International Journal of Engineering and Management Research
www.ijemr.net
e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-12, Issue-6, (December 2022)
https://doi.org/10.31033/ijemr.12.6.33

Effects of Temperature on the Rheological Properties of Rice Husk Modified Bentonite Drilling Fluids

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ABSTRACT

In this study, water base drilling fluids were developed using bentonite clay and rice husk. The pure and blends of bentonite clay and rice husk as specified by samples A with (pure bentonite), B (with pure rice husk), C (1:1 of rice husk to bentonite) and D (2:1 of rice husk to bentonite) were characterized using X-ray diffraction (XRD) and Fourier Transform Infrared (FTIR). The XRD result of the samples showed that samples C and D both contains montmorillonite as mineral with the most intense peak at 5.887^o. Samples A and B contain Quartz, and Montmorillonite respectively with the most intense peak at 2ϴ value of 26.642^o, 31.578^o, 5.887^o, 26.624^o and 26.627^o respectively. The results show strong interaction between sample A and C. FTIR results of samples A, B, C and D showed number of bands/peaks of 13,9,13 and 14 respectively and showed high level of interaction between pure and blends of the samples were with 14 peaks/bands each. Five water base drilling fluid samples produced using standard laboratory barrel (350 ml) method from bentonite and water with addition of rice husk in different proportion were investigated. The rheological properties (plastic viscosity, yield value, gel strength) of the samples were measured at different temperatures, using FANN 35 viscometer while the pH and density values were measured using pH meter and mud balance respectively. The pH values of all the produced drilling mud samples were alkaline (>7.0), close to the neutral value. Increase in temperatures bentonite drilling mud modified with rice husk does not have negative effect on the rheological properties of the drilling mud. The rice husk could be used as a viscosifier in the drilling mud for being capable of improving the viscosity of the mud at higher temperature.

Keywords— Temprature, Rheologicl Properties, Drilling, Fluids

I. INTRODUCTION

Drilling fluids are mostly used while drilling underground wells. They primarily serve the goal of controlling subsurface pressures in combination with density and numerous other additional pressures operating on the fluid column (annular or surface imposed). To remove drill cuttings from the wellbore, drilling fluids are typically pumped down the drill string, out the bit, and back up the annulus to the surface. In the business, drilling fluids go by a variety of names, acronyms, and slang phrases. Mud or drilling mud is the most frequently used word for it. It is made up of chemical, liquid, and solid components. Water-based, oil-based, and synthetic-based drilling fluids are typically the three main classifications of drilling fluids utilized in a broader sense. Although oil-based drilling fluid has the inherent benefits of higher temperature stability, superior lubricity, and strong shale hydration inhibitive ability, its widespread use is constrained by its high cost and potential environmental harm. As a result, water-based drilling fluids are more commonly utilized than other drilling fluids due to their low cost, environmental friendliness, and ease of preparation. To retain the necessary qualities during drilling, water-based drilling fluid is primarily made of water, bentonite, polymers, salts, and other ingredients.

An ever-growing global energy demand and the need to advance oil fields into new technological frontiers have driven a demand for more efficient and reliable technology, particularly in environments with challenging conditions like water-sensitive reservoirs, which are most common in offshore environments, high temperatures, and high pressures ("Oil Field Review" 2012). Additionally, as there is a greater need for energy, there is a greater demand for resource extraction methods that are both more affordable and environmentally acceptable. According to "Oil Field Review" (2012), the drilling process accounts for 80% of the drilling cost and drilling fluid development for 15% to 25%.

Drilling move in a regular procession from vertical inclined, horizontal to subsea and deep-sea drilling. All these require adequate and specialized drilling fluid to fulfill the objective looking at the fact that higher the adverse condition the deeper the operations. However, drilling fluids needs to be prepared in such a way that they suit drilling process and reservoir conditions. These reservoir conditions include high bottom hole temperature, highly deviated wells; salts domes across permeable formation and most importantly water sensitive shale must be given special consideration as they compete with drilling operation. Drilling fluids are used to carry drilled

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solids from the bottom of the hole to the surface, suspend drilled solids and weighting materials when the mud is static, provide a thin impermeable cake to seal pores and other openings in the formation and thereby restrict the movement of fluids, contain formation pressure, support the weight of casing and drill string, transmit hydraulic horse power to the bit, and assist with evaluation (Growcock & Harvey, 2005; Darley & Gray, 1988). Drilling fluid selection and design are crucial to achieving all of these properties during drilling operations. A properly designed drilling fluid enables operators to reach the desired geological ore at a lower cost, with improved bit and drill string penetration, easier penetration, faster bit cooling, minimal hole damage, and easier transport of cuttings to the surface at the end of the drilling operation. However, the environmental impact of utilizing the fluid, the expense of the fluid, and the fluid's impact on production from the pay zone must all be taken into account when choosing the fluid (Bilal, 2016). This drilling fluid when in slurry form, they are termed drilling moods. They are made up of chemical components like weighting agent, fluid components like water or oil-water mixture in an emulsion and solid components such as clay, xanthenes gum, rice husks which serve as viscosifier and fluid loss control additive.

With an annual consumption of 100,000 tons, this bentonite clay is used in a variety of industrial processes in Nigeria, including the formulation of drilling fluids, adsorbent, carrier material, adhesive, as support and clarifiers etc makes Nigeria a potential source for clay. However, on the other hand rice husk is one of the most available additive to consider in improving the quality of water based drilling fluid, considering the fact that the quantity of rice produced in Nigeria is high (Akinyemi and Fatai, 2022).

