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Original Research Article

Improvement of Rheological Properties of Drilling Fluid using Guar Gum-Tamarind Gum and Xanthan Gum-Tamarind Gum Blends

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ABSTRACT

Local consumption and the excessive cost of importing bentonite into Nigeria have led to the search for local alternatives for economic reasons. Thus, this work aims to improve locally sourced clay using blends of guar gum-tamarind gum and xanthan gum-tamarind gum for the application of drilling fluid (water-based mud). The clay sample was beneficiated to remove quartz and other impurities. The elemental and mineralogical characteristics of the clay sample were investigated. The drilling mud was formulated by mixing 22.5 g of the clay with 350 ml of water with a high-speed mixer. The natural gum (i.e. guar gum and tamarind gum) blend of 2.5 g was added to the mixture. The effect of natural gum blends on the rheological properties of the formulated drilling fluid was investigated using the FANN 35 viscometer. The tamarind gum-guar gum blend at ratio 1:3 in the formulated drilling fluid was found to have enhanced the yield point from 3 $lb_f/100ft^2$ to 39.5 $lb_f/100ft^2$. The mud enriched with these natural gum blends had high rheological properties comparable with the API specification 13-A for drilling fluid materials.

1. INTRODUCTION

Drilling muds are complex fluids that are relevant for the gas and geothermal drilling industry. This is because they transport cuttings to the surface, lubricate the drill, apply hydrostatic pressure in the wellbore to establish well safety and reduce fluid loss through permeable formations crating a filter cake on the wells of the wellbore (Abdou et al., 2013). The job of drilling fluid is to cross through formations with strong porosity while retaining all its rheological properties and without producing harm to the navigated formations (Baba Hamed and Belhadri, 2009). Polymers are included in drilling fluids to modify viscosity, yield stress and maximum shear stress to strengthen the drilling and assist in the transfer of cuttings from the bottom of the well to the surface in supplement to the above-named functions (Kelessidis et al., 2006).

The tamarind gum is a cheap viscosity modifier and may be employed in drilling fluid production. It is seven times cheaper than guar gum (Mahto and Sharma, 2004). Building blocks of tamarind gum are D-glucose, D-galactose, and D-xylose in the ratio 3:1:2. Xanthan gum is a remarkably high-molecular-weight polysaccharide formed by pure culture fermentation of glucose by *Xanthamonas campestris*. The substance is easily soluble in water, conveying a significant viscosity at low concentrations (Considine, 2005). The building blocks D-glucose, D-mannose, and D-glucuronic acid appear in a molecular ratio of about 3:3:2 (Wüstenberg, 2014). Guar gum is prepared from endosperm of cluster bean and in aqueous solutions exhibits shear-thinning behaviour (Mudgil et al., 214). Building blocks of this polysaccharide consisting of D-mannose and D-galactose in a molecular ratio of 1.6:1 (Wüstenberg, 2014).

Many researchers have studied the improvement of rheological properties of drilling fluid, particularly in Nigeria. Olatunde et al. (2012) improved the rheological properties of local clay to meet commercial standard using guar gum and polyanionic cellulose. Ibrahim et al. (2017) improved local clay using three carboxymethyl cellulose (CMC) with different average molecular weight. Ibrahim et al. (2018) attempted improving the rheological properties of local bentonite using tamarind gum, locust bean gum and xanthan gum. This work is aimed at improving rheological properties of drilling fluid using blends of guar gum-tamarind gum and xanthan gum-tamarind gum. Many researchers have studied the improvement of rheological properties of drilling fluid, particularly in Nigeria. Olatunde et al. (2012) improved the rheological properties of local clay to meet commercial standard using guar gum and polyanionic cellulose. Ibrahim et al. (2017) improved local clay using three carboxymethyl cellulose (CMC) with different average molecular weight. Ibrahim et al. (2018) attempted improving the rheological properties of local bentonite using tamarind gum, locust bean gum and xanthan gum. This work is aimed at improving rheological properties of drilling fluid using blends of guar gum-tamarind gum and xanthan gum-tamarind gum.

