11], rice husk [12], groundnut husk [13], cassava starch [14], okra shells [15], mandarin peel [16], Persea Americana [17], modified corn starch [18], coconut shell [19], and rice husk and sawdust [20].

In this research, the shells of African oil bean and hamburger beans are selected as potential filtrate retardant and rheological property enhancers in water-based drilling mud. The reasons for conducting this study are to:

• Determine the suitability of African oil bean and hamburger bean shell powders as fluid loss retardant additives in drilling mud for oil and gas operation.

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• Produce cheap fluid retardant additives to minimize the high cost of importation associated with the conventional fluid retardant additives.
• Reduce environmental degradation by applying eco-friendly and biodegradable additives for drilling mud formulation.

Reasons for the choice of the Shells

Cost: Table 1 contains the cost of different commercially available polymers and the shell powders used in the mud for filtration control. Moreover, the available data reveal that polyanionic cellulose (PAC) is the most expensive, followed by carboxylmethly cellulose (CMC) compared to the cost of hamburger bean and African oil bean shell powders.

Table 1 Cost of filtration control additive.

Material	Cost/Kg (USD)	Source
Polyanionic cellulose	6	[22]
Carboxylmethyl cellulose	4.96	[22]
African oil bean shell powders	0.42	[23]
Hamburger shell powders	0.30	[23]

Availability: For every kernel of African oil bean and hamburger bean produced, a corresponding shell is generated as a by-product. The states in Nigeria where Pentaclethra Macrophylla and Mucuna sloanei are produced include: Rivers, Cross Rivers, Akwa Ibom, Benue, Ekiti, Oyo, Ogun, Osun, Enugu, Ebonyi, Anambra, Abia, Imo, Delta and Edo. According to the National Agricultural Extension and Research Laison Services (NARERLS) [24], each tree of African oil bean produced an average of 25 kg of kernels, while Uwaezuoke et al. [25] reported that 63.9 metric tons of hamburger bean is produced per annum respectively with a corresponding 12-15 kg of the shells that is generated as waste.

Celloluse content: Both African oil bean and hamburger bean shells have a considerable quantity of cellulose, which is an interesting component. Otaigbe [26] reported that the shells contain cellulose (45-50% wt.), hemicellulose (25 -30% wt.), lignin (30-35% wt.) and extraneous (< 10% wt.)

Materials and Methods

Materials

Masid Engineering Limited, East-West road, Port Harcourt, Nigeria, supplied bentonite, barite, xanthan gum, Soda ash and carboxymethyl cellulose. A farmer in Kabangha, Khana local government Area, Rivers State, Nigeria, supplied hamburger bean and African oil bean.

Pre-conditioning of Samples

Samples (hamburger and African oil beans seeds) were cracked with a stone and manually selected to dispose other unwanted particle's shells. Moreover, the shells obtained were washed thoroughly with water and drained before they were oven-dried to a constant weight at 70 °C for 8 hours. Furthermore, the dried shells were ground in a locally fabricated grinding machine and thereafter, screened with a standard sieve size of 80μm to obtain uniform particle size. Then, the powdered shells were stored in a labelled, air-tight container to avoid contamination and moisture absorption. Moreover, Plate 1 shows the sample of hamburger bean, hamburger bean shells and HB shell powder, and Plate 2 shows Sample of African oil bean, AF shells and powder.

Plate 1. Sample of hamburger bean, hamburger bean shells and HB shell powder.

Plate 2. Sample of African oil bean, AF shells and powder.

Drilling Mud Formulation

350 mL water was poured into a 1L plastic cup followed by adding 3g bentonite, 78g barite, 3g soda ash, 2.8g xanthan gum and the weighted samples in sequence (Table 2) at 0.15hr intervals. Hamilton Beach mixer was used to stir the mixture at minimal speed to control spill. Thereafter, the formulated mud samples were allowed to age for 24h at room temperature before a filtration test specified by the American Petroleum Institute (API 13B-I) was conducted.

Table 2. Composition of drilling fluid with organic additives.