In order to develop and manage the rheological qualities of drilling fluid, materials like rice husks, polyacrylates, xanthan gums, and many other synthetic and natural polymers can be added. High temperatures can cause water-based drilling fluid to lose some of its qualities, which can have an impact on the viscosifying agents and reduce the fluid's velocity (Akinyemi & Alausa, 2020). Thus, in this study the effects of the variation of temperature on the rheological properties of drilling fluids produced with bentonite and water with different composition of rice husk was evaluated.

II. MATERIALS AND METHODS

2.1 Samples Collection and Preparation

Raw clay sample was collected from Ashaka, Funakaye LGA in Gombe State. The raw clay was later surface dried for about 1 week to dry the moisture content of the clay. The Rice Husks was obtained from local rice mills in Kafur LGA Katsina state. It was surface dried for about 3 days to remove the moisture content. The dried recipe was later ground in to small size with jaw crusher and ball mill and sieve to an average of 120-125 microns to get the fine particles (Angaji *et al.*, 2013). Later, the blends were prepared in to a container in accordance with specifications given in Table 1; the blends were mixed thoroughly with homogenizer and mixer to obtain a homogeneous mixture. A 350 ml of de-ionized water was poured in to each of the blends in the container and mixed for about 10 mins. These mud samples were grouped in to 20 and left for about 24hrs to age (Ahmed *et al.*,2012).

Table 1: Mud Components specifications

Sample	Bentonite (g)	Rice husk (g)
1	24.5	Nil
2	24.5	5
3	24.5	10
4	24.5	15
5	24.5	20

2.2 Characterization of the Samples

FTIR and XRD analysis of the samples were carried out to determine the structure and functional group of pure rice husk, pure xanthan gum, pure bentonite clay, with their blends at a given proportion as follows:
Sample A: Pure rice husk
Sample B: Pure Bentonite clay
Sample C: Rice husk: Bentonite clay (1:1)
Sample D: Rice husk: Bentonite clay (2:1)

2.2.1 Determination of Mineral Composition Using XRD

Standard X-ray diffractometry machine known as Empyrean Panalytical with a cupper anode material manufactured by Panalytical was used for the analysis. It is made up of water chiller for cooling system that cools the X-ray tube to uniform temperature. It has a system of compressed air for opening and closing of the cabinet door. Nweke *et al.* (2015) procedure was used for the analysis. The powdered sample was prepared using the sample preparation block and compressed in the flat sample holder to the samples were analysed using the reflection –transmission spinner stage using the two-theta setting. The tube current of 40 mA and voltage of 45kV were used. The spacing of each peak was then obtained by solution of the Bragg equation for the appropriate value of

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lamda. Once all the d-spacing of the unknown is matched to those of known materials, the material identified (Nweke *et al.*,2015).

2.2.2 Fourier Transform Infra-red (FTIR) Analysis

FTIR analysis was carried out using FTIR (Cary 624 Agilent technology equipment) at instrumentation laboratory of chemistry department ABU, Zaria, Nigeria. Sample A was placed on a crystal which was cleaned prior to use. The crystal was inserted into it is position inside the machine and machine was switched on. The machine performed the analysis with a computer interphase (Akinyemi and Alausa, 2020). A graph was generated by the computer. This same procedure was repeated for sample B, C, and D.

2.3 Characterization of Drilling Mud

The properties determined were:

i. Rheological, which include plastic viscosity, yield point
ii. Thixotropic property (gel strength)
iii. Density (Mud weight)
iv. pH

Viscosity and gel strength were measured using low temperature viscometer (FANN 35SA) which is a rotational instrument powered by an electric motor.

The mud sample was poured in to the viscometer cup to the scribed mark and placed on the stand of the viscometer as it was lifted to immerse the rotating sleeve. The rotor speed of 300 and 600 rpm were used throughout the analysis (i.e. two point data approach) (Labe *et al.*, 2015). The reading from rotor sleeve speeds of 300 and 600 rpm was used to determine plastic viscosity and yield point. The gel strength was determined using FANN 35SA viscometer. 10 seconds and 10 minute gel strength were measured. The formulated sample is poured into the sample holder and mounted to position and the base lifted until the mud reach the scribe line and the lock screw tightened. The sample was subjected to shear at 600 rpm for 10 seconds and the gear was then set to neutral position. The motor was shut off and waited for 10 seconds and the deflection at 3 rpm is recorded as 10 seconds gel strength in lb/100 ft^2. This procedure was repeated for the 10 minute gel strength (Hussaini *et al.*, 1983). The yield point was determined computationally taking the difference between dial readings 300 rpm and plastic viscosity. The same procedure was repeated for the 20 samples.

2.4 Determination of Mud Density

The density of the mud was determined using mud balance. The base was set down on a level, flat surface. The sample to be tested was placed within the balancing cup to the top, and the lid was then secured by slowly turning it until it was properly seated. To rid the sample of any entrained air or gas, make sure some of the test sample is forced out through the vent hole in the lid (Caenn *et al.*,2011). The assembly was balanced by moving the rider along the balancing arm after the knife edge of the arm had been inserted into the fulcrum. When the level bubbles move an equal distance to either side of the center, the mud balance is horizontal (Bourgoyne *et al.*,1991). The rider's side closest to the balancing cup was used to read the sample's weight; the measurement reading corresponds to the sample's specific gravity. The same procedure was repeated for the 20 samples.

