International Journal of Petroleum and Petrochemical Engineering (IJPPE)
Volume 9, Issue 1, 2024, PP 20-29
ISSN 2454-7980 (Online)
DOI: http://dx.doi.org/10.20431/2454-7980.0901003
www.arcjournals.org

Experimental Investigation of the Potential use of Banana Starch Flour as a Secondary Viscosifier in Water-Based Mud

Dankwa, O. K.[1],Amarfio, E. M.[2],Otoo, P.[3],Amenyah Kove, E. P.[4],

[1]*Petroleum and Natural Gas engineering Department, University of Mines and Technology (UMaT), Tarkwa*

[2]*Petroleum and Natural Gas engineering Department, University of Mines and Technology (UMaT), Tarkwa*

[3]*Petroleum and Natural Gas engineering Department, University of Mines and Technology (UMaT), Tarkwa*

[4]*Petroleum and Natural Gas engineering Department, University of Mines and Technology (UMaT), Tarkwa*

Corresponding Author:*Dankwa, O. K, *Petroleum and Natural Gas engineering Department, University of Mines and Technology (UMaT), Tarkwa*

Abstract: *Drilling fluids are mainly used in the oil and gas industry to ensure safe and productive oil and gas wells. Viscosity of water-based muds (WBMs) are generally improved by commercial additives such as carboxymethylcellulose (CMC) and hydroxyethyl cellulose (HEC), which are imported. However, there are available local materials in vast amounts that can be processed to serve as substitutes to the commercial additives. This study, thus, seeks to evaluate the possible use of banana starch flour as a viscosity enhancer for WBM and also assess the effects it has on the viscosity and rheological properties of WBM. Concentrations of banana flour from 0 g to 0.45 g at a step of 0.15 g were added to the drilling mud. Series of investigation were conducted on the viscosity, gel strength, yield point and density of the formulated mud samples at different temperatures of 25 ℃, 40 ℃ and 65 ℃. Results from the study showed that, the viscosities of the various mud samples increased with increasing temperatures and concentrations of banana starch flour. Furthermore, apparent viscosity and gel strength increased with increasing temperature and concentrations while plastic viscosity and yield point exhibited instabilities with increasing temperature and concentrations of banana starch flour. Moreover, additions of 0.15 g, 0.30 g and 0.45 g concentrations of banana starch flour yielded no increase in the weight of the mud. Based on the analyses of this study, there is the possibility to use banana starch flour to improve the viscosity of a water-based drilling fluid.*

Keywords: *Drilling fluid; Rheology; Starch; Water based mud; Viscosifier*

1. Introduction

A drillingmud basically is a circulating fluid mixture used to remove Drilling mud cuttings, to cool and lubricate the drill string, and to provide hole stability and pressure control. Drilling muds are usually classified based on its continuous phase; water-based, oil-based or synthetic based and pneumatic fluids (Caenn*et al*., 2016). Water based muds consist of a mixture of solids, liquids, and chemicals, with water being the continuous phase (Hossain and Al-Majed, 2015). They are divided into three main sub-classification; inhibitive, non-inhibitive and polymer fluids (Dosunmu and Ogunrinde, 2010). The oil-based or synthetic base-mud comprise of oil as the base fluid which include diesel, mineral oils and synthetic oil while pneumatic fluid include foam, mist and aerated fluid (Shah *et al*., 2010;Oghenejoboh*et al*., 2013). Not the same type of fluid is used to drill all formations, each type of drilling mud is designed specifically to fit a particular formation characteristics (Dankwa *et al*., 2018a).Water-based muds are the most preferable fluid type because they are easier to formulate, cheaper, and environment-friendly (Dankwa *et al*., 2018b). Essentially, about 85% of all drilling fluid compositions used today are water-based systems. (Van Der Horst, 2011). The drilling fluid's ability to execute its primary functions is determined by a set of qualities that are constantly refined to meet formation conditions during drilling operations. Some of the properties to be controlled are viscosity, fluid loss, gel strength, density and others. Failure of the drilling fluid to perform as intended can be exceedingly expensive in terms of materials and time (Rabia, 2000). In other words, because drilling fluid is such an important element of the drilling process, many of the issues that arise during the drilling of a well may be traced back to the drilling fluids, either directly or indirectly (Bourgoyne *et al*., 1986). As a result, these fluids must be properly formulated in order to perform their functions in the drilling process (Wami *et al*., 2015). In order to ensure that mud executes the task it was designed for, the drilling fluid should contain a minimum number of additives, ranging from weighting materials, viscosifiers, fluid loss agents among others, this aids in the preservation and verification of the drilling fluid's qualities.