2. MATERIALS AND METHODS

2.1. Raw Clay Collection and Beneficiation

The clay sample was acquired from Potiskum deposit in Yobe State, Nigeria. Three kilograms of the clay was weighed and crushed with ball mill crusher. The sample was then soaked in 30 litres of water in a plastic vessel and the mixture was stirred for three hours. The stirred mixture then allowed to remain in the vessel for 24 hours so that the coarse quartz impurities resolve to the bottom, leaving a colloidal solution of bentonite at the top. The colloidal bentonite was collected and separated from the quartz residues and sieved through a 75 μm sieve opening to remove additional impurities. The resulting cake was dried in an oven at 100°C for 24 hours, crushed and pulverized with a ball mill machine and then sieved with 106 μm mesh (Ahmed et al., 2012).

2.2. Extraction of Tamarind Gum

Tamarind seeds were collected and sun dried for five hours. The kernels were de-husked and crushed into fine powder. Exactly twenty grams of fine kernel powder was added to 200 ml of cold distilled water to prepare slurry. The slurry obtained was then poured into 800 ml of boiling distilled water and boiled for 20 min on a water bath to obtain a clear solution which was kept overnight. The thin clear solution was then centrifuged at 5000 rpm for 20 min to separate all the foreign matter. The supernatant was separated and poured into excess of absolute alcohol with continuous stirring. Precipitates obtained was collected by filtration method and washed with 200 ml of absolute ethanol and dried at 50 °C for 48 h. The dried polymer was milled and stored in a desiccator until further use.

2.3. XRF Analysis

X-Supreme 8000 X-ray fluorescence (XRF) spectrometer was used to determine the composition of the oxides present in the clay sample. The clay was dried in an oven at 105 °C for an hour and allowed to cool. Twelve grams of the clay sample was thoroughly mixed with 3 g of binder (stearic acid) in agate mortar. The mixtures were then formed into a pressed powder pellet using a hydraulic pressure press, a weight of 20 tons was used. The pressed powder pellets were then analysed for oxide composition using X-ray fluorescence XRF spectrometer, a computer system and software for the analysis.

2.4. XRD Analysis

X-Ray Diffraction (XRD) was carried out to detect the mineralogical structures or mineral phases of the beneficiated clay sample. The mineralogical phases for the clay was detected utilizing Shimadzu Model 6000 X Ray diffractometer. The clay sample was first pulverized and then sieved to achieve 1.5-micron particle size to satisfy the required equipment specification. The sample was oven dried for one hour at 60 °C and allowed to cool to room temperature. The sample was then mounted on a specimen holder of the diffractometer which was set at a voltage of 40 kV and current 30 mA. The sample was arrayed and evaluated between the angles at 3.0 degrees per minute for 21 min. The diffractograms was displayed automatically and processed using accompanied Shimadzu diffractometry software. The report of the diffractometer obtained from the XRD was based on the match techniques.

2.5. Drilling Mud Formulation

Drilling mud was formulated by mixing 22.5 g of the beneficiated clay to 350 ml of water with a high-speed mixer at 18 000 rpm for 60 s to obtain a homogenous mixture. The polymer blend of 2.5 g was also added to the mixture and then mixed at 18 000 rpm for 40 s. The mud formed was allowed to hydrate for 24 hours. The composition of the polymer blends was determined using Simplex lattice mixture design using design of experiment software, Design Expert 11. Similar procedure was done for other formulation of polymer blends as shown in Table 1.

