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Performance Characteristics of *Parkia biglobosa* as Fluid Loss Control Agent in Aqueous Mud System

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Abstract

Recent trend in the use of biomaterials in oilfield applications involves minimum refining and purification. The effectiveness of *Parkia biglobosa* as fluid loss control additive in aqueous based mud was tested according to API standard. The effect of temperature on the formulation was determined to identify any deviation due to presence of the material in the formulation. At 8ppb concentration used, 3.6mL fluid loss and 1.1mm filter cake thickness were recorded; compared with 8mL and 0.8mm, and 5.4mL and 0.8mm of *Pleurotus* and PAC respectively. Both fluid loss and filter cake thickness increased with increase in temperature. A low-flat discontinuous gel was observed at elevated temperatures which is desirable. Other drilling fluid rheological parameters were not adversely altered by the presence of the material, even at elevated temperature conditions. The biodegradable material was found to be suitable as fluid loss agent, both in effectiveness and environmental consideration since it is biodegradable, and might reduce cost of formulation since minimum processing is required.

Keywords: *Aqueous mud; Fluid loss control; Parkia biglobosa; PAC UL.*

1. Introduction

One of the most important functions of the mud is to wall the hole with an impermeable cake [1]. This prevents formation damage and provides borehole stability. Filter cake formation is directly related to fluid loss property of the mud, and represents fluid interaction with borehole wall under prevalent temperature and pressure conditions [2]. It is usually determined under static or dynamic conditions of fluid flow [3], and API fluid loss tests [4] are static tests and are commonly used. The soft surface layers of the static cake are not found in dynamic cake since its surface is eroded due to shear stress from the hydrodynamic force of mud stream.

A lot of materials have been published on fluid loss control both in water and oil based mud formulations, and the use of natural polymers for oilfield operations can be traced back to the 1930s. Recent trend in the use of green materials involves minimization of refining and purification processes, contrary to extraction, fractionation and other chemical and physical treatments previously used [5].

The fundamental theory of static filtration has been presented [3]. For a unit volume of stable solids suspension through a substrate; x = volume of filtrate, then 1-x volumes of cake is deposited on the substrate, Q_c=volume of cake, Q_w=volume of filtrate, and h=cake thickness;

$$\frac{Q_c}{Q_w} = \frac{1-x}{x} \qquad (1)$$

$$h = \frac{1-x}{x} Q_w \qquad (2)$$

From Darcy's law; $\frac{\mathrm{dq}}{\mathrm{dt}} = \frac{\mathrm{kP}}{\mu\mathrm{h}}$ (3)

where k=permeability (darcies); P=differential pressure (atm.); μ=-viscosity of filtrate (cP); q=filtrate volume (cm^3); A=area of filtrate; t=time (sec.); and q_o=spurt loss or zero error.

Substituting and integrating;

$$Q_w^2 = \frac{2\mathrm{kP}}{\mu} * \frac{x}{1-x} t \qquad (4)$$

$$Q_w^2 = \frac{2\mathrm{kP}}{\mu} * \frac{Q_w}{Q_c} t \qquad (5)$$

$$Q_w^2 = \frac{2\mathrm{kPA}^2}{\mu} * \frac{Q_w}{Q_c} t \qquad (6)$$

For a given pressure [6];

$$Q_w - q_o = A\sqrt{(\mathrm{Ct})} \qquad (7)$$

where: $C = \frac{2\mathrm{kP}}{\mu} * \frac{Q_w}{Q_c}$ (8)

Equation (6) is the fundamental equation that governs fluid loss under static conditions. The filter cake permeability can be determined from Equation (6);

$$k = Q_w Q_c \frac{\mu}{2\mathrm{tPA}^2} \qquad (9)$$

With standard API laboratory fluid loss tests and using pressure (100psig), time (30min) and filter cake area of 7-in^2;

$$k = Q_w Q_c \mu * 1.99\mathrm{x} * 10^{-5}\ \mathrm{md} \qquad (10)$$

In the wellsite, the filter cake is measured manually and Eq. (6) takes the form;

$$k = \frac{Q_w \mathrm{h}\mu}{2\mathrm{tPA}} \qquad (11)$$

and, with h given in millimeters;

