International Journal of Advanced Research and Development
www.multidisciplinaryjournal.net
ISSN: 2455-4030
Received: 18-12-2022, Accepted: 04-01-2023, Published: 20-01-2023
Volume 8, Issue 1, 2023, Page No. 7-13

Investigation into the effects of antioxidants on raphia sese oil base mud's performance as a drilling fluid

Manuella-Grace Syllou-Kongo[1*], Anthelme Tsoumou[2], Cyr Jonas Morabandza[2]
[1] Department of Petroleum and Natural Gas Engineering, University of Mines and Technology, Ghana
[2] Senior Lecturer, Ecole Normale Supérieure, Marien Ngouabi University, Republic of Congo
[2] Professor, Ecole Normale Supérieure, Marien Ngouabi University, Republic of Congo

Abstract
Various studies on the use of diesel as base fluid in oilfields applications have been done and revealed the high toxicity and high disposal cost of diesel. Substituting diesel with environmentally friendly oils which will keep the advantages of OBM was one way of avoiding issues associated with its use. Vegetable oils are known as a potentially environmentally friendly drilling fluid but have not received much attention because of its high instability issues. The main instability issue encounter in vegetable oils is oxidative stability. Antioxidants are the most efficient and cost-effective way to improve oxidative stability of oils. In this study, three muds were formulated for comparison. The first one was formulated using diesel oil (A), the other ones using raw Raphia sese oil (B) and (C) as Raphia sese oil with three antioxidants (Red Onion Skin Extract (ROSE), Propyl Gallate (PG) and Citric Acid (CA)), their mud rheological properties, densities, and pH were evaluated at unaged and aged conditions at 120 ˚F and 160 ˚F. From the results the addition of antioxidants improved the pH of the Raphia sese OBM from 8.31 to 10.64; Raphia sese OBM and Raphia sese OBM with antioxidants recorded similar densities 9.3 ppg and 9.2 ppg respectively which were higher than that of diesel OBM even with less addition of weighting material. Due to the possible test temperature, the addition of antioxidants did not improve the rheological properties of the Raphia sese OBM. Overall, the addition of antioxidants did not change much in the performance of the Raphia sese OBM as a drilling fluid this was observed from the rating test as Raphia sese OBM and Raphia sese OBM with antioxidants both scored 8 points. Further work will consider testing the muds at HPHT conditions to aid evaluate the effect of the additives on thermal stability. Again, there should be innovative ways of extracting the Raphia sese pulp oil to ensure consistency and quality.

Keywords: rheology, antioxidant, raphia sese (ester) oil, drilling fluid

Introduction

Various studies on the use of diesel as base fluid in oilfields applications have been done and revealed the high toxicity and high disposal cost of diesel. Substituting diesel with environmentally friendly oils which will keep the advantages of OBM was one way of avoiding issues associated with its use [1]. Aside the environmental challenges associated with the use of conventional oils, a study by [2] states that importing commercial oils increases the over drilling and completions cost. Over the years, synthetic based muds have been used to replace conventional oils. Some key advantages of Synthetic Based Muds (SBM) over Water Based Muds (WBM) and OBMs are higher penetration rates, thermal stability, lower reservoir damage, higher lubricity, low corrosion, longer bit life and lower fluid loss [3, 4]. The use of environmental drilling fluids is the most preferred drilling fluid. Vegetable oils (esters) are known to be environmentally friendly drilling fluid but have not received much attention because of its high instability issues [5, 6].

Further refinery processes are needed in most local vegetable oils before they meet API biodiesel standard. The OH-group in ricinoleic acid tend to increase significantly the viscosity of most vegetable oils because of the hydrogen bonding. At ambient temperatures, base viscosity of Synthetic Base Fluids (SBFs) are relatively 2 to 4 times higher than other oils-based fluids but as temperature increases, ester oils undergo thinning effect more than other oils [5]. However, oxidation reactions leading to the formation of dangerous secondary products, above all after drastic heat treatments can happen in fats and oils particularly those containing a high level of unsaturated fatty acids [7].

Vegetable oil oxidation is a series of complex chemical reactions undesired, degrading the quality of the oils. The delay of lipid oxidation has become a major challenge for most oils [8]. According to [9], the shelf life of vegetable oils in food uses and their applicability in industrial situations is greatly dependent on their oxidative stabilities. Among the methods of improving oxidative stability values are genetic modifications, compositional changes via chemical means and the inhibition of oxidation by substances known as antioxidants. [5] mentioned that antioxidants happen to be the most efficient and cost-effective ways to improve oxidative stability.