Table 1: Composition of polymer blends for drilling fluid formulation

Run	Component 1 Tamarind gum (g)	Component 2: Xanthan gum/Guar gum (g)
1	2.5	0
2	1.25	1.25
3	2.5	0
4	0	2.5
5	0	2.5
6	1.875	0.625
7	1.25	1.25
8	0.625	1.875

2.6. Determination of Rheological Properties of the Drilling Fluid

FANN 35SA viscometer was used to determine the rheological properties. The mud sample was mixed at 18 000 rpm with a mixer until a homogeneous mixture was obtained, while avoiding formation of foam. The sample was then poured into sample holder and mounted to position. The Model 35SA viscometers operate at six speeds. To select the 300 rpm, the gear shift knob was moved to the bottom and speed switch was set to low speed position. The 300 rpm reading was recorded when the indicator dial gauge value was steady. Similar procedure was done for 600, 200, 100, 6 and 3 rpm. The plastic viscosity (PV) and yield point (YP) were determined using Equations (1) and (2).

A.O. Ibrahim et al. / Nigerian Research Journal of Engineering and Environmental Sciences
4(2) 2019 pp. 912-920

$$PV = \{Dial\ readingat\ 600\ rpm - Dial\ readingat\ 300\ rpm\}\ cP \quad (1)$$

$$YP = \{Dial\ readingat\ 300\ rpm - PV\}\ \frac{lb}{100ft^2} \quad (2)$$

3. RESULTS AND DISCUSSION

3.1. Elemental and Mineral Composition of the Clay sample

The analysis of the elemental oxides and mineral composition are displayed in Table 2 and Figure 1 respectively.

Table 2: Summary of the oxide composition of the clay samples

Oxide composition	Raw clay (%)	Beneficiated clay (%)
MgO	7.375	7.223
Al_2O_3	13.653	15.098
SiO_2	41.616	44.804
K_2O	1.036	1.028
CaO	20.879	18.775
Fe_2O_3	9.683	9.417
TiO_2	1.036	1.253
SO_3	3.472	1.372

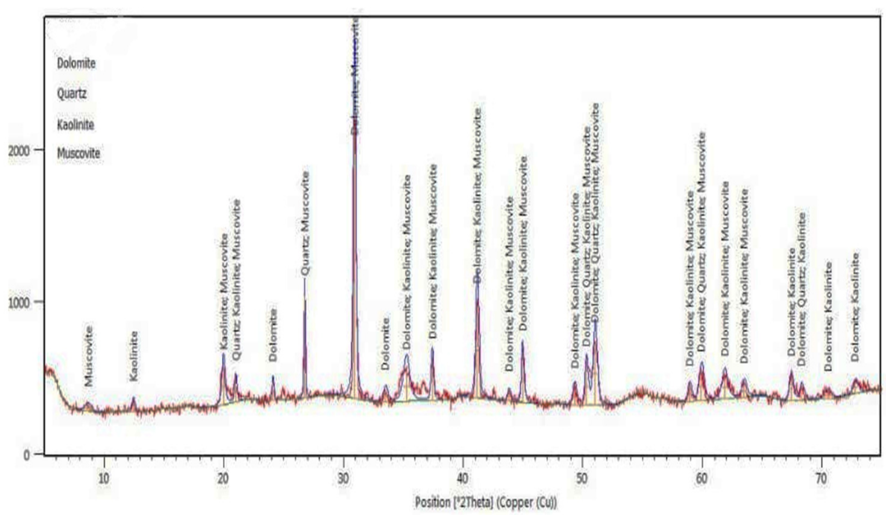

Figure 1: XRD Pattern of the beneficiated clay sample

The oxide composition revealed that the alumina composition of the raw clay sample was 13.65 wt%. The Al_2O_3 content raised to 15.098 wt% for the beneficiated sample. The silica content was 41.62 wt% for the raw specimen and rose to 44.80 wt% for the beneficiated sample. A reduction was predicted since quartz was withdrawn during beneficiation. The XRD results illustrated in Figure 1 proved that the clay was primarily comprised of dolomite, quartz, kaolinite, and muscovite. Kaolinite, ($Al_2Si_2O_5(OH)_4$) is a layered aluminosilicate with a dioctahedral 1:1-layer structure consisting of tetrahedral silicate sheets and octahedral aluminium hydroxide sheets (Baba Hamed and Belhadri, 2009). Quartz, SiO_2 and dolomite, $CaMg(CO_3)_2$ are non-clay minerals components of the clay sample (Murray and Staff, 2014).