Mud components	content	mixing duration	basic function
Distilled H_2O (mL)	350	-	base fluid
Barite (g)	78	0.15 hr	densifier
Bentonite (g)	3	0.15 hr	vicosifier
Xanthan gum (g)	2.8	0.15 hr	thickener
Soda ash (g)	3	0.15 hr	pH control
Hamburger bean shell (g)	5, 10, 15, 20	0.15 hr	fluid loss control additive
African oil bean shell (g)	5, 10, 15, 20	0.15 hr	fluid loss control additive

Determination of Rheological Properties of the Fluid

Mud samples were poured into a cylindrical steel cup to the required point in Faan viscometer (Model 35). The rotor was applied and the dial readings were noted at different revolution per minute (RPM) to calculate the Plastic viscosity (PV), apparent viscosity (AV) and yield points (YP) of the mud samples. The 10 seconds and 10 minutes gel strength were determined at 3RPM. The following equations were used as stated below:

$$AV = \theta_{600}/2 \quad (1)$$

$$PV = \theta_{600} - \theta_{300} \quad (2)$$

$$YP = \theta_{300} - \text{plastic viscosity} \quad (3)$$

where: θ_{600} = dial reading at 600 rotation per minute (RPM)

θ_{300} = dial reading at 300 rotation per minute (RPM)

Determination of Fluid Loss

Mud samples with different additive concentrations (5, 10, 15 and 20g) were introduced to a cylindrical mud cell fitted with filter paper (Whatman 50) and other filter screens at the base of the cell. The set-up was held on a low pressure low temperature (LPLT) filter press stand and thereafter, a 100 psi pressure at 25 °C was released from carbon (IV) oxide cartridge fitted to the mud cell containing the mud samples for 0.5hr (API 13B-I). Moreover, the filtrate was received in a beaker and the volume was noted as fluid loss from the drilling fluid. Furthermore, the cake thickness left on the filter paper was measured with a vernier calliper and labelled as filter cake thickness.

Results and Discussion

Plastic Viscosity

Plastic viscosity (Pv) is a fundamental parameter in drilling fluid that measures flow resistance resulting from solids content, size and shape of additive particles, and fluid viscosity [27]. The PV result for HB mud samples (Fig.1) showed that the mud sample containing 5 g (30 cP) and 10 g HB (29 cP) decreased while the samples containing 15 g (40 cP) and 20 g HB (38 cP) increased when compared to the reference fluid (Table 3). Also, the PV for the 5 g AF mud decrease by 9%, whereas adding 10 g, 15 g, and 20 g increased the PV by 8.3%, 15.4%, and 20%, respectively.

Apparent Viscosity

The apparent viscosity (AV) is a parameter of drilling fluid expected to be high enough to suspend drilled cutting and perform well cleaning effectively [28]. The apparent viscosity of HB mud samples (Fig.2) demonstrates a progressive increase in AV with an increase in HB content. The addition of 5g, 10g, 15g, and 20g increased the AV by 14.3%, 14.7%, 35.1%, and 35.8%, while the addition of 5g, 10g, 15g, and 20g AF to the mud produced AV of 80, 81, 84.5, and 94 $mPas^{-1}$, respectively, compared to the AV of the reference mud (Table 3). The increase in AV in the mud sample indicates the good cutting transportation capacity of the mud.

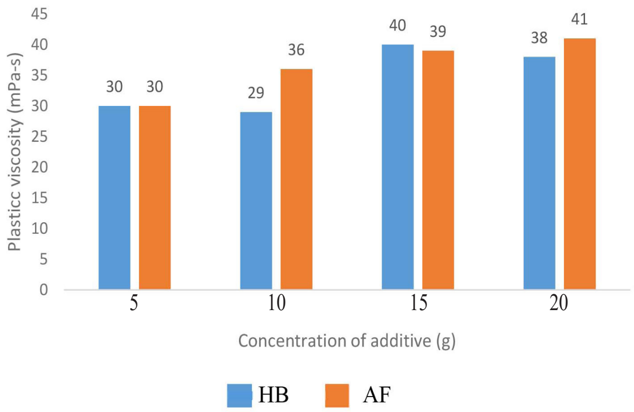

Fig. 1 Plastic viscosity of mud samples containing HB and AF.

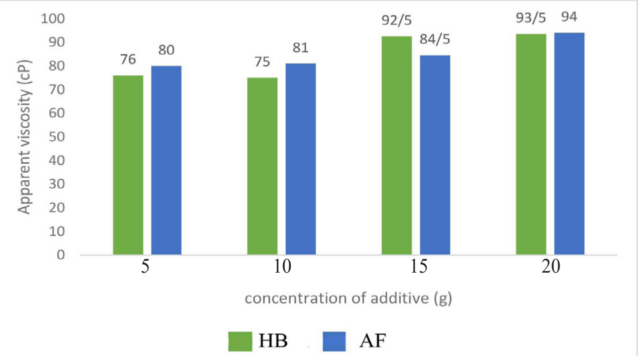

Fig. 2 Apparent viscosity of mud samples containing HB and AF.