Despite the presence of some natural antioxidants such as ascorbic acids, α-tocopherol, β-carotene, chlorogenic acids and flavanols in vegetable oils, they are still not stable when used under high temperatures [9]. Citric acid which is commonly used in vegetable oils as a metal chelator, binds the metal ions contributing to rancidity as they catalyse free-radical oxidation of lipids [10]. The tannins present in the protective layers polyhydroxyphenols of the flavonoids type in Red Onion Skin Extract (Allium Cepa) are good natural antioxidants [5]. Propyl Gallate is used as an effective antioxidant in cosmetics to stabilize vitamins, essential oils, perfumes, as well as fats and oils [11]. Studies by [10, 12, 5]; showed that when using antioxidant is better to do synergy. Synergism may be defined as two or more agents working together to produce a result not obtainable by any of the single agents independently. In such cases, one antioxidant reinforces the effect of the other for better. This study investigates the effect of antioxidants on the performance of Raphia sese OBM.

Material and methods

1. Mud Formulation

Three muds samples were formulated in this work. The first one was formulated using diesel oil (A), the other ones using raw Raphia sese oil (B) and (C) as Raphia sese oil with three antioxidants (Red Onion Skin Extract (ROSE), Propyl Gallate (PG) and Citric Acid (CA)) for comparison as presented in Table 1.

Table 1: Mud Formulations

Additives	A (Diesel OBM)	B (Raphia Sese SBM)	C (Raphia Sese SBM + Antioxidants)
Oil volume, ml	280	280	280
Water volume, ml	35	35	35
$Cacl_2$, g	9	9	9
PE, ml	5	5	5
SE, ml	2	2	2
Lime, g	5	5	5
OC, g	1	1	1
$CaCo_3$, g	99	61	61
ROSE, g	-	-	0.35
PG, g	-	-	0.35
CA, g	-	-	0.35

Table 2 shows the American Petroleum Institute (API) standard for an oil drilling fluid requirement.

The rheological properties of the muds such as plastic viscosity (PV), yield point (YP), flow index (n), apparent viscosity (AV), consistency index (K), shear stress (τ), shear rate (γ), density, and pH were determined using the equations below. These tests were carried out at unaged and aged conditions at 120 ˚F and 160 ˚F.

$$PV = \theta_{600} - \theta_{300} \quad (1)$$

$$YP = \theta_{300} - \mu_p \quad (2)$$

$$n = 3.32\log\left(\frac{\theta_{600}}{\theta_{300}}\right) \quad (3)$$

$$AV = \frac{\theta_{600}}{2} \quad (4)$$

$$K = \theta_{300}/(511)^n \quad (5)$$

$$\tau = 4.79 * Dial\ Readings \quad (6)$$

$$\gamma = 1.7034 * RPM \quad (7)$$

Table 2: API (13B) Specifications for Oil Base Fluids

Parameter	Numerical value requirement
Basic Oil Characteristics Requirements	
Flash Point	150˚F (66℃)
Fire Point	200˚F (93℃)
Aniline Point	140˚F (60℃)
Aromatics Contents	5% by weight (Max)
Mud Properties	
Density	0.9 g/cm3 to 2.64 g/cm3 (7.5 to over 22.0 ppg)
Plastic Viscosity (PV)	< 65 (cp) or ALAP
Yield Point (YP)	0.72 - 2.15 kPa15 – 45 (lb/100ft^2)
PV/YP Ratio	0.8 – 1.5
Gel Strength 10 seconds	0.14 – 0.96 kPa 3 –20 (lb/100ft^2)
Gel Strength 10 minutes	0.38 – 1.44 kPa 8 – 30 (lb/100ft^2)
Calcium Chloride	20 – 25 % by weight
Excess Lime	0.12 – 0. 36 g/cm^3 1 - 3 ppg
Electrical Stability	> 400 volts
HTHP Filtrate before rolling	10- 25 ml
HTHP Filtrate after rolling 176.7 ºC to 260 ºC (350℉ -500℉)	< 10 (ml/30 min)
API Fluid Loss	15.0 ml (maximum)
Oil/Water Ratio	65/35 to 95/5
Sand Content	< 2%
pH	8.5 – 10.5
Cuttings Carrying Index (CCI)	> 0.5

(Source: [3])