3.2. Rheological Properties of the Beneficiated Clay Mud

The rheological properties of the formulated mud with no additive is illustrated in Table 3. The viscometer dial reading at 600 rpm of the beneficiated clay mud was 11 cP which did not meet API specification 13-A for drilling fluid materials (API Specification 13A, 2010). The yield point of the formulated mud was less than that of El-Mahllawy et al. (2013). This is because the absence of montmorillonite in the beneficiated drilling mud. Montmorillonite is the active component in bentonite that's responsible for the high non-Newtonian rheological properties as well as it's shear-thinning characteristics (Ukeles and Grinbaum, 2004).

Table 3: Rheological properties of the beneficiated clay

Properties	Beneficiated clay	Wyoming clay (Ibrahim et al., 2017)
Viscometer dial reading at 600 rpm (cP)	11	30
Plastic viscosity (cP)	4	8
Yield point (lbf/100ft^2)	3	14

3.3. Rheological Properties of the Beneficiated Clay Mud Treated with the Polymer Blend

Figures 2 and 3 display the profiles of the viscometer dial reading at 600 rpm of the various polymer blends treated drilling fluid. The viscometer dial reading at 600 rpm of the drilling mud treated with guar gum-tamarind gum and xanthan gum-tamarind gum blends are shown in Figures 3 and 4 respectively. The results indicate viscometer dial reading at 600 rpm in clay sample was improved to 74.5 cP and 53.7 cP on adding guar gum-tamarind gum at blend ratio of 3:1 and xanthan gum-tamarind gum at blend ratio of 3:1 respectively. This exceeds the 30 cP reported in the commercial grade Wyoming bentonite in the work of Ibrahim et al. (2017). This suggests that guar gum allows the swelling of tamarind gum whereas xanthan gum made them more difficult to swell (Kaur et al., 2013).

Similarly, the plastic viscosity likewise exhibited some enhancement especially after inclusion of the polymer blends as illustrated in Figures 4 and 5. The values increased up to 17.5 cP and 9.3 cP on adding guar gum-tamarind gum at blend ratio of 3:1 and xanthan gum-tamarind gum at blend ratio of 3:1 respectively. The values matched well with the commercial grade of 8 cP (Ibrahim et al., 2017). The formulated mud treated with polymer blends was found to have lower plastic viscosity than the formulated mud with polynomic cellulose (PAC) as reported by Olatunde et al. (2012).

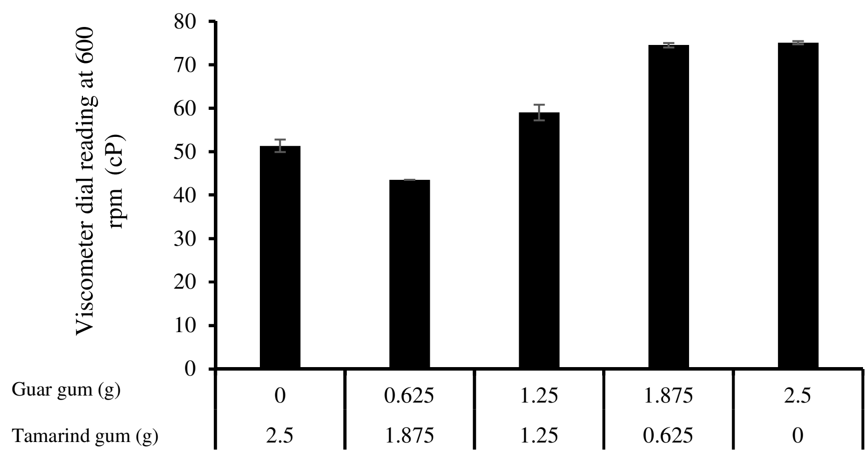

Figure 2: Viscometer dial reading at 600 rpm of the drilling mud treated with guar gum-tamarind gum blend

