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Improving the Rheological Properties of Water Based Mud with *Moringa oleifera* Leaves

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Authors' contributions

This work was carried out in collaboration among all authors. Author TCB designed the study, performed the statistical analysis, literature searches, wrote the protocol and wrote the first draft of the manuscript. Authors OA, AKK and OB managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

This paper aimed at improving the water-based drilling mud using *Moringa oleifera* (*M. Oleifera*) plant leaves. The rheological properties (plastic viscosity (PV), yield point (YP), and gel strength) of the mud were measured using standard procedures. The mud weight was not affected by *M. oleifera* concentration (10.03-10.63 pounds per gallon (ppg)). pH of the formulated mud decreased by 28% with increasing concentration of the M. oleifera leaves. The highest PV (33cP) was recorded by mud with 1% M. oleifera leaves at 50ºC while the least value (22cP) was given by control mud at 70ºC temperature. Highest YP (57 1b/100ft^2) was recorded by mud sample with 4% concentration of *M. oleifera* leaves while 1% gave the lowest YP value of 91b/100ft2 at 30ºC and

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49ºC respectively. Gel strength at 10 seconds showed improvement with 2% concentration of leaves by recording maximum of 5 1 b/100 ft^2 at 70ºC while the lowest gel strength was recorded by 1% leaves concentration at 49ºC. A good gel strength (30.21 b/100 ft^2) at 10 minutes was recorded by mud sample with 3% leaves of *M. oleifera* at temperature of 30ºC. The results indicated that the *M. oleifera* leaves significantly improved the rheological properties of the mud. It was also observed that the mud weight of formulated muds with *M. oleifera* leaves were not affected which leads to stability of the wellbore if the formulation is used. These great result calls for the need to use *M. oleifera* leaves to improve rheological properties of the drilling mud. An investigation of M. oleifera as fluid loss control should be done as well as need to carry out isolation and characterization of the active ingredients from *M. oleifera* leaves so as to establish the compound (s) associated with its activity in drilling mud.

Keywords: Moringa oleifera; drilling mud; rheology.

1. INTRODUCTION

Drilling mud is one of the important components of the drilling process and it forms significant part of drilling operations and should be formulated and controlled so as to achieve its functions in the well. Among the factors considered in proper fluid selection are drilling performance, expected well conditions, mud cutting disposals and safety of the personnel [1]. Some of the properties to be improved in drilling mud are rheological properties; pH, mud weight, fluid loss and thermal stability. When drilling into deeper formation, drilling mud has to endure elevated pressures and temperatures. Effect of temperature and pressure on the drilling mud rheological properties is complicated and leads to difficult challenges and mechanical concerns [2]. Rheology of the drilling mud has to be stable after aging in order for it to withstand downhole conditions. If the rheological properties decreases considerably, it means that the mud additives are not stable at the conditions down hole [3].

There are a variety of mud additives used in designing a drilling fluid system so as to meet its purpose like good density, mud rheology and fluid loss control property [4]. In the process of searching these mud properties, preservation of environment is a global concern and many organizations are advised to use nontoxic drilling mud additives. Pollution of the environment has been a serious threat while drilling wells that are complex with high temperatures which are managed by use of high performance water based mud and oil based mud [5].

Plants-based material have been reported to be used in drilling mud formulations [6], from their research on cassava concluded that cassava starch improves the rheological properties of water based mud at 4% being the optimum concentration. Another research was also done by Omotioma, et al. [7] and they found out that cashew and mango leaves extract improved rheological properties in water based mud because it showed suitable results as mud additives. Of the two plants, mango showed higher improvement than cashew nut [8]. Found out that cellulose from ground nuts shells could do better than polyanionic cellulose (PAC) when used to formulate the drilling mud. The results showed that mud density and specific gravity of the mud were higher than that of the standard mud. The results also showed that cellulose from ground nuts husk can significantly reduce fluid loss hence it can be used as fluid loss control agent. In their studies [9] compared the performance of cassava starch to polyanionic cellulose (PAC) as a fluid loss control agent and they found out that there is close similarity between cassava starch and PAC. It is therefore important to search for more bioactive materials which are plant-based because they are believed to be biodegradable and not harmful to life and can be utilized in petroleum industry. This research introduces a naturally available material (*Moringa oleifera)* which is believed to be nontoxic additive and can be used to formulate drilling mud. The need for using such material will go a long way in addressing the environmental concerns. This research aimed at improving the water-based drilling mud using *Moringa oleifera* (*M. Oleifera*) plant leaves.

