STATISTICAL INVESTIGATION OF LOCALLY SOURCED OILFIELD CHEMICALS FOR DRILLING FLUID DESIGN

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Abstract - Over the year, imported polymers have been in use to modify rheological properties and reduce fluid loss in drilling fluid performance hence, these imported polymers tend to make the cost of drilling fluid design significantly more expensive, and this imperatively affects the cost of the drilling operation generally. Experimental studies were conducted on locally sourced polymers such as Brachystegia eurycoma (achi), Detarium microcarpum (ofor) to ascertain its ability to enhance viscosity and minimize fluid loss within the temperature regimes of 80-150degree Fahrenheit. The rheological and fluid loss properties of the local polymers were compared with the imported polymers, Pac-R (polyanionic cellulose regular, and Pac-L. The results gotten from the experiments showed that the local polymers are good candidates for the rheological modifiers and fluid loss reducers at investigated temperatures. Furthermore, investigation statistical analysis was carried out and the results indicate that Detarium microcarpum can be used as a replacement for PAC R. The results from ANOVA showed that there was no significant difference between detarium microcarpum and PAC R. No doubt, results have shown that locally sourced polymers could be substitute to imported polymers.

Keywords: Brachystegia eurycoma, Detarium microcarpum, polymer, fluid loss, viscosity Drilling fluid technology has always been in constant development, and this is due to certain factors which include, the speedy increase in needs due to more crucial conditions such as high temperatures and high pressures of the well, etc. The convolution of problems encountered during drilling operations has brought about constant research and development of new techniques and additives for the formulation of appropriate drilling fluids'. The performance of a drilling fluid is a result of the quality of the fluid, and this plays a very vital role in the success of the entire drilling operation thus, an improper drilling fluid design will have a negative economic impact on the cost of drilling the well [1,,2]. To evaluate the efficiency of any drilling fluid, in terms of cutting removal, certain measurable parameters are required, such as the drilling fluid viscosity, flow rate, pipe rotation, slip velocity, and cutting transport efficiency[3]. As the drilling fluid is being pumped downhole during the drilling process, contaminants could greatly change the properties of the fluid downhole.

OVERVIEW OF DRILLING FLUID

Drilling is the process whereby a hole is bored into the earth's surface with the use of a drill bit, to generate a well for the production of hydrocarbon. It involves the penetration of the earth's crust to several thousand feet where the hydrocarbon is accumulated in the reservoir using a rotary drilling process. In the oil and gas industry, these drilling fluids are needed to enhance drilling operations and it executes several functions in the drilling operation, thereby drilling fluid is considered one of the key factors in the success of a drilling operation. Drilling fluid is a mixture of chemical additives, water or oil, and clay, pumped down the wellbore from the surface, to cool and lubricate the bit, control formation pressures, remove drilled cuttings from the wellbore to the surface, and generally help increase the drilling efficiency. A qualitatively formulated drilling fluid is required to avoid drilled cuttings from getting accumulated in the wellbore annulus and to defray stuck pipe situations from occurring. Poor hole cleaning and inefficient cutting transport may lead to other unwanted drilling problems such as excessive equivalent circulating density ECD, high torque and drag, lost circulation, and formation fracture, all of these could lead to an increase in non-productive time and drilling cost of the well The functions of drilling fluid which is crucial to drilling operations[4] which include: transport drilled cuttings to the surface; control subsurface pressure.; support the walls of the wellbore.; cool and lubricate the drill bit and drill string and soften the earth, to allow easier penetration with the bit.

However, in drilling operations, because cuttings and carvings are heavier than the drilling fluid, they tend to fall toward the bottom of the wellbore while they are being lifted by the drilling fluid during the drilling and circulating operations. The rate at which these particles fall through the flowing fluid depends primarily on the density and viscosity of the fluid, the size, shape, and density of the particles. The first objective in planning a mud program is selecting a mud that will minimize the amount of lost time in drilling operations. Before designing and using a drilling fluid, the complexity of the well being drilled, subsurface pressures, temperatures, and local experiences should be put into consideration. Generally, two or three kinds of water-based drilling muds are used bentonite drilling mud, polymer drilling mud without clays that diminish shale formation hydration, and a drill-in fluid that prevents permeability damage as well as possesses inhibitory properties depending on the borehole's depth and formations drilled at the time borehole drilling. The main ingredient of bentonite drilling mud is bentonite which acts as a structural building component[4]. However, in clay-free mud the, structure and viscosity is built by polymer XCD, high viscosity, plant-derived organic polymers ,or their mixtures[5]. Depending on the well design and other factors to be considered before selecting a drilling fluid, there is a variety of additives that can be used to design the drilling fluid properties, which includes alkalinity control, lubricants, shale inhibitors, weighing agents, viscosifiers, lost circulation additives, etc. With the required additives, the drilling fluid is suitably formulated for the given geological formations. Additives are available to enhance the desired properties of the drilling fluid, for maximum performance of the fluid to achieve a successful drilling operation.

Brachystegia Eurycoma (Achi)

In Nigeria and some other parts of the world, brachystegia Eurycoma (achi) as shown Figure 1 are generally used as soup thickeners. Brachystegia eurycoma, popularly known as achi in the Igbo language in Nigeria is a leguminous plant, belonging to the family caesalpiniceae, phylum spermatophyte, and order Fabaceae. Brachystegia eurycoma (achi) grows mainly along the river bank or swamps in western and eastern Nigeria and western Cameroon. It also grows best on a fertile mixture of top soil and river sand with a watering interval of up to 3 days[5]. It is propagated by seed. Brachystegia eurycoma is known by various tribal names in Nigeria. In Edo state, it is called (Okunen), in Efik, it is called (Okung), in Ejagham it is called (Etare), in Esan, it is called (Eku), in Igbo it is called (Achi), in Igbo ukwuani, it is called (Onyan),. Brachystegia eurycoma powder is a gotten by grinding the seed into fine powder form. Brachystegia eurycoma (achi) is generally known as a thickener, which are materials that can raise the viscosity of a fluid without affecting its other qualities. These fruit seed powder form viscous dispersions in liquid, also known as hydrocolloids. Hydrocolloids are colloid systems, made up of particles that form hydrophilic polymers when dispersed in a liquid

Figure 1: Brachystegia eurycoma (Achi Seed)

Detarium Microcarpum (Ofor)

Detarium microcarpum (ofor) tree is widespread and common across tropical West Africa. Detarium microcarpum, popularly known as ofor in Igbo language is generally used as thickeners in soups. Detarium microcarpum as shown in Figure 2 is a leguminous plant and it also belongs to family caesalpiniceae, phylum spermatophyte and order fabaccae. Detarium microcarpum tree is considered a very important specie of tree in the tropical region of West Africa. It is propagated by seed. Detarium microcarpum is known by various tribal names in Nigeria. In igbo, it is known as (ofor), in Yoruba, it is called (ogbogbo), and in Hausa it is called (taura). Just like brachystegia eurycoma, detarium microcarpum is also known as a thickener, which is a material that can raise the viscosity of a liquid without affecting its other qualities. The fruit powder also forms viscous dispersions in liquid, also known as hydrocolloids.

