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Development and Comparative Evaluation of Water-Based Drilling Fluid Performance Using Rice Husk and Groundnut Husk to Enhance the Fluid Loss Control and Rheological Properties

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Keywords

Bentonite, rice husk, water-based drilling fluid

Abstract

Numerous research studies have been carried out for development of water-based drilling fluid using rice husk, xanthan gum, bentonite clay, and other additives but the fluid loss analysis and groundnut husk as an additive has not been carried out. This research developed and characterized a water-based drilling fluid using bentonite clay, rice husk, groundnut husk, xanthan gum, and barite. Raw groundnut and rice husk were ground to 120 microns, forming 33 drilling fluid samples and 12 blend samples for FTIR analysis. Rheological properties were evaluated using a Model 35A viscometer at various speeds. Mud densities and filtration properties were measured. The Herschel-Bulkley and Casson models were employed to validate the experimental data. Optimal FTIR blending interaction/formation was observed for groundnut husk with xanthan gum in a 2:1 ratio, rice husk in a 1:1 ratio with groundnut husk, and bentonite with groundnut husk in a 1:1 and 2:1 ratio. RH improves the viscosity at 600 rpm, PV, and AV than GH whereas the groundnut husk improves the gel strength better, the addition of 5g barite to samples 18 and 21 increased viscosity slightly from 33.7566 cP & 29.5058 cP to 34.0121 cP & 30.0026 cP respectively. More viscosity improvements were noted when rice husk was added to samples 2 & 3, compared to groundnut husk whereas groundnut husk showed better performance when improving the viscosity of sample 4. Both rheological models showed reduced accuracy for samples with lower shear stresses @600rpm, with the Casson model performing better while for samples with higher shear stresses @600rpm and for the optimum samples, the Herschel-Bulkley model showed superior accuracy. All blends exhibited shear thinning behavior.

1. Introduction

A key part of the rotary drilling process is the use of drilling fluid, which plays essential roles such as removing rock fragments, maintaining borehole integrity, cooling and lubricating the drill bit. This fluid also applies hydrostatic pressure to prevent fluid ingress until the steel casing is cemented in place [1,2]. Water-base muds are made up of a combination of solids, liquids, and chemicals, with water acting as the continuous phase, solids that interact with the aqueous phase and dissolved compounds are referred to as active solids. The chemicals added to the mud inhibit the action of such solids, allowing certain drilling fluid parameters to be kept within acceptable ranges [3].

The properties of montmorillonite (Mt) that give value are its reactive and adsorptive properties and this depends on its ability to adsorb molecules at interlayer sites and its extensive surface area [4,5]. The good rheological properties of bentonite make it widely used in the development of water-based drilling fluids and is an example of Mt [6]. Bentonite clay, rice husk, xanthan gum, and other additives may be employed to develop water-based drilling fluids due to their proven good rheological properties [7-9]. Several researchers have investigated the effects of different viscosifiers such as bentonite, xanthan gum, and nanoparticles on the rheological properties of water-based drilling fluid, all of which are imported and quite expensive, so there is a need to look for a cheaper alternative source. Rice husk, being an agricultural waste and a low-cost commodity, may readily fit into the assignment if suitable. Rice husk is regarded as agro-waste in undeveloped and emerging nations such as Nigeria since farmers in these countries lack the technological know-how to capitalize on its potential [8].

Numerous research studies have been carried out for the development of water-based drilling fluid using rice husk, xanthan gum, bentonite clay, and other additives but the fluid loss analysis and groundnut husk as an additive has not been carried out [3,9]. The need to develop a novel water-based drilling fluid using rice husk, xanthan gum, bentonite clay, barite and the new addition of groundnut shell, its rheological properties and fluid loss are to be studied. The objectives of the research; to characterize groundnut husk and its blend with other components using FTIR analysis, develop enhanced water-based drilling fluids using various combinations of rice husk, groundnut husk, bentonite clay, and xanthan gum also, determine the enhanced water-based drilling fluid's rheological properties and other properties, perform the fluid filtration loss analysis on the produced drilling fluid using a filter press, identify optimum sample blends according to API specifications and compare performance between rice husk and groundnut husk blend and Validation of the Rheological data measured using Herschel Bulkley and Casson Rheological models and find the best suitable model for the formulated drilling mud.

2. Methodology

2.1 Collection and Treatment of Samples

Raw powdered and dried bentonite clay was procured from a supplier in Bauchi state, Northeast Nigeria. Xanthan gum and $BaSO_4$ were also procured through the head of the chemical engineering laboratory Lagos state university (LASU). Rice husk and groundnut husk were obtained from the local farmers in Bauchi State, Northeast Nigeria after harvest, all unwanted particles were removed, and the sample was then dried, crushed using a blender, and sieved into fine particles of 120-125 microns to get the fine particles as reported by Angaji et al. [5].

American Petroleum Institute (API) standard barrel of 350ml of deionized water was used in the formulation of the drilling mud by pouring into the individual blend mixed gently for homogeneity to be achieve and left for 24 hours to age [10]. The dried pure and blended samples were characterized using FTIR.

2.2 Fourier Transform Infrared (FTIR) Analysis

FTIR machine was used to characterize the pure samples and blends of the sample in the Chemical Engineering Laboratory of Ahmadu Bello University ATBU and the results were presented in a graph generated by a computer. FTIR precisely measures the amount of light absorbed by the sample by using an infrared (IR) light source to pass through the sample and onto a detector. To identify the sample's molecular structure and calculate the precise concentration of a certain compound in a mixture, this absorbance generates a distinctive spectral fingerprint. The infrared radiation for the sample was collected using an Agilent FTIR spectroscope (range: 4000-650 cm^{-1}), and the results are displayed on a transmittance wavelength graph [8].

2.3 Characterization of the Drilling Fluid

2.3.1 Plastic Viscosity (PV), Apparent Viscosity (AV) and Yield Point (YP) Determination

Low-temperature 35A model Fann viscometer was used for the characterization, 350ml of the aged and stirred mud sample was poured into the stainless-steel sample cup mark and the cup was raised to the scribed line mark on the rotor and the lock screw was tightened. The model 35A viscometer operates on six speeds (3, 6, 100, 200, 300, and 600 rpm) and reading was taken from each speed after the dial stabilizes. PV is a slope of a straight line from two dial readings 600rpm and 300rpm, YP stands for the hypothetical point where the projected straight line will cross the vertical axis (Model 35 Viscometer Instruction Manual, 2013). All of the prepared samples underwent the same process.

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

$$YP\ (lb/100\ ft^2) = \theta_{300} - PV \tag{2}$$

$$AV\ (cP) = \theta_{600}/2 \tag{3}$$

The conversion of the RPM to shear rate and the dial reading to shear stress is given as follows (Model 35 Viscometer Instruction Manual, 2013):

$$1^{o}Fann = 1\ lb/100ft^2 = 5.11\ dyne/cm^2 = 0.511\ N/m^2 \tag{4}$$

$$1/sec = 1.7023\ N \tag{5}$$

2.3.2 Gel Strength

The prepared sample was poured into the sample holder, mounted, and lifted until the mud reached the scribe line. The base is then raised, and the lock screw is tightened. The sample was stirred thoroughly at 600 rpm for 15 seconds, the gear shift knob was set to 3 rpm and the motor was turned OFF for 10 seconds. After the desired wait time, the motor was turned ON at the lowest speed, and the maximum deflection was read as the 10 seconds gel strength in (lb/100 ft^2), the same procedure was repeated for 10 minutes wait time as the 10 minutes gel strength (Model 35 Viscometer Instruction Manual, 2013). The same procedure was repeated for all the samples prepared.

2.3.3 Determination of Mud Density

Mud balance is used to estimate the mud's density. The base was placed on a flat, level surface. The balance cup was filled to the top with the test sample, and the lid was then tightened by gradually rotating it until it was properly seated. The part of the test sample is forced out through the vent hole in the lid to remove any entrained air or gas [11]. The balancing arm's knife edge was fitted into the fulcrum before the assembly was balanced by sliding the rider along the arm. The mud balance is horizontal when the level bubbles analysis moves equally to each side of the center [12].

2.3.4 Drilling Mud LPLT Filtration

The same procedure sample preparation above was followed in the preparation of the 33 samples for the filtration analysis. A 200 mL static filter press was employed, featuring a controlled air compressor pressurization system and a filter paper for support during the LTLP static filtration tests. For testing, the working pressure was set to 100 psi [6], while the temperature remained at atmospheric levels. To begin, 200 mL of the prepared sample was carefully measured in a beaker and poured into the filter press sample cup, ensuring minimal air gap at the top. The rubber seal was then positioned atop, followed by the filter paper. Subsequently, the cover was placed on top the filter paper and securely twisted to lock the assembly. The sample cup was affixed to the filter press frame and securely fastened.

Beneath the sample cup filtrate nozzle, a graduated cylinder was positioned, and the air compressor was initiated. The pressure regulator was adjusted to maintain 100 psi, and the needle valve, connecting the pressure line to the upper part of the sample cup, was opened. Simultaneously, the stopwatch was started as the valve was opened, and the filtrate volume was recorded at intervals of 10, 20, and 30 minutes.

Upon completion of the 30-minute test period, both the pressure regulator and the needle valve were closed. The sample cup was subsequently disengaged from the filter press frame, and the mud chamber was meticulously disassembled to prevent any harm to the filter cake on the filter paper. Following this, the filter paper was removed gently and finally, the thickness and weight of the filter cake and filter paper were measured in millimeters and grams, respectively. The filter cake weight and thickness were obtained by subtracting the already measured filter paper weight and thickness from the combined cake and filter paper weight and thickness.

2.3.5 Drilling Mud Rheological Models

Several mathematical models have been developed to explain the relationship between drilling fluid shear stress and shear rate. These models are used to describe flow characteristics to ascertain a fluid's capacity to carry out particular tasks [13]. The Bingham Plastic model and power law model are expanded to incorporate shear rate dependence in the Hershel-Bulkley rheological model (HBRM) [14]. Which will be used in this work in comparison with the Casson model [15]. The rheological modeling analysis will be used to have a better understanding of their rheological properties and validate the experimental data.

$$\tau = \tau_{OH} + K_H \; \Upsilon^{nH} \quad (6)$$

Where τ is the shear stress in Pa, γ is the shear rate in s^{-1}, n_H is the flow behavior index which is dimensionless, k_H is the HRBM consistency index in (Pa. s^n), and τ_{OH} is the HBRM yield stress (Pa). The yield stress is taken at 3 rpm and by linearizing it will result in a linear equation of the form;

$$log\,(\tau - \tau_{OH}) = log\,K_H \; + \; n_H \; log\,(\gamma) \quad (7)$$

A plot of log ($\tau - \tau_{OH}$) versus log (γ) will result in a straight line with intercept log k_H and slope n_H [14], the fluid is shear thinning when n_H is less than 1, and shear thickening when n_H is greater than 1 [16]. Visco-elastic fluid flow is described using the structure-based Casson Rheological Model [16]. The transition from the Newtonian to the Yield zone is more gradual in this model. The Casson model can be stated mathematically [14].

$$\tau^{0.5} = K_c^{0.5} + K_c^{0.5}\Upsilon^{0.5} \quad (8)$$

Where kc is the Casson plastic viscosity in cP and koc is the Casson yield stress (Nm^{-2}). When the square root of ∑the shear stress ($\tau^{0.5}$) is plotted against the square root of the shear rate ($\gamma^{0.5}$), it gives a straight line with a slope of kc and an intercept of koc. The Casson plastic viscosity is equal to the square of the slope, while the Casson yield stress is determined as the square of the intercept [14].

