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Application of Oil Palm Fruit Waste and Saw Dust as Filtration Loss Control Agents in a Water-Based Drilling Mud

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ABSTRACT

To reduce drilling costs and to combat waste environmental pollution, the study assessed the potential of two agro-waste materials as Filtration loss control agents in water-based drilling mud. Saw dust (SD) and oil palm fruit waste (OPFW) were pretreated and pulverized accordingly, into particle sizes of <150µm and 150µm - 250µm range to serve as additives. Drilling mud was formulated based on the standard procedure. Seventeen portions of the drilling mud were formulated, having the first portion as a control with no additive. Four groups of each portion were made from the remaining 16 and additives were added with varying amounts ranging from 5g to 20g. Drilling mud properties were measured according to standard methods before and after the addition of the additives. The relative performance of both SD and OPFW as additives was assessed. Results showed that filtration volume decreased with increasing quantity of additives while mud cake increased. The results also showed that although SD slightly outperformed OPFW only at lower particle sizes (<150µm), in terms of cake characteristics, fine and slippery mud cake formed with OPFW mud, as opposed to the rough and hard cake obtained from the mud formulated with SD, could also make OPFW preferable. The study concluded from the findings of this study that agro-waste materials, especially SD and OPFW are veritable candidates for alternative loss circulation materials in drilling fluids.

INTRODUCTION

The significance of drilling mud cannot be underestimated. They are used during the drilling operations to provide well control and subsurface pressure (Tehrani *et al*., 2014). This is achieved by exerting hydrostatic pressures on the formation thereby hindering the inflow of the formation fluids into the annulus. Other functions of drilling muds also include maintenance of both chemical and mechanical stability of the wellbore; transportation of the cutting from the well base to the surface; lubrication of strings and bits, cooling of the drilling bit, as well as alleviating the weight of the string. The main importance of drilling muds is to ensure the successful completion of drilling operations by consolidating the wall of the wellbore (Tehrani *et al*., 2014, Awele, 2014) and the execution of this role is a function of the formation type and drilling fluid properties, among other factors (Agwu, Akpabio and Archibong, 2019). This major role is achieved through the filtration of the dissolvable portion of the mud into the formation while the solid part forms a cake that coats the surface of the walls of a borehole (Feng *et al.*, 2018; Liu and Santamarian, 2018). Consolidation of the wellbore wall is key to the prevention of continuous fluid loss and its negative resultant effects, which include a reduction in oil production and formation damage

(Kosynkin *et al*., 2011). The huge cost of drilling operations is not only incurred from the general drilling rigs, but it is also associated with the contribution of the type and quality of drilling additives used as filtration loss control agents. Report has it that drilling fluids account for about 15 to 18% of the total cost of drilling operations, and the three basic requirements they are expected to fulfill include cheap availability/low cost, ease of use and environmental friendliness (Amanullah *et al*, 2016). Generally, CMS and PAC, conventionally used to minimize filtration loss problems, are expensive and not environmentally friendly, as shown in Table 1.

Table 1: Cost of Conventional Filter Loss Material and Agro-waste Materials

Filter Loss Materials Type	**Cost/kg (USD)**	**References**
Conventional Filter Loss Materials		
CMS	4.96	Okoro *et al*. (2018), Agwu *et al*., 2019
PAC	6.00	Okoro *et al*. (2018), Agwu *et al*., 2019
Agro-waste Materials		
Saw dust	0.12	Agwu *et al*. (2019)
OPFW	*0.00	*Oral interview with the farmers

*Readily available free of charge from several farmers in southwest Nigeria.

As presented in Table 1, the cost of sawdust appeared to be significantly small compared to CMC and PAC, while OPFW can be obtained with no cost from farmers. Interrogation with the farmers indicated their willingness to offer OPFW at no cost, as heaps of this material create a massive disposal bottleneck. Although the cost of these items could have changed over the years due to inflation, the low costs of sawdust and OPFW still present a great advantage.