Figure 2: Detarium Microcarpum (Ofor Seed)

Availability of Brachystegia Eurycoma (Achi) and Detarium Microcarpum (Ofor) in Nigeria

Over the years, companies involved in drilling fluid designs and production, for drilling operations in Nigeria have imported most polymeric additives, which has an adverse effect on the cost of drilling the well, and has not been of economic advantage. Nigeria is replete with natural resources in various forms, thus, researches to find how these raw materials can be utilized or how to find suitable substitutes which can be developed and sustained for research and technology advancements of Nigeria is very expedient[6]. Nigeria is the world largest producer of brachystegia eurycoma and detarium microcarpum. These seeds are largely found in the south eastern parts of Nigeria.

The objectives of this study are to; evaluating the rheological and fluid loss properties of water-based mud designed with brachystegia Eurycoma and detarium microcarpum under temperatures of (80 – 150 ^{0}F) and develop statistical models with experimental data.

Project Activity

The practical was conducted with dry Brachystegia eurycoma and detarium microcarpum seeds. The Imported polymers, (polyanionic cellulose regular, and pac-L) were provided by an oil company. The different drilling fluids were formulated with the same concentration of the local and imported polymers, after which, the rheological tests were conducted on the different mixtures of drilling fluids at different temperatures. The results of the properties of the drilling fluid samples that were formulated with local and imported polymers were then analyzed systematically and further compared to each other. The effect of the local polymers on the fluid was further evaluated.

Materials and Equipment.

The materials and equipment used for the practical are shown in Tables 3.1 and 3.2 respectively.

Table 1. List of Materials Used.

Items Materials Functions

Item	Equipment/Apparatus	Type/Model	Function
1	Hamilton Beach Mixer	Model 7000 	Constant Speed Mixer provides variable speed mixing from 100 to 21,000 no-load RPM with two preset constant speeds of 4,000 and 12,000 no-load RPM
3	Viscometer	Chandler model 3530 	Used to measure the viscosity and gel strength of cement slurry and drilling fluid.
4	API Filter Press	Ofite	Used to determine fluid loss and filter cake

			
5	Drying Oven	.Ofite 	To remove moisture content from the samples used

Materials

Freshwater, Universal solvent, Bentonite Binder/Viscosifier, Brachystegia eurycoma(achi), Viscosifier Detariuem microcarpum (ofor) Viscosifier, Pac-R Viscosifier and Pac-L Viscosifier

Preparation of Drilling Fluid.

Dry samples of the two additives were used at different concentrations (0.1% and 0.5%) were prepared and used for the experiment. The dry samples were blended separately into fine powder form. After blending, 20grams of detarium microcarpum (ofor), and 20grams of Brachystegia eurycoma (achi) respectively, were further dried in the drying oven for one hour, at a temperature of 105˚C, to remove its moisture content. After the drying process, the quantities were reduced to 18.9 grams and 17.59 grams, respectively, and this is because the moisture present in the samples was dried up in the drying oven. The various samples were weighed with the aid of an electronic balance before being added to the mixing fluid. Hamilton beach mixer OFITE model 9B 5spindle, was used to obtain a very homogenous mixture of the fluid. The Hamilton beach mixer was turned on, and the water was measured with the measuring cylinder, bentonite was then stirred in the mixer, to completely disperse them before the samples were added. This was done in separate mud cups. After the dry samples were added to the respective mud mixtures, the mixture was left in the mixer to properly mix for 60 seconds. The dry materials and the water temperature were kept at 80˚F before the mixing started. They were used to achieve the drilling mud preparations. The bentonite served as a control in the different mud sample designs. The various drilling fluids formulated were further subjected to rheological tests, fluid loss tests, pH tests, and Gel strength.

Table 3: Drilling Fluid Design for Control

Additives	Concentration
Bentonite	22.5
Freshwater	327.5

Table 4: Drilling Fluid Design for 0.1%

Additives	Concentration
Freshwater	327.15
Bentonite	22.5
Brachystegia eurycoma (achi)/ Detrarium microcarpum (ofor)/ Pac-R/ Pac-L	**0.35**

Table 5:Drilling Fluid Design for 0.5%

Additives	Concentration
Freshwater	327.15
Bentonite	22.5
Brachystegia eurycoma (achi)/ Detrarium microcarpum (ofor)/ Pac-R/ Pac-L	**1.75**

Rheological Test

After the various drilling fluids were prepared using the various samples, each of the samples was transferred into the viscometer cup independently and exposed to shear in a model 800-8speed viscometer. The torque response to each rotational speed gotten from the viscometer at 600RPM, 300RPM, 200RPM, 100RPM, 6RPM, and 3RPM, were recorded. At each of these rotational speeds, the readings of the revolution per minute (RPM) were taken when the rotation speed was stabilized. At temperatures above 80˚F, the drilling fluids were poured into the thermo-cup, to increase its temperature, and the thermos-cup was installed on the viscometer, at the rotational speed of 150rpm for 15 minutes, to obtain test temperatures of 120˚F to 150˚F. At each of the required temperatures, the drilling fluid was subjected to rheological tests and at each rotation speed, the dial readings were recorded when the rotation speed was stabilized. The rheological values obtained from the viscometer and the various calculations from the test results are shown below. The measurements and calculations were done using the American Petroleum Institute specifications. The readings obtained from the viscometer were further converted to oil field units, to get values for shear rate and shear stress, using equations 3.1 and 3.2 respectively.

Calculations for shear rate:

Shear rate (Sec^{-1}) =1.7023 × RPM, N (1)

Calculations for shear stress:

Shear stress (lb/100ft^2)= 1.065× 1˚Faan (2)

Calculation of Plastic viscosity (PV):

The plastic viscosity (PV) of the drilling muds was calculated using equation (3.3.)

PV (cp) = (Θ_{600} - Θ_{300}) (3)

Where Θ= dial reading.

