American Journal of Science, Engineering and Technology
2024, Vol. 9, No. 1, pp. 32-41
https://doi.org/10.11648/j.ajset.20240901.14

Research Article

Investigating the Effect of Palm Kernel Shell Powder on the Rheological and Filtration Properties of Water Based Mud

Sarah Abidemi Akintola*, Omotosho Temitope James, Omojola Ayobomi Fatai

Department of Petroleum Engineering, University of Ibadan, Ibadan, Nigeria

Abstract

During drilling operations, the use of drilling fluid plays a critical role, and over time, there has been considerable interest in enhancing drilling fluid characteristics in order to improve performance, reduce costs, and prevent environmental pollution. Deviating from conventional additives, recent studies have explored the use of alternative materials, as drilling fluid additives. In line with this trend, this study focuses on the laboratory investigation of the rheological and filtration properties of water-based drilling fluid treated with Palm Kernel Shell Powder (PKSP) with high viscosity polyanionic cellulose (PAC HV), used as control. To assess the impact of PKSP in water-based mud, experiments were carried out using concentrations spanning from 0.5g to 2.5g, temperatures of 27 ℃, 40 ℃, 60 ℃, and 80 ℃, and aging of 24, 48, and 72 hours. From the results the plastic viscosity of mud samples treated with PKSP were temperature dependent and also with increasing aging. The addition of PKSP showed improved performance in terms of reducing the filtrate volume as well as the cake thickness with increasing concentration of the additives, and the concentration that gave the best results across all aging duration was 2.5g. The mud weight and pH of all samples remained relatively constant, with no significant changes observed. However, PAC HV showed better results in all the cases of fluid loss and mud cake thickness. It could be attributed to the soluble contents in the PAC HV which increased the viscosity significantly and thus, kept the solid particles in suspension.

Keywords

Water Based Drilling Fluid, Rheological Properties, Filtration Properties, Palm Kernel Shell Powder (PKSP)

1. Introduction

Drilling fluids, commonly referred to as drilling muds, play a vital role in oil and gas drilling operations. Their use dates back to the early 20th century, when the first oil wells were drilled in the United States. Initially, drilling muds were made from water and clay, but over time, the composition and properties of drilling fluids have become increasingly sophisticated. Locally sourced materials are made up of majorly waste materials from the several industries, especially the agricultural industry. Agricultural waste refers to organic waste materials that are generated from agricultural activities, such as rice husks, sawdust, bagasse, banana peels, eggshell, gum, grass, peanut shells, palm kernel shell and many more. Employing agricultural waste as drilling fluid additives offers multiple advantages, including reduced environmental impact,

*Corresponding author: demiabdul27@yahoo.com (Sarah Abidemi Akintola)

Received: 20 February 2024; **Accepted:** 15 March 2024; **Published:** 2 April 2024

as it provides a sustainable alternative to synthetic additives derived from non-renewable resources. It can also help to reduce costs by utilizing waste materials that may otherwise be discarded, and provide economic benefits to farmers and other stakeholders by creating a new market for their waste products. The use of henna and hibiscus leaf extracts in water-based drilling mud was studied and the result revealed improved filtration and rheological properties, indicating effective potential for reducing filtrate loss and enhancing mud performance [1]. Grass Powder (GP) as an eco-friendly drilling fluid additive was investigated and it was observed to outperform starch in filtration by significantly reducing fluid loss. GP's potential as a biodegradable solution for non-biodegradable waste reduction was highlighted, while starch excelled in enhancing rheological properties. [2]. While varying particle sizes and mud density of grass powder (GP) applied to a water based mud, Machine learning techniques were employed, it was observed that GP significant enhancement of gel strength and viscosity. Notably, 150 µm GP in 8.7 ppg mud showed highest viscosity improvement. [3]. The use of local katira gum and xanthan gum in water-based drilling fluids was carried out at varying concentrations and the tested, revealed that xanthan gum's increase in viscosity and yield point values. The local katira gum had a comparatively lesser impact, highlighting their distinct influence on drilling fluid rheology [4]. Locally sourced Guar Gum and Ginger were blended and used as additives in water-based drilling mud. The study demonstrated effective viscosification by Ginger [5]. Incorporating biodegradable peanut shell powder (PSP) into water-based drilling fluid. PSP, a minimal impact on plastic viscosity was observed, while significantly decreasing yield point and gel strengths [6]. The effect of Egg Shell Powder (ESP) and Calcium Carbonate (CC) on a sodium bentonite-based drilling fluid from Algeria. CC (10-30g) was observed to improve the rheology, density, reduce cake thickness, and fluid loss. ESP altered properties, increasing pH, density, and reducing fluid loss, with concerns beyond 20g [7]. Assessing Cupressus Cones Powder (CCP) in water-based drilling mud for improved rheology and filtration, it was noted that the CCP concentrations (1-7 ppb) enhanced plastic viscosity, yield point, and gel strength. Optimal levels were 2-4 ppb for viscosity, 6 ppb for yield point. CCP-containing muds resisted temperature and salt, verified by SEM analysis [8]. The use of waste mandarin peel powder's particle size effect on water-based mud rheology was studied. Two categories were tested: <0.1 mm and 0.1-0.16 mm. Increasing mandarin peel powder concentration (0.5-2% by volume) reduced API filtration by up to 42%, PPT filtration by 61.54%. Rheological parameters increased within acceptable limits, suggesting optimal concentration of up to 1.5% [9]. Palm Oil Fuel Ash (POFA) as a water-based mud enhancer was explored for their rheological and filtration However, rheological performance declined after aging due to the silica oxide-dominant composition [10]. The use of Banana peel waste as additive in a water based mud was investigated, the study established the suitability and cost effectiveness of the use of BPP as additive as against the conventional chemical additives [11].