The regression equation obtained from the plot was used to calculate shear stress from the HBRM and Casson and a statistical tool was used to determine the most accurate Rheological model for the formulated water-based drilling fluids. The statistical tool used is the absolute average percentage error mathematically given [14].

$$\%\text{Error} = \frac{\mathbf{1}}{\boldsymbol{N}}\sum\left(\frac{\tau_{Measured} - \tau_{Calculated}}{\tau_{Measured}}\right)\times 100 \quad (9)$$

3. Results and Discussion

3.1 FTIR Analysis

Groundnut husk exhibited optimal blending with xanthan gum in a 2:1 ratio, indicated by the presence of functional groups such as ether, carboxylic acid, aromatic amine, primary amine, amide, aromatic ketones, and alkanes in both the pure and blend samples of groundnut husk and xanthan gum, whereas the highest interaction between rice husk and xanthan gum occurred at a 1:1 ratio, as reported by Akinyemi & Abdulhadi [9] with the least interaction observed in the 1:1 blend with xanthan gum.

The optimal interaction with rice husk was observed in a 1:1 blend with groundnut husk. This blend showed peak bands at 1507.7 cm^{-1} for pure groundnut husk and 1636.6 cm^{-1} for pure rice husk and the blend. Groundnut husk showed the best interaction with bentonite in samples with a 1:1 and 2:1 bentonite-to-rice husk ratio. At the same time, the best interaction between rice husk and bentonite was observed in a 2:1 rice husk-to-bentonite blend, as reported by Akinyemi & Abdulhadi [9].

3.2 Shear Stress and Viscosity

The primary goal of conducting the rheology test on the drilling fluid was to analyze its flow properties and behavior under different shear conditions. The resulting data provided valuable insights into the fluid's rheological characteristics and its potential performance during drilling operations. Specifically, the results revealed significant variations in the fluid's flow behavior and properties under varying shear conditions, highlighting its sensitivity to rheological changes at low temperatures and the possible implications for drilling activities as shown from Fig. 1 to Fig. 9. According to API the minimum dial reading viscosity at 600rpm is 30 cP and all samples attain the minimum except samples 1, 2 & 5-16, addition of rice husk and/or groundnut husk shows a significant increase in the viscosity.

When 5g barite was added to samples 18 & 21 (rice husk blend & groundnut husk blend) the viscosity at 600 rpm increase was very low from 33.7566 cP & 29.5058 to 34.0121 & 30.0026 respectively, whereas the addition of 5g, 10g, 15g & 20g rice husk to sample 3 (having 2g xanthan in the blend) increases the viscosity from 28.756 cP to 30.2559 cP, 33.7566 cP, 34.7568 cP & 36.7572 cP respectively while addition of similar blending ratio of groundnut husk to sample 3 increases the viscosity to 29.0057 cP, 29.5058 cP, 32.7564 cP & 35.0069 cP sequentially and observing the performance and comparing it clearly shows that rice improves the viscosity more than groundnut husk of similar blend ratio when improving sample 3.The groundnut husk blend demonstrated superior performance when 5g, 10g, and 15g were added to improve sample 4, which contained 5g of xanthan gum. The viscosity improved from 66.7631 cP to 80.2657 cP, 82.7662 cP, and 85.7668 cP, respectively. Similarly, adding rice husk in the same ratios to enhance sample 4 increased the viscosity to 74.5146 cP, 79.2655 cP, and 82.2661 cP, respectively.

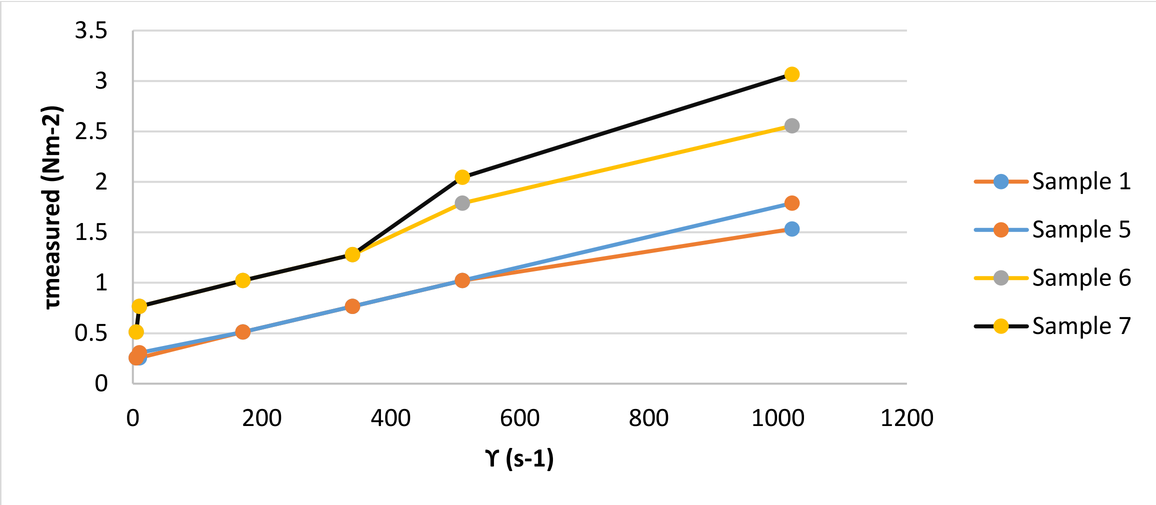

Fig. 1 *Shear stress against shear rate of rice husk samples without xanthan gum*

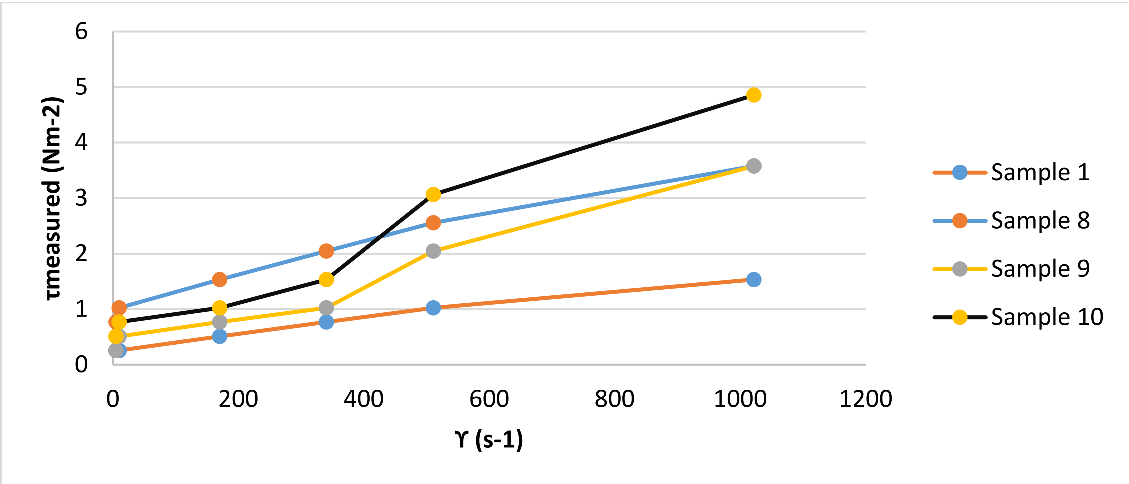

Fig. 2 *Shear stress against shear rate of G/nut husk samples without xanthan gum*

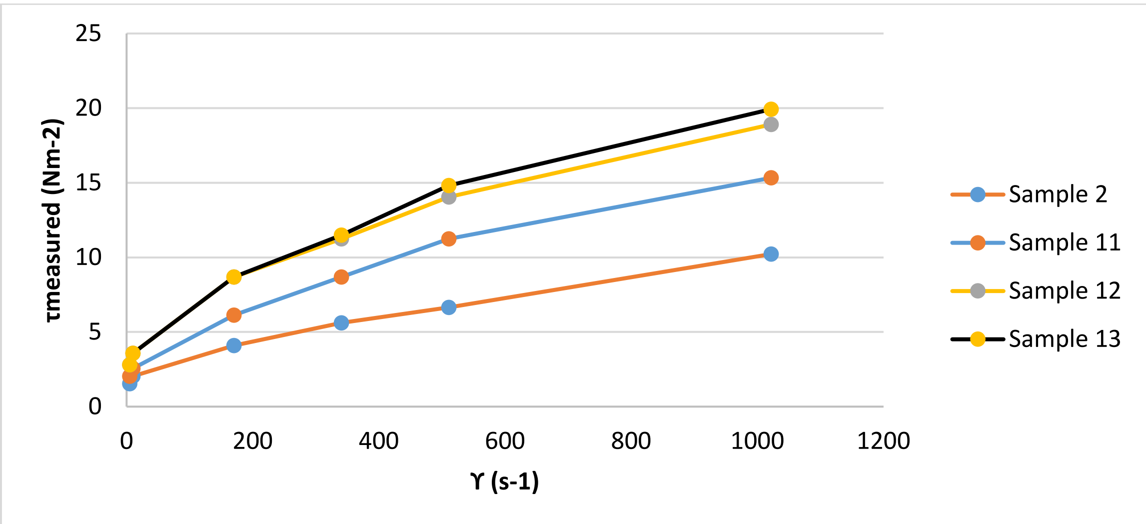

Fig. 3 *Shear stress against shear rate of rice husk samples with 1g xanthan gum*