2.5 Determination of pH Value

The concentration of hydrogen ions in an aqueous solution is determined using the pH test. Therefore, a drilling mud's pH value indicates whether it is acidic or alkaline (Afolabi *et al.*, 2017). The equipment used to measure the pH level of the mud sample is a pH meter, which is immersed in deionized water to standardize the meter before being filled with the mud sample in a beaker. The meter's probe was then put into the mud sample, and the meter's stable pH reading was recorded (Zhang, 2016). The same procedure was repeated for the 20 samples.

III. RESULTS

3.1 FTIR Analysis

The FTIR results are shown in Figures 1 to 4. From FTIR spectra of samples A, B, C and D, it was observed that the samples A, B, C, and D showed 13, 9, 14 and 14 bands/peaks respectively. It clearly showed that the highest level of interaction between the pure and blends of the samples were recorded in samples C and D with 14 peaks/bands each as shown in Figure 4.This indicate that there are more interaction of molecules between the blends of sample A and B in equal proportion and also more interaction between the blends of sample A and B in the ratio (2:1) when compared to sample A, B and blends of sample A and B in the ratio (2:1). However, the molecules of sample C and D shows a pattern of their structure. The appearance of the bands/peaks 2922.2 cm^{-1} and 2855.1 cm^{-1} for sample C and D (Figures 3 and 4) shows the formation/combination of the blends. On the other hand the disappearance of peaks/bands (e.g. 3283.8 cm^{-1} ,3008 cm^{-1} ,1744.4 cm^{-1} and 1640 cm^{-1} in sample A (Figure 1) and the existence of peaks/bands (e.g 3369.5 cm^{-1} ,2068.7 cm^{-1} ,1744.4 cm^{-1} ,1632.6 cm^{-1} in sample C (Figure 3), and existence of peaks/bands (e.g 3370.0 cm^{-1} ,2079.9 cm^{-1} ,1744.4,1632.2 cm^{-1} in sample D (Figure 4) indicates strong interaction of the molecules of the blends. Therefore, the strong interaction of the blends plays an important role in improving the viscosity of the water based drilling fluid.

The bands 3377.0 cm^{-1}, 3283.8 cm^{-1} ,2992.2 cm^{-1} ,2855.1 cm^{-1} indicates the presence of (O-H) functional group (Figures 1, 3 and 4). The band 1744.4 cm^{-1} (represents ketones (C=O) stretching (Figures 1, 3 and 4)). Moreover, the band 1640 cm^{-1} (Figure 1) and Alkene

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(C=C) ring stretch, 1461.1 cm^{-1} (Figure 1) represent (C-C) ring stretch. The band 1375 cm^{-1} ,1230 cm^{-1} and 1021.3 cm^{-1} (Figure 1) stands for –C-H bending (Vaia *et al.*, 1994), C-O stretching (ester) and C-OR stretching (ether) respectively.