This study is aimed at determining the potential benefits of PKSP as a drilling fluid additive.

2. Material and Methods

The materials and equipment used: thee PKSP which was procured from a local market in Ibadan South West local Government Area in Oyo State, The PAC -HV, bentonite and barite were donated to the department of Petroleum Engineering by Mi-Swaco, and distill water from the department of Chemistry, University of Ibadan. The Fann model 35 rotational viscometer, Fann mud balance, API Filter press, Hamilton mixer were are used at the department of petroleum engineering University of Ibadan Laboratory.

2.1. Collection and Preparation of Palm Kernel Shell Powder

The protective outer layer of palm seeds and were carefully selected after sieving with a wire woven mesh to eliminate any dirt or debris. 6kg of shell was dried using a Drying Oven SLN 15 oven set at 140 ℃ for four rounds of 30 minutes each and a post-drying weight of 5.1kg. was obtained. The dried palm kernel shells (Figure 1) were then pulverized (Figure 2) using a Dry Grinding machine and sieved using the ASTM standard with a Retsch Vibratory Sieve Shaker AS 200 basic used to obtain a fine powder (Figure 3).

Figure 1. *Palm Kernel Shell.*

Figure 2. *Grinded Palm Kernel Shell.*

Figure 3. *Palm Kernel Shell Powder.*

2.2. Characterization of PKSP

The PKSP was characterized via FTIR and SEM-EDX. A FTIR-530 FTIR Spectrometer was used to determine the sample FTIR. Result obtained shows that the palm kernel shell powder had 7 (Figure 4), and the chemical bonds (O=C=O, O-H, and C-Cl) and functional groups (-COOH) in the PKSP sample. The TESCAN model, type VEGA 3 LMH SEM machine was used for the SEM determination. For the SEM, 4 different magnifications to check for differences in the images was used. At the highest magnification, there was little or no significant difference in the images as shown in Figures 5–8. For the Energy Dispersive Xray (EDX) characterization, a 3 spot EDX was done to determine the elemental composition of the sample. Different elements were found in the different spots observed. Tables 1-3 and Figures 9a, b; 10a, 10b and 11a, 11b gave an overview of the elements found in the analysis. The results from the SEM-EDX characterization shows that the dominant elements in palm kernel shell powder with respect to all the spots are Oxygen (O_2), Silicon (Si), and Carbon (C).

