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Effects of Temperature on the Rheological Properties of Bentonite Drilling Fluids Modified With Rice Husk and Xanthan Gum

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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 cla1y and rice husk as specified by samples A with (pure rice husk), B (with pure xanthan gum), C (1:1 of rice husk to xanthangum) and D (5:1 of rice husk to xanthan gum) were characterized using X-ray diffraction (XRD) and Fourier Transform Infrared (FTIR). The XRD result of the samples A, B, C, and D Contains Quartz, Halite, Quartz and Quartz respectively with the most intense peak at 2ϴ value of 26.642^o, 31.578^o, 26.624^o and 26.627^o respectively. The results also shows sample D has less interaction than sample C due to increase in the value of 2ϴ at the most intense peak from 26.624^o to 26.627^o. FTIR results of samples A, B, C, and D shows number of bands/peaks of 13, 12, 14 and 12 respectively. It clearly shows that the high level of interaction between pure and blends of the samples were recorded in sample C with 14 peaks/bands. The appearance of the band/peaks 2922.2 cm^{-1} and 2855.1 cm^{-1} for sample C showed formation/combination of the blends. Thirtheen water based drilling fluid samples produced using standard laboratory barrel (350 ml) method from bentonite and water with addition of rice husk and xanthan gum in different proportion were investigated. FANN 35 viscometer was used to measure the rheological properties (plastic viscosity, yield value, gel strength) of the samples at different temperatures, while the pH and density values were measured using pH meter and mud balance respectively. The values of the pH for all the produced drilling mud samples were were between 7.5 and 9.8. 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: Drilling fluid, mud, rice husk, xanthan gum, rheology properties

I. Introduction

Drilling fluids 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. Although some of the aforementioned functions of a drilling fluid have been noted, it is also essential to note that these fluids' functionality greatly depends on their properties (Yunita et al., 2016), and the necessary properties can be obtained by modifying the composition of these fluids. Water-based drilling fluids are more commonly utilized than other drilling fluids (oil-based and synthetic-based) due to their low cost, environmental friendliness, and ease of preparation. In order to retain the necessary qualities during drilling, water-based drilling fluid is primarily made of water, bentonite, polymers, salts, and other ingredients. Some researchers have considered the utilization of xanthan gum as well as rice husk as part of the components of water based drilling fluids (Akinyemi and Fatai 2022, Akinyemi and Lawal, 2022)

It is well known that 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. Furthermore, the expense of the fluid, the fluid's impact on production from the pay zone and the environmental impact of utilizing the fluid must all be taken into account when choosing the fluid (Bilal, 2016). However, 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). 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. Water-based drilling fluid may lose some of its qualities at high temperatures and this can have an impact on the viscosifying agents and reduce the fluid's velocity (Akinyemi & Alausa, 2020). Xanthan gum also improves the rheology of the finished products due to its pseudoplastic behavior in solutions and because of its more Newtonian characteristics (Al-Khdheeawi *et al.*, 2019). 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 and xanthan gum were investigated.

II. Material And Methods

2.1 Samples Collection and preparation

The bentonite sample was collected from Ashaka, Funakaye LGA in Gombe State. It was later surface dried for about one 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)	Xanthan gum (g)
1	24.5	Nil	Nil
2	24.5	5	1
3	24.5	10	1
4	24.5	15	1
5	24.5	20	1
6	24.5	5	2
7	24.5	10	2
8	24.5	15	2
9	24.5	20	2
10	24.5	5	5
11	24.5	10	5
12	24.5	15	5
13	24.5	20	5

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 xanthan gum
Sample C: Rice husk: xanthan gum (1:1)
Sample D: Rice husk: Xanthan gum (5:1)

2.2.1 Fourier transform infra-red (FTIR) Analysis

FTIR (Cary 624 Agilent technology equipment) was used to carry out the FTIR analysis at instrumentation laboratory of chemistry department ABU, Zaria, Nigeria. The sample 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 all the samples A, B, C, and D.

2.2.2 Determination of Mineral Composition Using XRD

The machine used for the XRD analysis was Standard X-ray diffractometry machine known as Empyrean Panalytical with a cupper anode material manufactured by Panalytical. The machine 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. The procedure of Nweke *et al.* (2015) was used for the analysis. 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. Tube current of 40 mA and voltage of 45kV were used. Solution of the Bragg equation for the appropriate value of lamda was used to obtain the spacing of each peak. The material is identified once all the d-spacing of the unknown is matched to those of known materials (Nweke *et al.*,2015).

2.3 Characterization of Drilling Mud

To characterize the drilling mud (fluid) the following properties were determined:

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

The viscosity and gel strength were measured using low temperature viscometer (FANN 35SA) which is a rotational instrument powered by an electric motor. The drilling fluid 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. Rotor speed of 300 and 600 rpm were used throughout the analysis (i.e. two point data approach) (Labe *et al.,* 2015). The readings from rotor sleeve speeds of 300 and 600 rpm were used to determine plastic viscosity and yield point. Gel strength of the sample 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. The procedure was repeated for the 10 minute gel strength (Hussaini *et al.,* 1983). Yield point was determined by computationally taking the difference between dial readings 300 rpm and plastic viscosity. The same procedure was repeated for the 13 samples.

2.4 Determination of Mud Density

Density of the drilling mud was determined using mud balance. The base of the mud balance 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, such in the test sample is forced out through the vent hole in the lid (Caenn *et al.,* 2011). To balance the assembly it was done by moving the rider along the balancing arm after the knife edge of the arm had been inserted into the fulcrum. Whenever 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 13 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 and Discussion

3.1 FTIR Analysis

The results of the FTIR analysis carried out using FTIR (Cary 624 Agilent technology equipment) are shown in Figures 1 to 4. From the FTIR spectra of samples A,B,C,D and D, it was observed that the samples A,B,C and D shows number of bands/peaks of 13,13,14 and12 respectively. This clearly showed that the highest level of interaction between the pure and blends of the samples were recorded in sample C, 14 peaks/bands as shown in Figure 1. 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 (5:1). The appearance of the bands/peaks 2922.2 cm^{-1} and 2855.1 cm^{-1} for sample C shows the formation/combination of the blend. 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 existence of peaks/bands (e,g 3287.5 cm^{-1} ,2079.9 cm^{-1} ,1740.7 cm^{-1} ,1602.8 cm^{-1} and 1017.6 cm^{-1}) in sample C Figure 3 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 and 3). The band 1744.4 cm^{-1} (represents ketones(C=O) stretching (Figure (1 and 3). Moreover, the band 1640 cm^{-1} (figure B1) and Alkene (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.