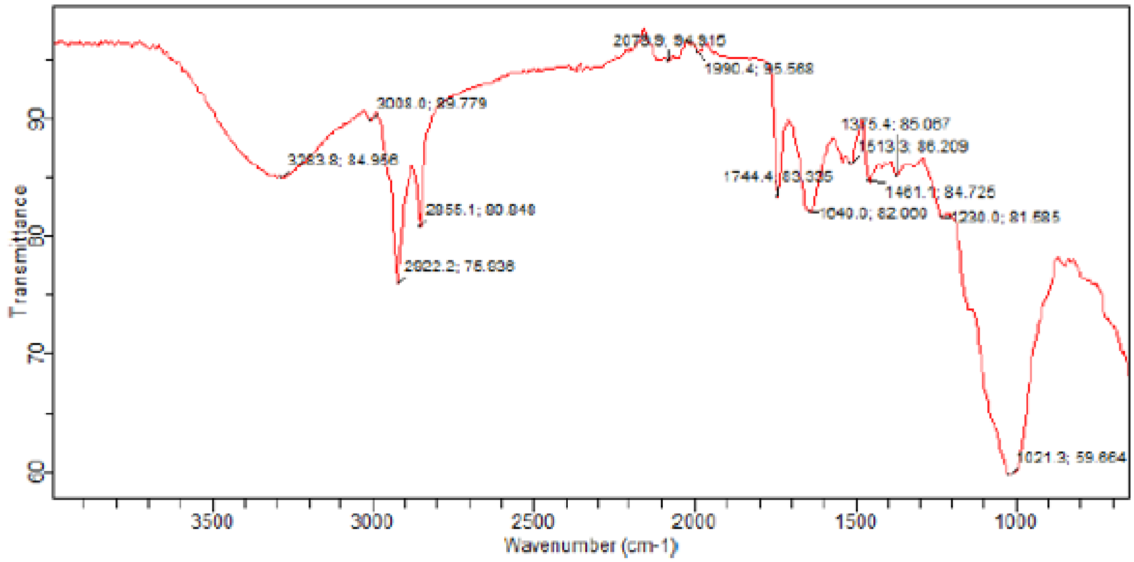

Figure 1: FTIR analysis of pure Rice husk, Sample A

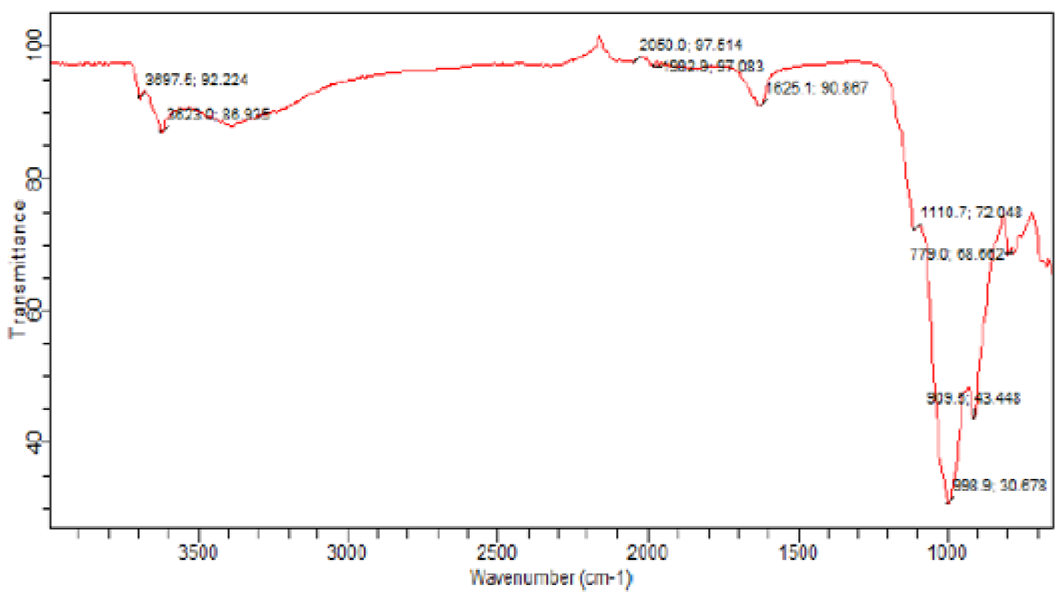

Figure 2: FTIR analysis of pure Bentonite clay, Sample B

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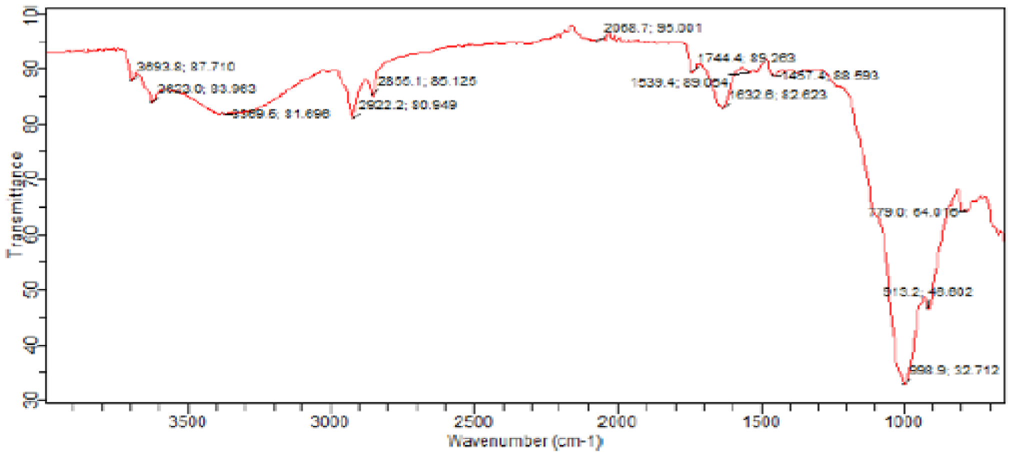