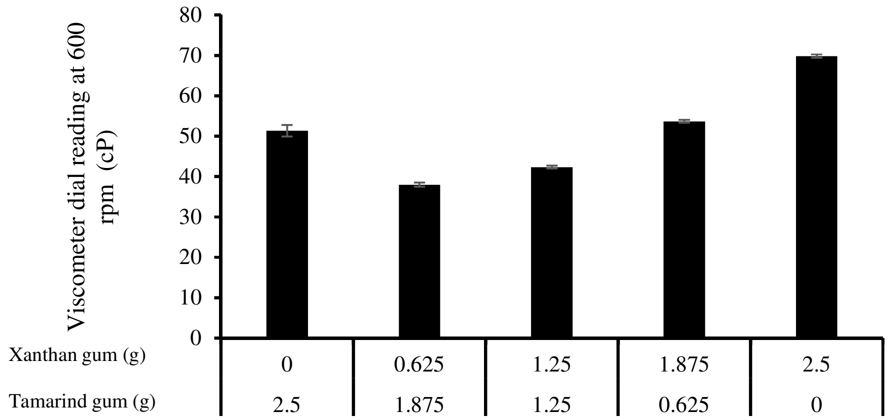

Figure 3: viscometer dial reading at 600 rpm of the drilling mud treated with xanthan gum-tamarind gum blend

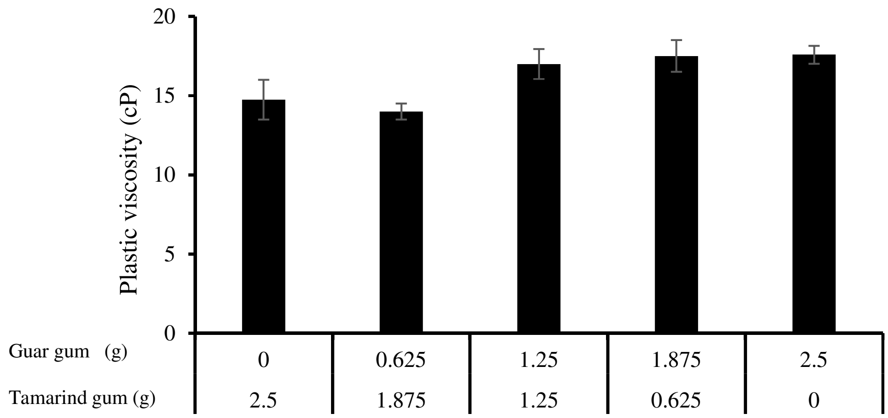

Figure 4: Plastic viscosity of the drilling mud treated with guar gum-tamarind gum blend

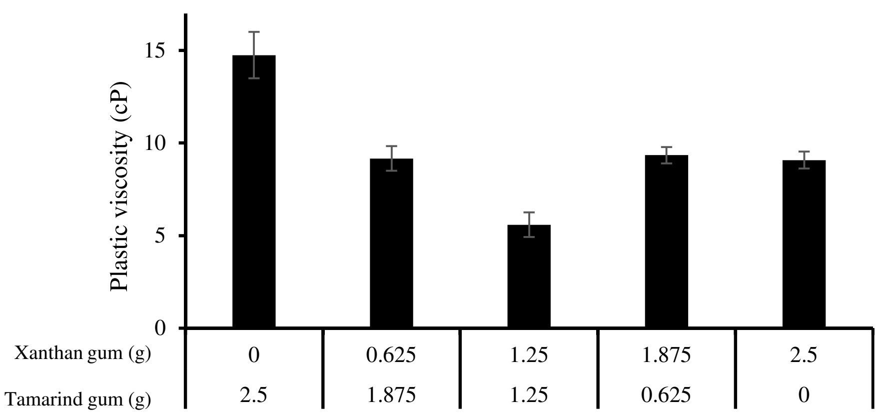

Figure 5: Plastic viscosity of the drilling mud treated with xanthan gum-tamarind gum blend