$$k = Q_w \mathrm{h}\mu * 8.95 * 10^{-3}\ \mathrm{md} \qquad (12)$$

Nonetheless, the mechanism of fluid loss control by the use of say bentonite, which lay platelets like packs of cards on the wellbore wall to control fluid loss, is different from that of biomaterials such as polymers that bridge on the flow channels due to their deformable cells [7]. Organic materials impart filter cake due to the ability of their hydrolyzed cells to deform, and due to small size that fit into and tend to plug the pore spaces in the formation adjacent the wellbore. However, with increase in solid concentration, fluid losses decreases and filter cake increases [3]. The impermeable layer should be flexible and thin. Ultimately, loss of the aqueous phase from the mud system into the formations due to positive differential pressure is reduced. Filter cake thickness in the range of 1/32 (0.8mm) to 2/32 (1.6mm) of an inch would be desirable, with an upper limit of 3/32" (2.4mm) not expected to be exceeded, high-pressure high-temperature tests inclusive. Spurt loss is usually observed in all the cases. It is determined by extrapolation to time zero of the plot of fluid loss against square root of time [8]. This is because it is after the spurt loss that fluid loss becomes proportional to the square root of time.

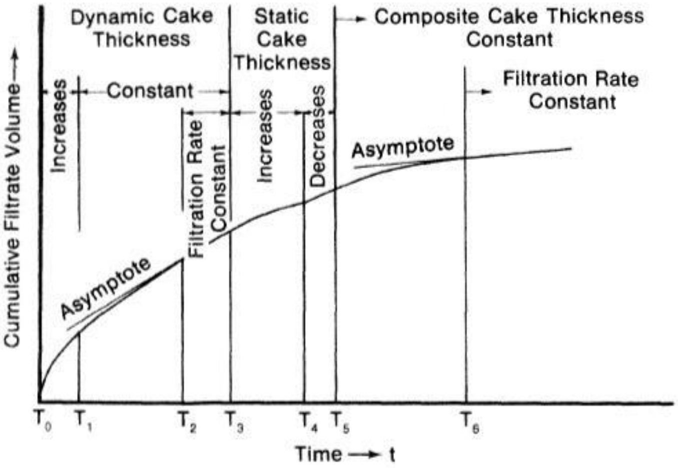

Figure1. Relative static and dynamic filtration in the wellbore [3]

For dynamic filtration, an illustration of the stages is shown (Figure 1). The filtration rate decreases and the filter cake thickness increases from time T_0 to T_1, while the filter cake thickness remains constant and filtration rate continues to decrease from time T_1 to T_2. The filtration rate is thus;

$$Q = \frac{k_1(\tau/f)^{-\nu+1}}{\mu\delta(-\nu+1)} \qquad (13)$$

where k_1=filter cake permeability at 1 psi; τ =shear stress exerted by the mud stream; f=coefficient of internal friction of the cake's surface layer; δ=thickness of the filter cake subject to erosion; and (−v+1) =a function of cake compressibility.

Experimental evaluation of performances of fluid loss additives under varying conditions is not new. Results of fluid loss rates in aqueous system using commercial agents such as carboxymethyl cellulose, polyacrylate and starch under dynamic conditions have been presented, and did not even conform to API fluid loss test rankings in terms of effectiveness [9].

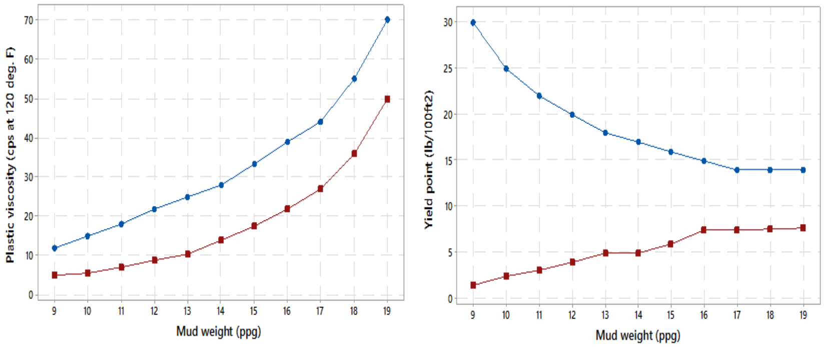

Figure 2. Acceptable ranges of PV and YP for a given mud weight [10]