Polymer additives have been some of the earliest and most common additives for drilling mud. They are used as viscosifiers, thinners, flocculants, surfactants and fluid loss control agents depending on their structure and reactive groups (Harry *et al*., 2016). Starch was the first and the most widely used polymer in drilling fluid as effective colloids, which decreases the filtration of water dispersing drilling fluids and increase viscosity (Ademiluyi*et al*., 2011). Starch or amylum is a polysaccharide carbohydrate that is made up of a large number of glucose units joined together by glycosidic bonds. Starch is the main reserve carbohydrate in tubers, cereals and legumes (Olatunde *et al*., 2017). Starch is commonly used in the technology of drilling fluids in modified statesbecause of its solubility in water. It is predominantly used as effective protective colloids to decrease filtration and increase viscosity (Ademiluyi*et al*., 2011). Starch can be obtained from sources such as corn, potato, tapioca, arrowroot, rice, plantain, yam, banana, sorghum and waxy. Banana is a generic term for a number of species or hybrids of the genus Musa of the family Musaceae produced in large quantities in tropical and subtropical region (Olatunde *et al*., 2017). According to the 2017 United Nations Food and Agriculture Organisation Statistical Database (FAOSTAT), the world's top producer of bananas is Asia with a share of 54.2% of the entire global production of 113.9 million tonnes with India contributing 30.5 million tonnes (Anon, 2018). Albeit, a precise production figure is not available, Ghana also contributes 88.3 thousand tonnes to the global production as of 2017. Banana is rich in carbohydrate and is one of the tender fruits providing more calories. It contains approximately 75 percent water and 25 percent carbohydrate along with trace amount of protein and fat as well as high levels of calcium and phosphorous. Starch is thought to be the major component in green unripe banana (Joshi and Sarangi, 2014), therefore banana starch might be able to serve as substitution of other starches such as potato, corn and wheat (Nimsung*et al*., 2005). Moreover, due to the large quantities of starch in unripe bananas (over 70 percent of dry weight), processing into starch is of interest as a potential resource for food and other industrial purposes. Starch contributes immensely to textural properties of many foods and is widely used in food and industrial applications as thickener, stabiliser and gelling agent (Olatunde *et al*., 2017).

Numerous types of additives for drilling fluids formulation are used in the oil and gas industry. Viscosifiers are materials added to drilling fluids with the goal of increasing its viscosity. Viscosifiers enhance the capability of the mud to remove cuttings from the wellbore and to suspend cuttings and other materials when the drilling is put on halt. Commonly used viscosifiersranges from clays and natural or synthetic polymers such as Drispac, CMC, HEC, polymer starch *etc.* (Nguyen, 2012; Wami *et al*., 2015). Most of these materials used as viscosifiers are imported which are very expensive. However,there are many of these chemical additives available locally in large quantities and could be sourced, processed for use in oilfield operations. This has led to the increase in research works into these available drilling materials in countries like Nigeria and Ghana, where there are more drilling activities to reduce the associated cost. Some locally available raw materials have been used by several researchers have formulate drilling fluids in order to improve the mud's viscosity and other related properties (Okumo and Isehunwa, 2007; Ademiluyi*et al*., 2011; Olantude*et al*., 2012; Undoh and Okon, 2012; Igbani*et al*., 2015; Osai, 2015; Harry *et al*., 2016; Ashikwei and Marfo, 2016; Nyande 2017; Assan, 2017; Dankwa *et al*., 2018b) yet, not much research has been done in an attempt to develop such drilling fluid system using unripe banana. Hence this study, therefore, focuses on the use of unripe banana as a potential source of starch for formulating water based drilling mud and to investigate its performance as a possible viscosity enhancer (secondary viscosifier) in water based drilling mud. This will then aim at reducing the cost of some expensive viscosifiers that are being imported for drilling mud formulation and will create employment as well for the local economy.

2. RESOURCES AND METHODSUSED

2.1. Preparation of Banana Starch Flour

Unripe local bananas were purchased in Tarkwa, 10 kg of the unripe banana washed and peeled. The banana pulp were then cut into 1-2 cm slices and immediately rinsed in sodium hydroxide solution for 15 minutes to inhibit oxidation. The rinsed slices were placed on trays and dried in the sun for 3 days.

The dried slices were then put in a forced air convection oven for 6 hours. After drying, the material was pounded in a mortar and the accumulated powder was sieved through 75 µm to eliminate coarse particles. It was then stored in a sealed container for mud preparation and testing.

2.2. Water Based Mud Samples Preparation

2.2.1.Formulation of Water Based Mud

The following are the procedural steps used for the formulation of the mud:

i. 150 ml of fresh water was fetched into four separate metallic beakers with the aid of a graduated measuring cylinder.

ii. Three separate quantities of banana flour (0.15 g, 0.30 g, 0.45 g) was measured using a mass balance into three of the metallic beakers containing fresh water while the last set of beaker had no banana flour (0 g)

iii. A handheld mixer was used to stir the three beakers containing the banana flour to dissolve the flour completely in the water.

iv. The mass balance was used to measure 22.5 g of bentonite and it was added to the four beakers.

v. The samples was stirred to dissolve completely the bentonite using a mixer and additional 200 ml of fresh water was added to each sample (i.e. 0 g, 0.15 g, 0.30 g and 0.45 g).

vi. The four separate samples were left to age for 16 hours in order to swell. Table 1 presents the various compositions of the mud samples used to perform the experiment.