Results and discussion

1. pH and Density

API recommends a density of 7.5 to over 22 lb/gal and pH of 8.5 to 10.5 for various drilling conditions. pH and density of the samples are presented in Figure 1. Diesel (DO) recorded a neutral pH of 7.0 while Raphia sese (RO), presented an acidic pH with a value of 5.53. The final mud pH samples were affected by those results. Raphia sese OBM (sample B)'s pH was slightly lower than the 8.5 minimum pH value for API, but with addition of more lime this could easily be enhance. However, the addition of the antioxidants (AO) in sample C enhanced the pH of the Raphia sese OBM be reading a value of 10.64. Samples B and C recorded higher density values (9.3 lb/gal and 9.2 lb/gal respectively) than sample A (8.4 lb/gal) due to the high viscosity of RO. These samples would require lesser amount of weighting material to produce the same mud weight thus saving cost in that regard.

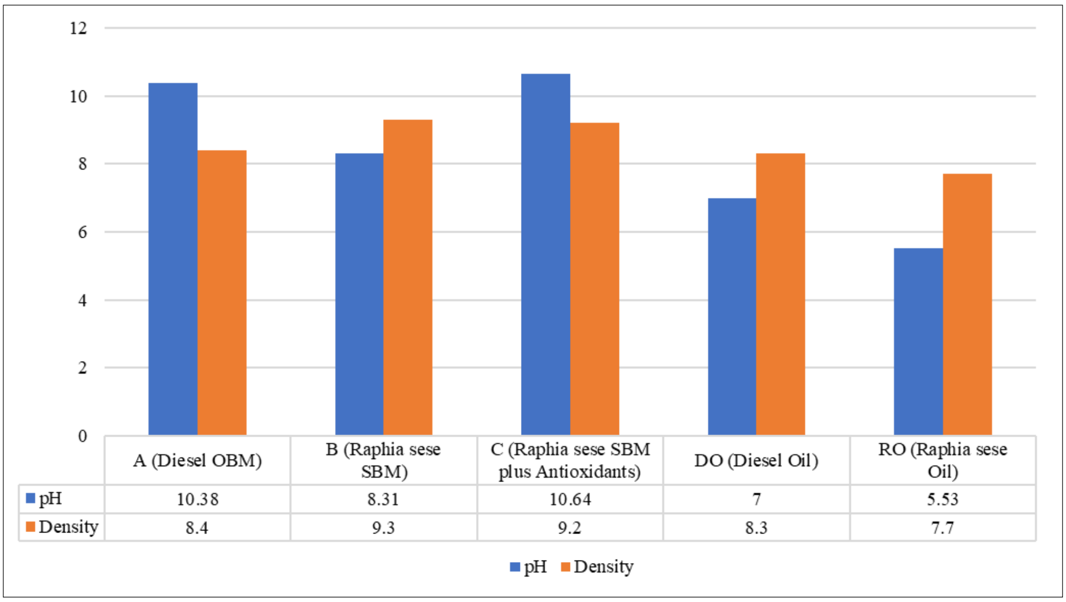

Fig 1: pH and Density of Samples

2. Rheological Properties of Mud Samples

2.1 Rheological Properties of Unaged Mud Samples

The values recorded for the unaged samples are presented in Table 3

Table 3: Rheological Properties of Unaged Mud Samples

Sample ID		A		B		C	
Temp (˚F)		120	160	120	160	120	160
Dial Readings in Degrees @	600	21	16	173	92	172	97
	300	11	8	97	59	90	51
	200	6	5	41	39	61	35
	100	4	3	5	21	32	19
	6	2	2	4	4	4	3
	3	2	1	4	3	3	3
Gel Strength @	10"	2	2	5	5	4	4
	10'	3	2	7	7	8	7
PV		10	8	76	33	82	46
YP		1	0	21	26	8	5
n		0.932	0.999	0.834	0.640	0.933	0.926
K		0.032	0.015	0.533	1.086	0.266	0.157
AP		10.5	8	86.5	46	86	48.5
PV/YP		10	-	3.619	1.269	10.25	9.2
Yield Stress		2	1.7	4	3	4	2.5

2.2 Rheological Models of Unaged Mud Samples

Conventionally, thinning effect made the viscosity to decrease with increase in temperature as shown in Table 3. In exception of sample A at 160 ˚F, the rest of the mud samples had flow index (n) values less than one suggesting a pseudoplastic fluid. All mud samples except sample B at 160 ºF had values less than one for the consistency index (K), suggesting that the fluids were less viscous. Almost all the mud samples recorded rheological models not passing through the origin because of their yield values, thus suggesting a Bigham or the Herschel Bulkley rheological model as shown in Figure 2. API recommends values in the range (0.8-1.5) for the PV/YP ratio. The PV/YP curves can be used to evaluate drilling fluids' stability. Also, they can serve as guidelines in the field control of drilling fluid systems as well as in taking timely actions [13]. Samples A and C failed to record values being in the API range at both temperatures while sample B at 160 ºF passed the PV/YP ratio.