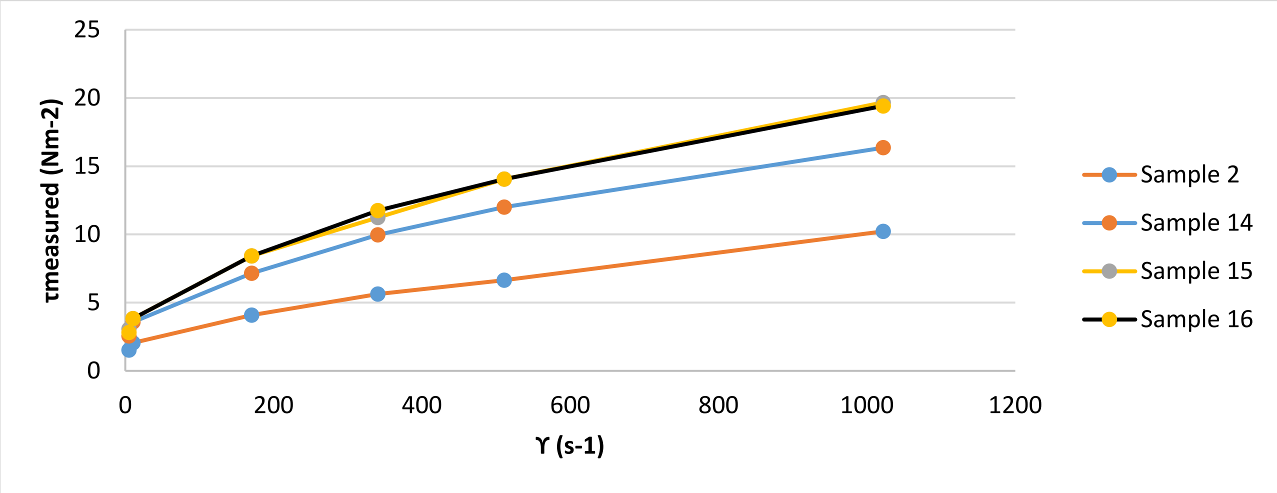

Fig. 4 *Shear stress against shear rate of G/nut husk samples with 1g xanthan gum*

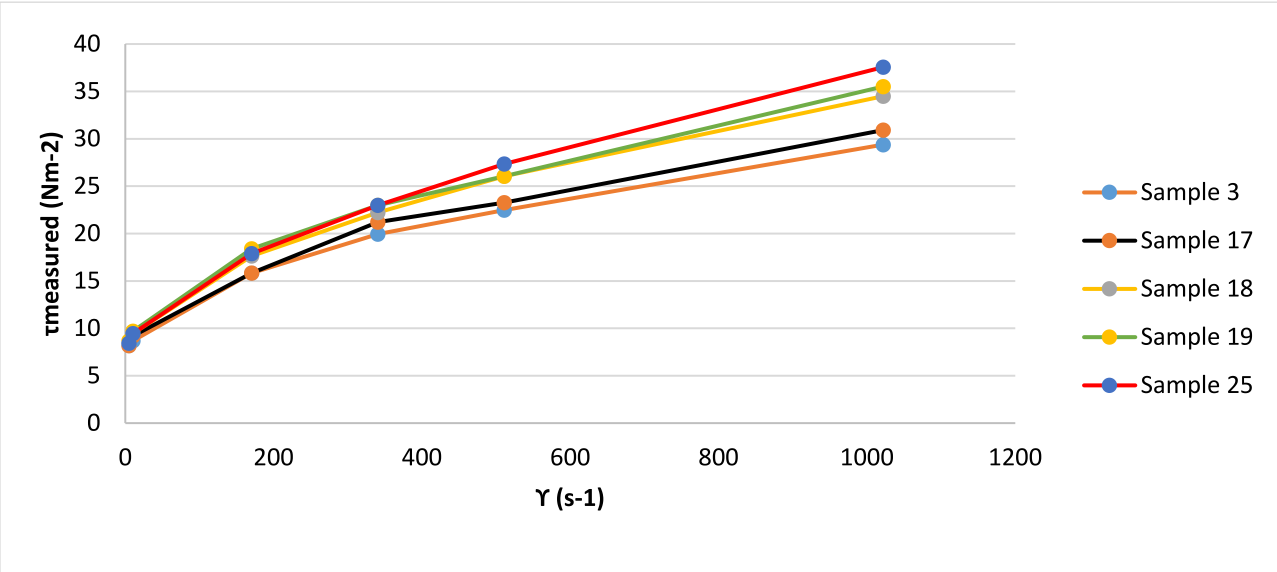

Fig. 5 *Shear stress against shear rate of rice husk samples with 2g xanthan gum*

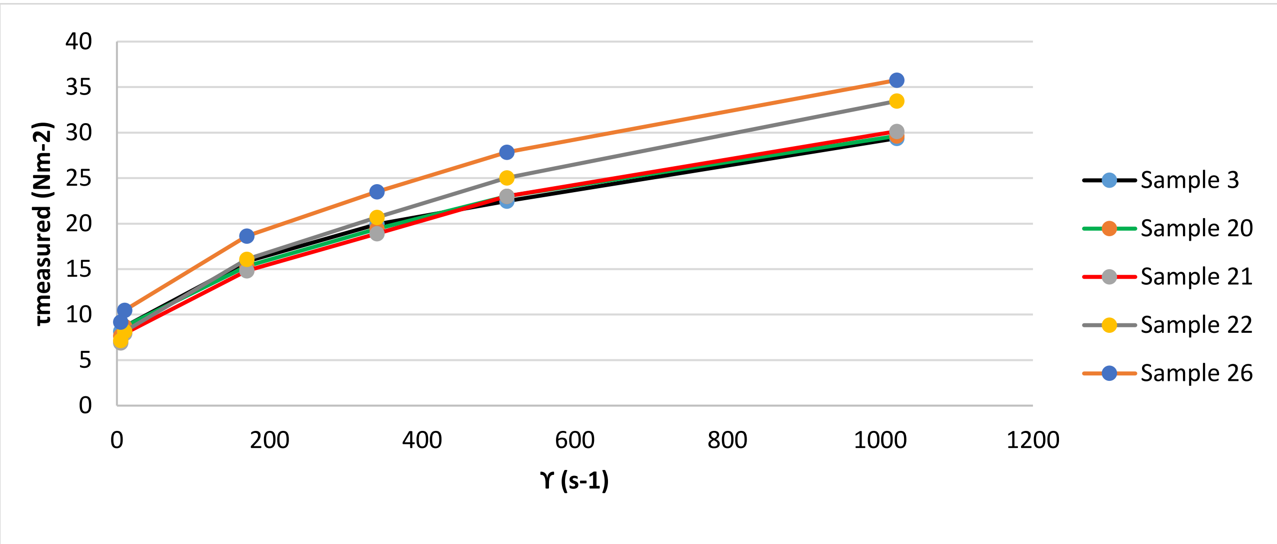

Fig. 6 *Shear stress against shear rate of G/nut husk samples with 2g xanthan gum*

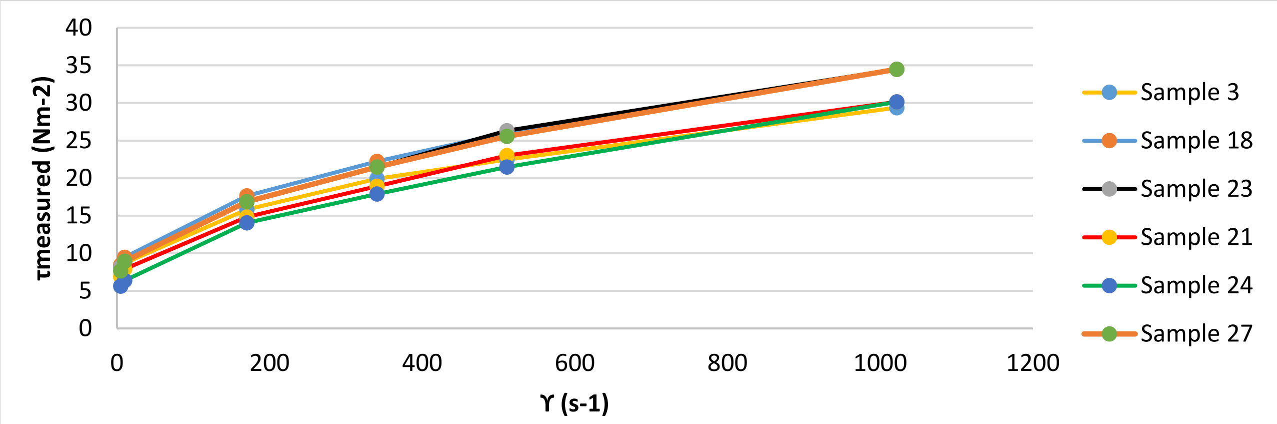

Fig. 7 *Shear stress against shear rate of effect of combined Rice husk and g/nut husk and effect of barite*

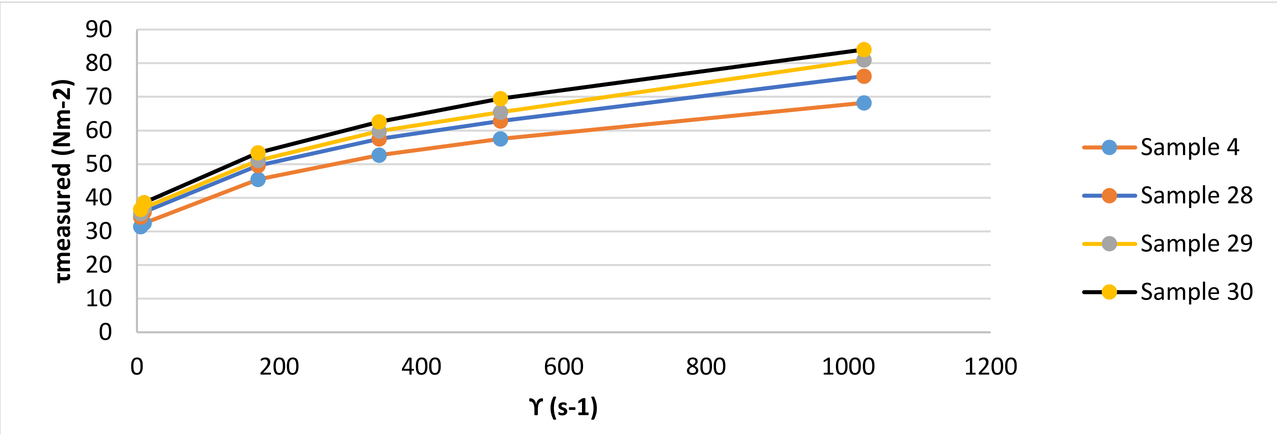

Fig. 8 *Shear stress against shear rate of rice husk samples with 5g xanthan gum*