Figures 6 to 9 display the yield and ratio of yield point to plastic viscosity of the various polymer blends treated drilling fluid. The yield point of the drilling mud exhibited some enhancement after addition of the polymer blends as illustrated in Figures 6 and 7. The yield point in clay sample was upgraded to 39.5 $lb_f/100ft^2$ and 35 $lb_f/100ft^2$ on adding guar gum-tamarind gum at blend ratio of 3:1 and xanthan gum-tamarind gum at blend ratio of 3:1 respectively. The formulated mud treated with polymer blends was found to have higher yield point than the formulated mud with carboxymethyl cellulose as reported by Olatunde et al. (2012). Likewise, the ratio of yield point to plastic viscosity showed some improvement after adding the polymer blends as illustrated in Figures 9 and 10. The values improved up to 2.3 and 8.3 on adding guar gum-tamarind gum and xanthan gum-tamarind gum blends respectively. The mud treated with xanthan gum-tamarind gum blend at ratios 1:1 and 3:1 exceeded API maximum value of 3 (API Specification 13A, 2010).

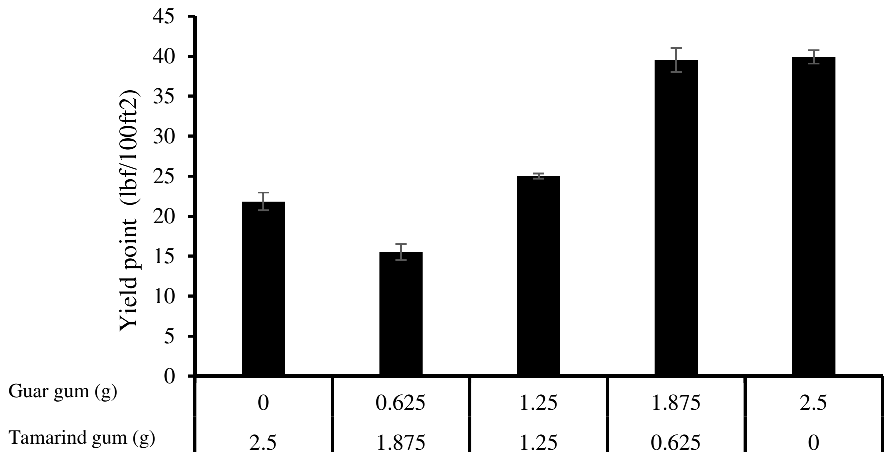

Figure 6: Yield point of the drilling mud treated with guar gum-tamarind gum blend

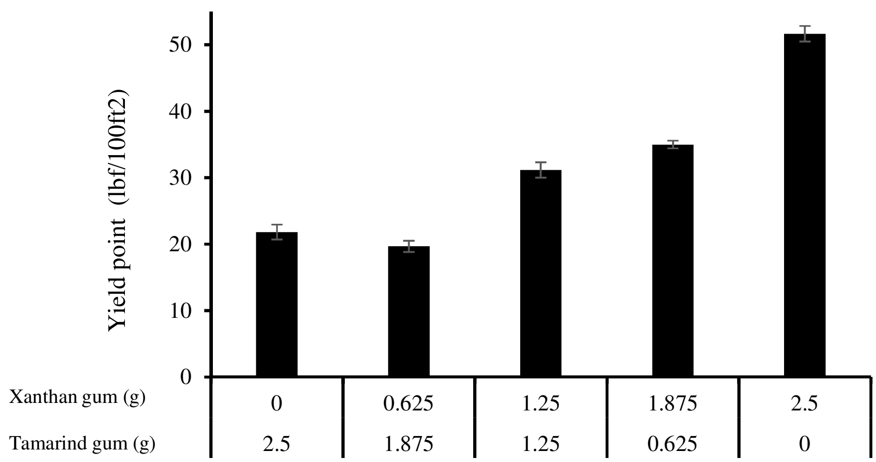

Figure 7: Yield point of the drilling mud treated with xanthan gum-tamarind gum blend