2. MATERIALS AND EXPERIMENTAL PROCEDURES

2.1 Plant Material

The plant leaves were collected from Choba area in Port Harcourt, Rivers states, Nigeria. The geographical coordinates of Choba is 4.8941ºN, 6.9263ºE. Fresh green leaves were

Table 1. Water based mud formulation

Products	Formulation 1 (Standard mud)	Formulation 2 (Standard + plant)	Function
Water	318.74 mL	318.74 mL	Base fluid
Bentonite	17.50 g	17.50 g	Viscosifier & Fluid loss control
Caustic Soda	0.25 g	0.25 g	pH control
KCl	10.70 g	10.70 g	Inhibitor
Hydro PAC LV	3.00 g	3.00 g	Fluid loss control & viscosifier
Barite	68.72 g	68.72 g	Weighting agent
Plant extract	-	1%, 2%, 3% and 4%	Mud property modifier

taxonomically identified at the Department of Plant Science and Biotechnology, University of Port Harcourt.

2.2 Mud Preparation

The formulated water-based mud had the following ingredients: water as a base fluid, bentonite, barite, hydro-polyanionic cellulose (PAC) low viscosity (LV), caustic soda, potassium chloride and plant material (*Moringa Oleifera*). The samples were mixed in Hamilton mixer for 45 minutes with five minute interval after each additive.

The formulation of each mud is indicated in Table 1.

All the chemicals used were purchased from Scientific Laboratory Suppliers, U.K. They were all of analytical grade (AG).

2.3 Experimental Procedures

2.3.1 Mud weight and pH

Mud weight was measured using mud balance [10] which was measured for all the mud formulated with different concentration of *Moringa oleifera* leaves. pH meter was used to determine the change in pH due to different concentration of *M. oleifera* according to Adesina, et al.[11].

2.3.2 Rheological properties

The rheological properties of the formulated mud was measured according to the American Petroleum Institute (API) standard procedures [12]. Plastic viscosity (PV), yield point (YP) and gel strength were measure using FANN viscometer [13]. For gel strength testing, two readings were taken, gel strength at 10 seconds and gel strength after 10 minutes [14]. All the rheological properties were measured at all test temperatures (30ºC-93ºC) and at all concentrations (1% - 4%) of the plant sample.

2.3.3 Aging process

The thermal stability tests involved heating the drilling mud from ambient temperature to a testing temperature for 16 hours with roller oven and then cooling it to ambient temperature [15] before testing the drilling mud properties.

Temperatures chosen for aging were 38ºC which is believed to be subsurface temperature, 65ºC is the temperature between surface temperature and bottom hole temperature and 93ºC is the maximum permissible temperatures for water based mud to perform rheological test so as to avoid degradation of polymers [16,17]. Temperature of 49ºC was taken as standard temperature to measure rheological properties of the mud [18] after aging.

3. RESULTS AND DISCUSSION

3.1 Mud Weight and pH

The results of mud weight and pH of the formulated drilling mud is as shown in Table 2. The mud weight did not change significantly after adding different concentrations of the *M. oleifera* leaves. The pH of control mud was more basic than the pH of the test mud. This could be due to the contents in the plants which could be acidic in nature. Some of the plants are believed to be acidic in nature and that is why when there is increase in plant percentage in the mud, the mud pH was decreasing [19].

3.2 Rheological Properties

Four different temperatures (30ºC, 49ºC, 50ºC and 70ºC) and four concentrations (1%, 2%, 3% and 4%) were used to check their effect on the rheological properties of the mud. The Bingham model was used to explain the behavior of fluid which calculates the plastic viscosity and yield point as follows:

$$Plastic\ viscosity\ (PV)\ cP = \theta\ 600 - \theta 300 \qquad (i)$$

$$Yield\ point\ (YP) 1b/100ft^2 = \theta 300 - PV \qquad (ii)\ [20].$$

The gel strength readings were taken after 10 seconds and 10 minutes from the Fann viscometer.

Table 2. Mud weight and pH of the formulated mud

	Mud weight (1b/gal)	pH
0%	10.3	10.44
1%	10.03	8.6
2%	10.63	8
3%	10.6	7.45
4%	10.6	7.63

Key: b/gal: barrel per gallon

The dial reading results of the drilling mud with and without *M. oleifera* leaves are presented in Table 3.