The calculation for Yield point:

The yield point for the drilling fluid was calculated using equation (4)

YP (lb/100ft^2) = (Θ_{300} - PV) (4)

The gel strength for 10 seconds was gotten from the viscometer 10 seconds after the drilling muds had been left static, and the gel strength for 10 minutes was gotten 10 minutes after the drilling muds had been left static. This is by the standard American Petroleum Institute procedure (API Rp 13B-1/ISO 10414-1, 2016).

API Fluid Loss Test

The fluid loss tests of the various drilling muds were carried out using the multiple API filter press following API standards. The various drilling fluids were poured into different API filter press cells, and all were covered properly. 250ml glass cylinders were rightly placed under each of the cells, to get the fluids lost during the test. Carbon dioxide (CO_2) gas was used to apply a pressure of 100psi on top of each of the cells. The test started when the outlet was opened for the Carbon dioxide gas to exert pressure on the cells. The filtrates gotten were measured and recorded, and further plotted against time. It was ensured that this filtration lasted for 30 minutes.

Rheological Models Fitting

The various results gotten from the drilling muds designed from the imported additives (Poly anionic cellulose regular, and Pac-L, and the local additives (Brachystegia eurycoma and detarium microcarpum), were all subjected to the constitute models, to ascertain the rheological model parameters. Herschel Bulkley, Bingham plastics, and power law rheological models were used in fitting all the data that were gotten in the rheological tests. The Viscosifiers at the different rotational speeds were further converted to shear rate and shear stress, to fit the model equations to determine the relationship between shear rate and shear stress

Statistical Analysis

One-way only variance (ANOVA) was used to analyse the viscosity data from the rheological test with the use of statistical software. The test (ANOVA) was used because it is used to evaluate differences among groups

Cost Evaluation Analysis.

Cost evaluation analysis was used to determine the least expensive between the imported polymers (PAC R and PAC L) and local polymers (Brachystegia eurycoma,achi, and detarium microcarpum, ofor,). To determine the cost of polymer required to formulate the investigated drilling fluid design as presented in Table 3 and 4, the laboratory units of the polymers are converted to the oil field units with the relationship.

RESULTS AND DISCUSSION

The results obtained from the formulation of the various drilling fluids of both imported polymers (Poly anionic cellulose regular and Pac-L), and the two local polymers (Brachystegia eurycoma and detarium microcarpum) were presented. The analysis towards determining the effects of the imported polymers and the local polymers on the rheological properties of the drilling fluid; fluid loss, were recorded and discussed. Cost analysis and evaluation were done and the results were recorded, to ascertain the economic advantage of the local polymers (Brachystegia eurycoma, and detarium microcarpum) as viscosifiers in the drilling fluid compared to the cost of using the imported polymers (Poly anionic cellulose regular, and Pac-L).

Rheological Properties of Drilling Fluids Formulated with Local Polymers (Brachystegia Eurycoma and Detarium Microcarpum) and Imported Polymers (PAC R and Pac L)

The rheological properties of the drilling fluids formulated with the local polymers (Brachystegia eurycoma and detarium microcarpum) and the imported polymers (PAC R and PAC L) were gotten with the use of viscometer as shown in Tables 6 to 14. The experiment showed that the viscosity of the drilling fluids formulated with the imported polymers and local polymers was affected by the speed of rotation and temperature for both drilling fluids of 0.1% and 0.5% concentrations, within the investigated temperatures (80-150degree Fahrenheit), therefore the dial readings from the rheometer increased with increase in temperature. The results obtained from the experiment showed that the rheological properties of the local based drilling fluid polymers (Brachystegia eurycoma and detarium microcarpum) performed favorably with the imported-based drilling fluid polymers (PAC L and pac R).

Table 6: Rheological Properties of Control at Different Temperatures.

RPM (Θ)	80˚F (29˚C)	120˚F (49˚F)	150˚F (66˚F)
600	31	31	32
300	25	29	29
200	24	29	28
100	20	24	25
6	15	20	22
3	15	20	22
10sec (lb/100ft^2)	20	22	24
10mins (lb/100ft^2)	23	26	27
PV (cp)	6	2	3
YP (lb/100ft^2)	19	27	26
Filtrate loss (ml)	18	18	18
pH	8	8	8

Table 7: Rheological Properties of Brachystegia Eurycoma (achi) Based Drilling Fluid at 0.1%

RPM (Θ)	80˚F (29˚C)	120˚F (49˚C)	150˚F (66˚C)
600	28	29	30
300	27	27	29
200	25	25	29
100	25	25	29
6	23	24	29

3	23	24	28
10sec (lb/100ft^2)	26	28	31
10mins (lb/100ft^2)	31	32	33
PV (cp)	1	2	1
YP (lb/100ft^2)	26	25	28
Filtrate loss (ml)	14.8	14.8	14.8
pH	8	8	8

Table 8: Rheological Properties of Detarium Microcarpum (ofor) Based Drilling Fluid at 0.1%

RPM (Ɵ)	80˚F (29˚C)	120˚F (49˚C)	150˚F (66˚C)
600	31	35	37
300	22	27	33
200	21	27	33
100	19	27	28
6	17	22	27
3	17	21	27
10sec (lb/100ft^2)	21	23	30
10mins (lb/100ft^2)	22	27	30
PV (cp)	9	8	4
YP (lb/100ft^2)	13	19	29
Filtrate loss (ml)	19.2	19.2	19.2
pH	8	8	8

Table 9: Rheological Properties of Pac-L-Based Drilling Fluid at 0.1%

RPM (Ɵ)	80˚F (29˚C)	120˚F (49˚C)	150˚F (66˚C)
600	30	29	26
300	26	25	25
200	20	24	25
100	20	24	19
6	10	16	17
3	10	16	16
10sec (lb/100ft^2)	20	19	26
10 mins (lb/100ft^2)	35	34	36
PV (cp)	4	4	1
YP (lb/100ft^2)	22	21	24
Filtrate loss (ml)	12	12	
pH	8	8	8

Table 10: Rheological Properties of Pac-R-Based Drilling Fluid at 0.1%

RPM (Ɵ)	80˚F (29˚C)	120˚F (49˚C)	150˚F (66˚C)
600	72	57	54
300	54	50	49
200	53	41	47
100	42	38	37

6	30	32	32
3	30	32	32
10sec (lb/100ft^2)	41	41	40
10mins (lb/100ft^2)	78	58	51
PV (cp)	18	7	5
YP (lb/100ft^2)	36	43	44
Filtrate loss (ml)	8	8	8
pH	8	8	8