Figure 3: FTIR analysis of Rice husk + Bentonite clay (1:1), Sample C

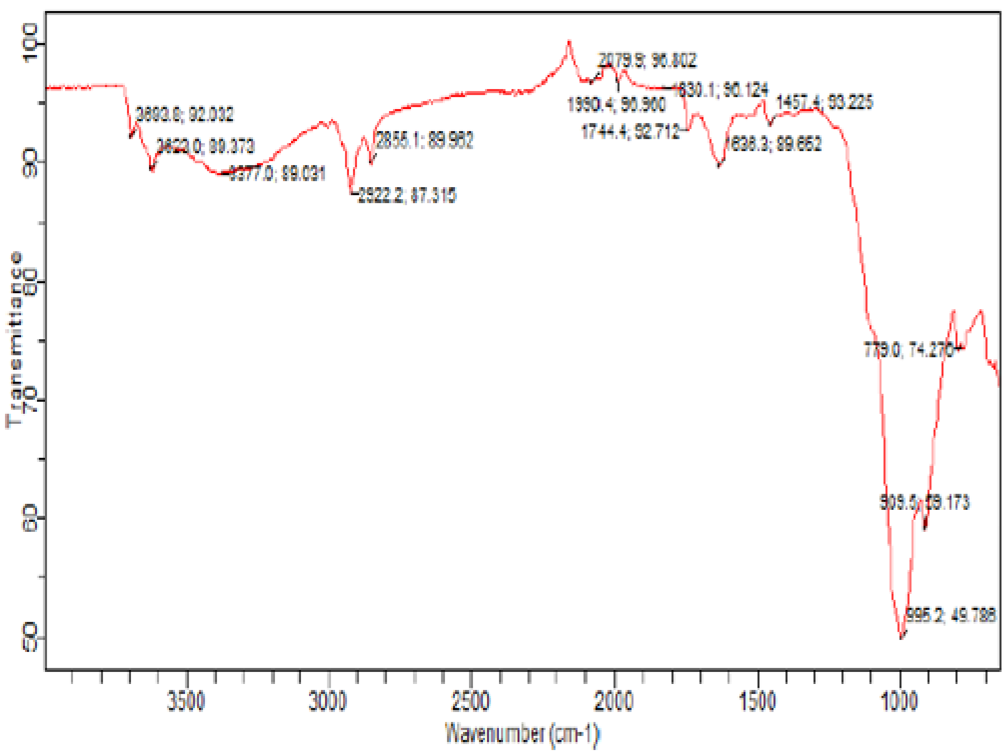

Figure 4: FTIR analysis of Rice husk + Bentonite clay (2:1), Sample D

3.2 XRD (Mineralogical) Analysis

XRD is an electrical technique design to provide more in-depth information about crystalline compounds including identification and quantification of the sample. XRD analysis is based on constructive interference of monochromatic x-rays and a crystalline sample. The x-rays are generated by a cathode-ray tube filter to produce monochromatic radiation collimated to concentrate and directed towards the sample, the interaction of the incident rays with the sample produce constructive interference when conditions satisfied Bragg's law that is lambda is equal to 2Ɵ sine theta. This law relates the wavelengths of electromagnetic radiation to the diffraction angle and the lattice spacing in a crystalline sample. This analysis

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provides the unique fingerprint of the crystal present in the sample. When properly interpreted by comparison with standard reference pattern and measurement. Each Mineralogical type produces a characteristic spectrum and with the help of a collection of spectra, mineral structure can be identified. In this work, the samples A, B, C and D were subjected to XRD analysis. The results obtained showed that sample A contains Quartz as minerals (Figure 5) with characteristics peaks at d-spacing and 2ϴ value of 4.25478Å and 20.861^0, 3.34321 Å and 26.642^0,2.45650 Å and 36.550^0, 2.28123 Å and 39.470^0, 2.23636 Å and 40.296^0 with most intense peak at 2ϴ value of 26.642^0, which implies the plane of maximum concentration of the mineral Quartz (Bilal,2016). However, analysis of sample B showed that the sample B is rich in montmorillonite with illites, kaolinites, Quartz as impurities (Figure 6). This indicates that the rich in smecite montmorillonite content of the clay is responsible for it is swelling characteristics. The characteristics of peak list observed at d-spacing and 2ϴ value values are 15.0000 Å and 5.887^0, 8.9800 Å and 9.482^0, 7.70481 Å and 11.476^0, 5.75640 Å and 15.380^0, 5.18000 Å and 17.104^0 with most intense peak at 2ϴ value of 5.887^0.

On the other hand, both samples C and D contain montmorillonite as mineral (Figures 7 and 8). Sample C and D showed the same characteristics peaks at d- spacing and 2ϴ values of 15.0000 Å and 5.887^0, 8.98000 Å and 9.842^0, 7.70481 Å and 11.476^0, 7.50000 Å and 11.790^0, 5.75640 Å and 15.380^0, 5.18000 Å and 17.104^0, 5.00000 Å and 17.725^0 with the most intense peak for both C and D at 2ϴ value of 5.887^0. The results showed a strong interaction between the blends of sample A and B.