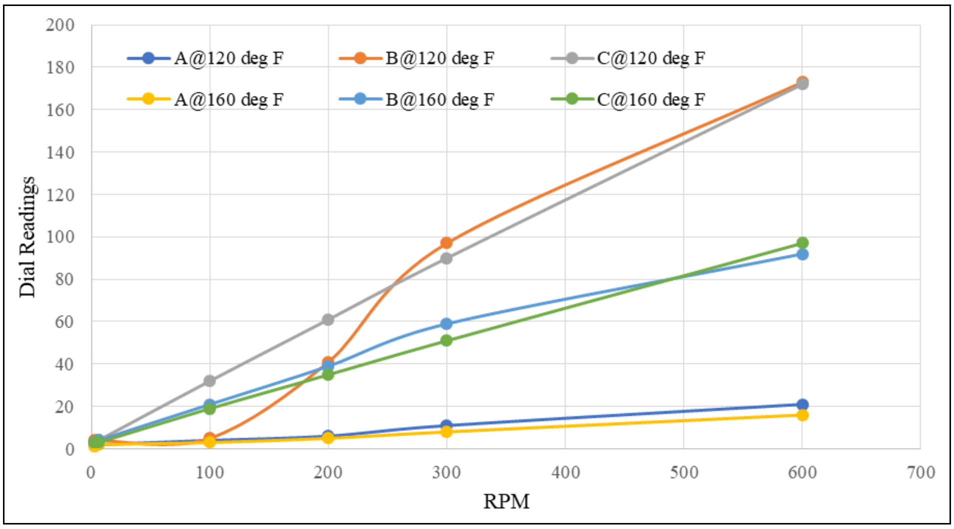

Fig 2: Dial readings for unaged mud samples

2.3 Rheological Properties of Aged Mud Samples: The mud samples were allowed to age for eight hours in an ageing chamber. The ageing was static. Table 4 presents the results obtained.

Table 4: Rheological Properties of Aged Mud Samples

Sample ID		A		B		C	
Temp (˚F)		120	160	120	160	120	160
Dial Readings in Degrees @	600	15	13	200	172	175	112
	300	8	7	109	93	94	60
	200	5	5	75	65	64	43
	100	4	3	39	34	32	25
	6	2	2	4	5	4	4
	3	1	1	3	4	3	3
Gel Strength @	10"	2	2	4	4	4	5
	10'	1	1	4	6	5	7
PV		7	6	91	79	81	52
YP		1	1	18	14	13	8
n		0.906	0.892	0.875	0.886	0.896	0.899
K		0.028	0.026	0.464	0.369	0.351	0.219
AP		7.5	6.5	100	86	87.5	56
PV/YP		7	6	5.055	5.642	6.230	6.5
Shear Yield		1	1	2.5	4	3	3

2.4 Rheological Model of Aged Mud Samples

From Table 4, all the mud samples had n (flow index) and K (consistency index) less than 1 which indicates a possible pseudoplastic fluids and a less viscous fluid respectively. But since the rheological plots do not pass through the origin because of their yield values, they follow the Bingham or the Herschel Bulkley rheological model as shown in Figure 3. The shear yield values of samples B and C were less than the yield point therefore suggesting that the fluid follows a possible Hershey Bulkley rheological model. The shear yield value of sample A was equal to the YP, suggesting that the fluid is a possible Bingham plastic fluid.