Table 11: Results of Rheological Properties of Detarium Microcarpum (ofor) Based Drilling Fluid at 0.5%

RPM (ϴ)	80˚F (29˚C)	120˚F (49˚C)	150˚F (66˚C)
600	187	184	127
300	171	171	113
200	165	167	112
100	155	152	110
6	95	95	54
3	81	82	40
10sec (lb/100ft^2)	60	57	34
10mins (lb/100ft^2)	57	56	34
PV (cp)	16	13	14
YP (lb/100ft^2)	155	158	99
Filtrate loss (ml)	19.6	19.6	19.6
pH	8	8	8

Table 12: Results of Rheological Properties of Pac-R-based Drilling Fluid at 0.5%

RPM (ϴ)	80˚F (29˚C)	120˚F (49˚C)	150˚F (66˚C)
600	217	190	165
300	179	155	136
200	160	140	123
100	133	114	104
6	75	68	66
3	74	67	66
10sec (lb/100ft^2)	84	73	70
10mins (lb/100ft^2)	113	112	119
PV (cp)	38	35	29
YP (lb/100ft^2)	141	120	107
Filtrate loss (ml)	6	6	6
pH	8	8	8

Table 13: Results of Rheological Properties of Pac-L-Based Drilling Fluid at 0.5%

RPM (ϴ)	80˚F (29˚C)	120˚F (49˚C)	150˚F (66˚C)
600	47	42	40
300	36	32	31
200	30	29	29
100	25	19	25
6	14	14	18

3	14	14	18
10sec (lb/100ft^2)	24	24	29
10mins (lb/100ft^2)	41	46	31
PV (cp)	11	10	9
YP (lb/100ft^2)	25	22	22
Filtrate loss (ml)	6.8	6.8	6.8
pH	8	8	8

Table 14: Results of Rheological Properties of Brachystegia Eurycoma (achi) Based Drilling Fluid at 0.5%

RPM (Θ)	80˚F (29˚C)	120˚F (49˚C)	150˚F (66˚C)
600	39	50	46
300	37	35	37
200	31	31	36
100	25	25	31
6	20	25	31
3	20	25	30
10sec (lb/100ft^2)	25	29	32
10mins (lb/100ft^2)	31	30	36
PV (cp)	2	15	9
YP (lb/100ft^2)	35	20	28
Filtrate loss (ml)	20	20	20
pH	8	8	8

Effects of Temperature on Shear Rate and Shear Stress Relationship on Imported Based Polymers (PAC L and PAC R), and Local Based Polymers (Brachystegia Eurycoma Achi and Detarium Microcarpum, Ofor) Drilling Fluids

Upon 0.1% concentration of **Pac L, Pac R**, achi and ofor respectively, the effect of temperature on was ascertained as shown in Figures 3 to 11. At The Lowest Shear Rate of 5.11/Sec, PAC R showed maximum shear stress of 34.08lb/100sqft and minimum shear stress of 31.95lb/100sqft. Brachystegia eurycoma (achi), showed a maximum shear stress of 29.82lb/100sqft, and a minimum shear stress of 24.495lb/100sqft. Detarium microcarpum, ofor, showed a maximum shear stress of 28.755lb/100sqft, and a minimum shear stress of 18.105lb/100sqft. PAC L showed a maximum shear stress of 17.04lb/100 sqft and a minimum shear stress of 10.65lb/100 sqft. At the highest shear rate of 1021.38/sec, PAC R showed a maximum shear stress of 57.51lb/100 sqft and a minimum shear stress of 76.68lb/100 sqft. Brachystegia eurycoma, achi, showed a maximum shear stress of 31.95lb/100 sqft, and a minimum shear stress of 29.82lb/100 sqft. Detarium microcarpum ofor showed a maximum shear stress of 39.405lb/100sqft and a minimum shear stress of 33.075 lb/100sqft. PAC L showed a maximum shear stress of 27.69lb/100 sqft and a minimum shear stress of 31.95lb/100 sqft. For 0.5%, at the lowest shear rate of 5.11/sec, PAC R showed a maximum shear stress of 70.291lb/sqft and a minimum shear stress of 78.810lb/100 sqft. Brachystegia eurycoma showed maximum shear stress of 31.951lb/100 sqft and minimum shear stress of 21.300lb/100 sqft. Detarium microcarpum showed a maximum shear stress of 42.611lb/sqft and a minimum shear stress of 86.265lb/100 sqft. PAC L showed a maximum shear stress of 19.271lb/100 sqft and a minimum shear stress of 14.911lb/100 sqft. At the highest shear rate of 1021.38/sec, PAC R showed a maximum shear stress of 175.725lb/100 sqft and a minimum shear stress of 231.105lb/100 sqft. Brachystegia eurycoma showed maximum shear stress of 48.991lb/100 sqft and minimum shear stress of 41.535lb/100 sqft. Detarium microcarpum showed a maximum shear stress of 135.255lb/100 sqft and a minimum shear stress of

199.155lb/100 sqft. PAC L showed a maximum shear stress of 42.611lb/100 sqft and a minimum shear stress of 50.055lb/100 sqft. This implies that there was a trend of increase and decrease of shear stress vs shear rate at different temperatures for local polymers and imported polymers. The graphs represent a linear relationship between the shear stress and the shear rate, and this implies that the drilling fluid does not flow until the shear stress has exceeded the critical values which are also known as yield point, and this gets to a point where the shear stress and the shear rate becomes proportional with temperature increase.

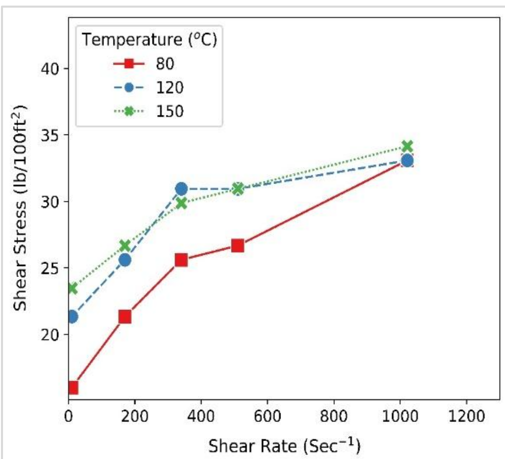

Figure 3: variation of shear stress vs shear rate of control at different temperatures