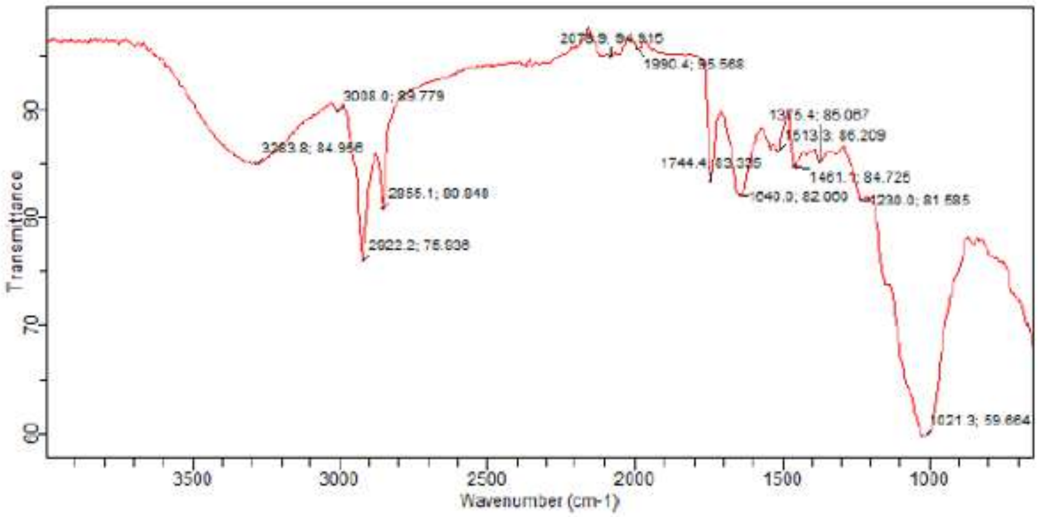

Figure 1. FTIR analysis of pure Rice husk, Sample A

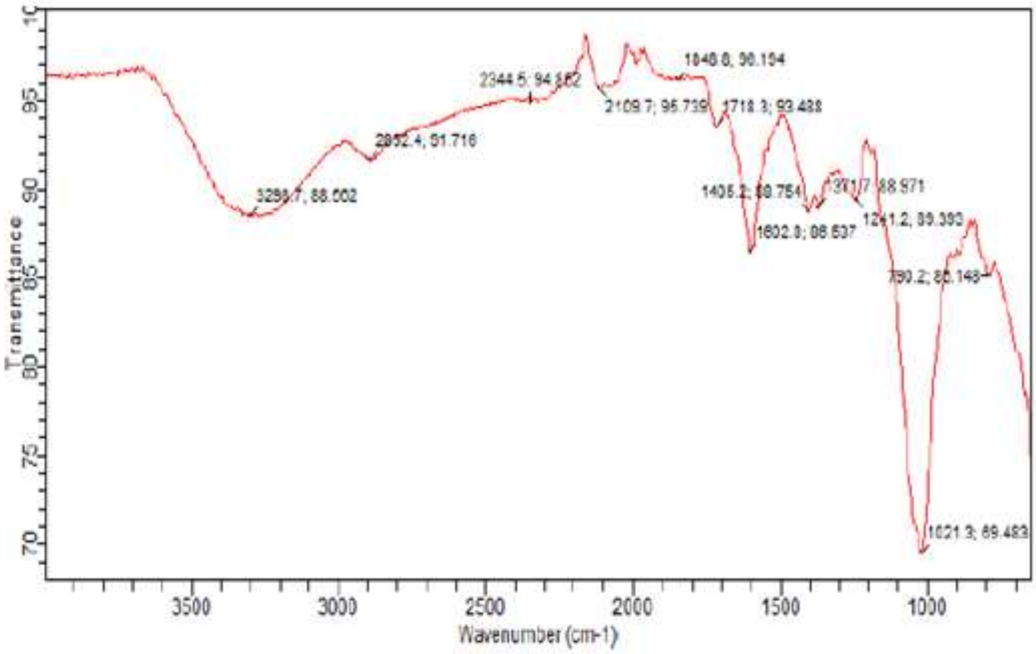

Figure 2. FTIR analysis of pure Xanthan gum, Sample B

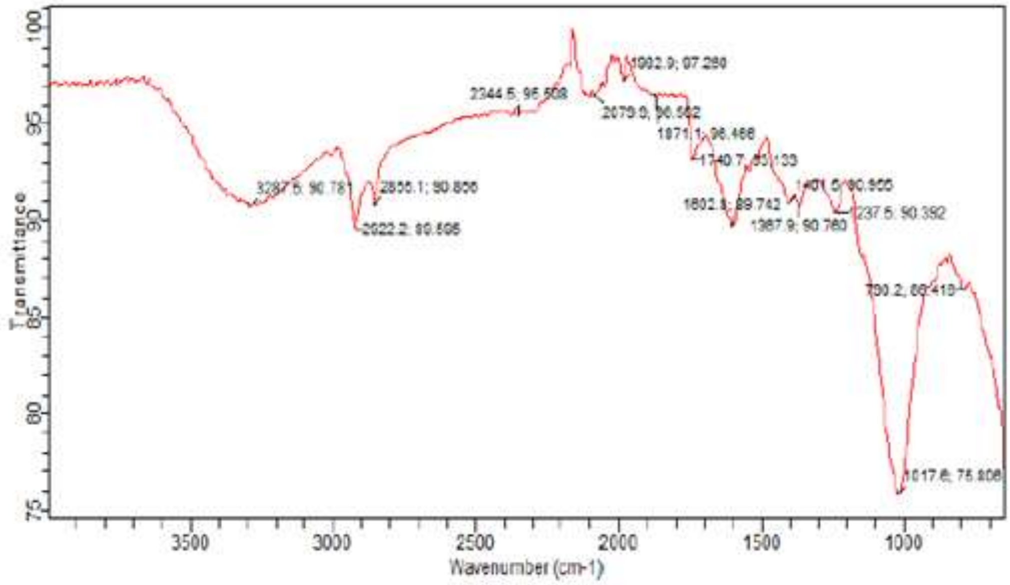

Figure 3. FTIR analysis of Rice husk + Xanthan gum (1:1), Sample C

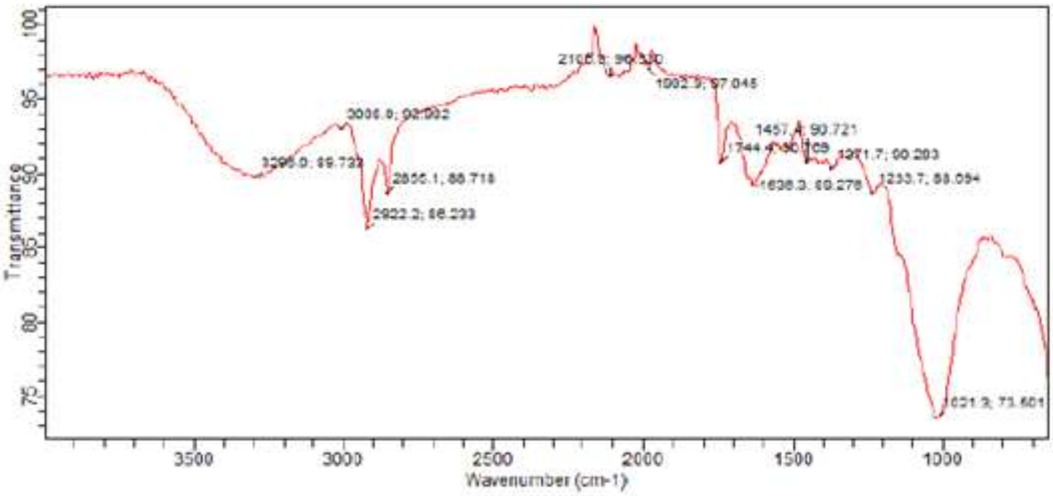

Figure 4. FTIR analysis of Rice husk + Xanthan gum (5:1), Sample D

3.2 XRD (Mineralogical) Analysis

From Figure 5 sample A contains Quartz as minerals with characteristics peaks at d-spacing and 2Ɵ 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 2Ɵ value of 26.642^0, which implies the plane of maximum concentration of the mineral Quartz (Bilal,2016).However, sample B Mineralogical analysis shows that the sample contains Halite mineral with characteristics peaks at d-spacing and 2Ɵ value of 3.26896 Å and 27.259^0, 2.83100 Å and 31.578^0, 2.00182 Å and 45.263^0 with the most intense peak at 2Ɵ value of 31.578^0 (Figure 6).