Apart from these, most of these conventional materials are not thermally stable and thus decompose at a static reservoir temperature to form residue (Igwe and Kinate, 2015; Izuwa *et al*., 2019); therefore, a need for a scientific shift from the use of polymers towards the use of cellulosic, low-income, readily available and eco-friendly materials such as agro-wastes. The attractiveness of agro-waste materials as filtration loss control agents is connected to their cost effectiveness, thermal stability and ecosystem conservation (Dagwa *et al*, 2012).

Some studies have reported the effectiveness of the use of cellulose-containing agricultural wastes to control filtration loss in drilling fluids. For instance, a combination of two or more agricultural waste materials has been reported to be more effective in preventing loss of circulation than when used alone (Agwu *et al*., 2018). The study further opined that the usage of these materials in drilling mud is advantageous as it reduces environmental pollution and drilling costs. Millet starch has also been reported, not only as a good material for filtration loss control but also stable at an elevated temperature (Ukachukwu *et al*., 2010), while a study by Ghazali *et al*. (2014) showed that the higher the concentration of corn starch, the lower the filtration loss. Similarly, sugarcane bagasse ash has been found to reduce filtration loss, although at increasing temperatures, cake thickness and filtration loss volume also increase (Saengdee and Terakulsatit, 2017).

This study assessed the potential of Oil Palm Fruit Waste (OPFW) and Saw Dust (SD) for the control of filtration loss in water-based mud. It also compared their relative effectiveness based on their filter cake characteristic in the formulated mud as well as their fluid loss control capabilities. Although several other research works have noted the potential of various agro materials as filtration loss control agents (Adebayo and Chinonyere, 2012; Anawe *et al*, 2014, Okon *et al*., 2014), a literature search showed that the use of OPFW and SD as filtration loss control agents in water based-mud has not been extensively reported.

OPFW is the empty fruit bunch (EFB) of palm oil, constituting one of the major biomass wastes obtained from the extraction of palm oil. It is the spikelet holding oil palm fruits and lignocellulose of varying compositions. Nigeria is ranked fifth fifth-highest palm oil producer globally, queuing behind Indonesia, Malaysia, Thailand and Colombia (FAOSTAT, 2017). Nigeria's palm oil production is still on the rise, with yearly production reaching 1.4 million metric tons in 2022 from 995,000 metric tons in 2015 (USDA, 2023), contributing about 1.8% to global palm oil production. This trend is an indication that in Nigeria, there would be a continuous increase in the generation of huge amounts of OPFW on an annual basis, because for every 1 ton of palm oil produced, at least 0.25 (250-300kg) of OPFW is generated (Koura *et al*., 2016). For example, in 2013 alone, when 0.93 million tons of palm oil were produced, 1.3 million tons of OPFW were generated (Anyaoha *et al*., 2018). The huge availability of OPFW, therefore, creates great environmental concerns as the commonly adopted disposal method is either abandonment on an open field to decompose or uncontrolled burning. The adverse effects of these practices include fouling, accumulation of pests and emission of air pollution, all of which threaten both human and environmental safety. Sawdust, on the other hand, is wood waste and a byproduct always generated from sawmills during wood or lumber cutting. It is mainly composed of highly flammable fine particles. Although a very cheap material, it has found its limited usage in the agricultural sector as a poultry-bedding material and source of soil nutrients. Its usage in the manufacturing of particleboard, in recent times, is fast becoming economically unfriendly due to the current shift to utilization of plastic materials (Okedere *et al*., 2017). In Nigeria, the number of sawmills has significantly increased due to the necessity to meet the rising demands for wood for building and other construction activities, and this has led to a continuous increase in the amount of sawdust generated. The total mass of sawdust generated annually in Nigeria's sawmills has been estimated to be about 5.2 million tonnes, with the expectation that the volume would increase as demand for wood products increases (Onochiea *et al*., 2018). Due to this limited usage, therefore, in Nigeria, the common practice of managing heaps of sawdust generated from wood processing involves open-space burning, which constitutes an environmental nuisance (Okedere *et al*., 2017). At times, the heaps are abandoned in the open space for several months. This practice can cause environmental pollution during the rainy period or fire hazards during the dry season. A literature search indicated that apart from submissions of few reported studies on sawdust as a filtration loss control agent (Adebayo and Chinonyere, 2012; Anawe *et al*, 2014), the potential of sawdust has been limited to energy generation (Oladeji, 2010; Fakinle *et al*., 2017, Elehinafe *et al*., 2017, Elehinafe *et al*., 2019a; Elehinafe *et al*., 2019b; Veeyee *et al*., 2021), while the suitability of OPFW as filtration loss control agent has not been documented. Furthermore, the majority of the studies on the use of agro-waste materials in this regard only focused on fluid loss and mud rheology, neglecting the description of cake characteristics, which is very critical to the success of the drilling operations.