Similarly, studies on effects of temperature on mud properties, which include fluid loss, are not new. The need to correct viscometric readings taken at surface temperatures to downhole circulation temperatures has been identified over six decades ago. A study on the effect of temperature on the flow properties of some water-based muds has been conducted [11]. Though recommended ranges of plastic viscosity and yield point for aqueous based muds have been presented (Figure 2), research has found that plastic viscosity and apparent viscosity decrease with an increase of temperature. However, the curves were not linear, and did not appear to follow any definite trends or patterns. Yield point data showed much more scattering. Several authors have presented their reports on the effect of temperature on mud properties [12-14]. Also, the study of fluid loss properties (plastering property) on muds has been carried out over seven decades ago [15]. Increase in fluid loss with increase in temperatures was reported.

The effect of temperature on gel strength was also presented within the same period [16]. Temperature affected gel strength, but to a certain degree depended on the mud type. Effects of temperature on biomaterial mud formulations with *Mucuna solannie* and *Brachystegia eurycoma* have been shown to be consistent with earlier research findings [17]. Also, reproducible properties of non-Newtonian liquids have been achieved by the use of polymers such as CMC and Xanthan gum [18]. Generally, rheological parameters determination is in accordance with the technique recommended and applied in previous works [19-20].

2. *Parkia biglobosa*

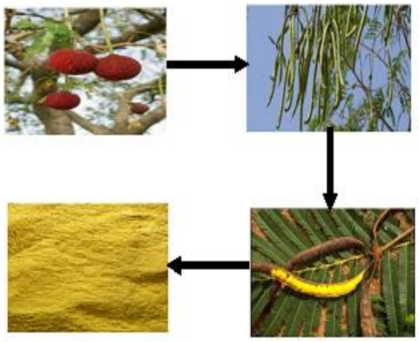

Figure 3. Parkia biglobosa pods are pink in the beginning and dark brown when fully mature

This is a perennial deciduous tree of the Fabaceae family found in South-Eastern part of Nigeria in West Africa and other African countries. The pods are 30-40 centimeters long on average, and can contain up to 25 seeds. The leaves are alternate and bipinately compound, about 30-40 centimeters long and bears up to 17 pairs of pinna. Also, the fluorescence is on drooping peduncle, biglobose and showy in red colour like an electric bulb (Figure 3). The seeds are embedded in yellowish pulp, with crude fibre and carbohydrate. The proximate analysis, mineral composition, physico-chemical analysis, reproductive biology, economic potential and taxonomy have been shown in detail in previous studies [21-25].

2.1. Summary of *Parkia biglobosa* fruit pulp characterization

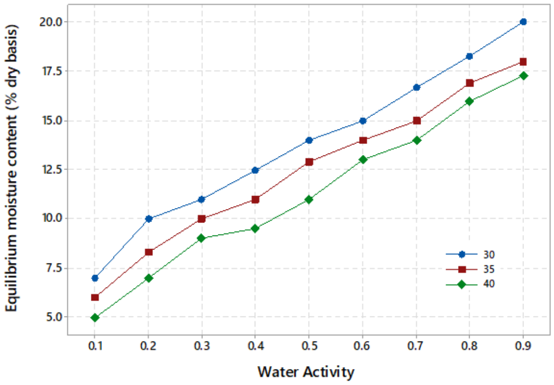

Fig. 4. Adsorption moisture sorption isotherms of *Parkia biglobosa* flour at 30, 35 and 40°C [27]

Literature reveals that it has a proximate composition of 30.0% protein, 15.0% fat, 4.0% crude fiber, 2.0% ash and 49.0% carbohydrate [26]. Also, the pulp contains more carbohydrates than the seeds, but less crude fiber. It has a hydrogen ion concentration (pH) of 5.22. It is the insoluble dietary fiber from the crude fiber that is essential for fluid loss control. Strong associative forces in the starch granules known to be responsible for viscosity stability have been reported· The adsorption moisture sorption isotherms at 30, 35 and 40°C have also been presented (Figure 4) [27]. Most biological products follow the sigmoid curve.