It was observed that sample C also contains Quartz as mineral with characteristics peaks at d-spacing and 2Ɵ values of 4.2573 Å and 20.848^0, with the most intense peak observe at 2Ɵ value of 26.624^0. From the result it can be clearly observed that there is decrease in the value of 2Ɵ for sample C when compared to sample A and B from 26.642^0 to 26.624^0 when compared to A and C and from 31.578^0 to 26.624^0 when compared to B and C. This is an indication of interaction between sample A and B (Figures 5 and 6). Meanwhile sample D contains Quartz as mineral but more concentration of Rice Husk added in the ratio of (5:1).This sample contains characteristics peaks at d-spacing and 2Ɵ values of 4.25392 Å and 20.865^0, 3.34225 Å and 26.647^0 with the most intense peak at 2Ɵ value of 26.647^0.This result shows that sample D has less interaction compared to sample C because there is increase in the value of 2ϴ at the most intense peak from 26.624^0 to 26.647^0 (Figure 8).

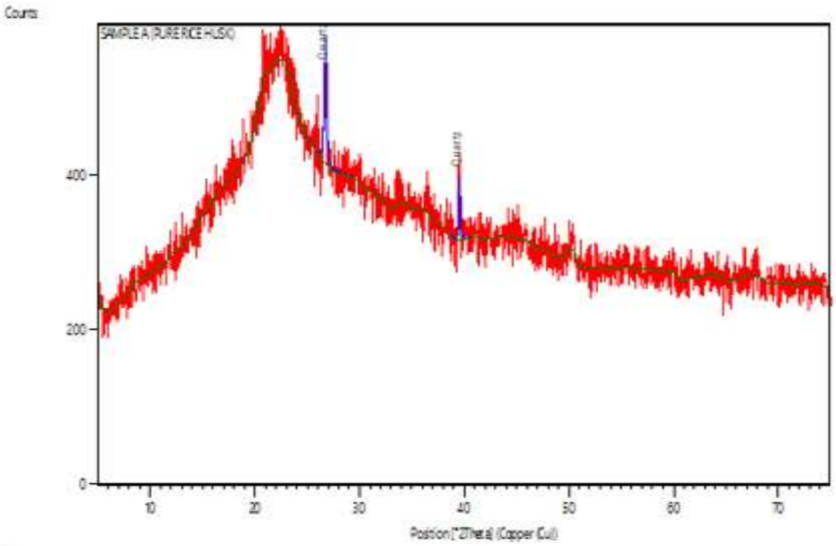

Figure 5 XRD result of Sample A

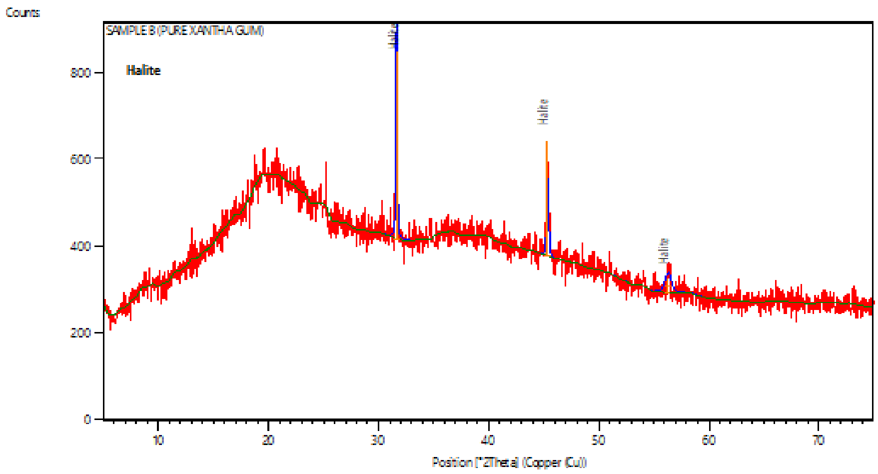

Figure 6 XRD result of Sample B

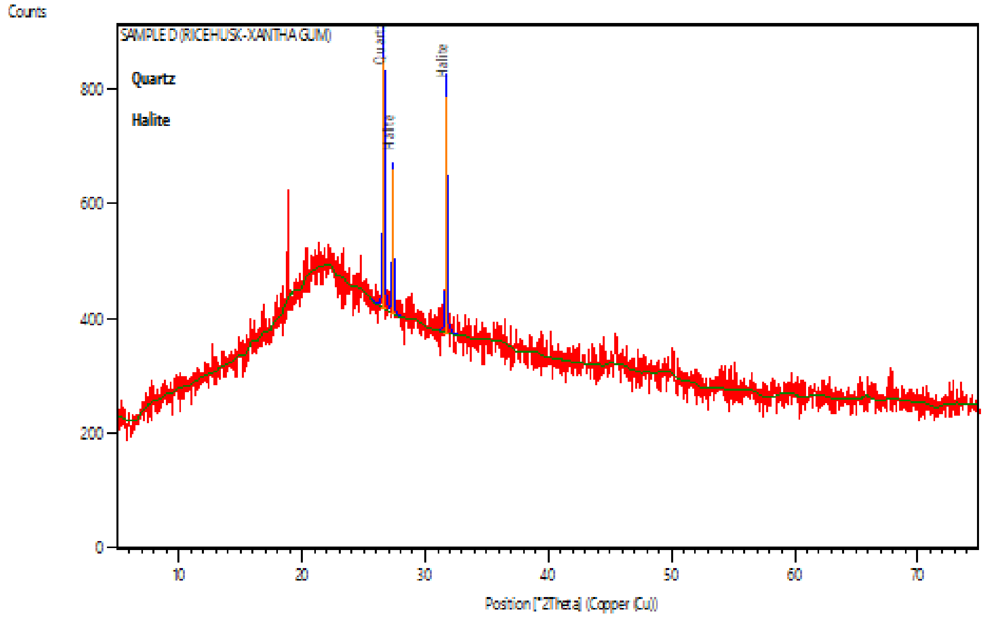

Figure 7 XRD reult of Sample C Rice husk: xanthan gum (1:1)