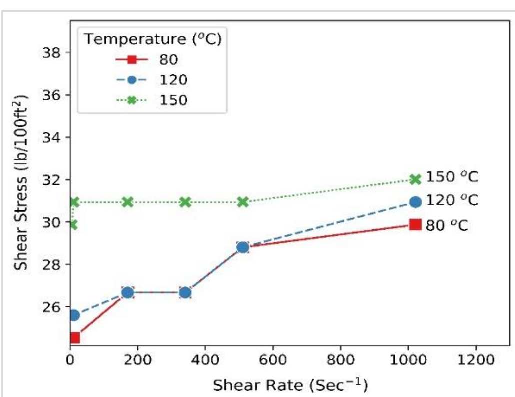

Figure 4: Stress-Strain Relationship of Brachystegia eurycoma for 0.1% at different temperatures

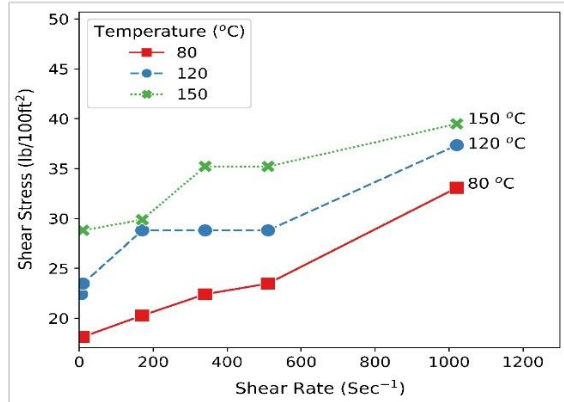

Figure 5: Stress-Strain Relationship of detarium microcarpum at 0.1% at different temperatures

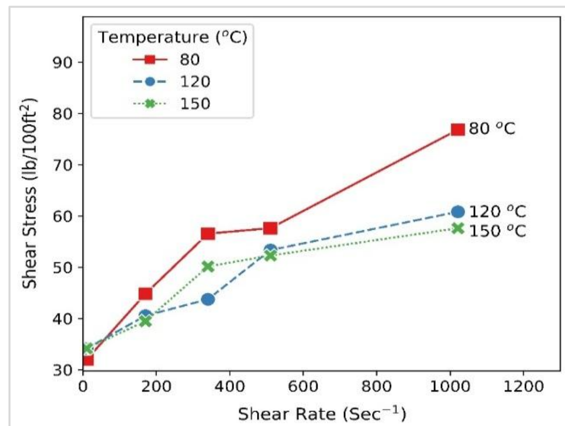

Figure 6: Stress-Strain Relationship of PAC R at 0.1% at different temperatures

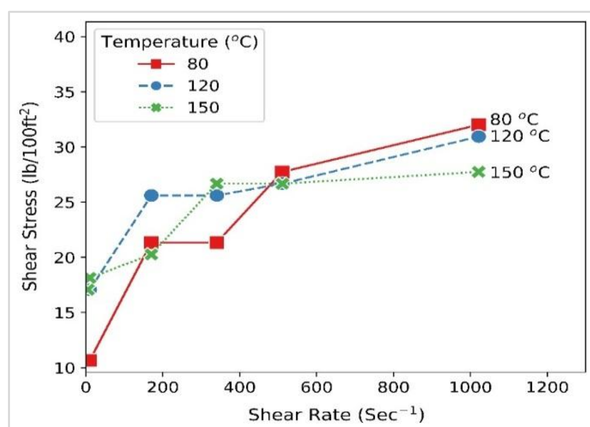

Figure 7: Stress-Strain Relationship of PAC L at 0.1% at different temperatures

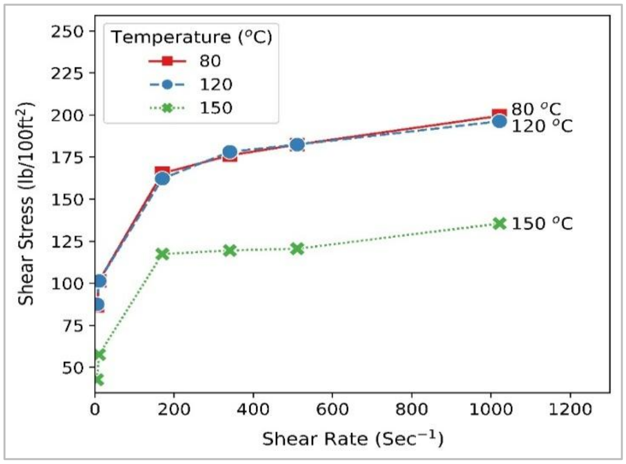

Figure 8: Stress-Strain Relationship of detarium microcarpum at 0.5% at different temperatures