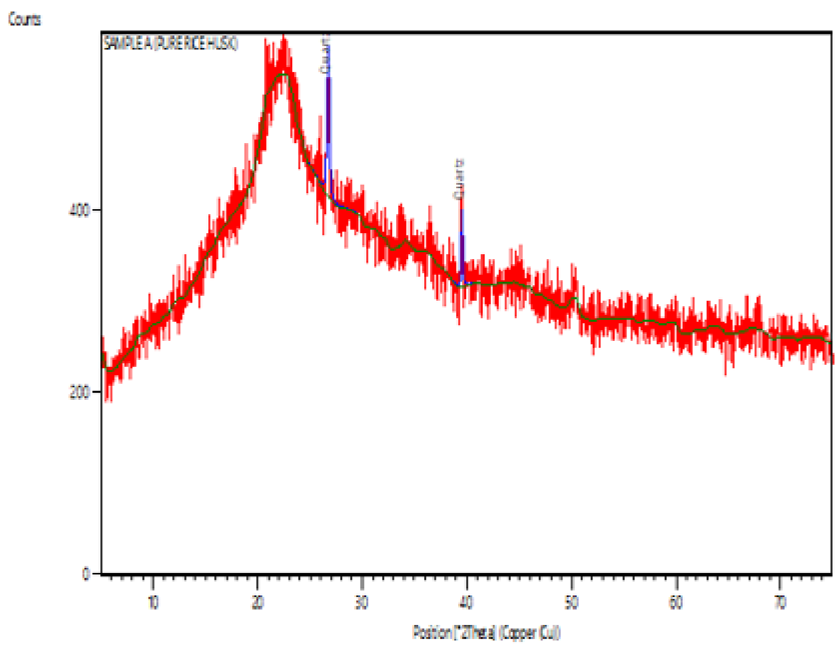

Figure 5: XRD result of Sample A

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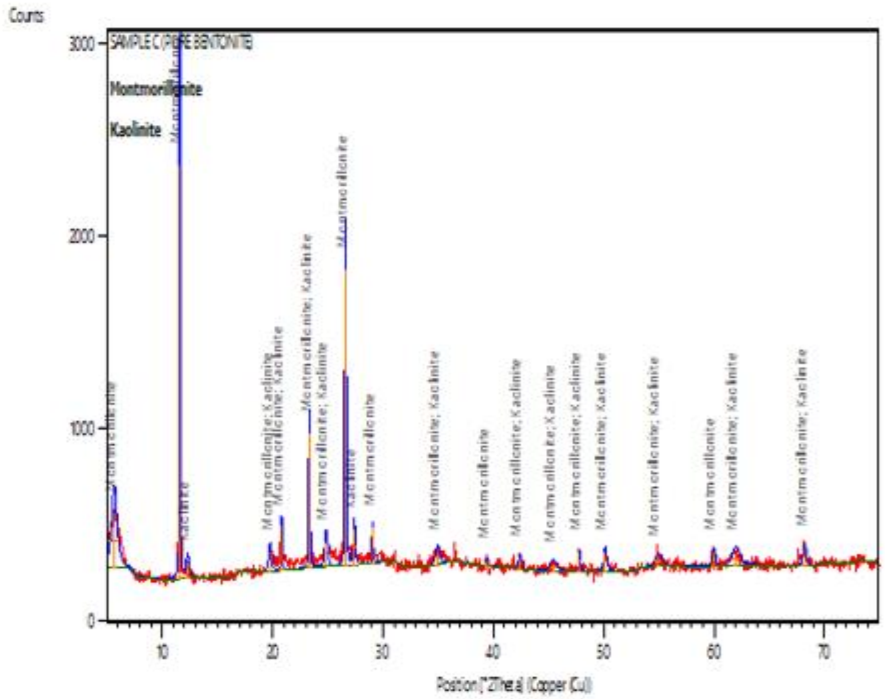

Figure 6: XRD result of Sample B

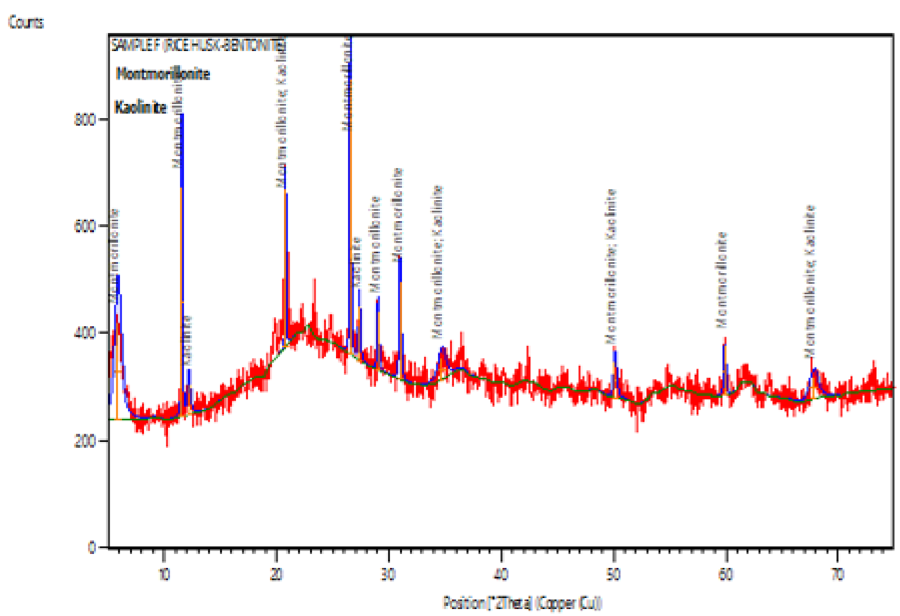

Figure 7: XRD result of Sample C

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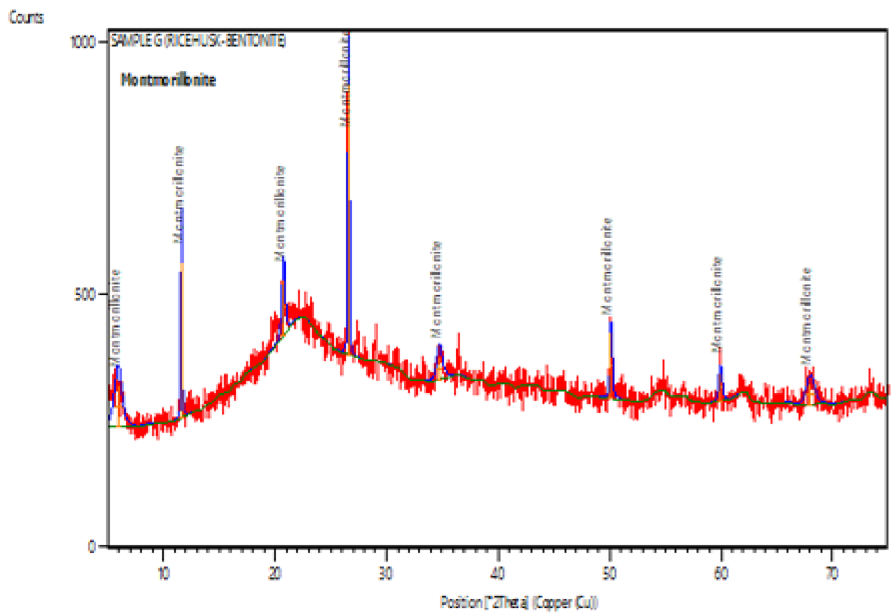

Figure 8: XRD result of Sample D

3.3 pH and Mud Weight

The pH and mud weight of the five samples as obtained from the analysis are shown in Table 2. It was observed the pH of each sample remain the same at the various temperature considered. Also, the mud weights of the samples remain the same for thevarious temperature considered in the study. However, addition of rice husk to the bentonite drilling mud reduced the pH of the drilling fluid from 10.5 to 9.2 on addition of the highest quantity of 20g rice husk. Addition of rice husk to the bentonite increased the mud weight of the bentonite drilling mud slightly (Table 2).

Table 2: pH and Mud weight of the sample

Sample No	**pH**	**Mud Weight (lb/gal)**
1	**10.5**	9.5
2	9.6	9.5
3	9.3	9.7
4	9.2	9.8
5	9.2	9.9

Addition of rice husk only to the bentonite increased the mud weight of the fluid (sample 1 compared with samples 2 to 5 in Table 1).