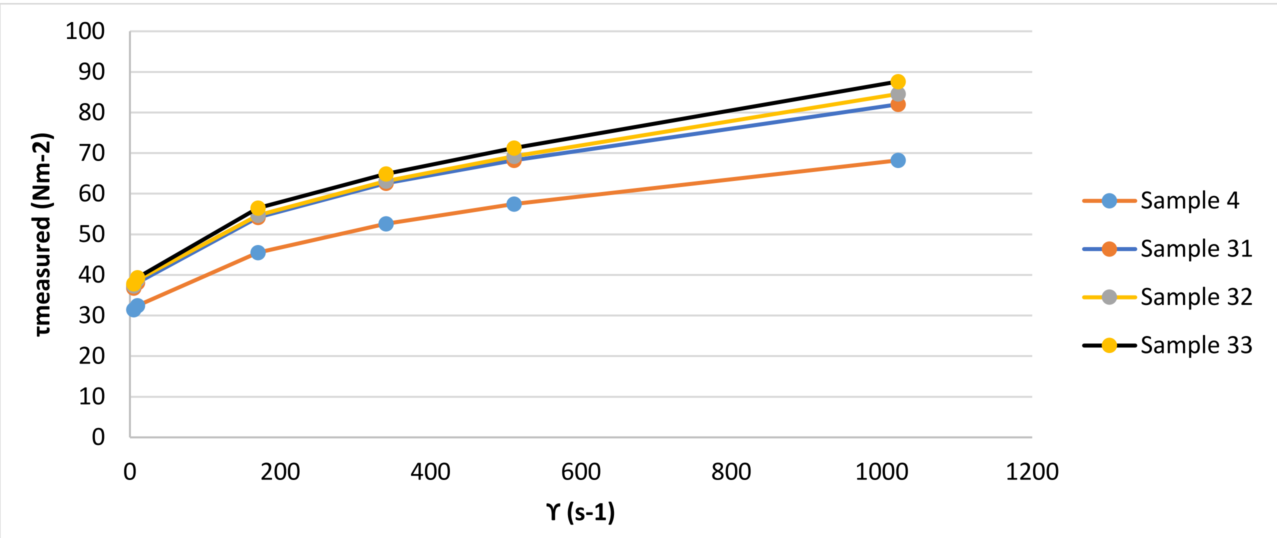

Fig. 9 *Shear stress against shear rate of G/nut husk samples with 5g xanthan gum*

3.3 PV, AV, and YP Determination

Plastic viscosity (PV) is a term used to describe the friction that occurs between the solid particles and the fluid layers [17], yield point (YP) refers to the initial resistance to flow caused by electrochemical interactions between particles. It is influenced by the surface characteristics and volume concentration of the mud solids. The yield point can be used to evaluate a mud's ability to remove cuttings from the annulus [18]. The American Petroleum

Institute (API) optimum PV is between 8-35 cP with a minimum yield point of 5 lb/100ft^2 and maximum of ≤ 3 × *PV*, (Tecla Biwott et.al 2019), all samples' PV falls within the optimum except sample 1, 2, 3, 5, 6, 7, 8, 9 &10. Sample 33 has the highest PV of 32 cP while the least of the optimum PV is recorded on sample 11 as 8 cP, sample 2 has PV 7 cP and the addition of 5g, 10g, and 15g groundnut husk increases PV to 8.5, 11 & 10.5 cP respectively similarly addition of rice husk to sample 2 in the same order gives PV 8, 9.5 & 10 cP respectively.