Table1.*Mud Samples Setup*

Sample ID	**Composition**
A	350 ml of water + 22.5 g of bentonite + 0 g of banana flour
B	350 ml of water + 22.5 g of bentonite + 0.15 g of banana flour
C	350 ml of water + 22.5 g of bentonite + 0.30 g of banana flour
D	350 ml of water + 22.5 g of bentonite + 0.45 g of banana flour

2.3. Mud Sample Testing

Table2.*Test Results from Laborary Experiment*

Parameter	Sample ID											
	A (Mud + 0 g banana flour)			**B** (Mud + 0.15 g banana flour)			**C** (Mud + 0.30 g banana flour)			**D** (Mud + 0.45 g banana flour)		
Temperature (°C)	**25**	**40**	**65**	**25**	**40**	**65**	**25**	**40**	**65**	**25**	**40**	**65**
600 rpm	18	20	23	19	20	25	19	22	25	20	22	27
300 rpm	12	13	16	14	13	19	14	14	19	15	16	20
200 rpm	9	11	14	9	11	15	10	13	16	12	13	17
100 rpm	7	8	10	8	9	13	8	9	12	10	9	12
6 rpm	4	4	7	5	6	9	6	7	9	6	7	10
3 rpm	3	4	5	3	5	6	4	5	7	5	6	7
PV (cP)	6	7	7	5	7	6	5	8	6	5	6	7
AV (cP)	9	10	11.5	9.5	10	12.5	9.5	11	12.5	10	11	13.5
YP (lb/100 ft^2)	6	6	9	9	6	13	9	6	13	10	10	13
Gel Strength @ 10 sec	3	5	8	4	6	8	6	8	9	6	8	10
Gel Strength @ 10 min	10	14	17	12	16	18	13	18	22	14	18	19
Density (lb/gal)	8.84			8.84			8.84			8.84		

After the laboratory experiment, physical propertiesof the mud samples such as rheological properties and density were tested in accordance withAmerican Petroleum Institute (API) recommended practice 13B-1 for testing water based mud. The density of the mud samples were determined with a mud balance. The viscosities (plastic viscosity, apparent viscosity, yield point) as well as timed gel strength

(10 seconds and 10 minutes) of the mud samples were measured using the fan viscometer 3500 model. Readings were taken at desired speed of 3, 6, 100, 200, 300 and 600 rpm first at 25 ℃, and then heated with the aid of a thermo cup at 40 ℃ and 65 ℃ and the test repeated. The plastic viscosity in centipoise (cP), apparent viscosity in centipoise (cP) and yield point values in (lb/100 ft^2) were calculated using Equations (1), (2) and (3) (Caenn*et al*., 2016) respectively.

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

$$\text{Apparent Viscosity (AV)} = \frac{\theta_{600}}{2} \quad (2)$$

$$Yield\ \text{Point}\ (YP) = \theta_{300} - PV \quad (3)$$

where, θ_{600} and θ_{300} denotes the dial reading at 600 and 300 rpm respectively; rpm is revolution per minute

3. Results and Discussion

Table 2 presents the results obtained from the laboratory experimentsas well as parameters which have been calculated using Equations 1 to 3. All discussions are based on the results from Table 2.

3.1. Fluid Behaviour Analysis of Mud Samples

Rheology defines the deformation and flow of matter. Rheology study is an important factor in drilling fluid because it allows the fluid to be specifically analysed in terms of fluid viscosity, pressure loss, hole cleaning etc. (Malkin and Isayev, 2017). From Figs. 1 to 4, it can be observed that, increase in the amount of banana starch flour concentration increased the viscosity thereby increasing the shear stress of the drilling mud. Amanullah and Yu (2004) stated that the short branching chains in the amylopectin are the main crystalline component in granular starch. Therefore, any disparity in the amount of amylose and amylopectin in a starch changes the behaviour of the starch. The amylose component of starch controls the gelling behaviour since gelling is the result of re-association of the linear chain molecules. Amylopectin is usually larger in size, hence, large size and branched nature of amylopectin reduce the mobility of the polymer and their orientation in an aqueous environment (Ademiluyi*et al*., 2011). It can also be seen that, at different temperatures, the viscosities of both the untreated and treated mud samples increased with increasing temperature. This is because, as temperature of water based mud is increased, water is lost by evaporation enabling the fluid to become more viscous thereby increasing their viscosities. Except for the viscosity of sample D (0.45 g) which decreased (10 – 9 cP) from 25 °C to 40 °C at 100 rpm. This could be because of lower solid concentrations in mud sample D. Furthermore, it was observed that, at the different temperatures, both the treated and untreated samples exhibited a Non-Newtonian fluid behaviour. This is because their flow curves displayed a non-linear relation between the shear stress and shear rate. Moreover, the viscosity of both treated and untreated mud samples increased with increasing shear rate.