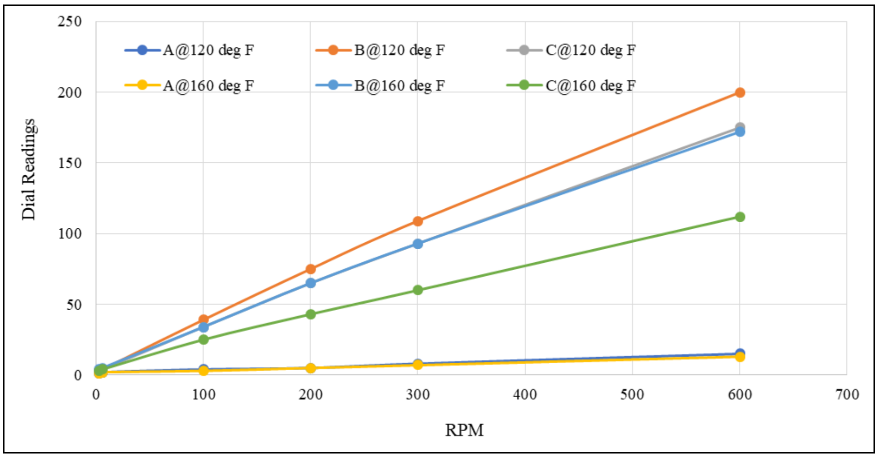

Fig 3: Dial readings for aged mud samples

3. Plastic Viscosity for Unaged and Aged Mud Samples

From API standards, Plastic viscosity (PV) should be less than 65 cP and as low as possible to prevent solid sagging and provide easy cleaning of the wellbore. A low PV indicates the ability of the mud to drill rapidly because of the low viscosity of mud exiting at the bit. High PV is a result of a viscous base fluid and excess solids [15]. From Figure 4, sample A passed the test at all the temperatures while B and C passed the test at 160 ˚F only. The PV efficiency was in the following order: C<B<A for unaged samples. Only aged samples A at both temperatures and C at 160˚F passed the API PV test as shown in Figure 4. Aged sample B had values higher than 65 at both temperatures. The efficiency of the PV was in the order of C<A for aged samples. The presence of the antioxidants in sample C have made it stable to the extent that it was able to pass PV test after ageing at 160˚F.

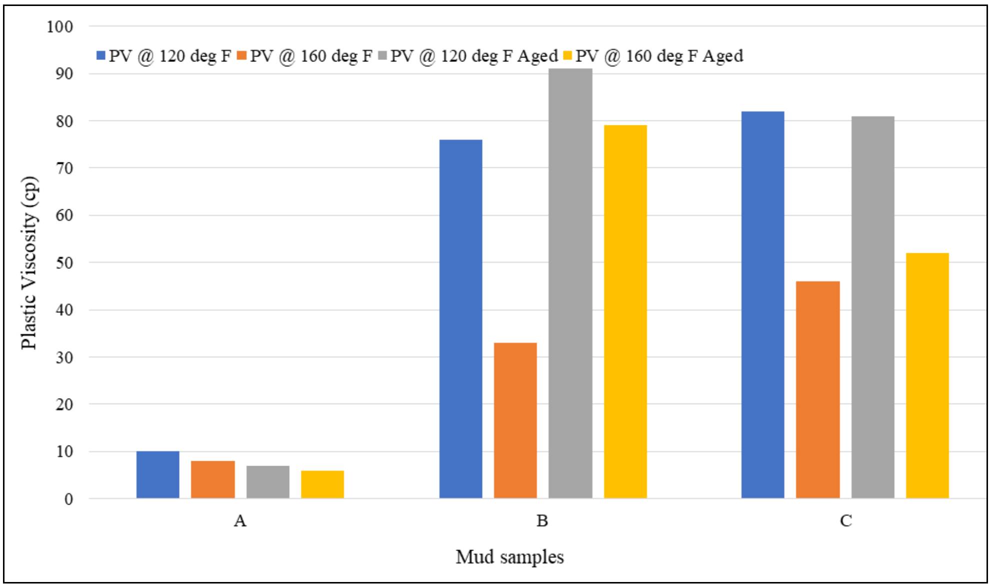

Fig 4: Plastic viscosity for unaged and aged mud samples

4. Yield Point of Unaged and Aged Mud Samples

The yield point (YP) is used to evaluate the ability of a mud to lift cuttings out of the annulus. A high YP implies a non-Newtonian fluid; which has the ability to carry cuttings better than a fluid of similar density but lower YP [14]. From API standards, a range value of 15 - 45 lb/100 ft^2 is required for YP. Figure 5 presents the YPs of the mud samples at both conditions. At unaged conditions, only sample B passed the test at both temperatures and its best YP was at 120˚F. Though samples A and C couldn't pass the test, very low values were recorded for sample A. After ageing, only sample B passed the test at 120˚F. Samples A and C failed at both temperatures. The addition of antioxidants at both conditions did not improve the YP of Raphia sese OBM.