A.O. Ibrahim et al. / Nigerian Research Journal of Engineering and Environmental Sciences
4(2) 2019 pp. 912-920

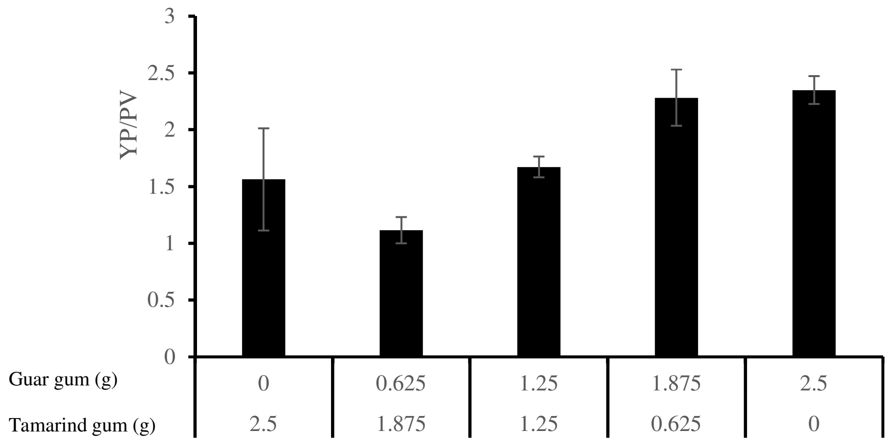

Figure 8: Ratio of yield point to plastic viscosity of the drilling mud treated with guar gum-tamarind gum blend

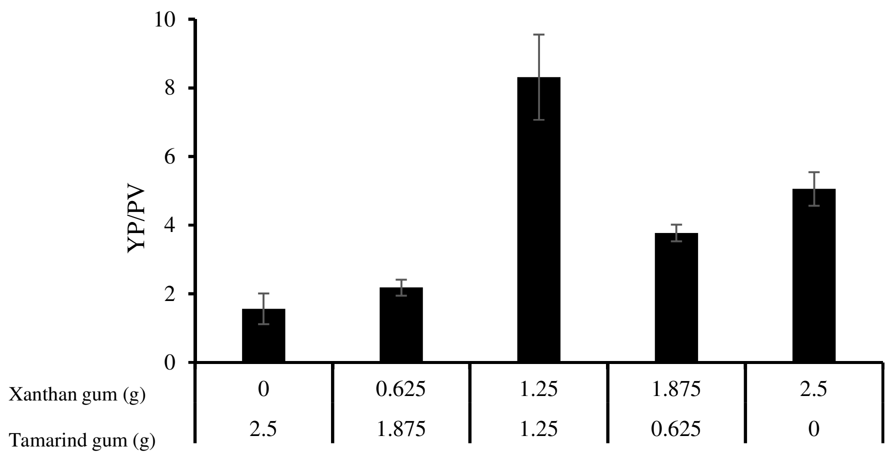

Figure 9: Ratio of yield point to plastic viscosity of the drilling mud treated with xanthan gum-tamarind gum blend

4. CONCLUSION

In this study, the clay was beneficiated and rheological properties including yield point, plastic viscosity and the ratio yield point to plastic viscosity of formulated mud enhanced with guar gum-tamarind gum and xanthan gum-tamarind gum blends were investigated. Based on X-ray diffraction (XRD) analyses the clay had kaolinite. Viscometer dial reading at 600 rpm of the beneficiated bentonite clay was 11 cP which was lower than commercial grade of 30 cP. Treatment of the clay with guar gum-tamarind gum and xanthan gum-tamarind gum blends resulted to high values of rheological properties comparable with the API specification 13-A for drilling fluid materials.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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