They are known to be rich in flavonols, hence, the ability to act as anticancer factors, anti-inflammatory agents, antioxidants, and regulate different cellular signalling pathways. Their chemical structure and representations are shown (Figure 5; Figure 6). Similarly, the solubility and swelling patterns of *Parkia biglobosa* and *Zea mays* starches compare favourably (Figure 7; Figure 8). The photomicrograph is shown (Figure 9).

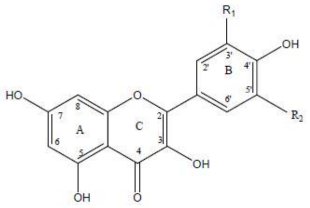

Figure 5. Chemical structure of flavonols [28]

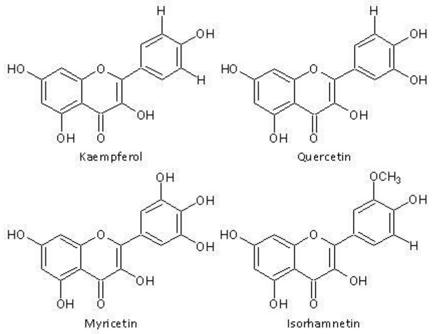

Figure 6. Flavonols represented by glycosides [28]

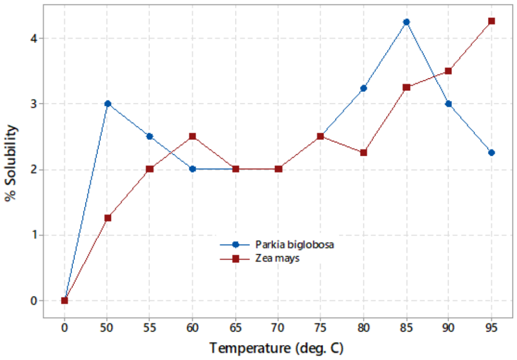

Figure 7. Percent solubility pattern of *Parkia biglobosa* and *Zea mays* starches [29]

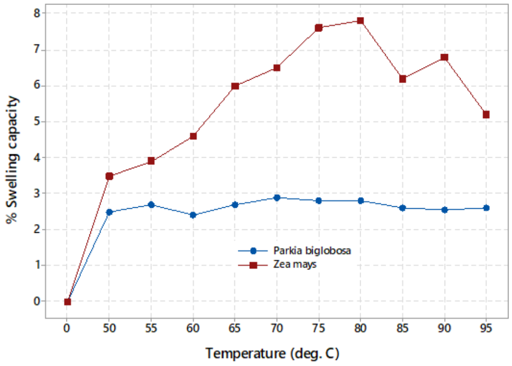

Figure 8. Percent swelling pattern of *Parkia biglobosa* and *Zea mays* starches [29]

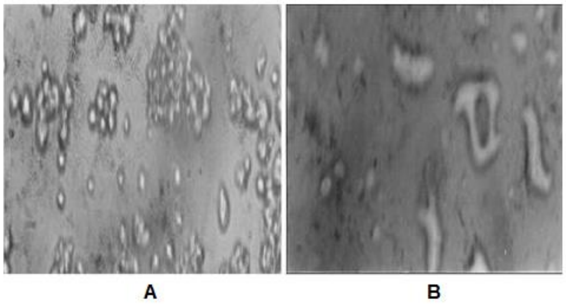

Figure 9. Photomicrograph of *Zea mays* (A) and *Parkia biglobosa* (B) starches [29]

2.2. PAC UL

PAC UL is a cream coloured low viscosity polymer. It is a free flowing powder with specific gravity in the range of 1.5-1.8 and pH of 6.5-8.0. It is used as fluid loss control additive in salt water, KCl, seawater and fresh water muds. It is environmentally acceptable and resists bacterial attack; hence, biocides might not be necessary when used in a formulation. Its temperature limit of application is 250°F.