3.2.1 Plastic viscosity

Fig. 1 shows the effect of temperature on PV of the formulated mud with different concentrations of *M. Oleifera* leaves at different temperatures. When concentration of *M. oleifera* leaves was increased, there was increase in PV while increase in temperature decreased the PV of the mud. High temperatures degrade some mud additives [21]. The same result was observed, where increased temperature, ended with reduced PV of the drilling mud which had mango and cashew extracts [22]. The PV of the control mud (mud without *M. oleifera* powder), recorded lower values of PV (41-22 cP) compared to the drilling mud with *M. oleifera* powder at higher concentrations (2-4%). Comparing the PV values of the mud with plant material at different concentrations, the mud with 4% concentration recorded the highest PV of 109cp at 30ºC while the lowest PV value was recorded by the mud with 2% which had 23cP at 70ºC. Decrease in viscosity is observed because flocculation increased. This leads to the general reduction in solid volume which allows the free movement of aggregates in the aqueous phase leading to reduction of internal friction [23].

3.2.2 Yield point

Fig. 2 shows the effect of YP with increase in temperature and concentration of *M. oleifera.* The obtained yield point showed that after addition of *M. oleifera* leaves powder, there was increase in YP when compared with control without the *M. oleifera* leaves powder. There was general decrease in the YP when the temperatures were increased which is in agreement with the trend observed by other researchers [7]. The highest YP (57 1 b/ft^2) was recorded by the sample having 4% concentration of *M. oleifera* leaves powder which could be attributed to the interaction of active additives that can lead to reduction in electrostatic forces between the additives [24]. The lowest YP (8 1 b/ft^2) was recorded by control sample at temperature of 50ºC. Comparing the temperatures, it shows that the lowest YP is recorded by mud tested at high temperature.

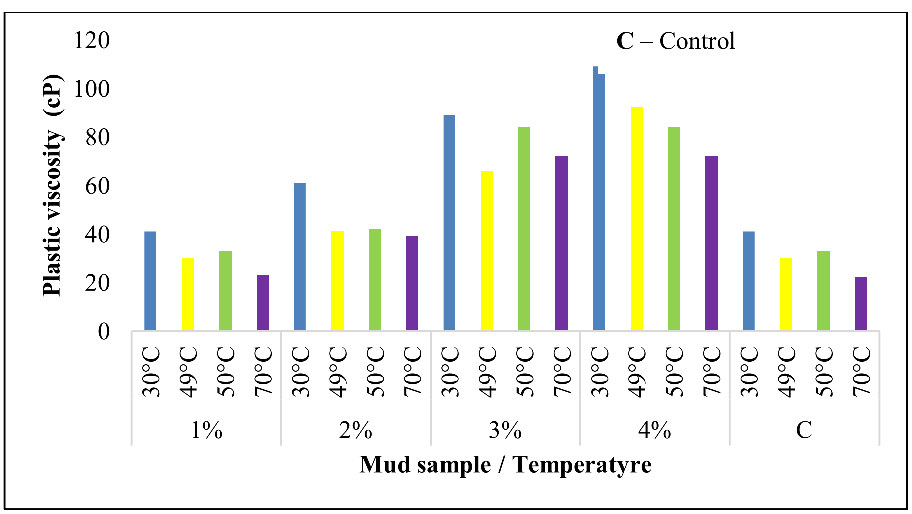

Fig. 1. Effect of temperature and concentration on PV

Table 3. Dial readings of the formulated mud with different concentrations of *M. oleifera* leaves at different temperatures

Temp/	1%				2%				3%				4%				C			
RPM	30°C	49°C	50°C	70°C	30°C	49°C	50°C	70°C	30°C	49°C	50°C	70°C	30°C	49°C	50°C	70°C	30°C	49°C	50°C	70°C
600	102	71	74	55	169	113	119	108	233	176	207	184	275	225	207	183	76	65	55	54
300	61	41	41	33	104	72	77	69	144	110	123	112	166	133	123	112	46	43	33	33
200	45	30	30	24	79	54	57	55	107	82	95	87	125	99	96	87	35	25	24	25
100	26	18	18	14	50	35	37	37	66	50	61	56	77	62	61	56	20	15	14	15
6	3	2	2	2	9	7	8	12	12	13	12	18	14	12	13	18	2	1	1	2
3	2	1	1	1	8	6	8	11	11	9	11	17	13	12	11	17	1	1	1	2