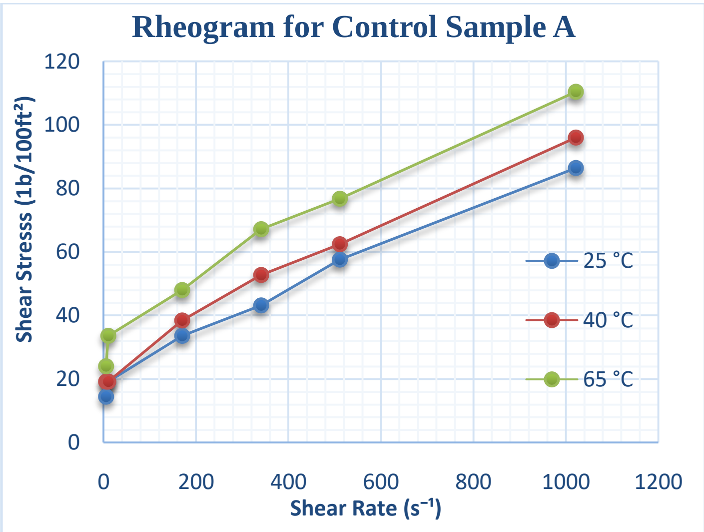

Figure1.*Rheogram for Sample A (Mud + 0 g Banana Flour)*

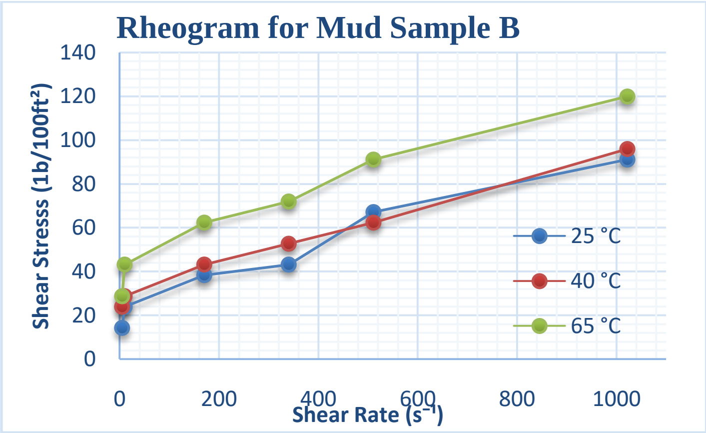

Figure2.*Rheogram for Sample B (Mud + 0.15 g Banana Flour)*

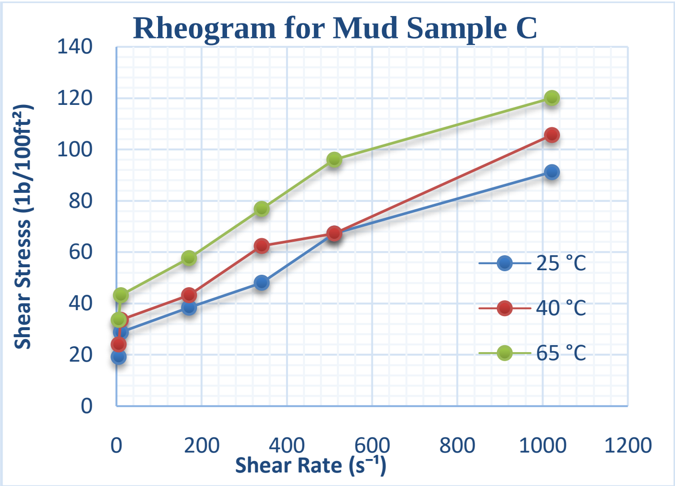

Figure3.*Rheogram for Sample C (Mud + 0.30 g Banana Flour)*

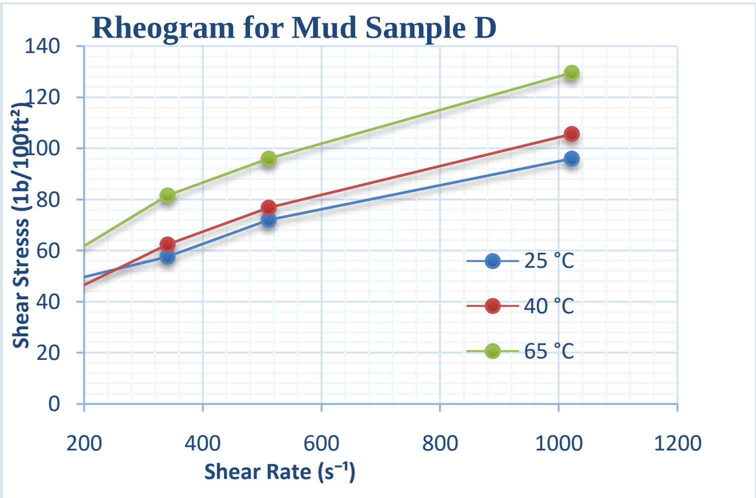

Figure4.*Rheogram for Sample D (Mud + 0.45 g Banana Flour)*

3.2. Effect of Banana Starch Flour on Plastic Viscosity of Mud Samples

Plastic Viscosity (PV) is an indicator of high shear rate viscosities. PV shows the resistance of fluid flow. Any increase in solid content in drilling fluid such as barite, drill solids, lost circulating materials among others will result in higher PV. In order to ensure optimum drilling, API recommends that PV should be less than 65 (<65) centipoise (cP) for water based drilling mud. This is because low PV shows that the mud is capable of drilling rapidly because of low viscosity of mud flowing out the bit. Fig. 5, shows that, all recorded plastic viscosities values of the various mud samples at different temperatures respectively met the acceptable requirement. It was also observed that, both the control mud (Sample A) which is without banana starch flour and mud samples with their respective concentrations of banana starch flour (Samples B, C and D) had plastic viscosities increasing with increasing temperature except for Sample B (0.15 g of banana flour) and C (0.30 g of banana flour) which exhibited an increase at 40 °C and a subsequent decrease at 65 °C. This could be because, as the temperature of samples B and C was increased, the solid contents were improperly diluted or controlled with the mud. Moreover, this situation can as well be attributed to the fact that increase in temperature tends to break the polymer bonds in the banana starch as a result of starch degradation as the liquid phase of mud is lost due to evaporation. This occurrence is also seen in previous work reported by Dankwa *et al*. (2018b), Sarah and Ishenwu (2015) and Ademiluyiet al. (2011).

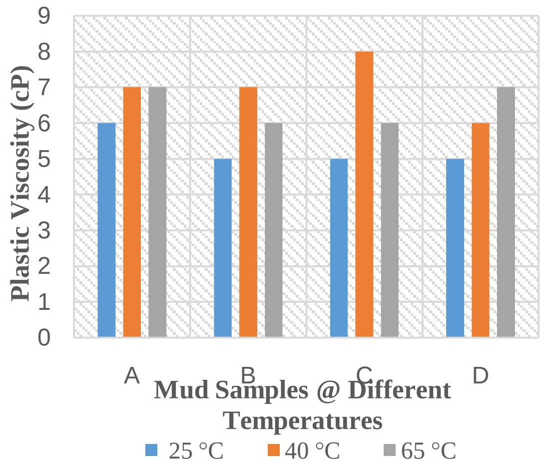

Figure5.*Yield Point vs Conc. of Banana Flour at Various Temperatures*