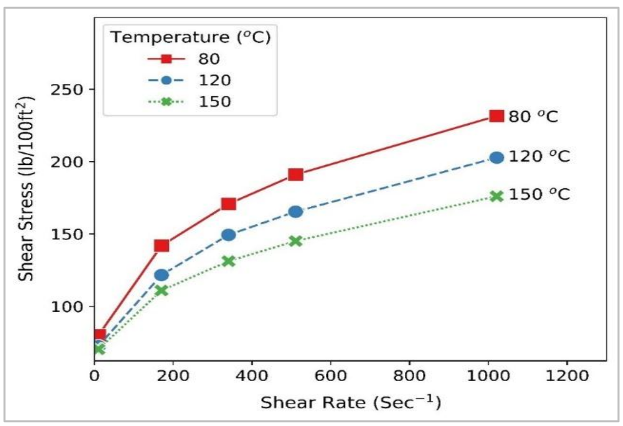

Figure 9: Stress-Strain Relationship of PAC R at 0.5% at different temperatures

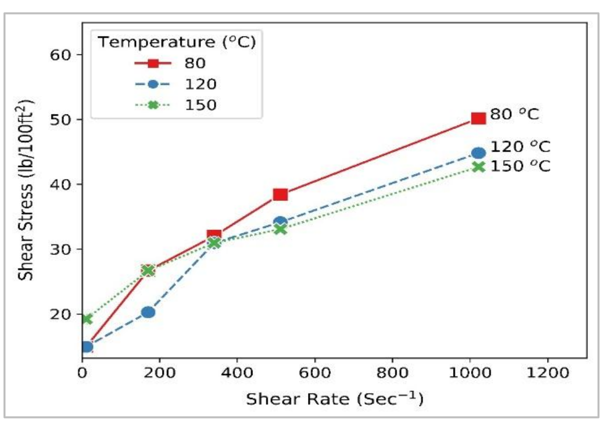

Figure 10: Stress-Strain Relationship of PAC L at 0.5% at different temperatures

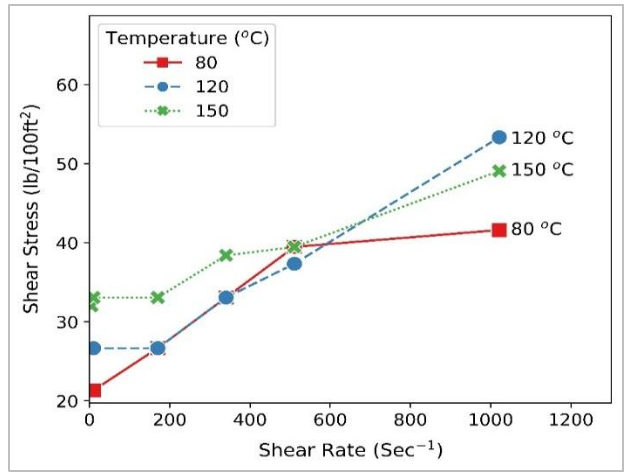

Figure 11: Stress-Strain Relationship of Brachystegia eurycoma at 0.5% at different temperatures

Effects of Temperature on Plastic Viscosity of Drilling Fluids Formulated with Imported and Loaal Polymers

At a concentration of 0.1% and 0.5%, of the various drilling fluid polymer samples, it was observed that the plastic viscosity decreased with increasing temperatures of 80 to 150 degrees Fahrenheit, as shown in Figures 12 and 13. This shows that the drilling muds with these samples will pump more rapidly as a result of the decrease in viscosity due to temperature increase because high plastic viscosity will bring rise to problems in the pumping ability to drill fluid passing through the drill bit. After all, an increment of solid particles in the drilling fluid brings about higher viscosity.

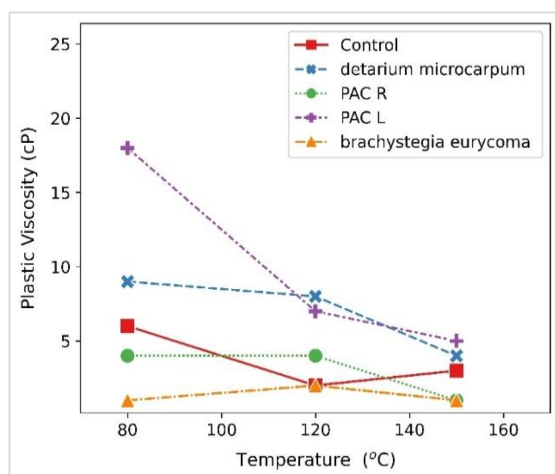

Figure 12: Plastic Viscosity as a function of different temperatures at 0.1% concentration

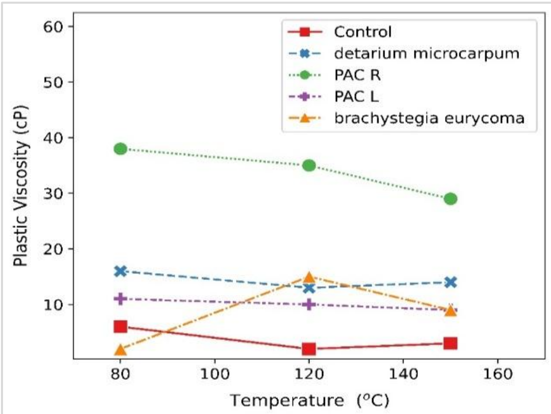

Figure 13: Plastic Viscosity as a function of different temperatures at 0.5% concentration

Effects of Temperature on Yield Point and Gel Strength of Imported and Local Polymer-Based Drilling Fluids

The yield point and gel strength of the drilling fluids were shown in Figures 14 and 17, at 0.1% and 0.5% concentrations. At 0.1%, there was a corresponding increase in yield point and gel strength with an increase in temperatures on the drilling fluids formulated with Brachystegia eurycoma and detarium microcarpum and Pac L, while the yield point and gel strength of the mid formulated with PAC R decreased with increasing temperatures. The yield point of the drilling mud can lift cuttings to the surface, there is a fluid with a higher yield point that can lift drilled cuttings better than a fluid that has a lower yield point. At 0.5%, there was a corresponding decrease in yield point with increasing temperatures. These results indicate that temperature affects the rheological properties of drilling fluid significantly.

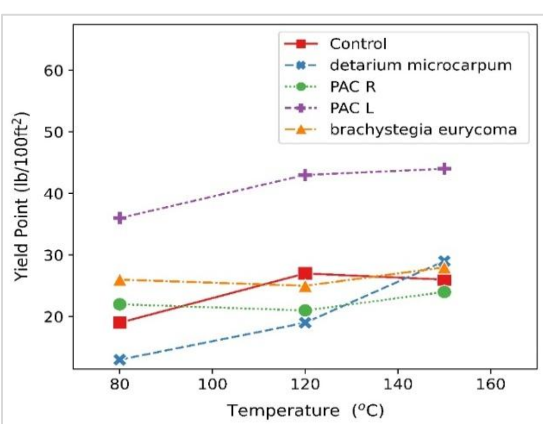

Figure 13: Yield Point as a function of different temperatures at 0.1% concentration for different polymers

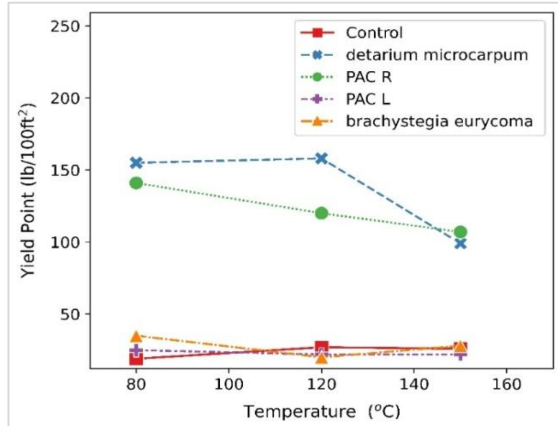

Figure 4.13: Yield Point as a function of different temperatures at 0.5% concentration for different polymers

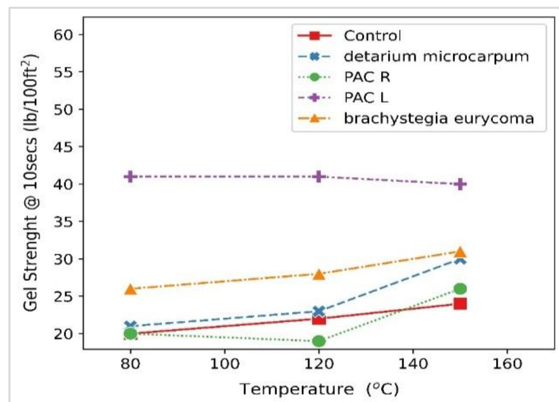

Figure 14: Gel Strength @10secs as a function of different temperatures for 0.1% concentration for different polymers