Key: C – Control (Without plant material); Rpm – Rotation per minute

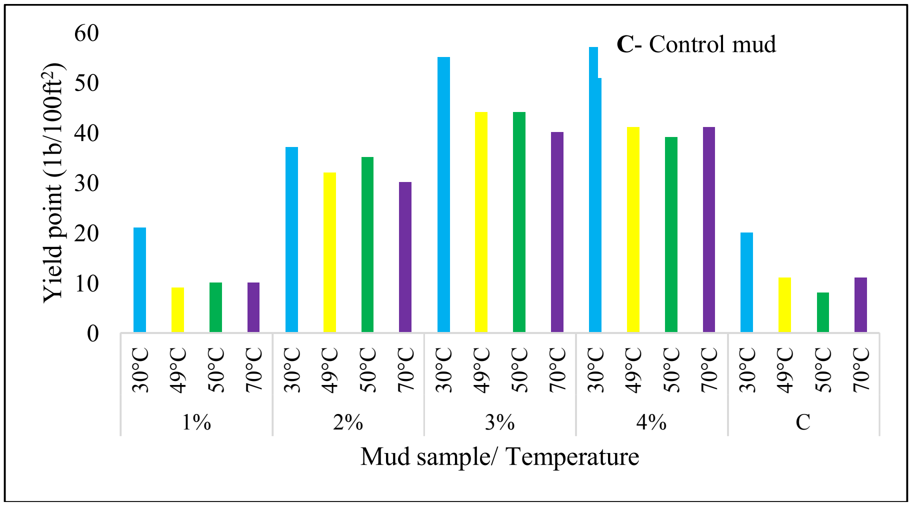

Fig. 2. Effect of temperature and concentration on YP

3.2.3 Gel strength

Fig. 3 shows the effect of temperature, concentration and time on gel strength.

Gel strength of the formulated mud with different concentration of *M. Oleifera* at different temperatures varied from 0.9 to 17.2 1b/100 ft^2 for 10 seconds gel strength and 1- 47 1b/100 ft^2 for 10 minute gel strength. Increase in temperatures decreased the gel strength significantly as it can be seen from Fig. 3.

The gel strengths showed that there was a progressive gel strength for the muds with 4% concentration of *M. Oleifera* leaves. Control mud had flat gel strength at 10 seconds. As seen in Fig. 3, 10 minute gel strength profile shows the flat gel strength where there is an increase in gel strength at the beginning of the profile and becomes steady for the samples with 2 % concentration of *M. Oleifera*. The same trend was observed by Igwilo, et al. (2016). For the muds with plants extracts, 1% showed the least of all. There was progressive gel strengths as the concentrations of the samples increased. Progressive gel strength is not desirable because it makes the circulation of the drilling mud to be hard. Similar trend of results was observed by [25] where increase in concentration of SnO_2 nanoparticles resulted in progressive gel strength.

3.3 Effect of Aging

Table 4 shows the results of the rheological properties after aging. Mud sample with 2% concentration were aged at three different temperatures (35ºC, 65ºC and 93ºC) and their

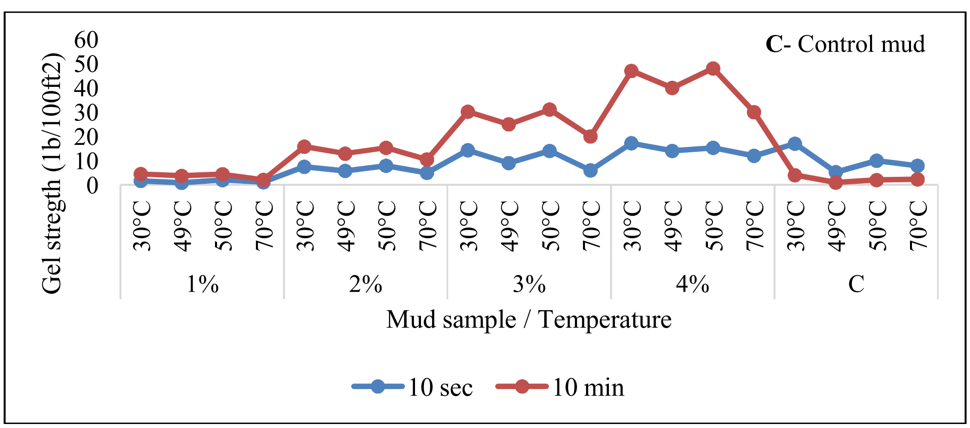

Fig. 3. Effect of temperature, concentration and time on gel strength

Table 4. Rheological properties of the developed mud formulation with 2% of *M. oleifera* leaves before and after aging