Table 3 Properties of reference drilling mud

65	Apparent viscosity (cP)
35	Plastic viscosity (mPas^{-1})
64	Yield point (Ib/100ft^2)
22	Gel strength 10seconds (Ib/100ft^2)
26	Gel strength (10minutes) (Ib/100ft^2)
8.4	pH
1.8	Cake thickness (mm)
13.6	Fluid loss (ml) 30 mins

Yield Point

Yield Point (YP) measures the initial flow resistance resulting from the electrochemical forces between the fluid particles due to surface charges dispersed in the fluid phase. In addition, the YP results (Fig.3) for HB mud samples show 90, 92, 105, and 111 kg/m^2 for 5 g, 10g, 15g and 20 g mud samples, respectively. Also, adding 5g, 10g, 15g, and 20g AF produced 100, 92, 91, and 106 kg/m^2, respectively. Moreover, both HB and AF in the mud samples enhanced the YP for improved surface properties and the ionic environment of the liquid surrounding the solids for better hole cleaning.

Gel Strength

The gel strength for the fluid system containing HB and AF additives (Fig. 4) was found to increase steadily with an increase in additive content. Moreover, the 10-second and 10-minute gel strengths for the sample containing 20 g HB increased from 30 to 40 kg/m^2, respectively. Gel strength for the mud sample with 15 g AF was found to be better gel strength than other AF-based samples. Furthermore, the results show that the gel strength for the mud system is effective for better cutting suspension in a static condition for a recorded time interval.

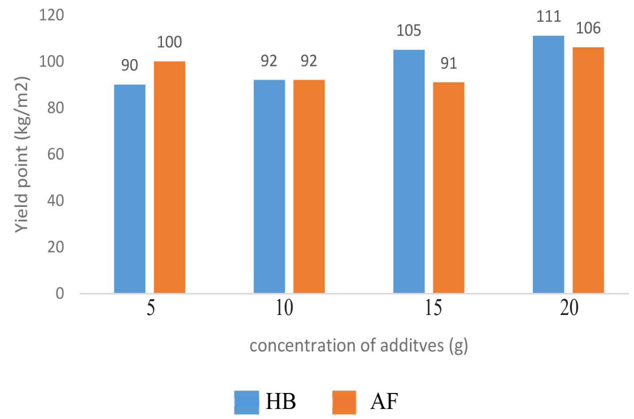

Fig. 3 Yield point of mud samples containing HB and AF.

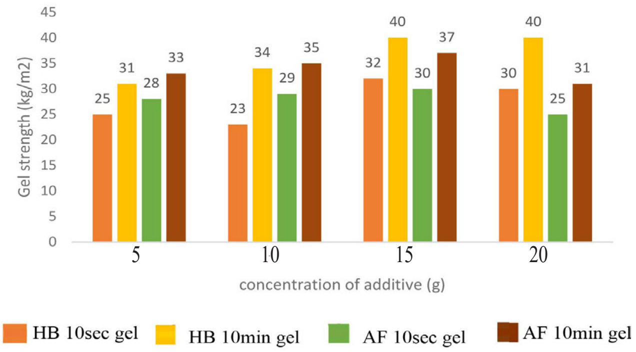

Fig. 4 Gel strength of mud samples containing HB and AF.

Filtration Properties

Using HB shell powders as a fluid loss control additive in drilling mud samples (Fig.5) led to a progressive reduction in filtration rate. In addition, it was found that fluid loss decreased by 1.47%, 8.82%, 14.71%, and 20.6% after the addition of 5g, 10g, 15g, and 20g of HB. Also, the results obtained from AF mud samples (Fig.6) showed that the volume of loss from AF fluid increased with an increase in the concentration of the AF additive. Moreover, the volume of fluid loss after 30 minutes was found to be 16.8 ml, 18.2 ml, 20.2 ml, and 21.8 ml for the mud sample containing 5 g, 10 g, 15 g, and 20 g AF, respectively. Furthermore, AF mud sample results demonstrate that the AF additive failed to meet the 15-ml API standard.