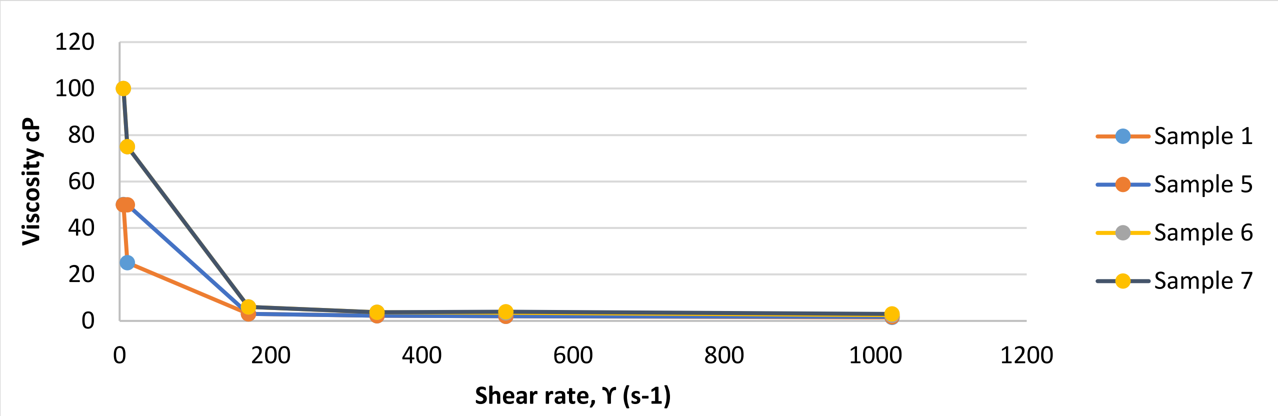

Fig. 10 *Viscosity against shear rate of rice husk samples without xanthan gum*

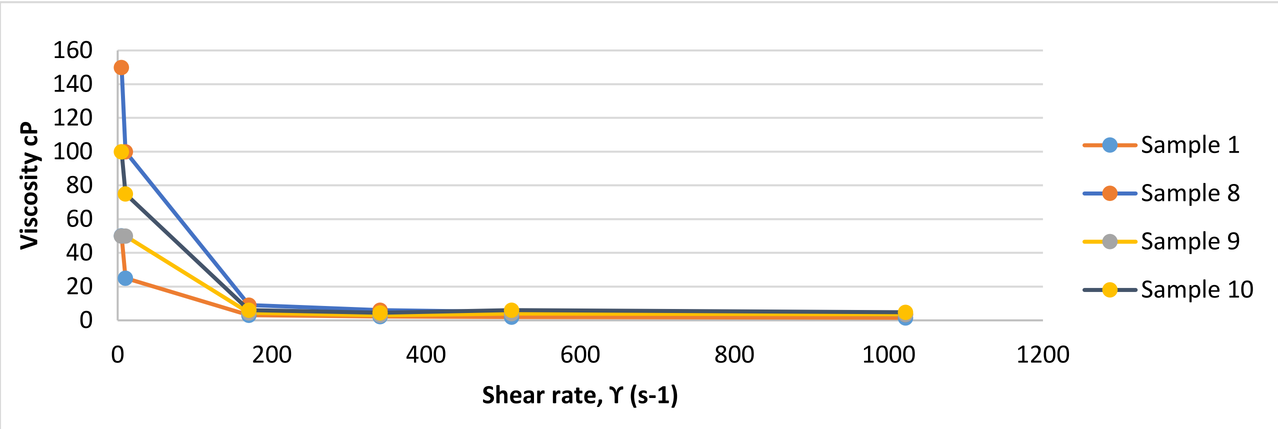

Fig. 11 *Viscosity against shear rate of g/nut husk samples without xanthan gum*

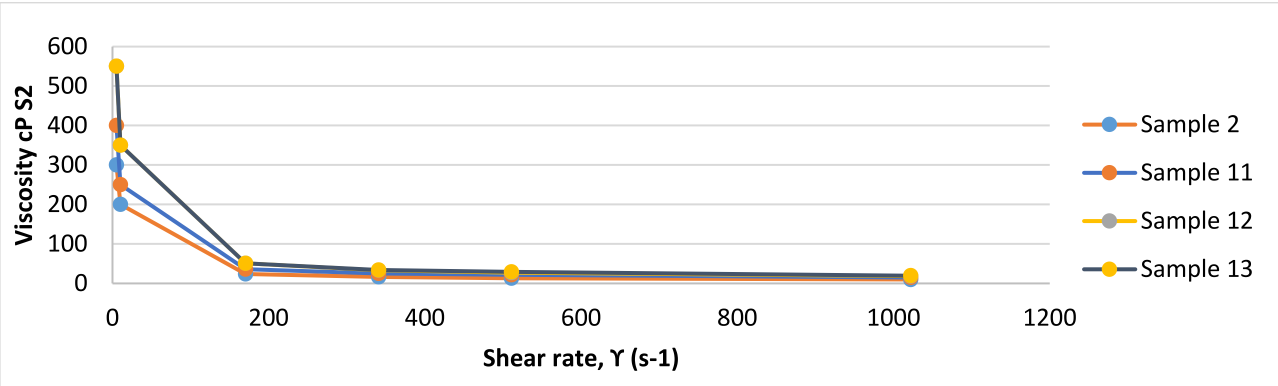

Fig. 12 *Viscosity against shear rate of rice husk samples with 1g xanthan gum*

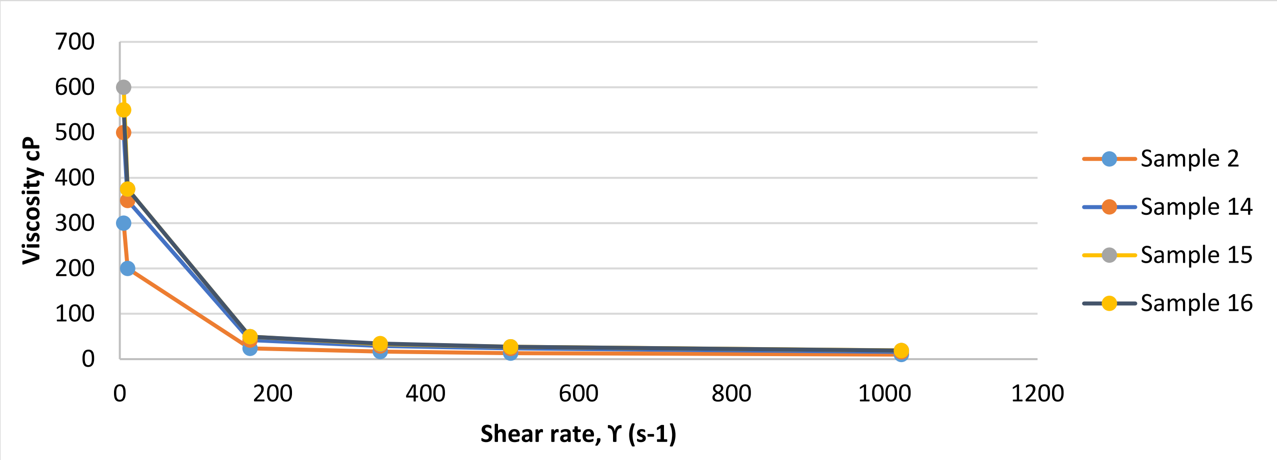

Fig. 13 *Viscosity against shear rate of G/nut husk samples with 1g xanthan gum*

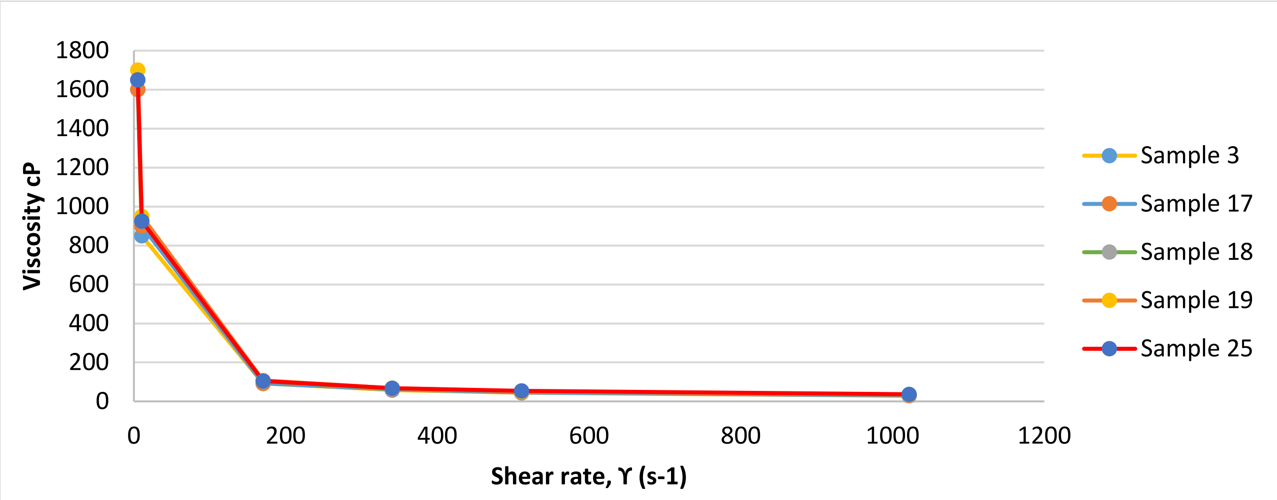

Fig. 14 *Viscosity against shear rate of rice husk samples with 2g xanthan gum*

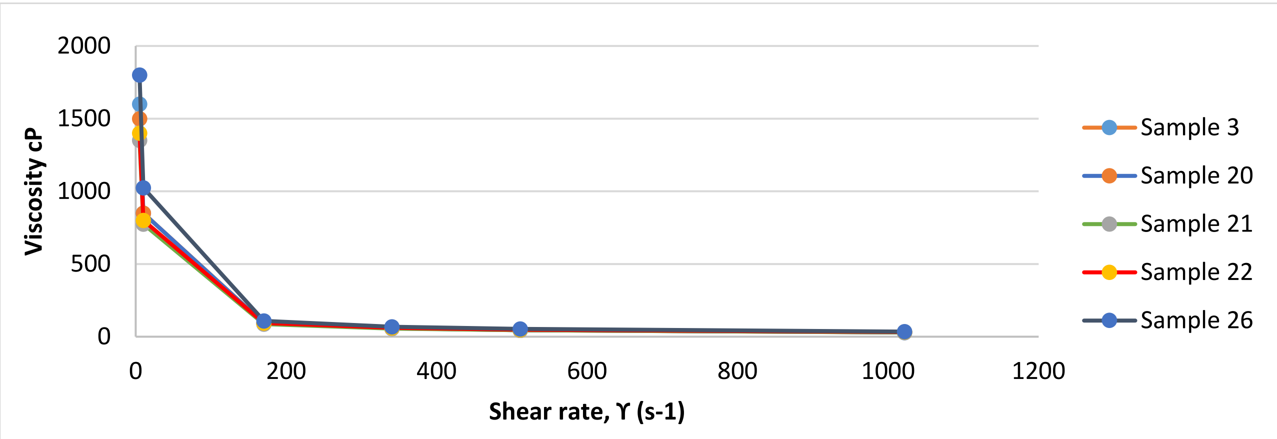

Fig. 15 *Viscosity against shear rate of G/nut husk samples with 2g xanthan gum*

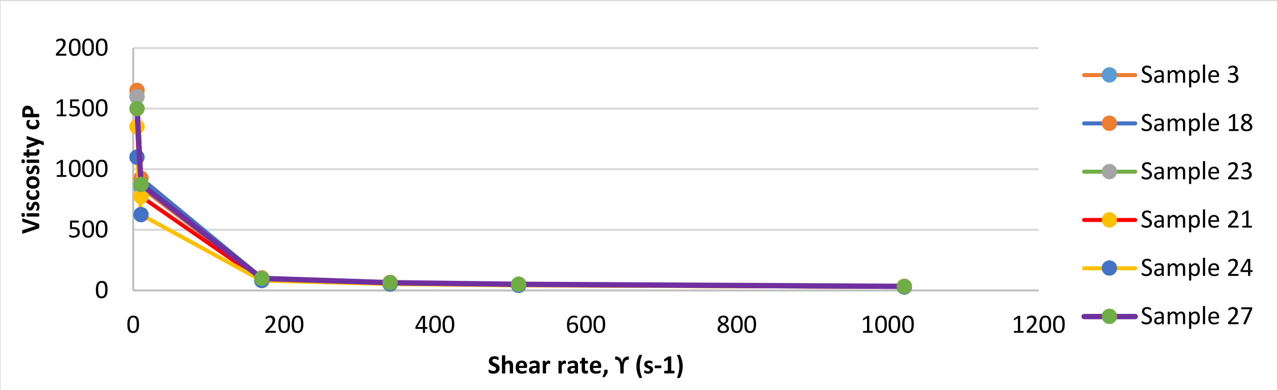

Fig. 16 *Viscosity against shear rate of effect of combined Rice husk and g/nut husk and effect of barite*

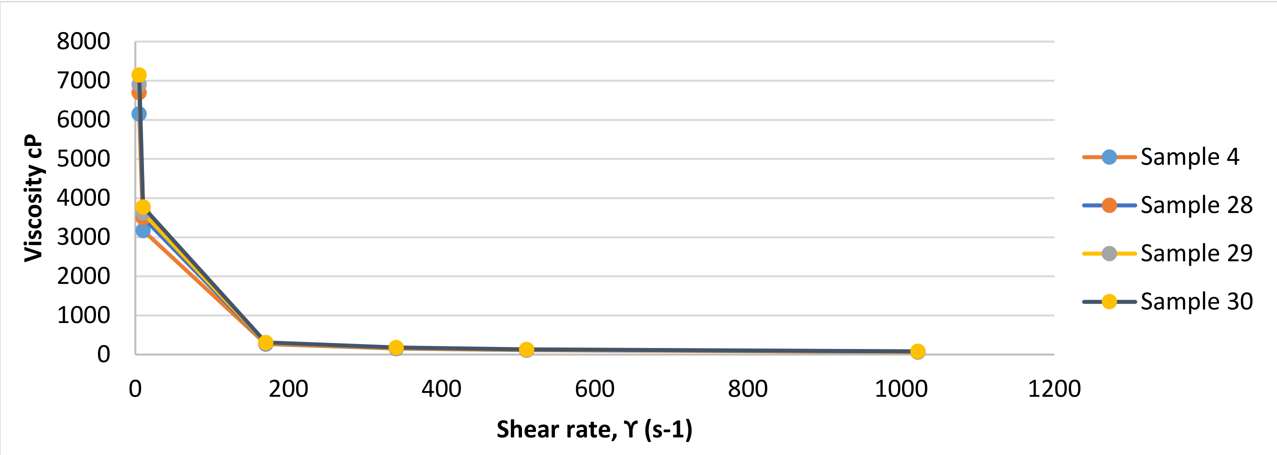

Fig. 17 *Viscosity against shear rate of rice husk samples with 5g xanthan gum*

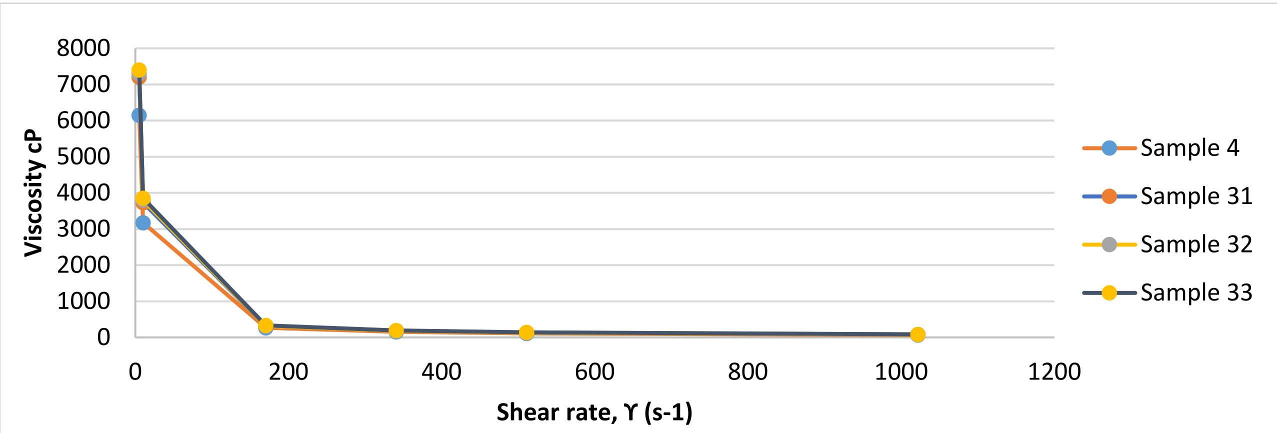

Fig. 18 *Viscosity against the shear rate of G/nut husk samples with 5g xanthan gum*

3.4 Gel Strength Analysis

The capacity of drilling fluid to form a gel and suspend solid waste is determined by its thixotropic or gelation properties, measured by gel strengths. Understanding the attractive forces under static conditions over time is crucial for effective oil exploration, as noted by Suleiman & Bilal [19]. Leloni et al. [20] and Adesina et al. [21] suggest that a gel strength of approximately 5 lb/100ft^2 is sufficient for suspending cuttings and ensuring effective carrying capacity in low-temperature (25^{o}C) operations. Nwabueze & Ighalo [3] also reported that API standards recommend 3-20 lb/100ft^2 for 10 seconds and 8-30 lb/100ft^2 for 10 minutes, all the formulated drilling muds have gel strength of ≥ 5 lb/100ft^2 except for samples 5, 6 & 7 (rice husk blend) having a flat 3,3 & 4 lb/100ft^2 respectively which all these samples are not containing the viscosifier xanthan gum but sample 8, 9 & 10 (groundnut husk blend) have 5,7,& 6 lb/100ft^2 also, addition of 5g,10g & 15g Rice husk and similar addition of groundnut husk to sample 4 gives more increase with groundnut husk from 62.5 lb/100ft^2 for 10 seconds to 65, 68 & 70 lb/100ft^2 for rice husk and 68,69 &71 lb/100ft^2 for groundnut husk, this shows that groundnut husk can improve the gel strength better than rice husk of same amount. It is observed that the highest gel strength recorded was sample 5g xanthan and 15g groundnut husk as 71 lb/100ft^2 which is also flat and all samples exhibit flat or nearly flat thixotrophy. A low, stable, and nearly constant gel strength over time is desirable because it shows a consistent gelation rate. Extremely high gel strengths can hinder the efficiency of swabbing and surging and complicate the separation of cuttings from the soil.