3.3. Effect of Banana Flour on Yield Point of Mud Samples

Yield Point (YP) denotes the resistance of initial flow of fluid or the stress required to move the fluid caused by electrochemical forces between particles (Azar and Samuel, 2007). The YP indicates the capacity of the drilling mud to lift cuttings to the surface. Therefore to ensure optimum drilling, the YP should not be very low as the fluid will flow faster leaving the cuttings behind in the wellbore. From Fig. 6, it is evident that, a gradual increase in the yield points values were obtained for the mud sample making them acceptable for drilling. Contrariwise, the YP need not be too high as higher YP will lead to higher pressure loss while the drilling mud is being circulated. Also, if the YP is too high, high pumping pressure would be required to initiate flow. In water based mud, the YP will increase by high temperature as well as introduction of contaminant such as salt, cement, anhydrite among others (Opoku Appau, 2016). It is worth noting that, both the control mud and mud samples with their respective concentrations of banana starch flour had yield points increasing with increasing temperature except for Sample B (0.15 g of banana flour) and C (0.30 g of banana flour) which exhibited a decrease at 40 °C and a subsequent increase at 65 °C. This could be because of lower solid concentrations in both mud samples.

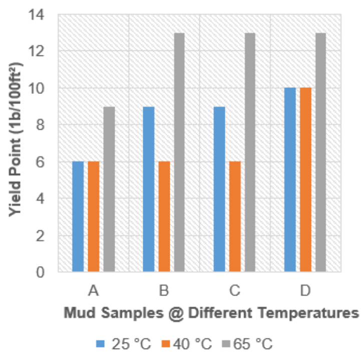

Figure6.*Yield Point vs Conc. of Banana Flour at Different Temperatures*

3.4. Effect of Banana Flour on Apparent Viscosity of Mud Samples

Apparent viscosity is the viscosity that a drilling fluid has at 600 rpm (1022 sec^{-1} shear rate). It is a reflection of the plastic viscosity and yield point combined. An increase in either or both will cause a rise in apparent viscosity (Amorin, 2015). Figure 7, indicates both the control mud (without banana starch flour) and mud samples with banana starch flour had apparent viscosities increasing with increasing temperature and concentration of the banana starch flour. It is therefore clear that, temperature and concentration of banana starch flour had a profound effect on the various mud samples at 600 rpm.