Therefore, this study aims to investigate the potential of OPFW and SD for controlling filtration loss in drilling mud based on their filter cake characteristics in the formulated mud as well as their fluid loss control capabilities following the American Petroleum Institute (API) method (API, 2010). The driving forces behind this study include (i) environmental concerns or waste management issues that emanate from the generation of a large quantum of these wastes and their non-economic values in developing nations (ii) paucity of scientific information on the potential of Oil Palm Fruit Waste (OPFW) and Saw Dust (SD) as filtration loss control agents in drilling mud and (iii) the need for holistic characterization of agro-waste materials for their complete usage as filtration loss agents,

A comparison of their relative effectiveness as filtration loss agents was also carried out. The choice of these wastes is based on some criteria: cellulose content, availability, cost, environmental friendliness and waste management strategy. The study will provide a holistic scientific explanation of the candidature of these materials as filtration loss control agents in water-based drilling mud.

METHODOLOGY

Collection of Materials

Oil palm fruit waste was collected from the Odo-Ode area Sepeteri, Saki East, Oyo state, Nigeria. The sawdust was obtained from Ajisope sawmilling station, Oke-Sunah Sepeteri Saki East, Oyo state, Nigeria.

Physical Pretreatment of the Materials

The samples (oil palm fruit waste and sawdust) were manually cleaned to remove foreign materials and then dried in an oven at 60 ^{0}C for 7 hours before being ground into smaller pieces (Agwu *et al*., 2018). The samples were milled with the aid of a hammer mill in Figure 1. The samples were then sieved into two different particle sizes of 150µm and 250 µm. Grinding is necessary to enhance homogeneity and to minimize the uncertainty of particle size. It has been shown that mud filtrate volume reduces with reduced particle size of the fluid additive (Ghazali *et al*., 2014; Lomba,2010); hence, the choice of these two particle sizes.

Figure 1: (a) Raw OPFW, (b) Dry OPFW, (c) pulverized OPFW, (d) Raw saw dust, (e) pulverized sawdust

Mud Formulation and Properties

Following the method described by the American Petroleum Institute, samples of sawdust and OPFW were utilized to formulate water-based mud (API, 2010) of 18.5g of highly treated bentonite to 350 mL of water with the addition of sodium hydroxide for alkalinity control. A standard Hamilton Beach Commercial high-speed mixer (Model 550) was used to mix each sample. Each sample was blended slowly for 600 seconds to prevent fluid loss. The formulated mud was divided into seventeen equal portions. The first portion (denoted as CTRL MUD) was prepared with no additives and was used as a control experiment. The remaining sixteen portions were grouped into four equal parts. For the naming, mud formulated with xg oil palm fruit waste having a particle size of <150µm was named OPFW-A (xg) while the second particle size was named xg OPFW-

B (e.g., 5g of 150µm particle size of empty oil palm fruit bunches was named as OPFW-A (5g) and that of (150µm - 250µm) range was named as OPFW-B (5g)). A similar naming pattern was used for muds formulated with sawdust. Varying amounts of oil palm fruit waste and sawdust in increasing order of 5, 10, 15 and 20 g were added to each sample of each group. Before further testing, the prepared muds were allowed to mature for 24 hours at room temperature.