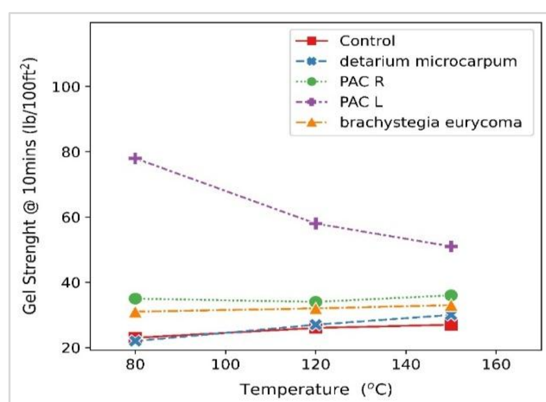

Figure 15: Gel Strength @ 10 mins as a function of different temperatures for 0.1% concentration for different polymers

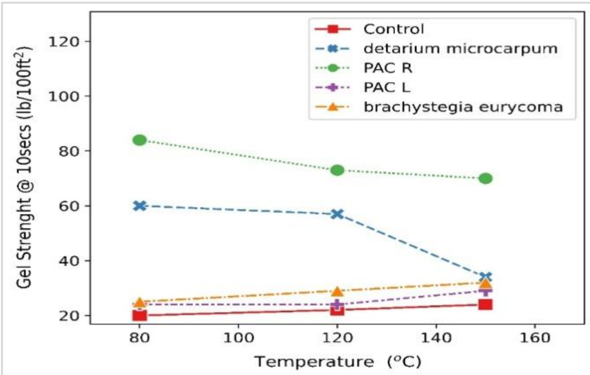

Figure 16: Gel Strength @ 10 secs as a function of different temperatures at 0.5% concentration for different polymers

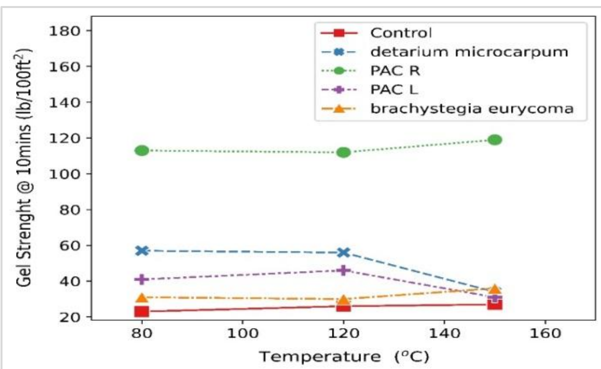

Figure 17: Gel Strength @ 10 mins as a function of different temperatures for 0.5% concentration for different polymers

Statistical Analysis

Analysis of Variance of Plastic Viscosities and Yield Point of the Imported and Local-Based Drilling Fluid Polymers

Tables 15 and 22 shows the turkey multiple comparison tests and the analysis of variance of plastic viscosities and yield point of drilling fluid for 0.1% and 0.5% respectively. For drilling fluid design for 0.1% concentration, the mean plastic viscosity for PAC R was 3.00, the mean plastic viscosity for pac L was 10.00, the mean plastic viscosity for detarium microcarpum was 7.00, the mean plastic viscosity for Brachystegia eurycoma was 1.33, and for control was 3.66. There was a significant difference between the plastic viscosities of the four polymers that were used as viscosifiers. For drilling fluid of 0.5% concentration, the mean plastic viscosity for pac R was 34.00, the mean plastic viscosity for detarium microcarpum was 14.33, the mean plastic viscosity for pac L was 10.00, the mean plastic viscosity for Brachystegia eurycoma was 8.66, and for control was 3.66. This also shows that there was a significant difference between the plastic viscosities for the four polymers. These results showed that when pac R additive was added to the drilling mud, it produced significantly higher plastic viscosity than the remaining additives. It also showed that detarium microcarpum had a relatively good plastic viscosity, which implies that it can serve as a substitute for PAC R.

Table 15: Analysis of Variance for plastic viscosity for 0.1% concentration

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	4	144.667	36.167	2.840	0.082
Error	10	127.333	12.733		
Corrected Total	14	272.000			

Computed against model Y=Mean(Y)

Table 16: Tukey multiple comparison tests for plastic viscosity for 0.1% concentration

Category	LS means	Standard error	lower bound (95%)	Upper bound (95%)	Groups
PAC L	10.000	2.060	5.410	14.590	A
detarium microcarpum	7.000	2.060	2.410	11.590	A
Control	3.667	2.060	-0.924	8.257	A
PAC R	3.000	2.060	-1.590	7.590	A
brachystegia eurycoma	1.333	2.060	-3.257	5.924	A

Values with different superscripts (a, b, c) were significantly different from each other ($p < 0.05$) and those with the same superscripts were not significantly different.

Table 17: Analysis of Variance for plastic viscosity for 0.5% concentration

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	4	1653.733	413.433	29.115	< 0.0001
Error	10	142.000	14.200		
Corrected Total	14	1795.733			

Computed against model Y=Mean(Y)

Table 18: Tukey multiple comparison tests for plastic viscosity for 0.5% concentration

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups		
PAC R	34.000	2.176	29.152	38.848	A		
detarium microcarpum	14.333	2.176	9.486	19.181		B	
PAC L	10.000	2.176	5.152	14.848		B	C
brachystegia eurycoma	8.667	2.176	3.819	13.514		B	C
Control	3.667	2.176	-1.181	8.514			C

Values with different superscripts (a, b, c) were significantly different from each other ($p < 0.05$) and those with the same superscripts were not significantly different.

Table 19: Analysis of Variance for yield point for 0.1% concentration

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	4	814.400	203.600	9.426	0.002
Error	10	216.000	21.600		
Corrected Total	14	1030.400			

Computed against model Y=Mean(Y)

Table 20: Tukey multiple comparison tests for yield point for 0.1% concentration

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups	
PAC L	41.000	2.683	35.021	46.979	A	
brachystegia eurycoma	26.333	2.683	20.355	32.312		B
Control	24.000	2.683	18.021	29.979		B
PAC R	22.333	2.683	16.355	28.312		B
detarium microcarpum	20.333	2.683	14.355	26.312		B

Values with different superscripts (a, b, c) were significantly different from each other ($p < 0.05$) and those with the same superscripts were not significantly different.