Samples	Aging Temperature (ºC)	Plastic viscosity (cP)	Yield point (lb/100 ft^2)	Gel strength 10 sec (1b/100 ft^2)	Gel strength 10 min (1b/100 ft^2)
Blank	Before aging	22	21.3	1	5.3
	35	28	35	4	6
	65	36	64	26.8	55.8
	93	22	30	2	2
PLM	Before aging	30	9	0.9	3.7
	35	28	34	4	8
	65	24	9	0.6	4.1
	93	25	36	3	7

rheological properties tested at 49ºC [26]. The thermal stability test was done as per API recommended procedures and the results before and after aging are shown in Table 4. It was observed from the data that the PV were decreasing with increase in aging temperatures for mud with 2% concentration of *M. Oleifera.* However all the PV were within the recommended values after aging at all temperatures [27].

It is evidence that viscosity of the drilling mud is more of a function of temperature than pressure [28] hence very important to measure the viscosity at elevated temperatures. The YP of the formulated mud increased drastically (9-36 Ib/100 ft^2) for the drilling mud with *M. Oleifera* leaves. The YP for control sample after aging at 65°C recorded the highest YP of 64 Ib/100ft^2. The increase on YP values can be due to flocculation of clay and degradation of polymer (Gumfekar, et al. 2017). Gel strengths shows that there was an increase in gel strength as the aging temperatures increased. Control mud showed a higher increase after aging at 65ºC by recording high value of 26 Ib/100 ft^2. Observed gel strengths indicated that control mud had progressive gel strength which is undesirable (Mohmoud, et al. 2011), while the mud with *M. Oleifera* leaves had flat gel strength.

4. CONCLUSION

Test conducted in this work shows that most of the properties (plastic viscosity, yield point, and gel strength) of water based drilling mud are affected by temperature and concentration.

It can be concluded that plastic viscosity of the mud without *M. oleifera* leaves was lower than that of the mud with *M. oleifera* leaves especially at higher concentrations (4 and 3%). However, the control mud PV was stable at varying temperatures i.e. PV decrease drastically. Yield point of the control mud reduced by 25% with increasing temperature while the test mud decreased with higher percentage despite recording high value of PV.

Gel strength of the control mud had progressive gel strength while that of test mud had flat gel strength. The rheological properties of the test mud increased with increase in concentration of *M. oleifera.* In conclusion *M. oleifera* can be used to improve rheological properties of the drilling mud. In this study, the investigation done shows that the rheological properties of the formulated mud were affected by aging.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Cobb M, Irvine M, Fichera M, Jeter J. Document title Midia gas development document subtitle drill cuttings disposal-best practicable environmental option ERM Project No. 0497814 Date 2 April 2019 Version 2.0; 2019.
2. Ponmani S, Nagarajan R, Sangwai JS. Effect of nanofluids of CuO and ZnO in polyethylene glycol and polyvinylpyrrolidone on the thermal, electrical and filtration-loss properties of water-based drilling fluids. SPE Journal. 2016;21(02):405-415.
3. Smith SR, Rafati R, Haddad AS, Cooper A, Hamidi H. Application of aluminium