Rheology and Filtration Test

Using mud balance, the samples' densities were determined, while apparent viscosity was read from viscometer dial readings. The standard API filtration test was conducted using a low temperature, low pressure (LTLP) filter press, which consists of a cylindrical-shaped cell. Through the use of a back regulator connected to a nitrogen tank, an air compressor supplied the top of the cell with a pressure of 100 psi. A graduated cylinder was positioned underneath the cell for 30 minutes to collect the filtrate. The filtrate volume collected within this period was taken as the volume of the fluid loss and the thickness of the deposit on the filter paper, measured with a ruler (in millimeters), was taken as the filter cake thickness. Cake characteristics were determined based on the API qualitative approach that is, using physical examination to describe the texture and slickness of the cake. Shown in Table 2 are fluid loss values as specified by API for conventional additives.

Mud cake permeability

Mud cake permeability, P, was estimated following the equation developed by Lomba (2010) as represented by equation 1

$$P = \mu t V_f (8.95x10^{-5}) \quad (1)$$

V_f, t and µ are filtrate loss volume (ml), mud cake thickness (mm) and viscosity (cp), respectively.

Table 2: API Specification for Conventional Additives

Properties	Specification	References
Filter case Thickness	<2mm	Drilling Formula (2016); Agwu *et al.* (2019)
API Filter loss	API (PAC)=23 ml (maximum) API (CMC)= 10 ml (maximum)	API (2010), Agwu *et al.* (2019)

RESULTS AND DISCUSSION

Result of Filtration Test

Figures 2a and 2b show the filtration experiment's results. The data showed that the more the quantity of the additives, the lower the volume of the filtration volume loss. Higher fluid loss was also observed when mud without additives (CTRL) was used. This indicates the significance of the additives in fluid loss control.

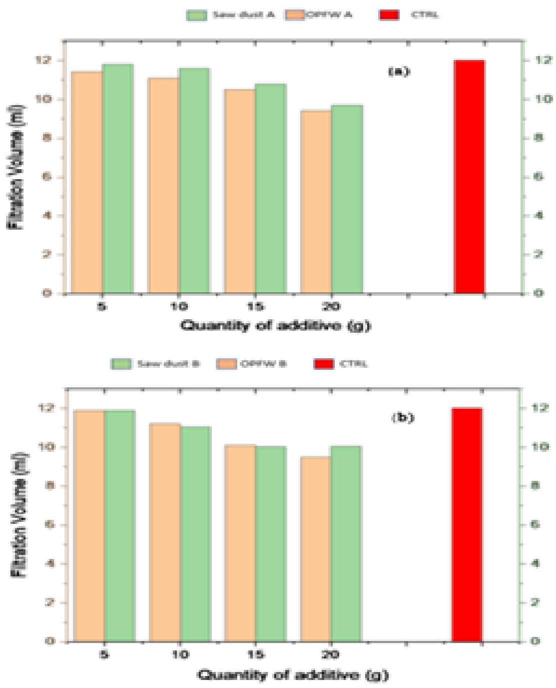

Figure 2: (a) Mud filtrate volume comparison of saw dust-A and OPFW-A and (b) Mud filtrate volume comparison of saw dust-B and OPFW-B

Mud spurt loss and additives' concentrations

Spurt loss, which is the initial filtration loss, was found to be dependent on the quantities of both OPFW and sawdust. It was noticed that there was a continuous decrease in spurt loss with increasing amounts of the additives, hence a linear relationship between the quantity of the additives and spur loss in Figure 3. This result agrees with Agwu *et al.* (2019) documented report. As the quantities of both additives rose from 5g to 20g, spurt loss decreased from 9.4 to 7.5 ml for sawdust and from 9.7 to 8.7 ml for OPFW in Figure 3a. A similar trend was observed in Figure 3b.