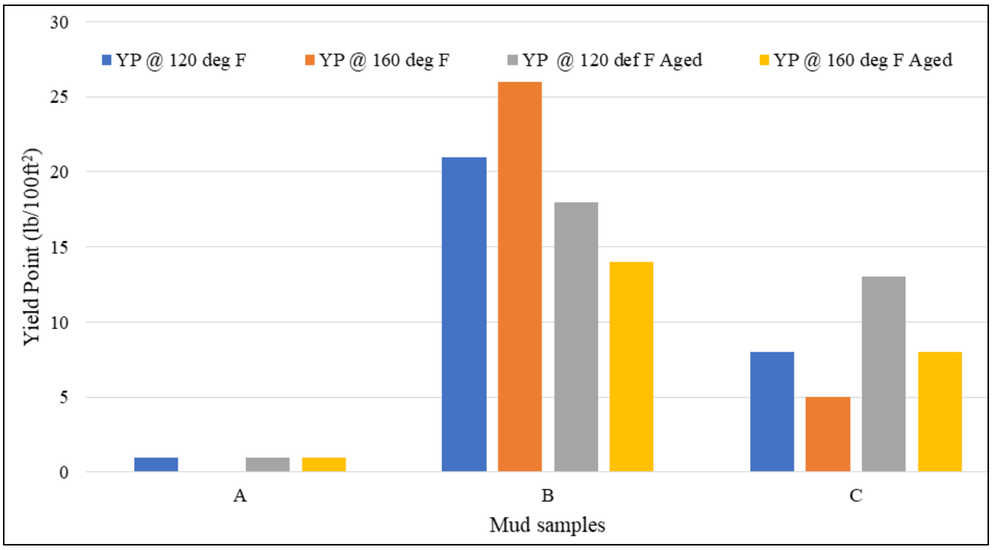

Fig 5: Yield point for unaged and aged mud samples

5. Gel Strengths of Unaged and Aged Mud Samples

API recommends ranges of 3 - 20 (lb/100 ft^2) and 8 - 30 (lb/100 ft^2) for 10 seconds and 10 minutes gel strength respectively. Gel strength indicates strength of attractive forces in drilling under static conditions. This also describes the ability of the mud to suspend cuttings in a static condition and the pressure to flow the mud after it has been static for some time [15]. As shown in Figures 6 and 7, unaged sample A failed both tests while unaged samples B and C passed the 10 seconds gel test. Also, unaged sample C passed the 10 minutes gel strength at 120 ˚F. Again, from Figures 6 and 7, aged samples B and C passed the gel strength test at 10 seconds but failed gel strength at 10 minutes. Aged sample A failed both tests. The presence of antioxidants in sample C made it able to pass the 10 seconds test at both conditions with the observation that after ageing, the test values increased with temperature as sample C recorded 4 at 120 ˚F and 5 at 160 ˚F. Also, sample C passed the 10 minutes Gel Strength at 120 ˚F without aging.