oxide nanoparticles to enhance rheological and filtration properties of water based muds at HPHT conditions. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2018;537:361-371.
4. Amanullah M, Ramasamy J, Al-Arfaj MK, Aramco S. Application of an indigenous eco-friendly raw material as fluid loss additive. Journal of Petroleum Science and Engineering. 2016;139:191-197.
5. Talukdar P, Kalita S, Pandey A, Dutta U, Singh R. Use of tannate derived from tea waste as drilling fluid additive. International Journal of Applied Engineering Research. 2018;13(16):12463-12468.
6. Tiskatine R, Oaddi R, El Cadi RA, Bazgaou A, Bouirden L, Aharoune A, Ihlal A. Suitability and characteristics of rocks for sensible heat storage in CSP plants. Solar Energy Materials and Solar Cells. 2017;169:245-257.
7. Omotioma M, Ejikeme P, Mbah G. Comparative analysis of the effects of cashew and mango extracts on the rheological properties of water based mud. Journal of Engineering Research and Applications. 2014;4:56-61.
8. Al-Hameedi ATT, Alkinani HH, Dunn-Norman S, Al-Alwani MA, Alshammari AF, Albazzaz HW, Alkhamis MM, Rusul A, Al-Bazzaz WH. Proposing a new eco-friendly drilling fluid additive to enhance the filtration properties of water-based drilling fluid systems. Paper presented at the SPE Gas & Oil Technology Showcase and Conference; 2019.
9. Nmegbu CGJ, Bekee B. Evaluation of corn cob cellulose and its suitability for drilling mud formulation. International Journal of Engineering Research and Applications. 2014;4(5):112-117.
10. Ihenacho P, Burby M, Nasr G, Enyi G. 50/50 oil-water ratio invert emulsion drilling mud using vegetable oil as continuous phase. International Journal of Chemical, Molecular, Nuclear, Materials and Metallurgical Engineering. 2016;10(3):239-242.
11. Adesina F, Gbadegesin A, Olalekan O. Formulation and environmental impact evaluation of walnut and soya bean oil based drilling fluid. Current Journal of Applied Science and Technology. 2016;1-9.
12. Tchameni A, Zhao L, Frimpong I, Nagre R. Investigating the effect of high thermal–saline conditions on the rheological properties of waste vegetable oil biodiesel-based emulsion mud. Journal of Petroleum Exploration and Production Technology. 2018;8(1):155-164.
13. Mohideen AAM, Saheed MSM, Mohamed NM. Multiwalled carbon nanotubes and graphene oxide as nano-additives in water-based drilling fluid for enhanced fluid-loss-control & gel strength. Paper presented at the AIP Conference Proceedings; 2019.
14. Khamehchi E, Tabibzadeh S, Alizadeh A. Rheological properties of Aphron based drilling fluids. Petroleum Exploration and Development. 2016;43(6):1076-1081.
15. Lifton V, Gorka J, Parrish D, Davidson J. Dry liquids on silica as secondary emulsifiers for drilling mud applications. Paper presented at the SPE Annual Technical Conference and Exhibition; 2017.
16. González LML, Reyes IP, Romero OR. Anaerobic co-digestion of sugarcane press mud with vinasse on methane yield. Waste Management. 2017;68:139-145.
17. Mao H, Qiu Z, Shen Z, Huang W. Hydrophobic associated polymer based silica nanoparticles composite with core–shell structure as a filtrate reducer for drilling fluid at utra-high temperature. Journal of Petroleum Science and Engineering. 2015;129:1-14.
18. Chen L, Junhui X, Juntian H, Zhijun S, Yaoxing C, Cuiting L. Method for preparing organic environment friendly snow-melting agent by using salt mud from two-alkali method. In: Google Patents; 2019.
19. Lukowska M, Józefaciuk G. Osmotic stress induces severe decrease in cation exchange capacity and surface groups of medium acidity in roots of cereal plants. Acta Physiologiae Plantarum. 2016;38(1): 31.
20. Gallagher MT, Wain RA, Dari S, Whitty JP, Smith DJ. Non-identifiability of parameters for a class of shear-thinning rheological models, with implications for haematological fluid dynamics. Journal of Biomechanics. 2019;85:230-238.
21. Akpan EU, Enyi GC, Nasr G, Yahaya AA, Ahmadu AA, Saidu B. Water-based drilling fluids for high-temperature applications and water-sensitive and dispersible shale formations. Journal of Petroleum Science and Engineering; 2019.
22. Jimoh K, Muritala K, Musliu O. Oil field chemicals from macromolecular renewable

resources in nigeria: An integration of hydrocarbon recovery with bioresource utilization. NSCHE Journal. 2018;33(1):86-86.
23. Dong X, Wang L, Yang X, Lin Y, Xue Y. Effect of ester based lubricant SMJH-1 on the lubricity properties of water based drilling fluid. Journal of Petroleum Science and Engineering. 2015;135:161-167.
24. Elochukwu H, Sia LKS, Gholami R, Hamid MA. Data on experimental investigation of methyl ester sulphonate and nanopolystyrene for rheology improvement and filtration loss control of water-based drilling fluid. Data in Brief. 2018;21:972-979.
25. Zoveidavianpoor M, Samsuri A. The use of nano-sized tapioca starch as a natural water-soluble polymer for filtration control in water-based drilling muds. Journal of Natural Gas Science and Engineering. 2016;34:832-840.
26. Luo Z, Pei J, Wang L, Yu P, Chen Z. Influence of an ionic liquid on rheological and filtration properties of water-based drilling fluids at high temperatures. Applied Clay Science. 2017;136:96-102.
27. Elkatatny S. Assessing the effect of micronized starch on rheological and filtration properties of water-based drilling fluid. Paper presented at the SPE Middle East Oil and Gas Show and Conference; 2019.
28. Yunita P, Irawan S, Kania D. Optimization of water-based drilling fluid using non-ionic and anionic surfactant additives. Procedia Engineering. 2016;148:1184-1190.

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