3.4 Plastic Viscosity (PV) and Yield Point (YP)

From Figure 9, the plastic viscosity of thebentonite drilling fluid increased with increase in temperature but for every particular temperature the PV of the mud slightly decreased with addition of 5g rice husk to the bentonite mud but increased steadily as the quantity of the rice husk increased from 10g to 20 g. This is an indication that the rice husk is capable of working as a viscosifier in the bentonite drilling fluid. This is in agreement with the finding of Akinyemi and Fatai (2022). The highest PV value obtained was 2.0cP for bentonite drilling modified with 10g and 15g rice husk separately at 25^{o}C. It was further observed that the viscosity of each of the samples reduced with increased in temperature from the range of 25^{o}C to 50^{o}C. This is in agreement with the findings of previous researchers (Akinyemi and Lawal, 2022; Akinyemi and Fatai, 2022). However, for the bentonite mud and 5g rice husk modified betenonite mud displayed slight increased in viscosity at temperatures of 35^{o}C to 40^{o}C while further decrement in PV was observed for temperatures above 40^{o}C. From the results, it was observed that the best PV values for the first 4 samples were at 50^{o}C while the best for sample 5 was at 40^{o}C. The carry capacity of the fluid became best at these values and will enhance good hole-cleaning.

The yield point values of the samples increased with increased in temperature for all the samples considered as shown in Figure 10. The YP of the bentonite modified with 5g rice husk gave the highest value of YP at

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50°C. It was further observed that the best YP value (maximum value) for each of the sample tested was at 50°C.

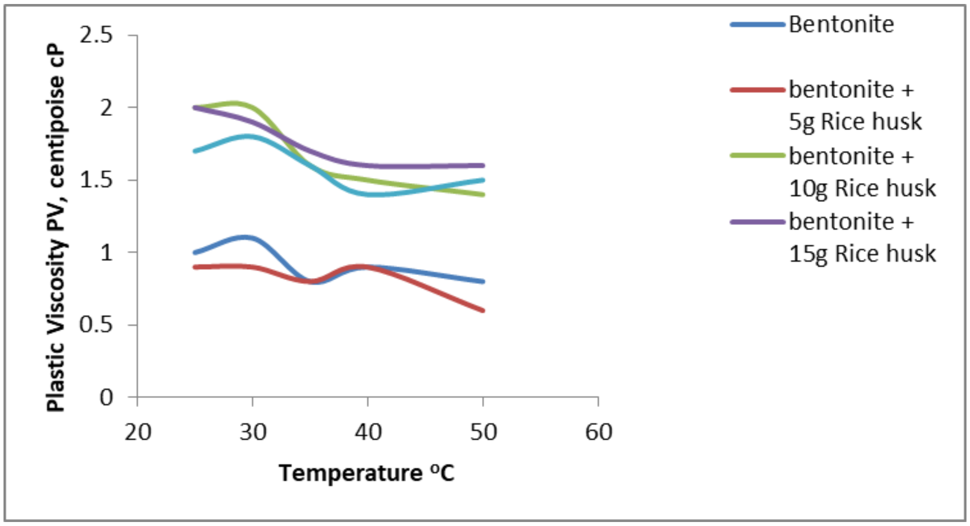

Figure 9: Plastic viscosity of samples against Temperature for Samples 1 to 5

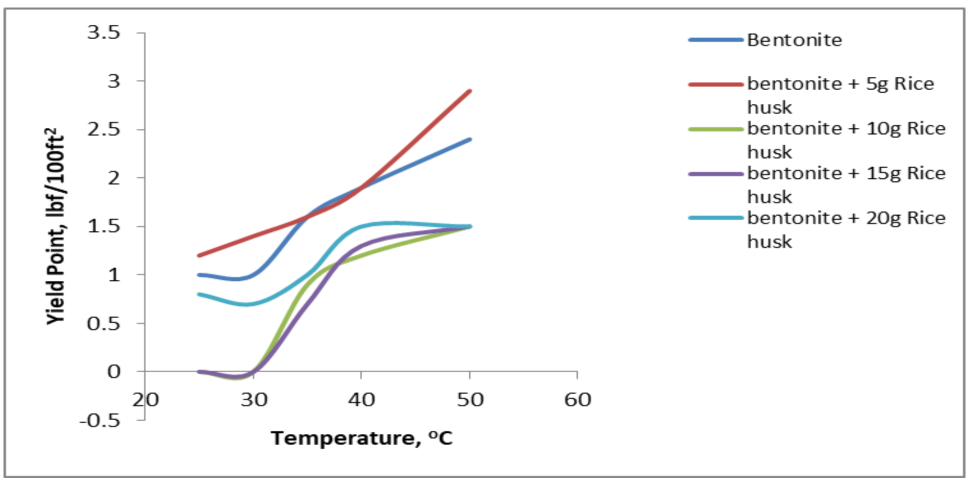

Figure 10: Yield point against temperature for Samples 1 to 5

The ratio of yield point to plastic viscosity (YP/PV) of the samples 1 to 5 were also determined and the results given in Table 3. The results showed that YP/PV for virtually all the samples increased with increased in temperature, with sample 5 displaying a little decrease in YP/PV value at low temperatures. This is in agreement with the findings of other researchers (Alawi *et al.*, 2019).