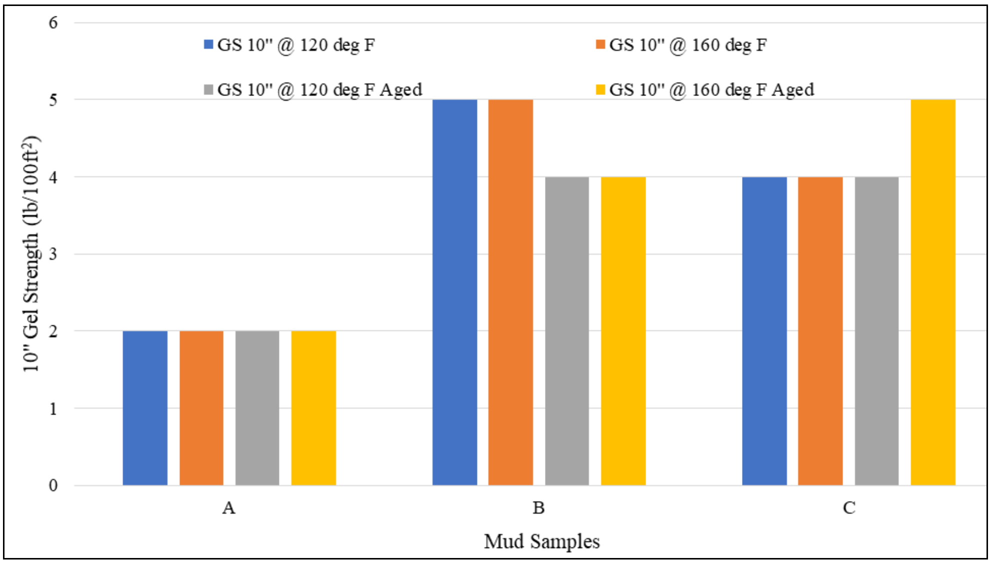

Fig 6: 10 seconds Gel Strength for unaged and aged mud samples

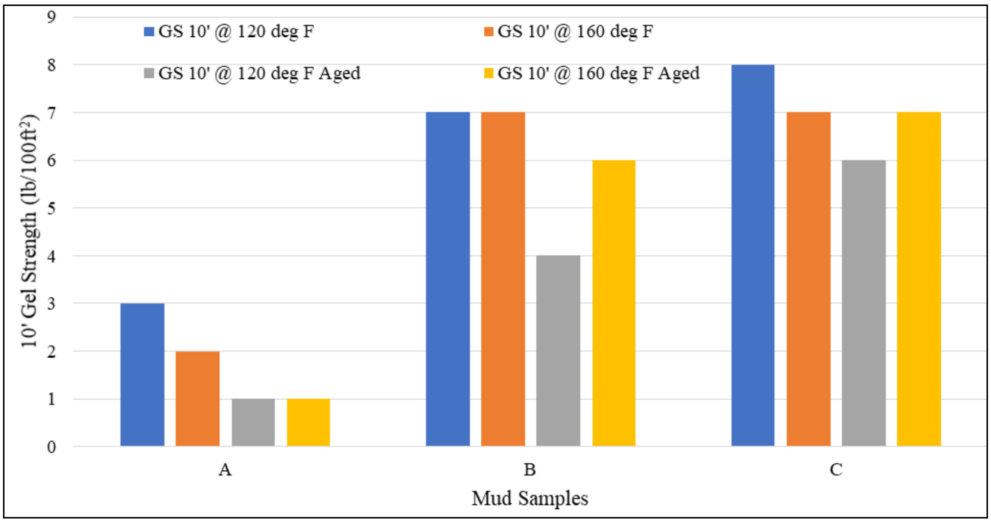

Fig 7: 10 minutes Gel Strength for unaged and aged mud samples

6. Rating Performance of Unaged and Aged Samples

To obtain the rating performance of the mud samples, values were assigned to them using a deviation method. Whenever a sample passed an API test, a value '1' was assigned to it, else it was a '0'. Table 5 presents the total rating performance of unaged and aged mud samples. It can be seen that samples B and C had the same performance, which was higher than that of Sample A. Figure 8 depicts a plot of rating performance against the mud samples.

Table 5: Rating Performance of Unaged and Aged Mud Samples

	Sample ID	**A**		**B**		**C**	
	Temp °F	**120**	**160**	**120**	**160**	**120**	**160**
Rheological properties of unaged samples	PV	1	1	0	1	0	1
	YP	0	0	1	1	0	0
	GS 10"	0	0	1	1	1	1
	GS 10'	0	0	0	0	1	0
Rheological properties of aged samples	PV	1	1	0	0	1	1
	YP	0	0	1	0	0	0
	GS 10"	0	0	1	1	1	1
	GS 10'	0	0	0	0	0	0
Total		4		8		8	