3. Materials and method

Parkia biglobosa fruit pods were plucked from a tree in Abia State, Nigeria during the March/April fruiting season of 2019. The fruit pods (10kg) were sorted and cleaned of extraneous materials and manually split. The yellow pulps and the seeds were removed from the hulls. It was sun dried at 29 +/- 1.5°C for 4 days and pounded with a pestle in a mortar. The pulps were separated and milled in a hammer mill (Model RLA 201 – 800014, UK) and the powder was sieved with BS sieve 200mm (0.15mm aperture) to fine sized particles for quality assurance. The processed flour was packed in high density polyethylene (HDPE, 0.77mm thickness) bags, heat sealed with a sealing machine. A relative humidity of 75% was reported. It was stored in a refrigerator ready for use when required in the preserved unrefined form [5]. The American Petroleum Institute recommended test procedures for oil and gas well aqueous based drilling fluids were used. The mud formulation is presented in Table 1. Two other mud formulations with *Pleurotus* and *PAC UL* as fluid loss control agents were used as control samples. *Mucuna solannie* and *Brachystegia eurycoma* have been used in mud formulations where they exhibited predictable characteristics [30].

Table 1 Raw materials used for the formulation of drilling mud sample

Raw material	Quantity	Function(s)
Water	233.35	Base fluid
Potassium chloride	20	Inhibitor
Caustic soda	0.25	pH control
Mucuna solannie	6	Viscosifier
Brachystegia eurycoma	6	Mild Viscosifier
Parkia biglobosa	8	Fluid loss agent
XCD polymer	1	Rheology
Barite	75.4	Weighing agent

4. Results and discussion

4.1 Results

Presented are the observations in the fluid loss test performed according to American Petroleum Institute (API) recommended procedures. Figure 10 and Figure 11 show variations of fluid losses and filter cake thicknesses with additive concentration and temperature effect on rheological properties, respectively.

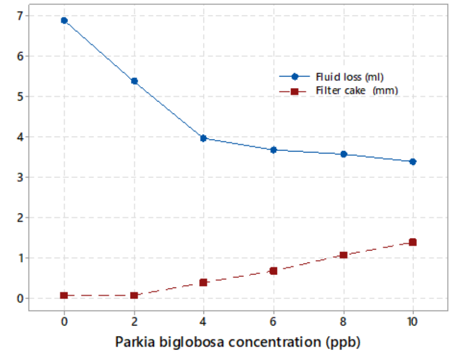

Figure 10. Fluid loss and filter cake thickness variation with concentration

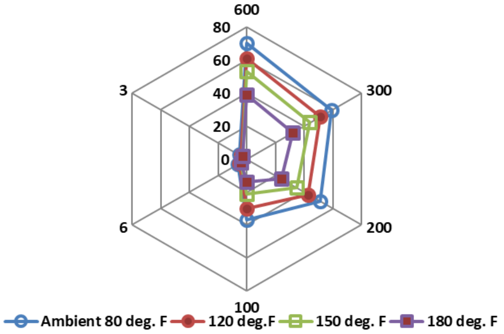

Figure 11. Effect of temperature on rheological properties at 8ppb concentration

Table 2 presents the observed effects of temperature on the fluids rheological parameters, particularly the effect on the gel strength in the presence of *Parkia biglobosa.* Similarly, the type of gel and the effect of time on the fluid loss are presented in Figure 12 and Figure 13 respectively. Figure 13 highlights the effect of temperature on the spurt loss.

Table 2. Effect of temperature on other rheological parameters at 8ppb concentration

Parameter	Ambient 80°F	120°F	150°F	180°F
Fluid loss (mL)	3.6	3.9	4.2	4.3
Filter cake (mm)	1.1	1.2	1.21	1.4
10sec./10min. gel strength (lb/100ft^2)	5/6	4/5	4/4	3/4
YP (lb/100ft^2)	4	3	2	2
PV (cP)	11	10	9	7