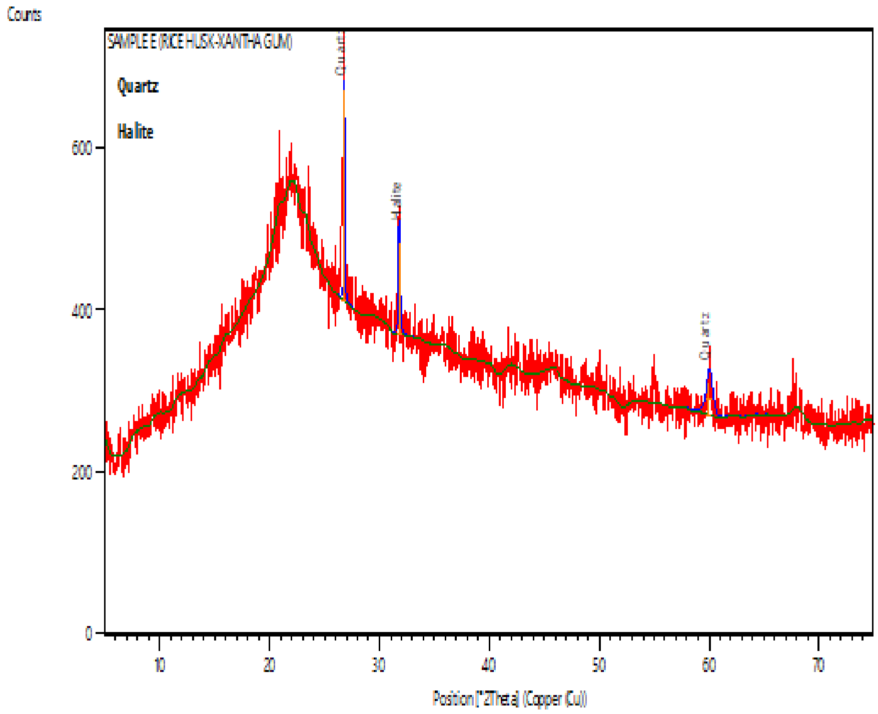

Figure 8 XRD result of Sample D (5:1)

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 and xanthan gum in ration 5g to 1g to the bentonite drilling mud reduced the pH of the drilling fluid from

10.5 to 9.0. When more rice husk were added with the same quantity of xanthan gum the pH of the samples decreased further up to 8.8 after addition of 20g rice husk. Conversely, the mud weight of the bentonite drilling mud modified with mixture of 1g of xanthan gum and 5 g of rice husk increased and increased progressively from 9.5 to 10.0lb/gal as the quantity of the added rice husk increased till 20g.

Using the same trend of addition of rice husk (5g to 20g) with 2g of xanthan gum to the bentonite drilling fluid displayed the same trend like the one with 1g of xanthan gum but decreased the pH at faster rate than that of 1g xanthan gum. As shown in Table 2 the decrement of pH was from 10.5 to 8.6, while the increment in mud weight was from 9.5 to 10.3 at 20g rice husk with 2 g xanthan gum. For 5g xanthan gum, the addition of rice husk with xanthan gum reduced the pH at a further faster rate from 10.5 to 7.6 while increasing the mud weight from 9.5 lb/gallon to 10.5lb/gallon. Thus, the rice husk combined with xanthan gum in appropriate ratio can give a better quality to bentonite water based drilling fludid with the pH approaching a neutral condition.

Table 2 pH and Mud weight of the sample

Sample No	**pH**	**Mud Weight (lb/gal)**
1	**10.5**	9.5
2	9.0	9.6
3	8.9	9.7
4	8.8	9.8
5	8.8	10.0
6	8.9	9.6
7	8.8	9.8
8	8.7	9.8
9	8.6	10.3
10	8.3	9.8
11	7.9	9.9
12	7.6	10.0
13	7.2	10.5

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

It was observed that the plastic viscosity of thebentonite drilling fluid modified with 5g of rice husk and 1 g of xanthum gum decreased with increase in temperature at low temperatures ranging from 25^{o}C to 35^{o}C and increased with increase in temperature at temperatures of 40oC and above (Figure 9). For bentonite drilling fluid modified with higher amount of rice husk at the same quantity of xanthan gum (1 g), the plastic viscosity increased slightly with increase in temperature at low temperatures and later began to decrease with increase in temperature from 30^{o}C to 35^{o}C (Figure 9). For 15g and 20g rice husk with 1 g xanthan gum in particular, the PV increased steadily with increase in temperature at temperatures above 35^{o}C. It was further observed that the bentonite drilling fluid modified with 15g rice husk exhbitied the highest plastic viscosity at all the temperatures considered for 1 g xanthan gum addition (Figure 9). From Figure 10, bentonite drilling fluid modified with 20g rice husk and 2g xanthan gum exhibited the highest plastic viscosity at all the temperatures considered for 2g xanthan gum mixture. Also, Figure 10 showed that plastic viscosities of all the samples containing 2g xanthan gum decreased with increase in temperature between 25^{o}C and 30^{o}C with slight increase between 30^{o}C and 35^{o}C and further went to decrease with increase in temperature between 35^{o}C and 50^{o}C. It was observed from Figure 11 that the bentonite drilling fluid with 20g rice husk and 5g xanthan gum exhibited conspicuous highest plastic viscosities at all temperatures considered for drilling fluid containing 5g xanthan gum. Similar to the trend observed with bentonite drilling fluid with 2g xanthan gum, the plastic viscosities of all the 5g xanthan gum contained drilling fluids slightly increased between 30^{o}C and 35^{o}C with increase in temperature, but decrease with increase in temperature at temperatures below 30^{o}C and above 35^{o}C. The performance of the combination of rice husk and xanthan gum, especially at 20g rice husk and moderate composition of xanthan gum (2g to 5g) could be regarded as an advantage to utilizing the duo as viscosifier in the bentonite drilling fluid. This is in agreement with the findings of previous researchers (Akinyemi and Fatai 2022; Akinyemi and Lawal, 2022). The increament in temperature may not adversely affect the viscosifying ability of the product contianng rice husk and xanthan gum. Thus, the carry capacity of the drilling fluids containing rice husk and xanthan gum in appropriate proportion is favoured at the temperature range from 35^{o}C amd above and this will enhance good hole-cleaning.