3.5 Mud Density

The mud density was observed to be within 8.72 – 8.95 lb/gal. The addition of 5g barite to samples 18 & 21 increases the mud density from 8.82 lb/gal to 8.9 lb/gal each. All samples mud density falls within the API standard limits of 8.65 lb/gal – 9.6 lb/gal [22].

3.6 LPLT Filtration Analysis

The API filter press machine was used to examine the 33 samples for a 30-minute filtration time, Fig. 19 – Fig. 29 where samples 1, 2, 3 & 4 were used as a base sample. API standard allows a maximum of 15 ml fluid loss in a 30-minute filtration cycle as reported by Shuwa et al. [23] and Queendarlyn & Joshua [24], a thin, tough, and impermeable filter cake is ideal. Filtrate volume collected for all samples was within the limit except for samples 1, 2, 3 & 5 - 16, with filter cake thickness ranging from 0.5 mm – 7.5 mm and filter cake weight between 6.36 g – 44.26 g. The addition of 5g, 10g & 15g (rice husk) to a sample of pure bentonite clay (sample 1) reduces the filtrate volume from 190 ml to 120 ml,118 ml & 120 ml respectively whereas the addition of groundnut husk in the same order reduces it to 175 ml for all ratio also, the addition of 5g barite each to sample 18 (10g rice husk blend) & 21 (10g groundnut husk blend) reduced the filtrate volume from 13.5 ml & 15 ml to 12.4 ml & 13.5 ml respectively. Indicated in figure B1 shows that by adding 5, 10 & 15g rice husk and another set of blends by adding groundnut husk in the same order as sample 4 the filtration performance was enhanced better by the rice husk blend than the groundnut husk blend which for rice husk the filtrate volume was reduced from 11.3 ml to 10.5 ml, 10 ml & 9.8 ml and for groundnut husk to 11.3 ml, 10.8 ml & 10.2 ml respectively. The filtrate volume was reduced by little when rice husk and groundnut husk were combined in a blend of 10g gram each as compared to individual 10g blend of rice husk performance from 13.5 ml to 13.2 ml, while it is enhanced significantly when compared to 10g blend of groundnut husk from 15 ml to 13.2 ml. For all samples with a similar blend ratio, the rice husk blend has better-improved filtration performance compared to the groundnut husk blend.