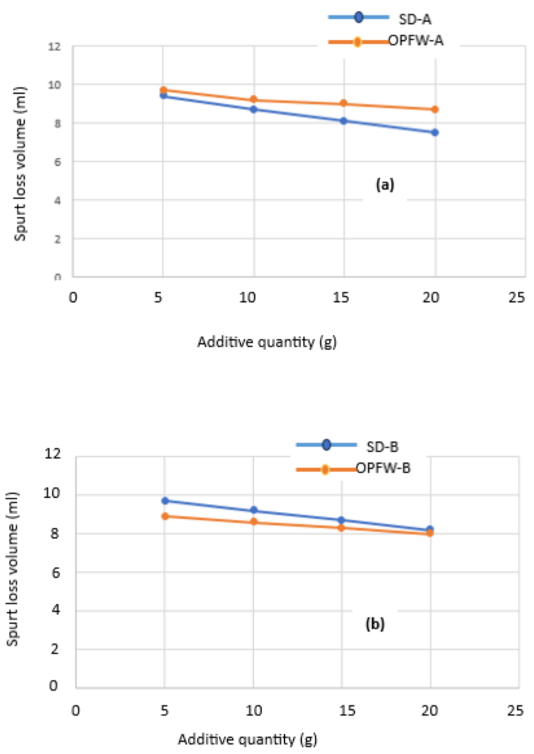

Figure 3: Plot showing the effects of additive quantity on spurt loss

Filter Cake: Mud cake texture, slickness, thickness and permeability

The texture and slickness of the mud cake were assessed by physical examination (Agwu *et al.*, 2019). It was observed that, although the filter cake obtained from sawdust A was smooth, firm and sticky, the cake from OPFW was smoother, slippery and less solid.

Similarly, the filter cake prepared from sawdust-B is partially smooth, firm and sticky, while the one formulated from OPFW-B is strongly rough, slippery and less solid. This was similar to the observations recorded by a previous study (Ghazali *et al.*, 2014).

The thickness of the mud cake observed in Figure 4a ranged from 1.2mm to 4mm for sawdust-A and 2mm to 4.5mm for OPFW-A. Similarly, as observed in Figure 4b, the thickness of the mud ranged from 1.5mm to 5mm for sawdust-B and 2.2mm to 6mm for OPFW-B. This clearly shows that the mud cake thickness for OPFW is higher than that of sawdust Cake permeability for water-based mud formulated with sawdust and OPFW is presented in Table 3.

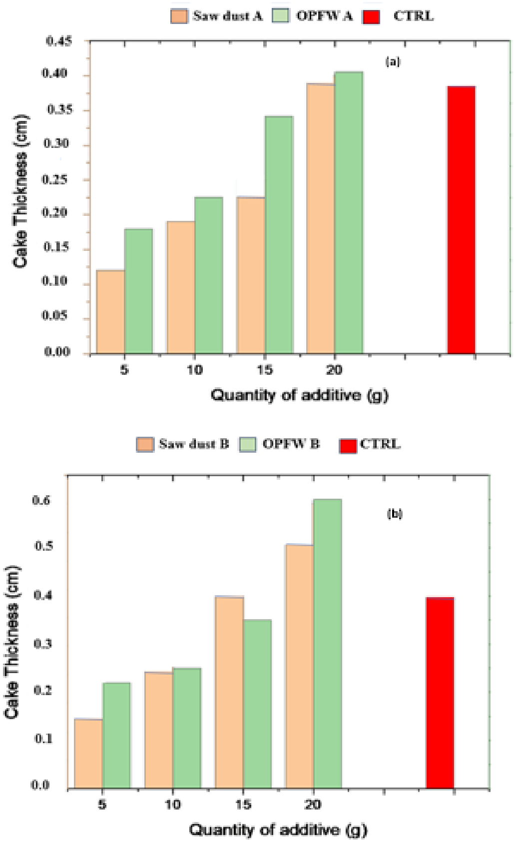

Figure 4: Mud cake thickness of (a) saw dust-A and OPFW-A and (b) saw dust-B and OPFW-B

It can be seen from the Table that cake permeabilities from saw dust-formulated mud are generally higher than those from OPFW in all.