Furthermore, it was observed that yield point of al the samples containing rice husk and 1 g xanthan gum increase with increase in temperature in all the categories of mixing compositions (Figures 12) except for the bentonite drilling fluid containing 5g rice husk and the one contiaing 15g that showed slight decrease in yield point between 35°C and 40°C. The drilling fluid with 20g rice husk and 1g xanthan gum displayed the highest yield point throughout the temperatures considered (Figure 12). For bentonite drilling fluids containing 2g xanthan gum mixed with different proportion of rice husk and those continanig 5g xanthan gum mixed different proportion of rice husk, the yield points increased with increase in temperature at all the temperatures considered (Figures 13 and 14). The best yield point value for all the categories of drilling fluid samples tested with various composition of rice husk and xanthan gum was at 50°C where the maximum yield point was obtained in each case (Figures 12 to 14).

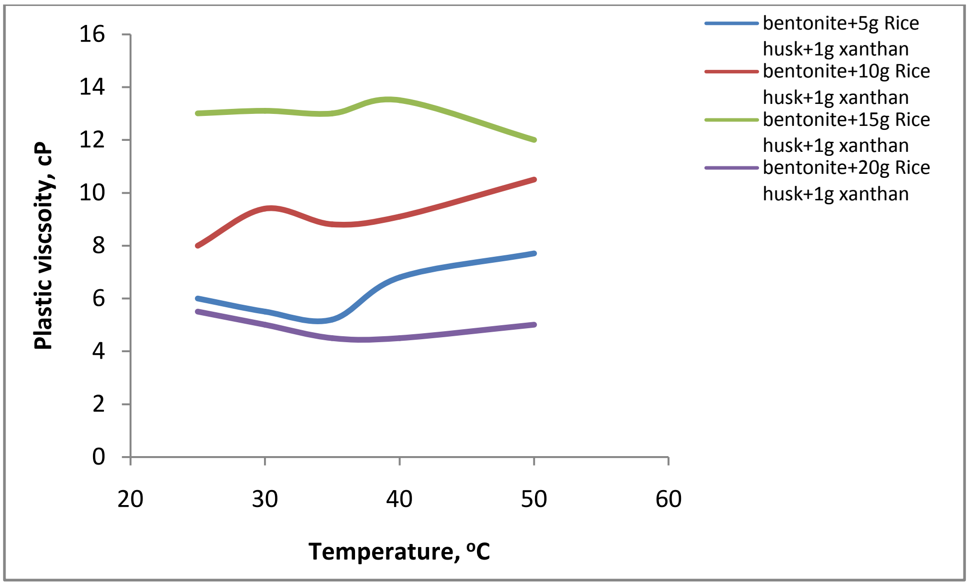

Figure 9 Plastic viscosity against temperature for Samples 2 to 5

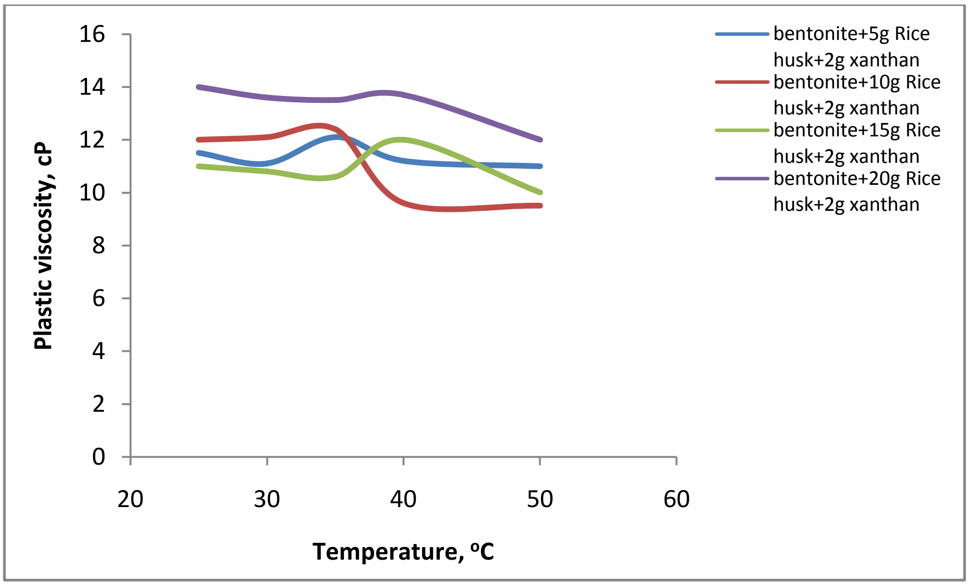

Figure 10 Plastic viscosity against temperature for Samples 6 to 9