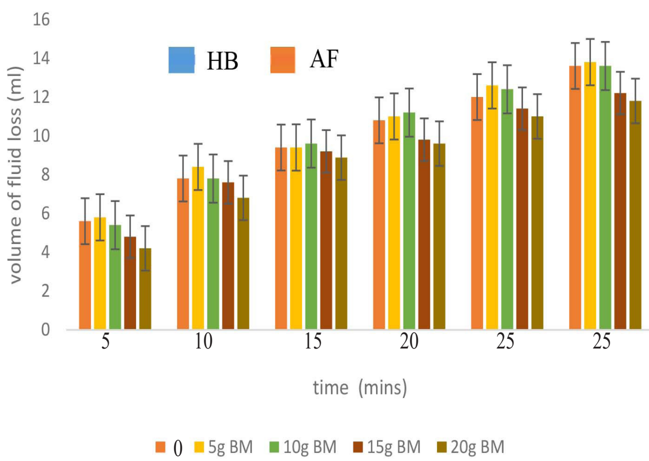

Fig. 5 Volume of fluid loss from mud samples with HB.

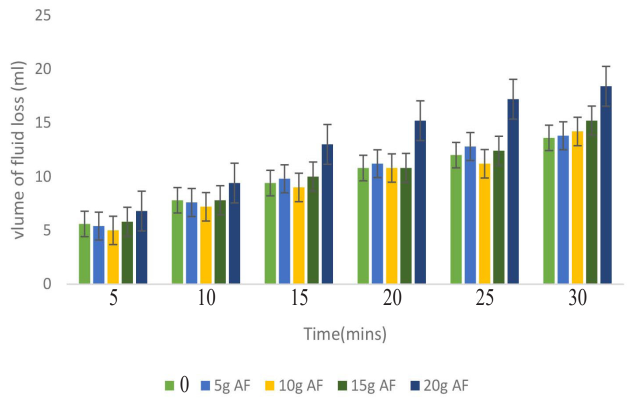

Fig. 6 Volume of fluid loss from mud samples with AF.

Mud Cake Thickness

The filter cake from mud samples with HB showed a consistent cake thickness decrease from 1.7 to 1.22 mm proportional to the reduction in filtrate volume (Fig.7). In addition, the filter cake from HB-based mud was thin, smooth, and flexible, and it meets the API requirement of less than 2 mm. Also, the cake thickness from the AF mud system showed a progressive increase in cake thickness as the AF contents increased. Moreover, it was found that the cake thickness ranges between 2.4 mm and 3.8 mm, and it failed to conform to the API requirement, which recommended less than 2 mm. Furthermore, the increase in the cake thickness was attributed to the increase in the filtrate volume since the presence of AF in the mud sample didn't reduce the volume of fluid loss.

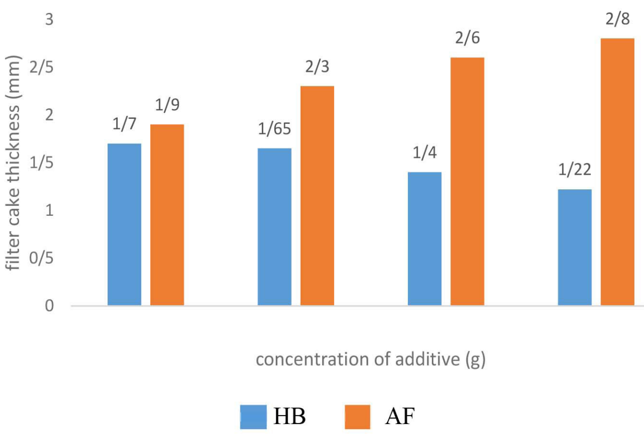

Fig. 7 Filter cake thickness of mud samples containing HB and AF.

Conclusions

The current study examine the potentials of hamburger bean (HB) and African oil bean (AF) shell powders as filtration control additives in water-based drilling mud. Based on the experimental results, the following conclusions are made:

1. The presence of HB and AF in the mud improved the rheological properties, facilitating transportation of drill cuttings from the subsurface to the surface.
2. Hamburger bean (HB) shell powders reduced fluid loss progressively with increased concentration.
3. Ultimately, HB is a cost-effective and sustainable green additive that can be a local alternative to the imported and expensive conventional filtration control additives.

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