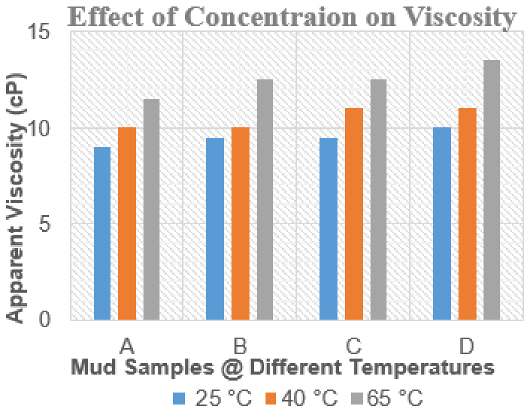

Figure7.*Apparent Viscosity vs Conc. of BananaFlour at Different Temperatures*

3.5. Effect of Banana Flour on the Gel Strength (10 sec and 10 min) of Mud Samples

Gel strength refers to the minimum amount of energy needed to move fluids when it is stable. It therefore provides an indication of the pressure required to initiate flow after the mud have been static for some time. The gel strength of the drilling mud also provides a clue of the suspension ability of cuttings by the mud (Amorin, 2015). For the use of water based mud, API recommends that the mud's timed gel strength for 10 seconds and 10 minutes should be in the range of 3-20 lb/100 ft^2 and 8-30 lb/100 ft^2 respectively. From Fig. 8 and 9, the gel strength of the various mud samples met all the acceptable requirement. It is also worth mentioning that, all the mud samples gel strength increased with both increase in temperature and concentrations of the banana starch flour. This is because increasing the concentrations of the banana starch flour increased the viscosities of the mud samples thereby enhancing the suspension ability of the mud samples. This shows that when such mud is used for drilling, they will be able to hold the drilled cutting and other related materials when the drilling operation is put to hold for a while.

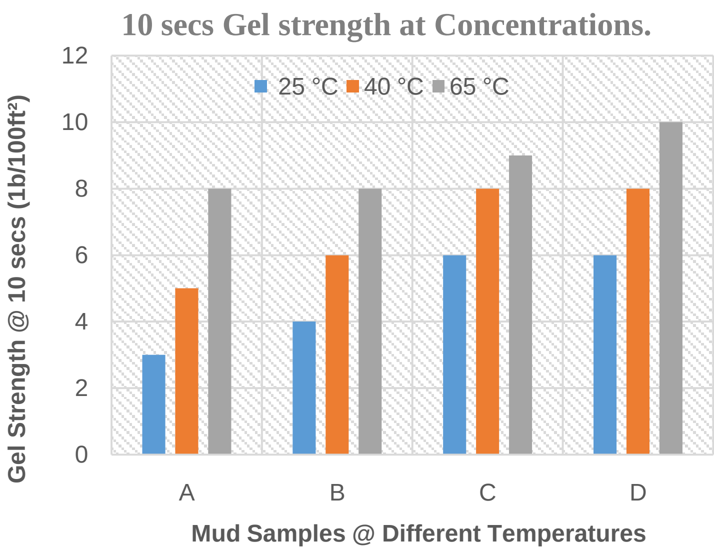

Figure8.*Gel Strength @ 10 seconds vsConc. of Banana Flour atDifferentTemperatures*

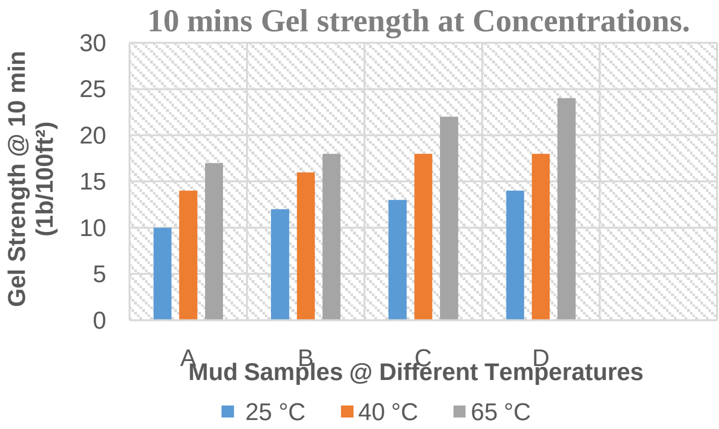

Figure9.*Gel Strength @ 10 minutes vs Conc. OfBanana Flour at Various Temperatures*

3.6. Density Test Analysis

Density is the determination of the weight of the drilling mud which is an important property for controlling subsurface pressures during drilling operation. The drilling fluid must attain certain density (exceeding formation pore pressure) to prevent migration of formation fluids into the wellbore. Nevertheless, the density should not be too great as to cause fracture and subsequent collapse of the formation. From Fig. 10, it is clearly seen that, all the various samples with varying concentrations of banana flour produced the same density of 8.84 1b/gal. This could be due to the small concentrations of banana flour used and also, it means the banana flour is not a good weighting agent like barite. In addition, the API specification of density of a drilling mud is in the range of 7.5 to over 22 lb/gal., and from Fig.10, all the samples met the standard API requirement.