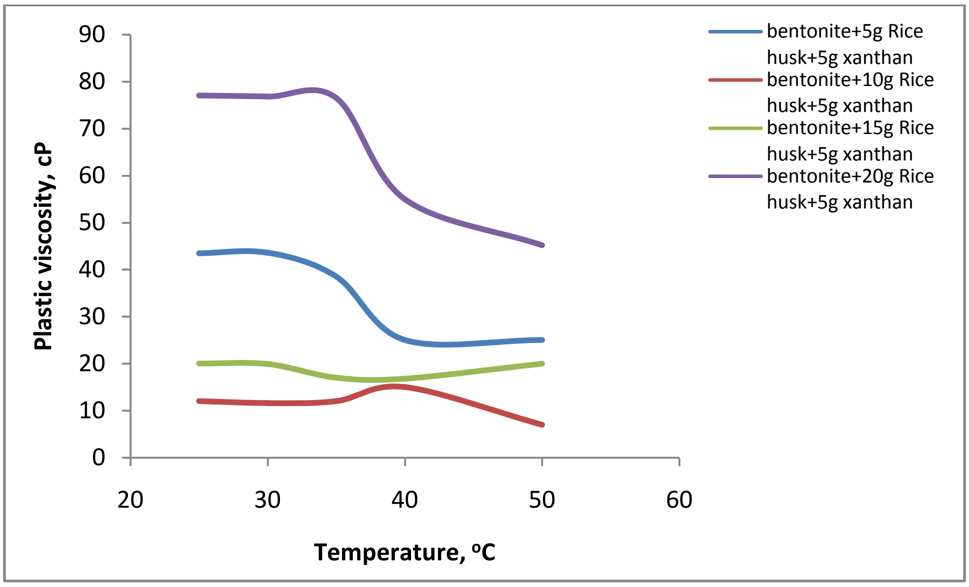

Figure 11 Plastic viscosity against temperature for Samples 10 to 13

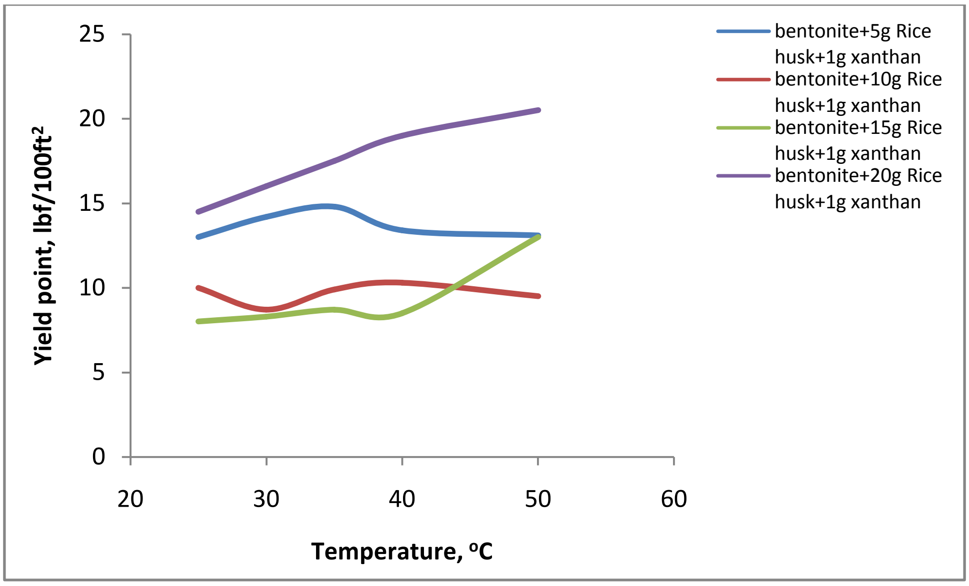

Figure 12 Yield point against temperature for Samples 2 to 5

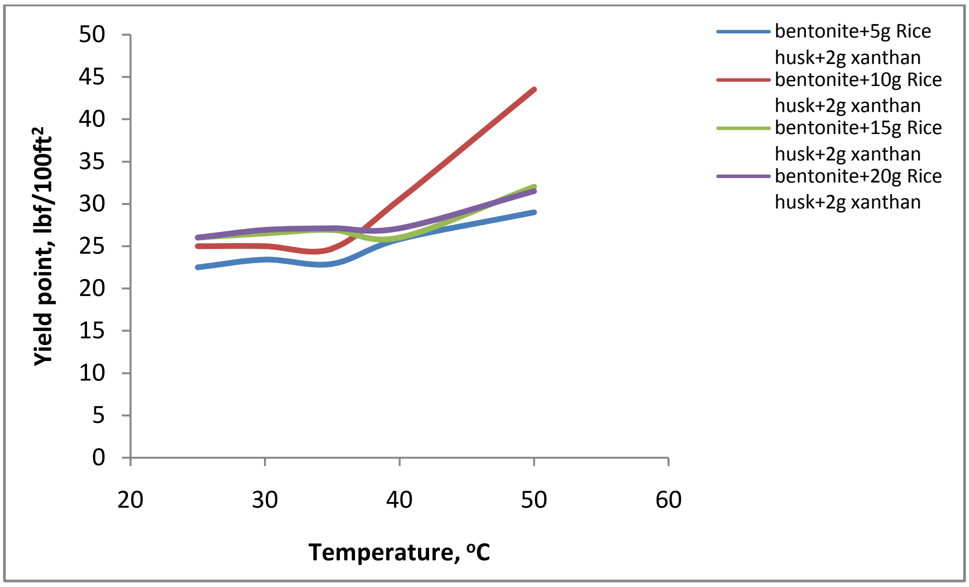

Figure 13 Yield point against temperature for Samples 6 to 9

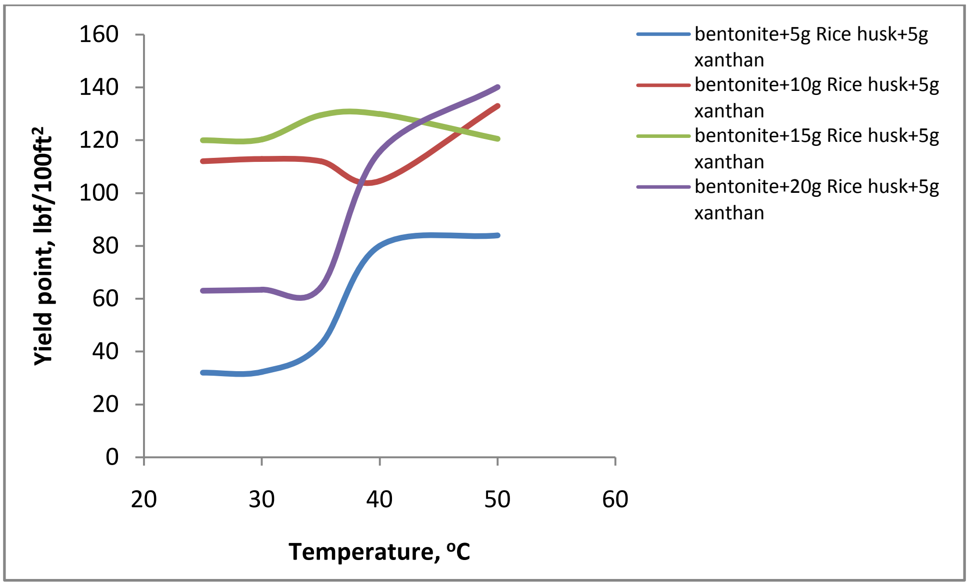

Figure 14 Yield point against temperature for Samples 10 to 13

The ratio of yield point to plastic viscosity (YP/PV) of the samples 2 to 13 were also determined and the results given in Tables 3 to 5. The results showed that YP/PV for virtually all the samples with 1g xanthan gum and rice husk in different proportion increased with increased in temperature up to 35^{o}C and thereafter began to increase, except for the sample with 20g rice husk that increase up to 40^{o}C before starting to decrease (Table 3). This is in agreement with the findings of other researchers (Alawi *et al.*, 2019). Bentonite drilling fluid with 2g xanthan gum and rice husk in different proportion also followed the same trend, except the sample with 10g rice husk that YP/PV ratio decreased with increase in temperature between 25^{o}C and 35^{o}C (Table 4).