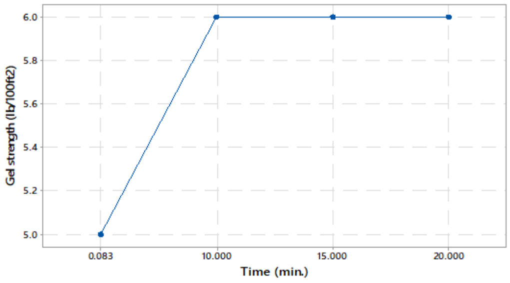

Figure 12. Gel strength characteristics at 80°F (low-flat gel)

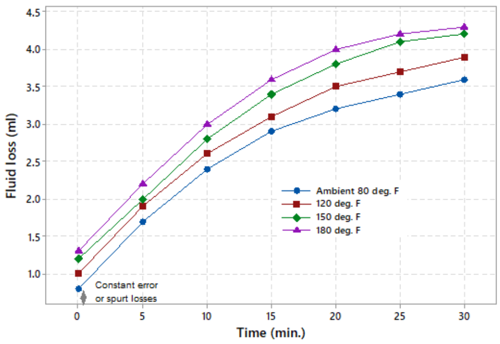

Figure 13. Relation of fluid loss to time

A summary of the comparison of the performance of the *Parkia biglobosa* additive in the fluid loss experiment with other additives used to prepare muds in the same quantity is shown as Figure 14.

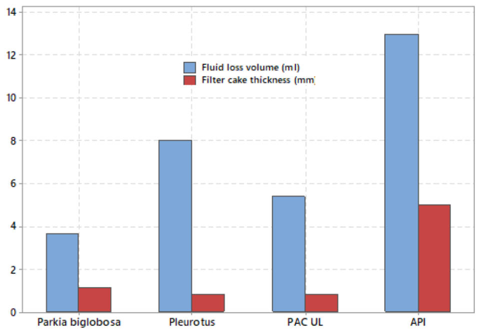

Figure 14. Fluid loss and filter cake values at 80°F mud weighted with barite

4.2. Discussion

The density of the weighted mud was 9.4ppg. As the additive concentration increased, fluid losses decreased and filter cake thickness increased (Figure 10) [3]. The rheological properties increased with decrease in temperature (Figure 11). The 10 sec. gel strengths are within the range recommended by API standard, whereas the YP and PV values fall below the range (Table 2). However, the YP and PV values are acceptable for the measured mud weight (Figure 1). The yield point presented in Table 2 decreased with temperature, though the estimated values could vary, and depends on the method of calculation applied [19]. It showed that *Parkia biglobosa* is not expected to appreciably alter the expected yield point values of the water-based mud formulation from the green material. A low flat gel was also observed (Figure 12). Spurt loss is also temperature dependent (Figure 13). The effect of temperature on the fluid loss is due to the effect on filtrate viscosity. At 8ppb concentration used, 3.6ml fluid loss and 1.1mm filter cake thickness were recorded; compared with 8ml and 0.8mm, and 5.4ml and 0.8mm of *Pleurotus* and PAC respectively. Both fluid loss and filter cake thickness increased with increase in temperature (Figure 14). The material is biodegradable and therefore environmentally friendly, though biocide might be required to retard bacterial activity.

5. Conclusion and recommendation

The fluid loss and filter cake values are within the recommended API static test values. The fluid loss control capacity of *Parkia biglobosa* might be attributed to the insoluble dietry fiber [26] and starch contents [29] that plugged the pore spaces and created an external bridge. The mud exhibited similar trends in fluid loss property with increase in fluid loss with temperature, and the use of biomaterials in mud formulations is a recent trend [5, 31-32]. High temperature gelation was not observed, since low-flat or discontinuous gelling was only obtained even at elevated temperature conditions (Table 2; Figure 12). These are gels that do not appreciably alter with time. Pumping of the mud might not be difficult if drilling is interrupted. The pH of 5.22 would inhibit microbial activities to some extent in any mud formulation.

Recommended treatment for *Parkia biglobosa* is from 6 to 12ppb, with an expected optimum concentration of 10ppb, since increase in temperature increases fluid loss. The recommended concentration of *Parkia biglobosa* is 10ppb, so that the API recommended filter cake thickness will not be exceeded. However, the effect of the fluid loss additive on the aged mud was not considered. It is recommended that further test be carried out on aging mud at lower concentrations.

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