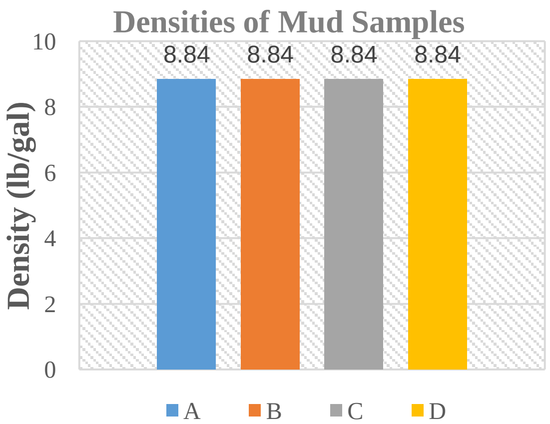

Figure10.*Density of Mud Samples*

4. CONCLUSIONS

From the results achieved from the experimental investigation of the use of modified banana starch as a secondary viscosifier in a water based mud, it can be concluded that:

- Banana starch thus has the potential to be used because, it was able to improve the viscosity of the mud in this experiment.
- Gel strength at both 10 seconds and 10 minutes increased with increasing temperature and concentrations. This means that, the banana flour had a positive effect on the gel strength since it will be capable of suspending the cuttings when drilling is halted.
- Recorded apparent viscosity increased with both temperature and concentration while the plastic viscosity and yield point exhibited instability with both increase in concentration and temperature at 40 °C and 65 °C

- Addition of banana flour at 0.15 g, 0.30 g and 0.45 g did not improve the density of the water-based mud. This can be attributed to the small concentration used and also because banana starch is not regarded as a weighting material.

REFERENCES

Ademiluyi, T., Joel, O. F., Amuda, A. K. (2011), "Investigation of Local Polymer (Cassava Starches) as a Substitute for Imported Sample in Viscosity and Fluid Loss Control of Water Based Drilling Mud", *ARPN Journal of Engineering and Sciences*,Vol. 6, No.12, pp43 - 48.

Amanullah, M. and Yu, L. (2004), "Superior corn-based starches for oil field application",*4th International Crop Science Congress*, Brisbane, Australia, pp. 1 - 6.

Amorin, R. (2015), "Drilling Fluids", *Unpublished BSc Lecture Notes*, University of Mines and Technology, Tarkwa, pp. 120.

Anon. (2017), "API RP 13B-1", *Recommended Practices for Field testing of Water-Based Drilling Fluids*, 5th ed., American Petroleum Institute (API),Califonia, USA, 121pp.

Anon. (2018), *http://www.fao.org/faostat/en/#data/QC/visualize*. Accessed on December 30, 2018.

Assan, P. (2017), "The Use of Modified Starch (Potato Starch) as a Secondary Viscosifier in a Water Based Mud", *Unpublished BSc Project Report,* University of Mines and Technology. Tarkwa, 42 pp.

Ashikwei, D. A., Marfo, S. A. (2016), "Evaluation of the Suitability of Corn Cob Cellulose as a Viscosity Modifier in Water Based Drilling Fluid", 4th UMaT Biennial International Mining and Mineral Conference, Tarkwa, Ghana, pp. 66 - 70.

Azar, J. J. and Samuel, G. R. (2007), Drilling Engineering, PennWell books, Oklahoma, 486 pp

Bourgoyne, A.T., Millheim, K. K., Chenevert, M. E., Young, F. Jr. (1986), *Applied Drilling Engineering. Richardson*, U.S.A, 502 pp.

Caenn, R., Darley, H. C. H., Gray, G. R. (2016), "Composition and Properties of Drilling and Completion fluids", 7th ed. Gulf Professional Publishing: Houston, Texas, USA.

Dankwa, O. K., Opoku Appau, P., Broni-Bediako, E. (2018), "Evaluating the effects of Monovalent and Divalent Salts on the Rheological Properties of Water Based Mud", *The Open Petroleum Engineering Journal*, Vol. 11, No.1, pp. 98-106.

Dankwa, O. K., Opoku Appau, P., Tampuri, M. (2018), "Performance Evaluation of Local Cassava Starch Flour as a Secondary Viscosifier and Fluid Loss Agent in Water Based Drilling Mud", *Ghana Mining Journal*, Vol. 18, No. 2, pp. 68-76.

Dosunmu, A., Ogunrinde, J.O. (2010), "Development of Environmentally Friendly Oil Based Mud using Palm-Oil and Groundnut-Oil", *34th Annual SPE International Conference and Exhibition*, Tinapa-Calabar, Nigeria, 9 pp.