Table 3 YP/PV Ratios of Samples 2 to 5 at different temperatures

Temperature (^{o}C)	**YP/PV Ratio**			
	2	**3**	**4**	**5**
25	2.17	1.25	0.62	2.64
30	2.58	0.926	0.63	3.2

35	2.79	1.125	0.67	3.89
40	1.97	1.13	0.63	4.22
50	1.70	0.9	1.08	4.1

Table 4 YP/PV Ratios of Samples 6 to 9 at different temperatures

Temperature (^oC)	YP/PV Ratio			
	6	7	8	9
25	1.96	2.083	2.36	1.86
30	2.11	2.07	2.45	1.98
35	1.89	1.99	2.54	2.01
40	2.5	3.18	2.17	1.98
50	2.64	4.58	3.2	2.63

Table 5 YP/PV Ratios of Samples 10 to 13 at different temperatures

Temperature (^oC)	YP/PV Ratio			
	10	11	12	13
25	0.74	9.33	6.0	0.818
30	0.74	9.73	6.05	0.826
35	1.11	9.33	7.62	0.839
40	3.2	6.97	7.73	2.1
50	3.36	19	6.03	3.10

3.5 Gel Strength

Figure 15 to 17 showed the gel strengths for the samples tested at 10sec for 1g, 2g and 5g xanthan gum mixed with different proportion ofrice husk respectively. Gel strength in 10 seconds for bentonite drilling fluid modified with 15 g rice husk and 1 g xanthan gum was found to be highest at all the temperatures considered (Figure 15). The bentonite drilling fluid modified with 10g rice husk and 2g xanthan gum was found to be highest at all the temperatures considered (Figure 16) while bentonite drilling fluid modified with 20 g rice husk and 5 g xanthan gum was found to be highest at all the temperatures considered (Figure 17). Similarly, Gel strength in 10 minutes for bentonite drilling fluid modified with 5 g rice husk and 1 g xanthan gum was found to be highest at all the temperatures considered (Figure 18). The bentonite drilling fluid modified with 10g rice husk and 2g xanthan gum was found to be highest at all the temperatures considered (Figure 19) while bentonite drilling fluid modified with 20 g rice husk and 5 g xanthan gum was found to be highest at all the temperatures considered (Figure 20).

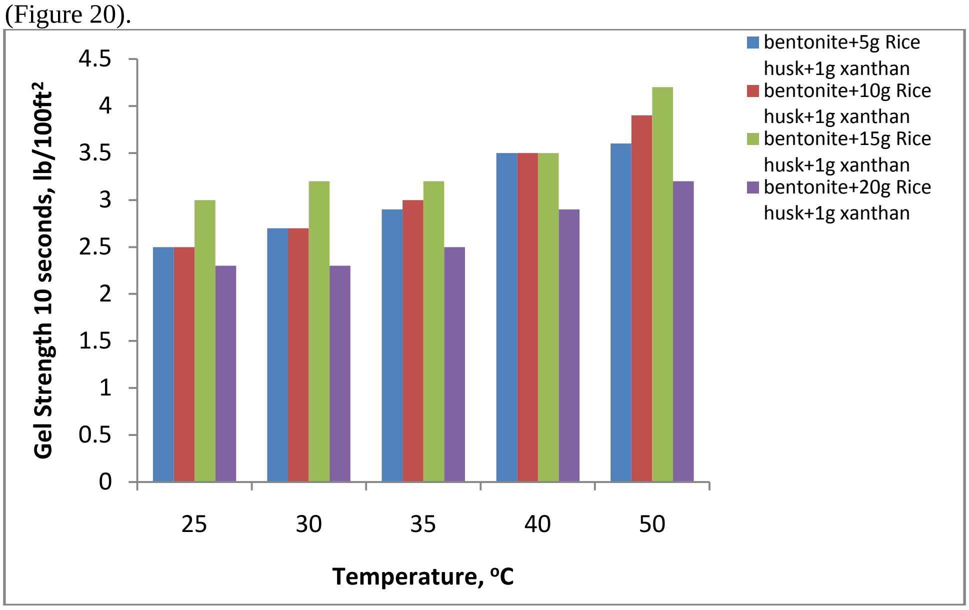

Figure 15 Gel strengths (10 secs) for the samples 2 to 5 at various temperatures

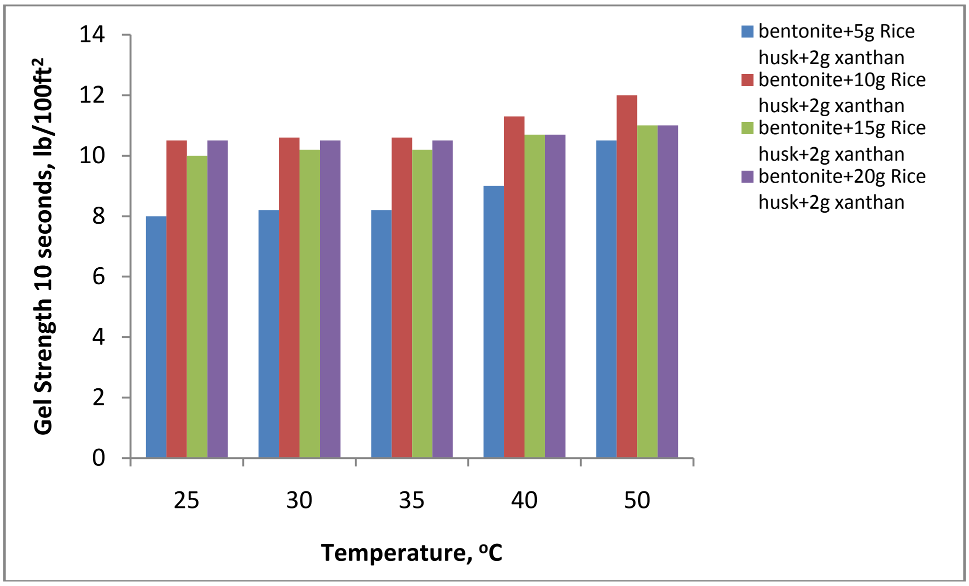

Figure 16 Gel strengths (10 secs) for the samples 6 to 9 at various temperatures

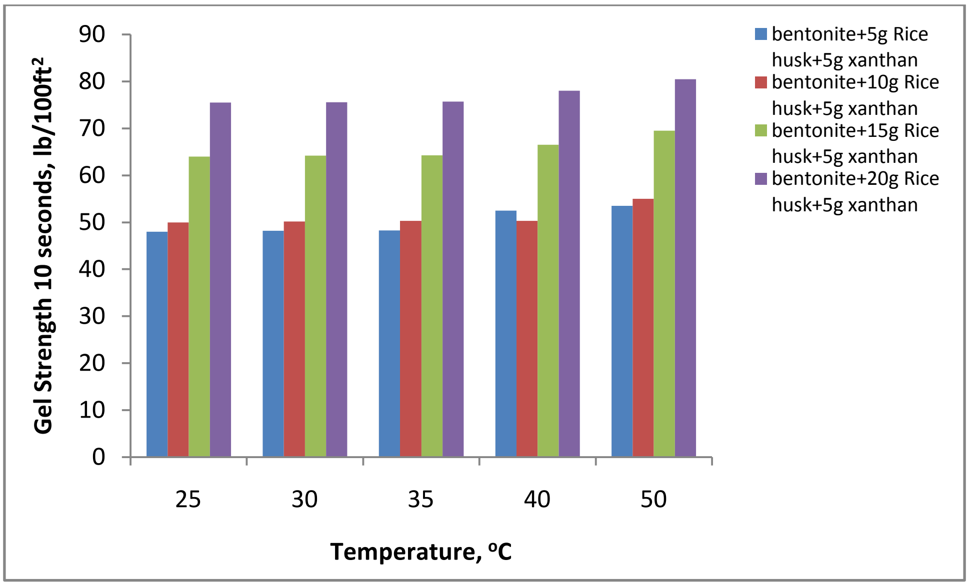

Figure 17 Gel strengths (10 secs) for the samples 10 to 13 at various temperatures