Table 3: Cake permeability for water-based mud formulated with sawdust and OPFW

concentration (g)	cake permeability (mD (x10^{-3})			
	saw dust-A	OPFW-A	saw dust-B	OPFW-B
5	4.8	4.4	10	5.8
10	6.9	6.4	12.6	7.2
15	12.5	11.4	23.5	11.5
20	17.8	8.8	31.7	13.7

Rheological Properties: Apparent viscosity and density

Figure 5 (a and b) shows the results of apparent viscosity and density.

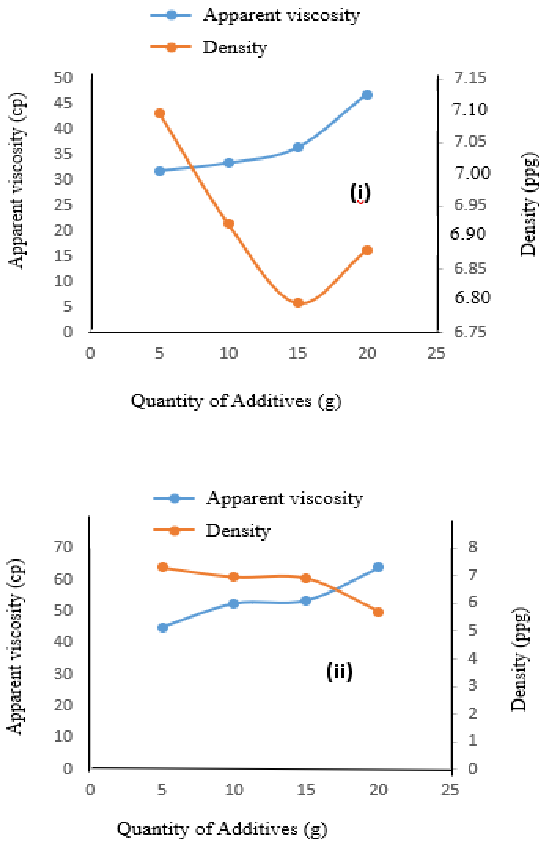

Figure 5a (i) Plot of apparent viscosity and mud density vs additives concentration of saw dust-A and (ii) apparent viscosity and mud density vs additives concentration of saw dust-B.

In Figure 5a, it was observed that the increase in the quantity of saw dust readily decreased the mud density but increased the viscosity. Similar situation was observed in Figure 5b except in Figure 5b(ii) where the density increased with increasing quantity of the OPFW, while apparent viscosity increased when quantity of OPFW increased beyond 10 g.