Harry, T. F., Joel, O. F., Ademiluyi, F. T., Oduola, K. (2016), "Performance Evaluation of Local Cassava Starches with Imported Starch for Drilling Fluid",*American Journal of Engineering Research*, Vol. 5, pp. 111 – 120.

Hossain, M. E., Al-Majed A. A. (2015), *Fundamentals of Sustainable Drilling Engineering*, 1st ed. Wiley-Scrivener, New York, USA, 786pp.

Igbani, S., Peletiri, S. P., Egba, S. U. (2015), "A Study on the Individual Impact of Cassava Starch and Hydroxyl Propyl-Modified Starch on Mud Density", *International Journal of Engineering Trends and Technology (IJETT)*, Vol. 29, No. 1, pp. 1 - 5.

Joshi, G. and Sarangi, M. K. (2014), "A Review on Banana Starch", *Inventi Rapid: Planta Activa Journals*, Vol. 3, pp. 1 – 8.

Malkin, A. Y.and Isayev, A. I. (2014), *Rheology: Concepts, Methods, and Applications*, 3rd ed. ChemTec Publishing, Toronto, Canada, March 10, 2018, 486pp.

Nguyen, T. (2012), "Drilling Fluid Components", *www.Infohost.nmt.edu*, Accessed: January 13, 2018.

Nimsung, P., Thongngam, M., Naivikul, O. (2005), "Some Properties of Raw Banana Flour and Starch from Thai Banana Cultivars", *The 3rd Conference on Starch Technology*, Bangkok, Thailand, pp. 201 – 206.

Nyande, K. A.(2017), "Comparative Analysis of Local Cocoyam (Colocasia Esculanta) and Yam (Dioscorea) as Secondary Viscosifiers and Fluid Loss agent in Water Based Muds", *Unpublished BSc Project Report*, University of Mines and Technology, Tarkwa, 31pp.

Oghenejoboh, K. M., Orugba, H., Oghenejoboh, U. and Agarry, Samuel (2021). "Value added cassava waste management and environmental sustainability in Nigeria: A review", *Environmental Challenges*. 4. 100127. 10.1016/j.envc.2021.100127.

Olatunde, A. O., Usman, M. A., Olafadehan, O. A., Adeosum, T. A. and Ufot, O. E. (2012), "Improvement of Rheological Properties of Drilling Fluid Using Locally Based Materials". *Journal of Petroleum and Coal*, Vol. 54, No. 1, pp. 65 – 75.

Okumo, I., Isehunwa, S. O. (2007), "Prediction of the Viscosity of Water Base Mud Treated with Cassava Starch and Potash at Varying Temperature Using Factorial Design", *31st Nigeria Annual International Conference and Exhibition*, Abuja, Nigeria, pp. 1- 9.

Olatunde, G. O., Arogundade, L. K., Orija, O. I. (2017), "Chemical, Functional and Pasting Properties of Banana and Plantain Starches Modified by Pre-Gelatinisation, Oxidation and Acetylation", *Cogent Food and Agriculture*, Vol. 3, pp. 1 – 12.

Opoku Appau, P. (2016), "Evaluating the Effects of Monovalent and Divalent Salts on the Properties of Water Based Mud", *Unpublished BSc Project Report*, University of Mines and Technology, Tarkwa, 31pp .

Rabia, H. (2000), *Well Engineering and Construction*, Graham and Trotman Publication. London, U.K., 638pp.

Shah, S. N., Shanker, N. H., Ogugbue, C. C. (2010), "Future Challenges of Drilling Fluids and their Rheological Measurements", *AADE Fluids Conference and Exhibition*, Houston, Texas, pp 1 - 16.

Strachan, F. M. (2010), "Studies on the Impact of a Water Based Drilling Mud Weighting Agent (Barite) on Some Benthic Invertibrates", *Unpublished BSc Project Report*, Heriot-Watt University, Edinburgh, U.K, 179 pp.

Udoh, F. D., Okon, A. N. (2012), "Formulation of Water-Based Drilling Fluids Using Local Materials" *Global Science Publications*, Vol. 14, No. 2, pp. 167 - 174.

Van Der Horst, P. M. (2011), "Use of CMC indrilling fluids", *https://patents.google.com/patent/US7939469B2/en*, Accessed: September 29, 2021.

Wami, E. N., Nmegbu, C. G. J., Pius, J. I. (2015), "Drilling Mud Formulation Using Potato Starch", *International Journal of Engineering and Applications*. Vol. 5, pp. 48 – 54.

Citation: *Dankwa, O. K. et al. (2024). "Experimental Investigation of the Potential use of Banana Starch Flour as a Secondary Viscosifier in Water-Based Mud", International Journal of Petroleum and Petrochemical Engineering (IJPPE), 9(1), pp.20-29, DOI: http://dx.doi.org/10.20431/2454-7980.0901003*