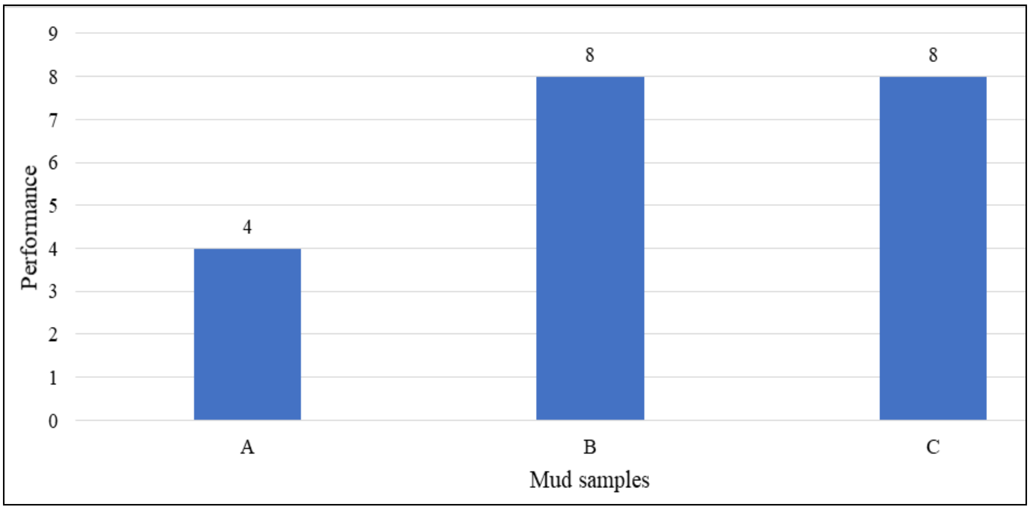

Fig 8: Rating performance of mud samples

Conclusion

The presence of antioxidants improved the pH of the Raphia sese OBM from 8.31 to 10.64, but it did not change much in the performance of the Raphia sese mud. This was observed from the rating test as both Raphia sese OBM and Raphia sese OBM with antioxidants scored 8. The lack of antioxidants effect on the Raphia sese oil may be due to the low temperature at which the tests were done. Further work will consider testing the muds at HPHT conditions to aid evaluate the effect of the additives on thermal stability. Again, there should be innovative ways of extracting the Raphia sese pulp oil to ensure consistency and quality.

Acknowledgements

The authors thank Mr Obel Okeli Patrick for his support concerning the realization of this study. The authors also acknowledge Mr Kofi Dabo for his support through this study.

References

1. Fadairo AS, Tozunku KS, Kadiri TM, Falode OA. Investigating the Effect of Electrolytes and Temperature on Rheological Properties of Jatropha oil-based mud, 2012 SPE Nigerian Annual International Conference and Exhibition held in Abuja, Nigeria, 2012, 6-8.
2. Woodland F, Dankwah JR, Amorin R, Dabo K. Evaluation of the Effect of Water Hyacinth Ash (WHA) as an Additive on Local Portland Cement for Oil Well Cementing. International Journal of Scientific Development and Research,2022:7(8):1-11.
3. Amorin R, Broni-Bediako E. Evaluating the Rheological Properties of Antioxidated Local Pseudo Oil Base Muds for Geothermal Drilling Environment. Ghana Journal of Technology,2020:5(1):93-103.
4. Udoh FD, Itah JJ, Okon AN. Formulation of Synthetic-Based Drilling Fluid Using Palm Oil Derived Ester. *Asian Jr. of Microbiol. Biotech. Env. Sc.*,2012:14(2):175-180.
5. Amorin R, Dosunmu A, Amankwah KR. Enhancing the stability of local vegetable oils (esters) for high geothermal drilling applications. Journal of Petroleum and Gas Engineering,2015:6(8):90-97.
6. Gharby S. Refining Vegetable Oils: Chemical and Physical Refining. Hindawi the Scientific World Journal, 2022, 1-10.
7. Blasi F, Cossignani L. An Overview of Natural Extracts with Antioxidant Activity for the Improvement of the Oxidative Stability and Shelf Life of Edible Oils. Processes,2020:8-956:1-15.
8. Mendoza GPDM. Enrichment of vegetable oils with phenolic antioxidants for food applications, Published Phd Project Report, Bordeaux University, Bordeaux, 2020, 244.
9. Aluyor OE, Ori-Jesu M. The use of Antioxidants in Vegetable Oils – A Review. African Journal of Biotechnology,2008:7(25):4836-4842.
10. Akaranta O, Akaho, AA. Synergic effect of Citric Acid and Red Onion skin extract on the Oxidative stability of Vegetable Oil, J. Appl. Sci. Environ. Manage.,2012:16(4):337-343.
11. Patil D. Role of antioxidants in Stability of Edible Oil, Trends in Post-Harvest Technology,2013:1(1):68-73.
12. Nguyen VH, Le MN, Nguyen HB, Ha KO, Pham THV, Nguyen TH *et al*. Propyl Gallate. *Molbank* M1201, 2021. https://doi.org/10.3390/M1201
13. Syllou-Kongo MG, Amorin R, Tsoumou A. Evaluation of the Rheological properties of Raphia sese oil as base fluid for oilfields application. European Journal of Technology,2022:6(4):1-9.
14. Agwu OE, Okon AN, Udoh FD. A Comparative Study of Diesel Oil and Soybean Oil as Oil-Based Drilling Mud, Journal of Petroleum Engineering, 2015, 1-10.
15. Amorin R. “Drilling Fluids”, Unpublished BSc Lecture Notes, University of Mines and Technology, Tarkwa, 2015, 74.