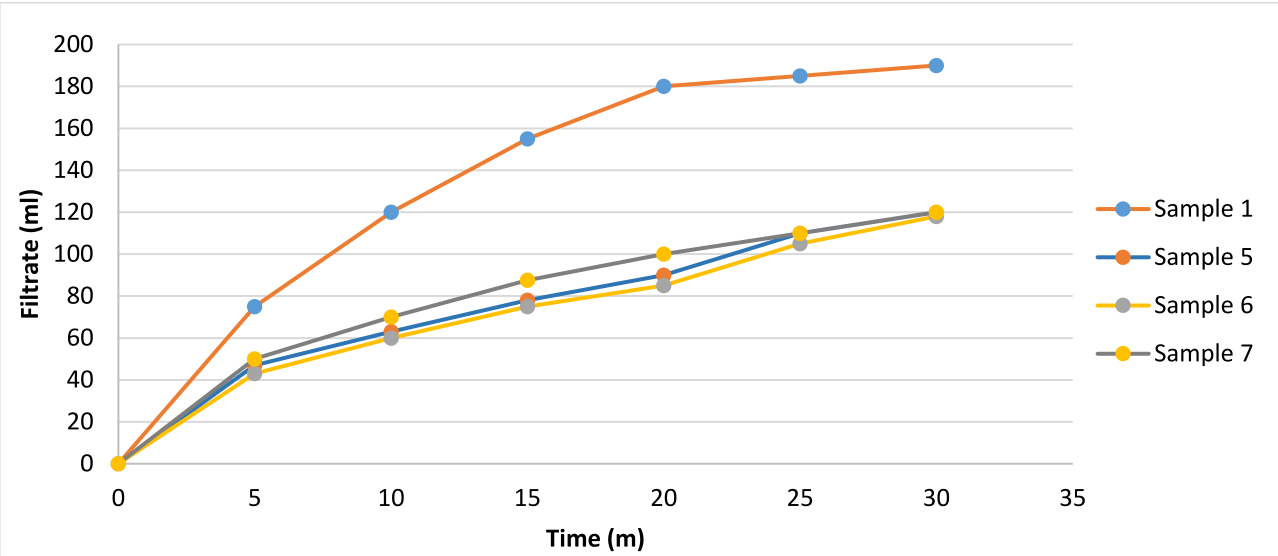

Fig. 19 *Rate of filtration of rice husk samples without xanthan gum*

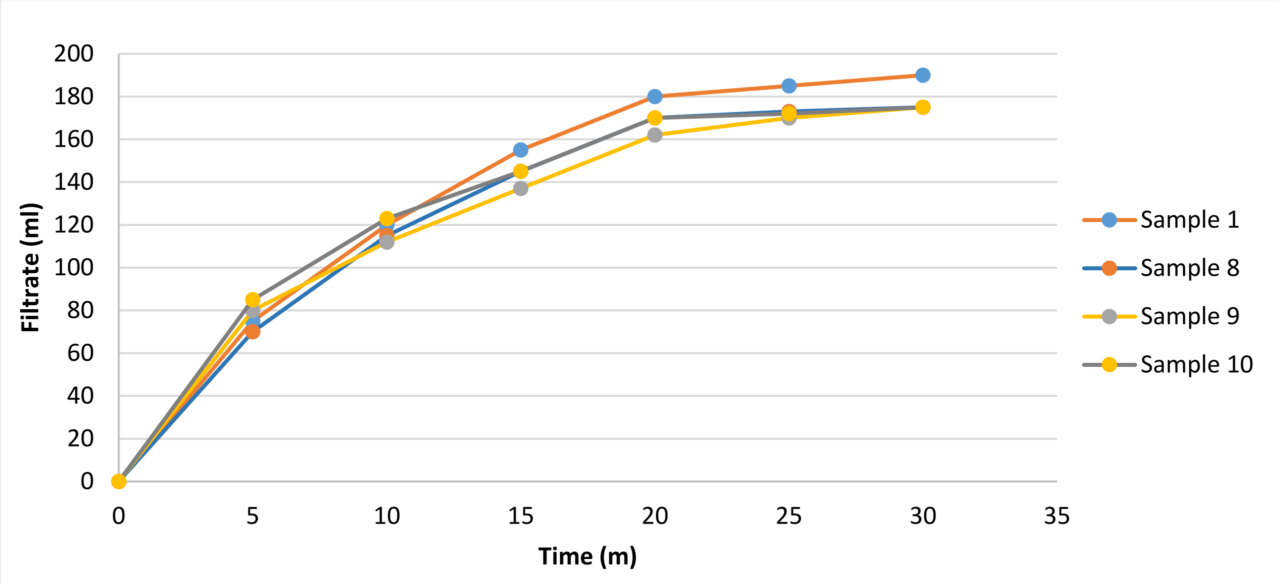

Fig. 20 *Rate of filtration of g/nut husk samples without xanthan gum*

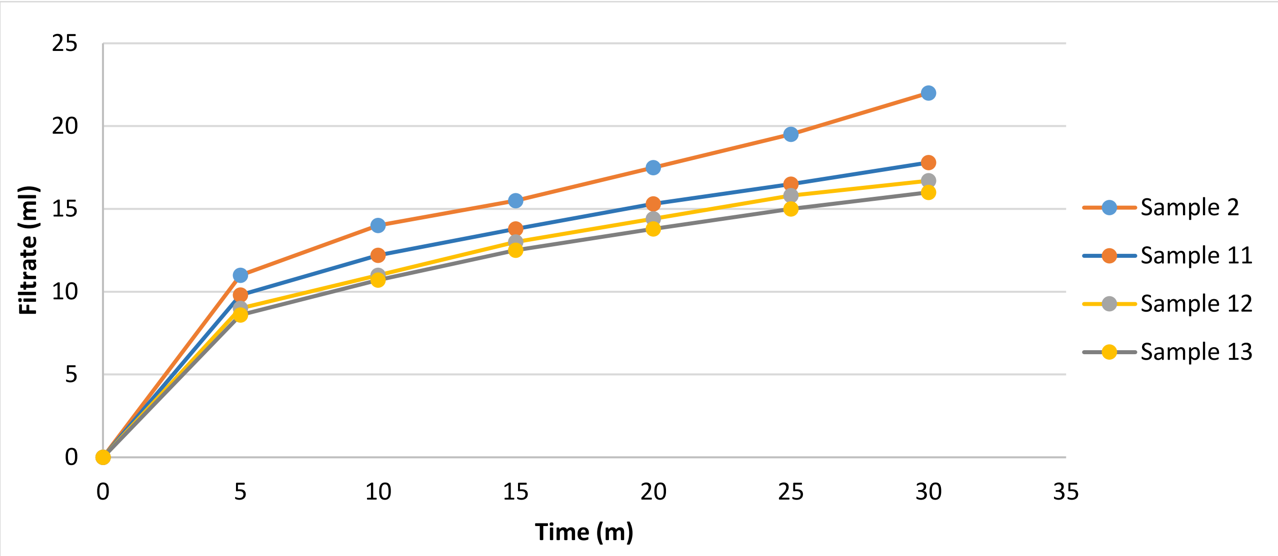

Fig. 21 *Rate of filtration of rice husk samples with 1g xanthan gum*

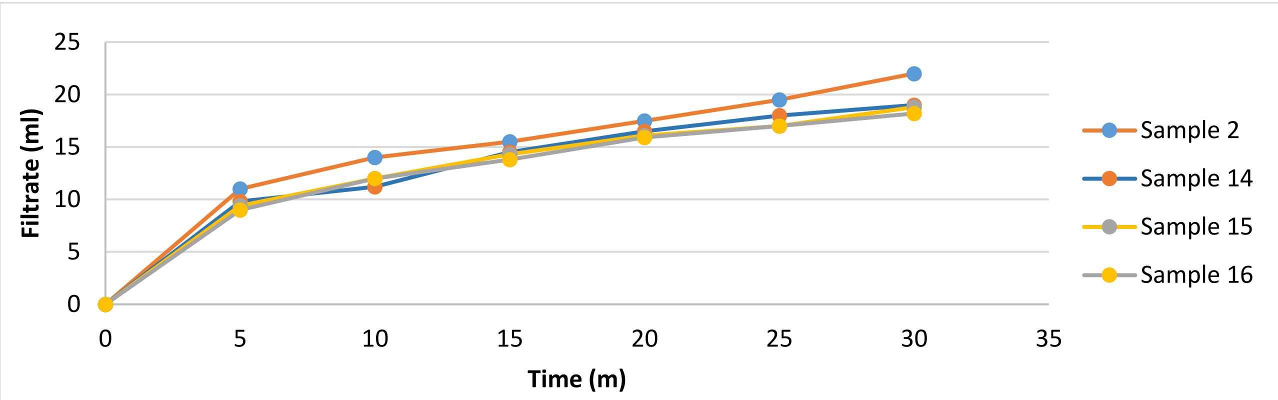

Fig. 22 *Rate of filtration of G/nut husk samples with 1g xanthan gum*

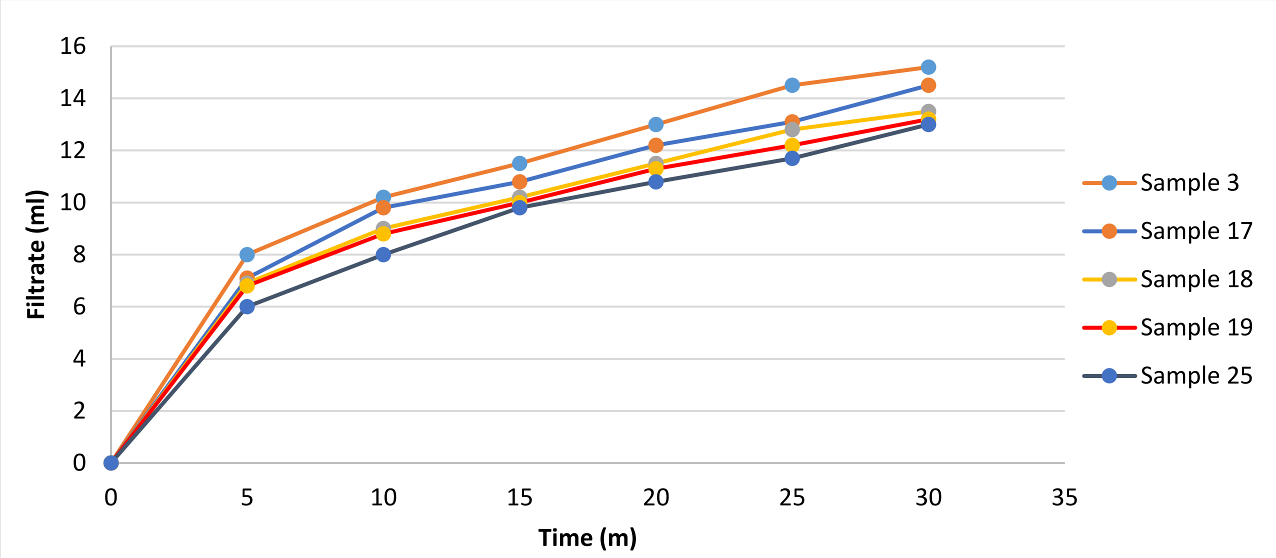

Fig. 23 *Rate of filtration of rice husk samples with 2g xanthan gum*

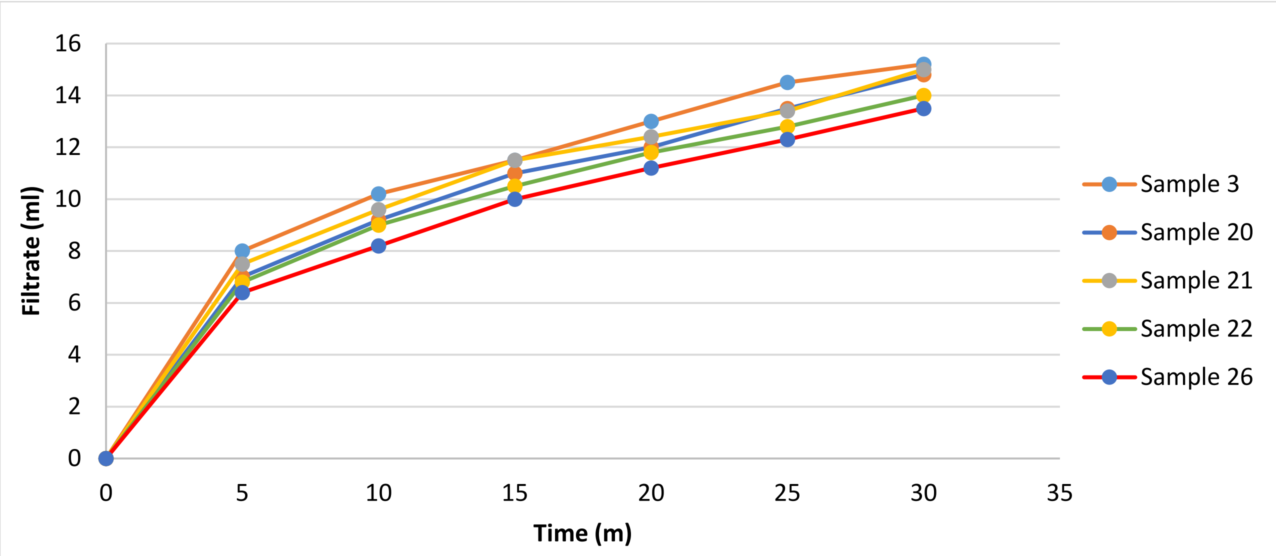

Fig. 24 *Rate of filtration of G/nut husk samples with 2g xanthan gum*

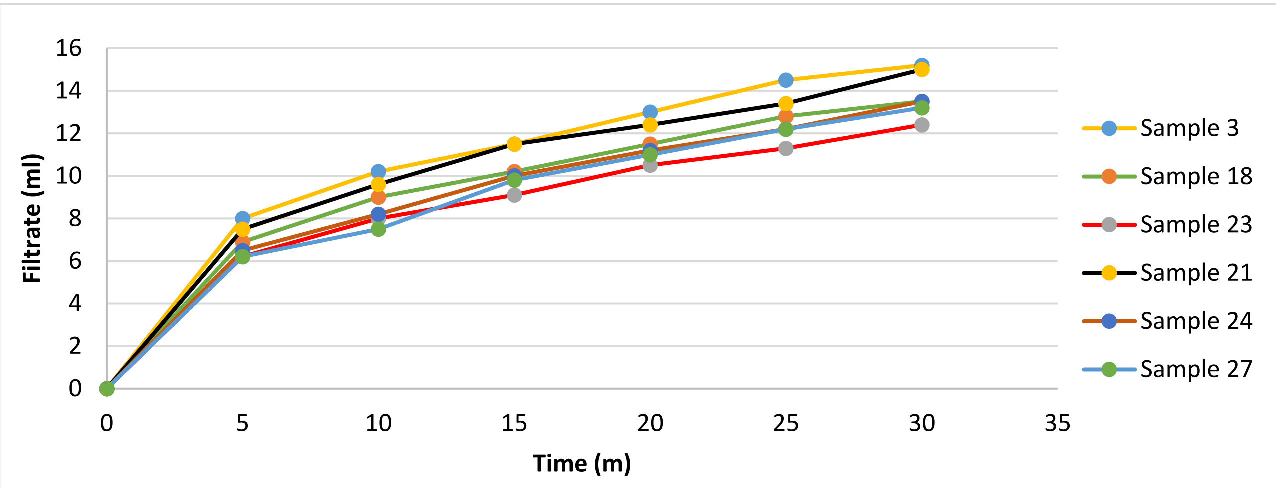

Fig. 25 *Rate of filtration of the effect of combining Rice husk and g/nut husk and effect of barite*