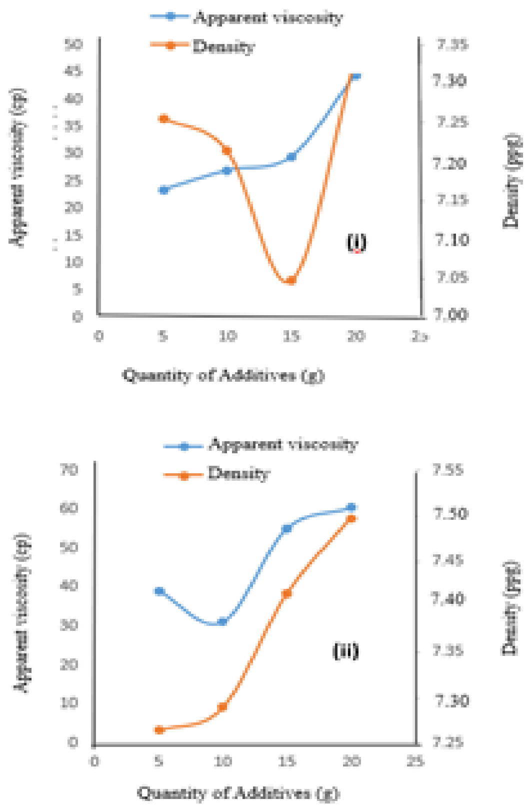

Figure 5b (i) Plot of apparent viscosity and mud density vs additives concentration of OPFW-A and (ii) Plot of apparent viscosity and mud density vs additives concentration of OPFW-B

Discussion on Filtration loss

As the amounts of additives increase, mud cake thickness also increases and thus lowers the filtration loss. The filtration loss obtained is consistent with previous studies (Agwu *et al.*, 2014; Anawe *et al*., 2014; Okon *et al*., 2014; Agwu *et al.*, 2018), while the trend obtained is different from Izuwa *et al*. (2019) trend. This may be due to the use of different species of agro-waste materials. Sawdust and OPFW performances as filter loss control agents are comparable to the required API standard in the case of high viscosity API carboxymethyl cellulose (CMC), as seen in Table 2, only when the additives are more than 10 and 15g, respectively, in the water-based mud.

Ghazali *et al* (2014) also reported a drop in the volume of filtration loss when the quantities of the additives increased, although 20g of the additives is not desirable as it forms a thicker mud cake. The effect of the quantities of additives on filtration loss volume is similar to spurt loss. Sawdust was found to perform better in terms of spurt loss control, possibly because of its sticky nature, which can easily block pores of various diameters. Although, this attribute may also be disadvantageous as this may hinder the flow of formation fluid.

Filter cake

The variation in textural and sticky properties could be due to the varying chemical compositions of the two agro-waste materials. In drilling operations, slippery mud cake is advantageous and most desirable because sticky mud cake produces higher frictional drag on drill pipe than slippery mud cake (Okon *et al*., 2014; Agwu *et al*., 2019) and this hinders the flow of formation fluid. There was an increase in the thickness of mud cake with an increase in the amounts of all the additives irrespective of the particle sizes. It is important to state that the reverse of this observation is possible if a dynamic filtration test had been conducted. Research by Okon *et al* (2014) has also reported direct proportionality between mud cake thickness and concentration of additives. The range of thickness of sawdust mud cake in this study is lower than the range recorded by Adebayo and Chinonyere (2012). It could be inferred, therefore, that all the additives met the API standard cake thickness, ranging between 4 and 6 mm for thick mud. It could also be opined that mud cake permeability and thickness are negatively correlated but directly proportional to filtration loss. It thus follows that filter loss volume controlled by sawdust is higher than that of OPFW, possibly because of the sticky nature of its mud. The cake thickness of OPFW, which is higher than that of the sawdust is thought to be responsible for the low cake permeability of OPFW.

Apparent viscosity and density

Apparent viscosity is related to the rate of penetration and, together with density, must be given adequate consideration while formulating the mud (Adebayo and Chinonyere, 2012). According to Adebayo and Chinonyere (2012), 0.5 mm of sawdust could cause an initial increase in the density of the mud up to about 3.3% weight of the sawdust, after which the mud density would decline with increasing weight of the sawdust. The observation recorded in this study was also in line with the research of Ghazali *et al*. (2014), which reported an inverse and direct relationship of quantity of additives with mud density and apparent viscosity, respectively… Considering the relationship between density and apparent viscosity, it is expected that the optimum performance for the sawdust and oil palm fruit waste (OPFW) should be where the density and viscosity curves cross each other (Adebayo and Chinonyere, 2012).

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