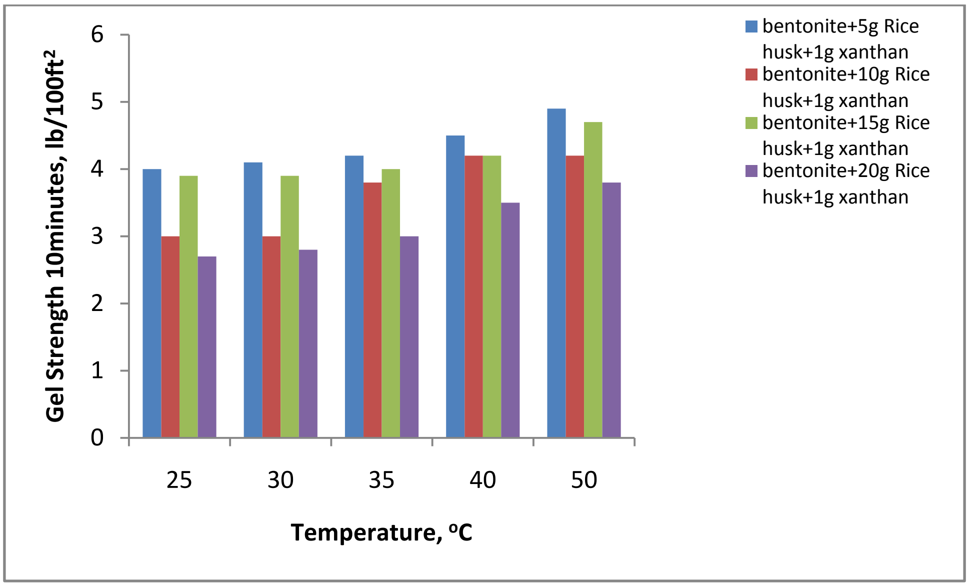

Figure 18 Gel strengths (10 minutes) for the samples 2 to 5 at various temperatures

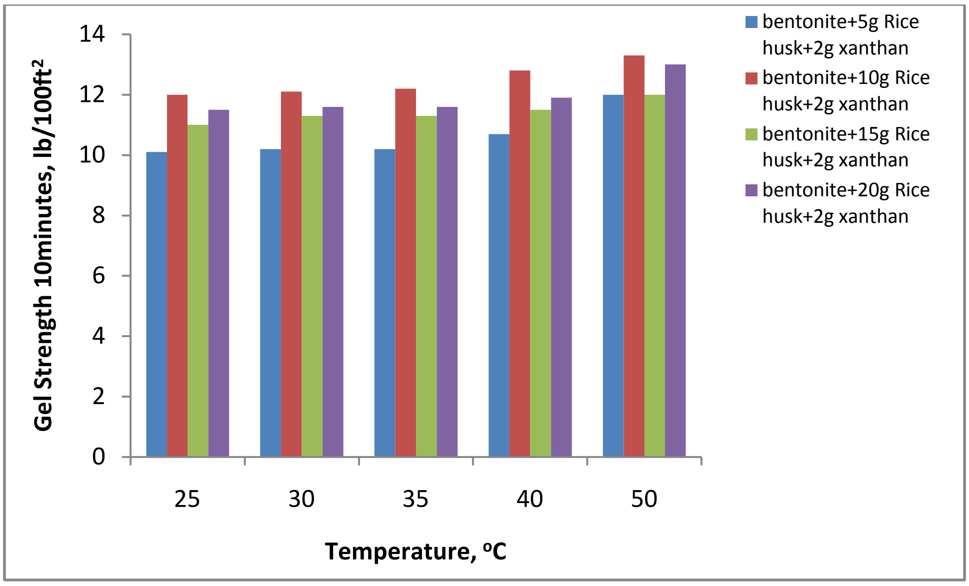

Figure 19 Gel strengths (10 minutes) for the samples 6 to 9 at various temperatures

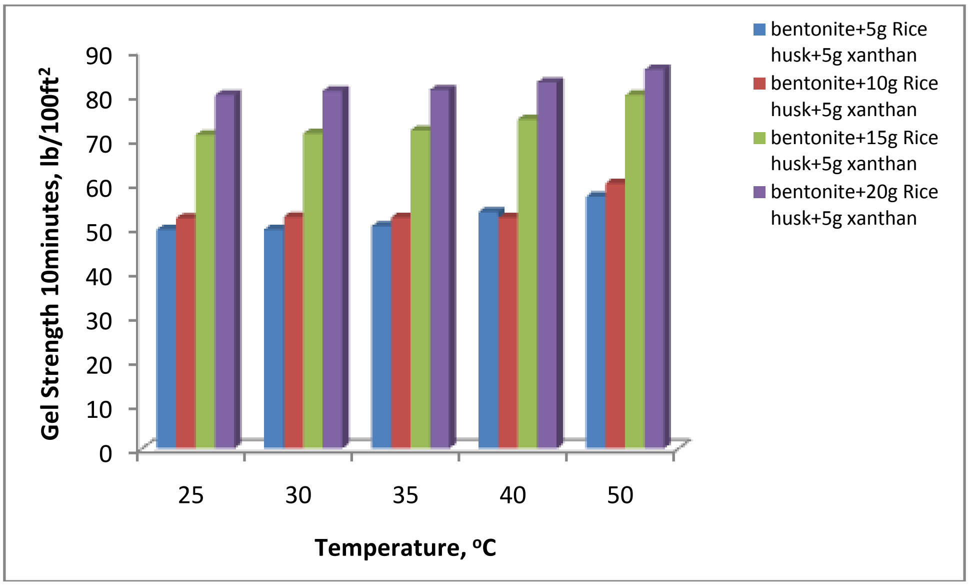

Figure 20 Gel strengths (10 minutes) for the samples 10 to 13 at various temperatures

IV. Conclusion

Water based drilling fluid with standard bentonite composition modified with rice husk and xanthan gum was investigated in this study to determine the effect of variation of temperature on the rheological properties of fluid. It could be concluded that rice husk could blend effectively with the xanthan gum as revealed by the results obtained from FTIR and XRD analysis. The modification of the bentonite drilling fluid with rice husk and xanthan gum could reduce the pH value from 10.5 to as low as 7.6. Increase in temperatures bentonite drilling mud modified with rice husk and xanthan gum enhanced the rheological properties of the drilling mud. The rice husk in combination with xanthan gum in the right proportion could be used as a viscosifier in the drilling mud for being capable of improving the viscosity of the mud at higher temperature.

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