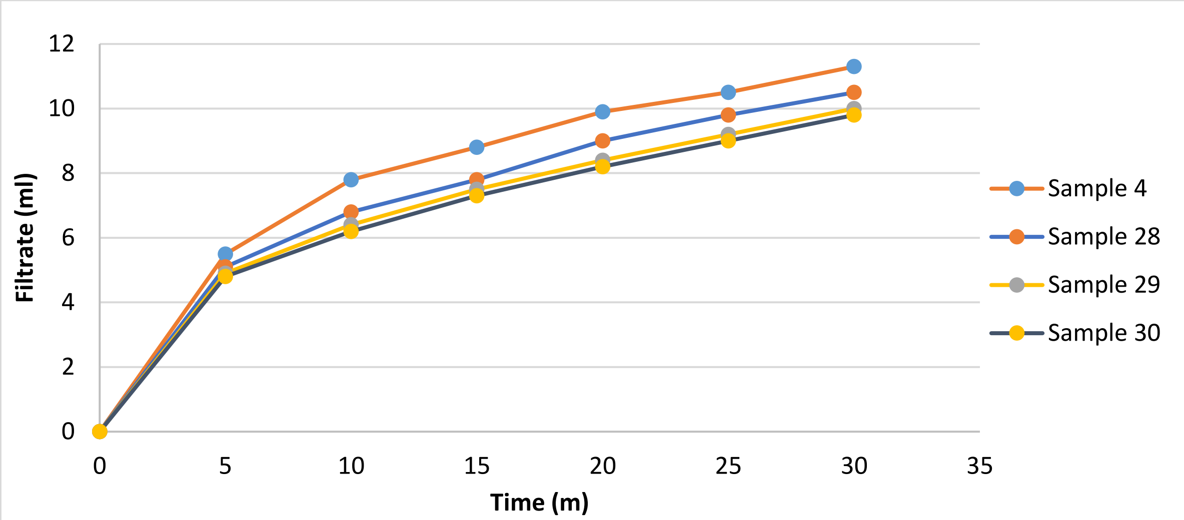

Fig. 26 *Rate of filtration of rice husk samples with 5g xanthan gum*

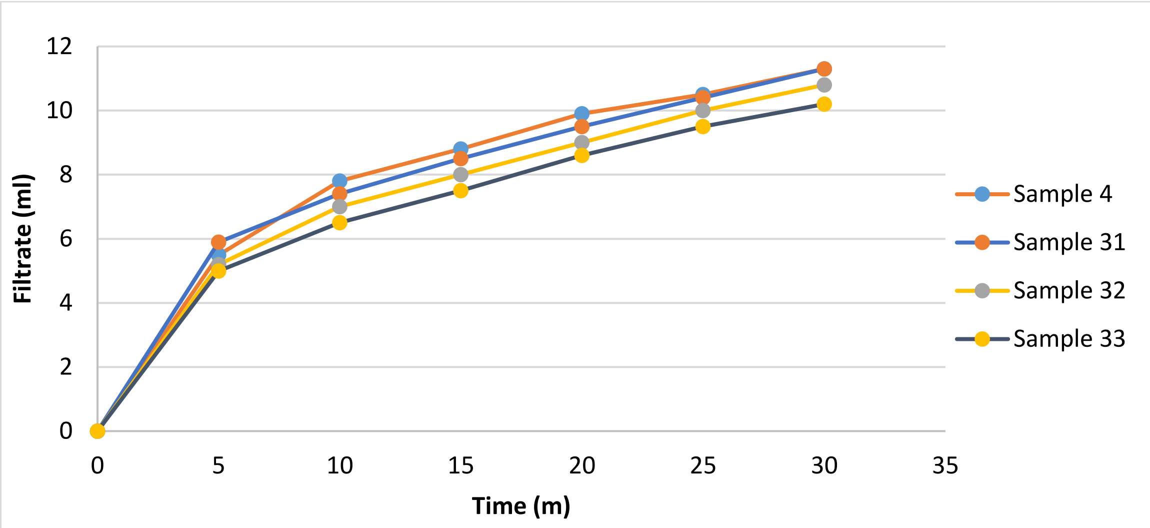

Fig. 27 *Rate of filtration of G/nut husk samples with 5g xanthan gum*

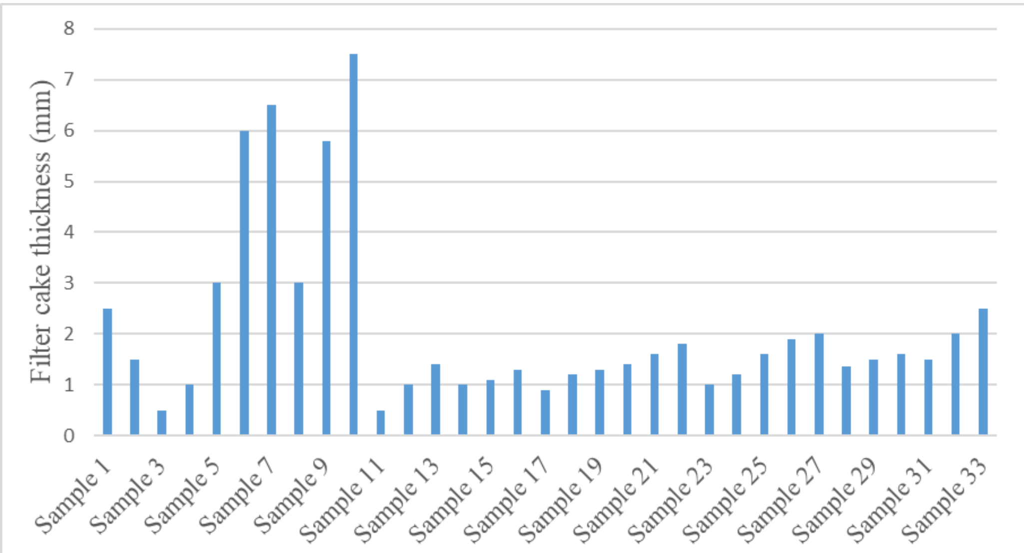

Fig. 28 *Filter cake thickness against different sample composition*

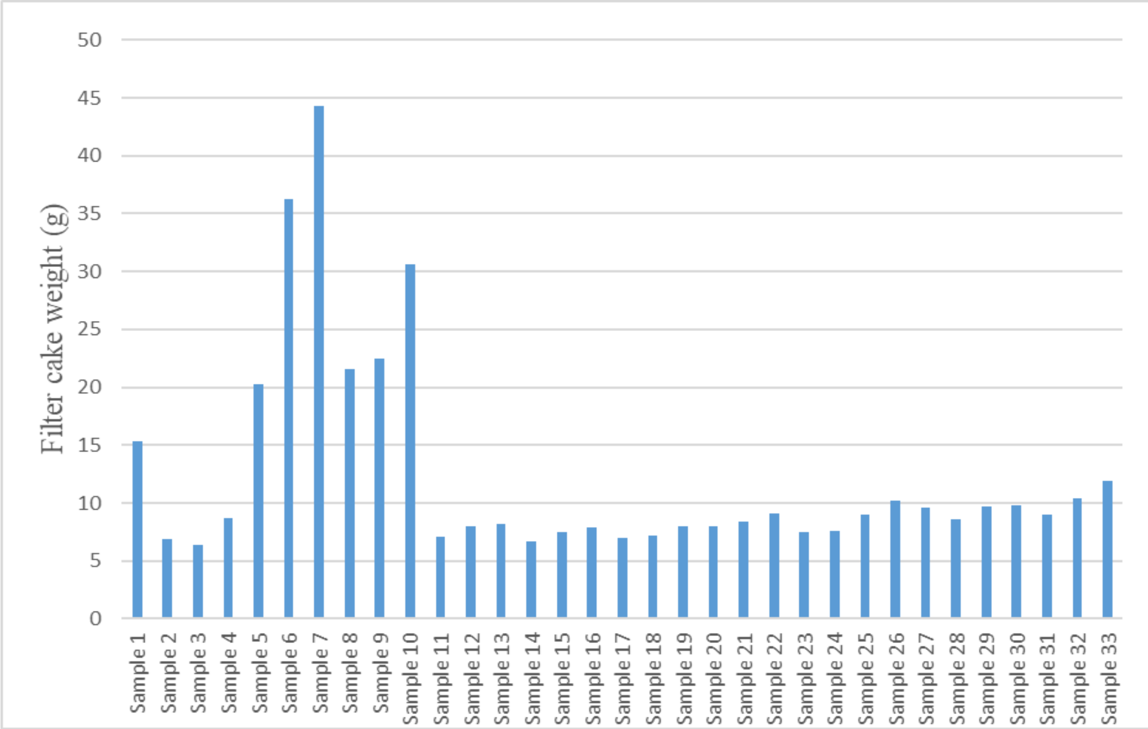

Fig. 29 *Filter cake weight against different sample composition*

3.7 Rheological Models

Experimental shear stress and strain data from viscometer analysis were assessed using a nonlinear regression analysis in MS Excel. This assessment aims to shed light on the rheological behavior of the drilling fluid and enhance the understanding of its flow characteristics. The following discussion will provide a comprehensive analysis of the rheology test results, the data fitting to rheology models, and the implications of the findings for drilling engineering. The outcomes of applying the least-square analysis and absolute average percentage error to standardize the statistical regression behavior of formulated drilling fluids are examined. To derive meaningful conclusions from the goodness-of-fit, the overall dispersion of the model functions from the observed data must be considered.

As drilling fluids are non-Newtonian fluids, this study utilized a nonlinear curve fitting method. Non-Newtonian fluids typically conform to one of two models: the Casson plot model or the Herschel-Bulkley Rheological model (HBRM). The coefficient of determination (R^2) is the primary criterion for choosing the model that best describes the shear stress and shear rate of the formulated drilling fluid.

It was observed that both model shows less accuracy when samples with lower shear stress (≤ 5 Nm^{-2} @ 600rpm) are considered having R^2 and %error between 0.8231-0.9933 and ±0.1870% -±4.3149% for HBRM and 0.9232-0.9938 and ±0.0562% - ±2.6143% for Casson plot respectively but Casson has better accurately representing the experimental data both in terms of overall fit (R^2) and individual prediction accuracy (%error). Samples with high shear stress at 600rpm and optimum samples within shows better performance with the two rheological models having R^2 and %error within the range of 0.9834 – 0.9997 and ±0.0025% - ±0.7293% for HBRM and 0.9852 – 0.9982 and ±0.0412% - ±1.2666%, for Casson. HBRM more accurately represents the experimental data in terms of both overall fit (R^2) and individual prediction accuracy (% error) and with high R^2 and less %error. All the sample blends fall under the shear thinning region as $n<1$ for all.

4. Conclusion

In this research, bentonite clay, rice husk, groundnut husk, xanthan gum, and BaSO4 were utilized in various compositions to develop a water-based drilling fluid. The raw groundnut and rice husk were surface dried and ground to approximately 120 microns. Twelve samples of pure and blended groundnut husk, bentonite clay, rice husk, and xanthan gum were analyzed using FTIR. These materials were used to formulate 33 samples of water-based drilling fluids. The formulated samples were tested at room temperature for their rheological properties using a Model 35A viscometer at six different speeds (600, 300, 200, 100, 6, and 3 rpm). Additionally, mud densities and filtration properties were evaluated using mud balance and an API filter press machine respectively, where both filtrate volume and filter cake thickness were measured and recorded. From the viscometer results, two rheological models, the Herschel-Bulkley model, and the Casson model, were utilized to validate the experimental data and characterize the fluid properties, and model that best fit the formulated drilling mud was selected based on the overall fit (R^2) and individual prediction accuracy (% error). Based on these above findings, the optimal drilling fluids blends were determined according to API specifications. The following conclusions were drawn from the study.

The FTIR of groundnut husk demonstrated optimal blending with xanthan gum in a 2:1 ratio (sample L), evidenced by 11 distinct spectral peak bands. The most effective interaction with rice husk was observed in a 1:1 blend with groundnut husk, as seen in sample G, which exhibited 7 spectral peak bands. Additionally, groundnut husk showed the best interaction with bentonite in samples B and C, which had bentonite-to-groundnut husk ratios of 1:1 and 2:1 respectively both having 5 spectral peak bands.

The addition 5g of barite to samples 18 and 21 (rice husk blend and groundnut husk blend) slightly increased the viscosity at 600 rpm from 33.7566 cP and 29.5058 cP to 34.0121 cP and 30.0026 cP, respectively. The groundnut husk blend showed superior performance when 5g, 10g, and 15g were added to sample 4 (with 5g xanthan gum), increasing the viscosity from 66.7631 cP to 80.2657 cP, 82.7662 cP, and 85.7668 cP. According to API standards, the minimum dial reading viscosity at 600 rpm is 30 cP, all samples met this minimum, except samples 1, 2, and 5-16. Overall, adding rice husk and/or groundnut husk significantly increased the viscosity. For all samples with similar blend ratios, the rice husk blend offers superior filtration performance by reducing filtrate volume and producing a thinner filter cake compared to the groundnut husk blend. Additionally, increasing the mass of either rice husk or groundnut husk in a blend result in a further decrease in filtrate volume and an increase in filter cake thickness and weight.

Based on API specifications for plastic viscosity (PV), mud density, YP, YP/PV, dial readings at 600 rpm, and maximum allowable filtrate volume, samples 17-27 were identified as the optimal formulations. Both rheological models showed decreased accuracy for samples with lower shear stress (≤ 5 Nm^{-2} @ 600 rpm). For optimum samples, both models performed well, with HBRM providing better accuracy. The HBRM is noted for its superior prediction of mud rheology across various shear rates, while all samples exhibited shear thinning behavior with $n<1$. The following are recommended for further studies.

Further study the biodegradability of rice husk and groundnut husk to assess their impact on the longevity of drilling fluids formulated with these materials. Furthermore, SEM analysis can be used to provide additional characterization of the filter cake.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*Both the Researchers contributed to the **design**, **implementation**, and **analysis of the project**.*

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