Table 21: Analysis of Variance for yield point for 0.5% concentration

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	4	40132.933	10033.233	33.965	< 0.0001
Error	10	2954.000	295.400		
Corrected Total	14	43086.933			

Computed against model Y=Mean(Y)

Table 22: Tukey multiple comparison tests for yield point 0.5% concentration

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups	
detarium microcarpum	137.333	9.923	115.223	159.443	A	
PAC R	122.667	9.923	100.557	144.777	A	
brachystegia eurycoma	27.667	9.923	5.557	49.777		B
Control	24.000	9.923	1.890	46.110		B
PAC L	23.000	9.923	0.890	45.110		B

Values with different superscripts (a, b, c) were significantly different from each other ($p < 0.05$) and those with the same superscripts were not significantly different.

Analysis of variance for gel strength of 10 seconds and 10 minutes of imported and local-based drilling fluid polymers

The results of the analysis of variance for gel strength at 0.1% and 0.5% concentration, respectively are presented in Tables 23 to 30. The mean gel strength for 10 seconds for drilling fluid design for 0.1% concentration was 40.667 for pac L, while gel strength for 10 seconds for Brachystegia eurycoma, detarium microcarpum, PAC R, and control was 28.33, 24.66, 21.66, and 22.00 respectively. This result shows that PAC L had a higher gel strength, compared to the other polymers, and there was no significant difference between the gel strength of PAC R, detarium microcarpum, and Brachystegia eurycoma. The mean gel strength for 10 minutes for drilling fluid design for 0.1% concentration was 62.33 for PAC L, while gel strength for PAC R, brachystegia eurycoma, detarium microcarpum, and control were 35.00, 32.00, 26.33, and 25.33 respectively. These results also showed that PAC L had a significantly higher gel strength, compared to the rest polymers, and there was no significant difference between the gel strengths of PAC R, Brachystegia eurycoma, and detarium microcarpum. The mean gel strength for 10 seconds for drilling fluid design of 0.5% concentration was 75.667 for PAC R, while the gel strength for 10 seconds for Brachystegia eurycoma, detarium microcarpum, PAC L, and control were 28.667, 50.33, 25.667, and 22.00. These results showed that PAC R had a significantly higher gel strength than the rest polymers, and there was a significant difference between the gel strength of PAC L, detarium microcarpum, and Brachystegia eurycoma. The mean gel strength for 10 minutes for the drilling fluid design for 0.5% concentration was 114.667 for PAC R, 49.000 for detarium microcarpum, 39.333 for PAC L, 32.333 for brachystegia eurycoma, and 25.333 for control. These results showed that PAC R had a significantly higher gel strength, compared to the other polymers.

Table 23: Analysis of Variance for gel strength @ 10sec for 0.1% concentration

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	4	739.067	184.767	19.518	0.000
Error	10	94.667	9.467		
Corrected Total	14	833.733			

Computed against model Y=Mean(Y)

Table 24: Tukey multiple comparison tests for gel strength @ 10sec for 0.1% concentration

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups	
PAC L	40.667	1.776	36.709	44.625	A	
brachystegia eurycoma	28.333	1.776	24.375	32.291		B
detarium microcarpum	24.667	1.776	20.709	28.625		B
Control	22.000	1.776	18.042	25.958		B
PAC R	21.667	1.776	17.709	25.625		B

Values with different superscripts (a, b, c) were significantly different from each other ($p < 0.05$) and those with the same superscripts were not significantly different.

Table 25: Analysis of Variance for gel strength @ 10mins for 0.1% concentration

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	4	2752.400	688.100	15.710	0.000
Error	10	438.000	43.800		
Corrected Total	14	3190.400			

Computed against model Y=Mean(Y)

Table 26: Tukey multiple comparison tests for gel strength @ 10mins at 0.1% concentration

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups	
PAC L	62.333	3.821	53.820	70.847	A	
PAC R	35.000	3.821	26.486	43.514		B
brachystegia eurycoma	32.000	3.821	23.486	40.514		B
detarium microcarpum	26.333	3.821	17.820	34.847		B
Control	25.333	3.821	16.820	33.847		B

Values with different superscripts (a, b, c) were significantly different from each other ($p < 0.05$) and those with the same superscripts were not significantly different.

Table 27: Analysis of Variance for gel strength @ 10sec for 0.5% concentration

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	4	6107.067	1526.767	27.134	< 0.0001
Error	10	562.667	56.267		
Corrected Total	14	6669.733			

Computed against model Y=Mean(Y)

Table 28: Tukey multiple comparison tests for gel strength @ 10sec for 0.5% concentration

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups		
PAC R	75.667	4.331	66.017	85.316	A		
detarium microcarpum	50.333	4.331	40.684	59.983		B	
brachystegia eurycoma	28.667	4.331	19.017	38.316			C
PAC L	25.667	4.331	16.017	35.316			C
Contro	22.000	4.331	12.350	31.650			C

Values with different superscripts (a, b, c) were significantly different from each other ($p < 0.05$) and those with the same superscripts were not significantly different.

Table 29: Analysis of Variance for gel strength @ 10mins for 0.5% concentration

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	4	15583.067	3895.767	75.990	< 0.0001
Error	10	512.667	51.267		
Corrected Total	14	16095.733			

Computed against model Y=Mean(Y)

Table 30: Tukey multiple comparison tests for gel strength @ 10mins for 0.5% concentration

Category	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups		
PAC R	114.667	4.134	105.456	123.878	A		
detarium microcarpum	49.000	4.134	39.789	58.211		B	
PAC L	39.333	4.134	30.122	48.544		B	C
brachystegia eurycoma	32.333	4.134	23.122	41.544		B	C
Control	25.333	4.134	16.122	34.544			C

Values with different superscripts (a, b, c) were significantly different from each other ($p < 0.05$) and those with the same superscripts were not significantly different.

CONCLUSION

The following listed below are the conclusions gotten in this study.

1. The local polymers (Brachystegia eurycoma ,achi,and detarium microcarpum, ofor,) used in the drilling fluid design performed significantly good as a rheological agent at various temperatures studied at 80 degree farhenheit to 150 degree farhenheit
2. Bingham plastic model gave more favorable predictions of the rheological properties of the drilling fluid
3. The drilling fluids formulated with brachystegia eurycoma, achi, had a lower fluid loss compared to the mud formulated with detarium microcarpum

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