Table 3: YP/PV Ratios of Samples 1 to 5 at different temperatures

Temperature (°C)	YP/PV Ratio				
	1	**2**	**3**	**4**	**5**
25	1	1.33	0	0	0.47
30	0.909	1.56	0	0	0.389
35	2.0	2.0	0.56	0.412	0.625
40	2.1	2.11	0.8	0.8125	1.07
50	3.0	4.83	1.07	0.938	1.0

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3.5 Gel Strength

The gel strengths for the samples tested at 10sec are given in Figure 11 while those of gel strength at 10 minutes are shown in Figure 12. Gel strength in 10 seconds for bentonite with 5 g rice husk was found to be highest at all the temperatures considered (Figure 11). Similarly, Gel strength in 10 minutes for bentonite with 5 g rice husk was found to be highest at all the temperatures considered (Figure 12). It was generally observed that the gel strength of the samples increased with increased in temperatures at both 10seconds and 10 minutes of static conditions. The gel strength values observed were not too high, so addition of necessary chemicals may be required to improve the gel strength of the samples.

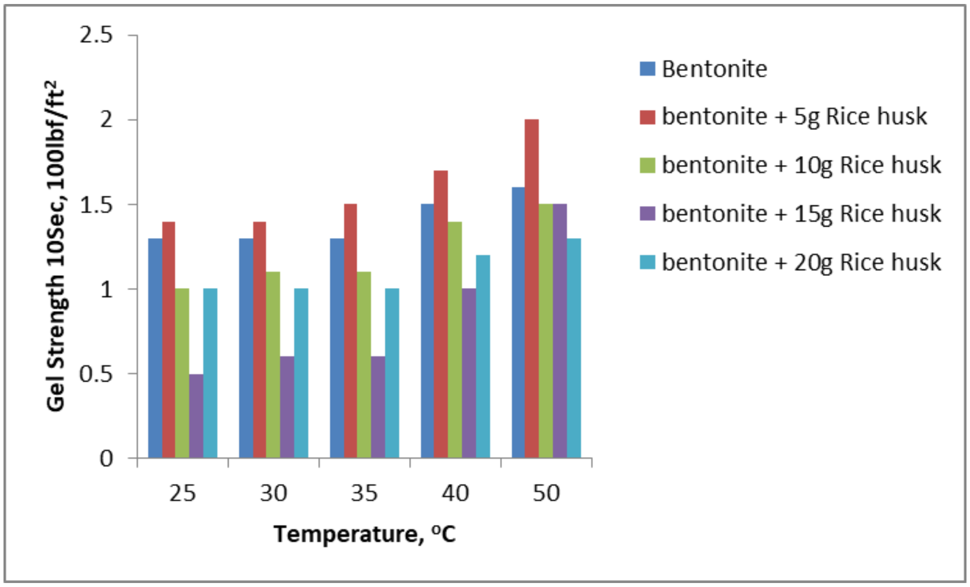

Figure 11: Gel strengths (10 secs) for the five samples at various temperatures

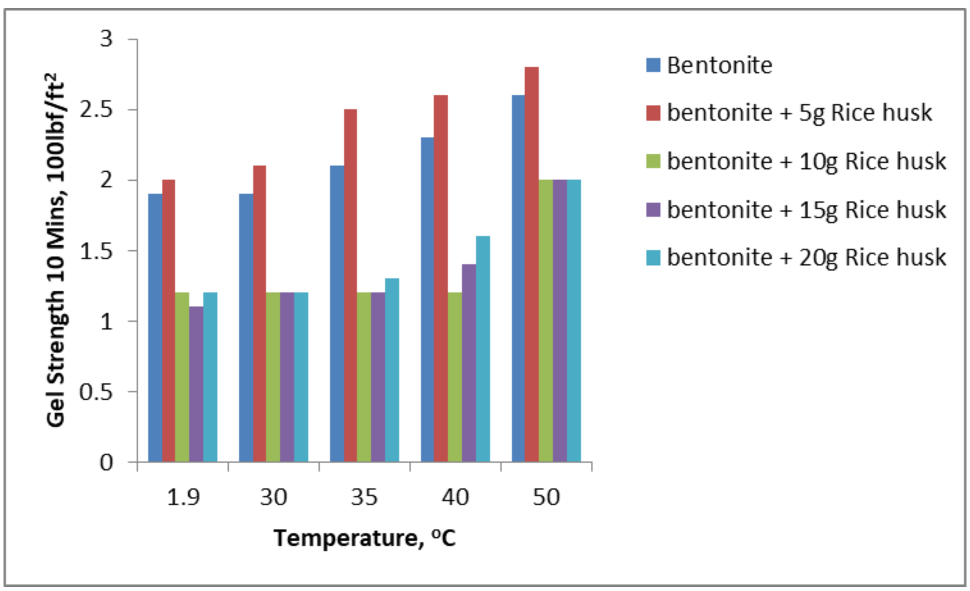

Figure 12: Gel strengths (10 minutes) for the five samples at various temperatures

IV. CONCLUSION

Water based drilling fluid with standard bentonite composition was investigated in this study to determine the effect of temperature on the fluid when modified with rice husk in various composition. It could be concluded that rice husk could blend effectively with the bentonite based on the results obtained from FTIR and XRD analysis. The

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pH values of all the produced drilling mud samples were alkaline, close to the neutral value. Increase in temperatures bentonite drilling mud modified with rice husk does not have negative effect on the rheological properties of the drilling mud. The rice husk could be used as a viscosifier in the drilling mud for being capable of improving the viscosity of the mud at higher temperature. However, additional chemicals may be needed to improve on the gel strength of the bentonite-rice husk drilling mud.

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