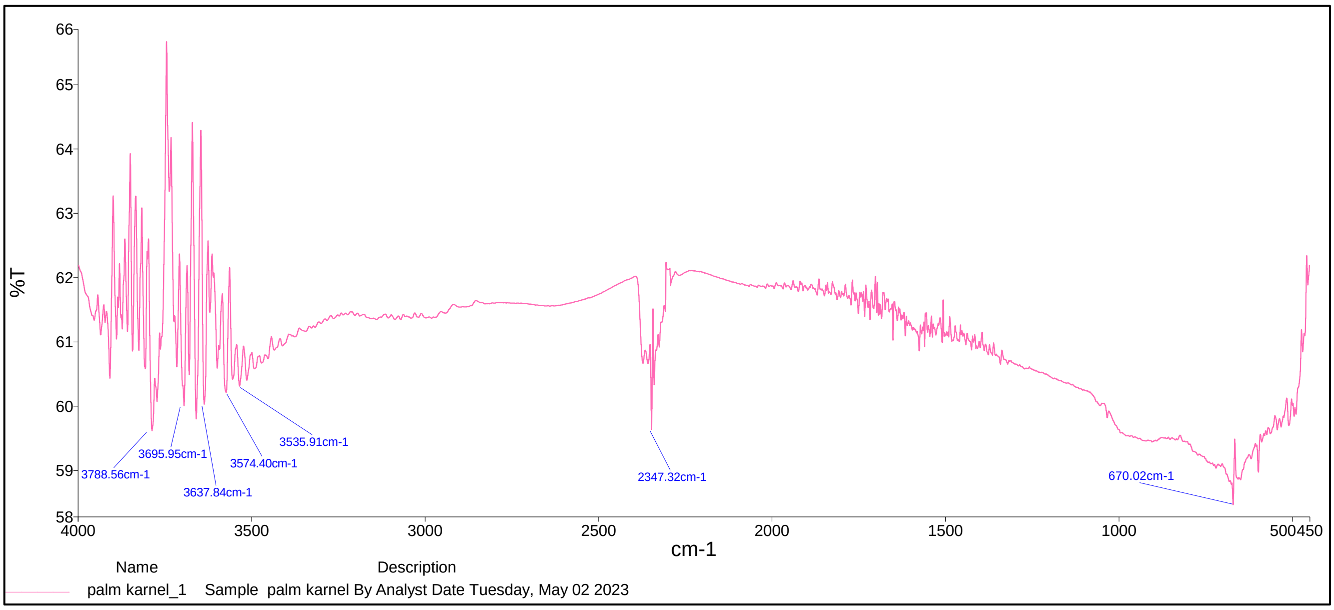


Figure 4. *The FTIR of PKSP.*

Table 1. *EDX characterization result for Spot 1.*

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
8	O	Oxygen	71.13	63.78
14	Si	Silicon	17.57	27.66
7	N	Nitrogen	8.63	6.77
6	C	Carbon	2.67	1.80

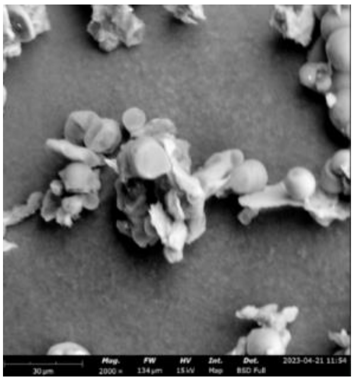


Figure 5. SEM 2000x magnification.

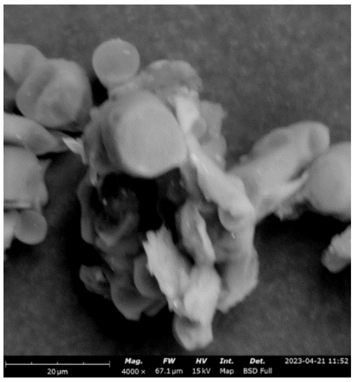


Figure 7. SEM 4000x magnification.

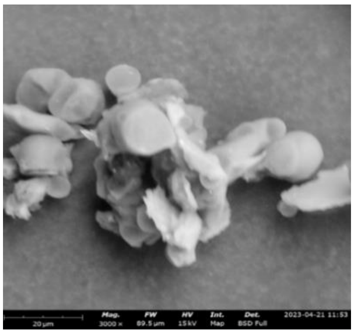


Figure 6. SEM 3000x magnification.

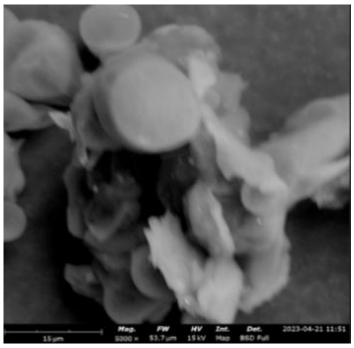
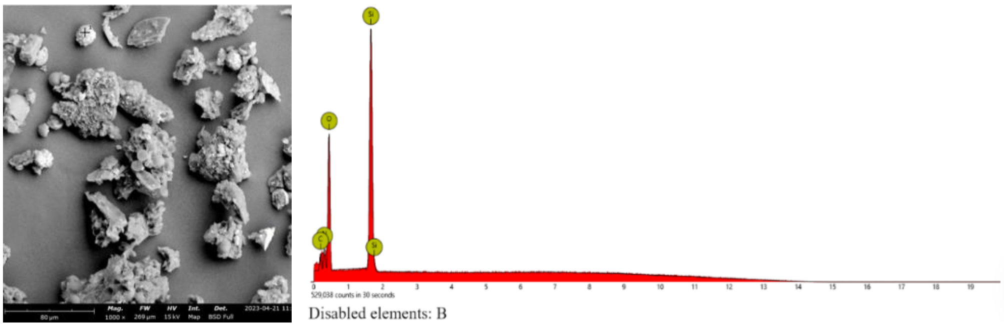
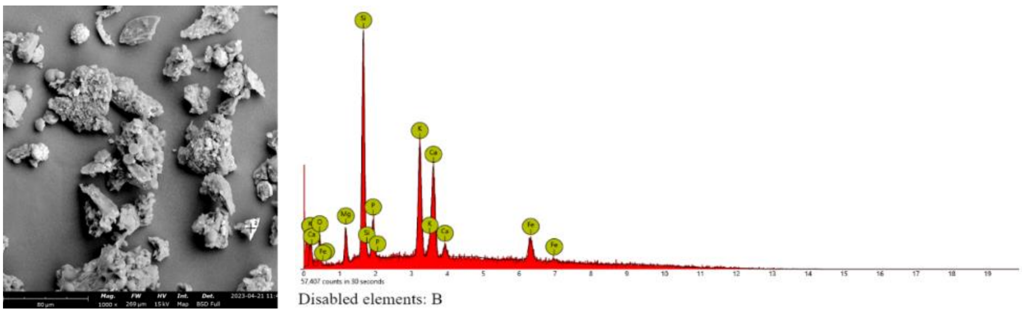


Figure 8. SEM 5000x magnification.



(a) (b)

Figure 9. a. Spot 1 EDX b. EDX image of the distribution of Spot 1.

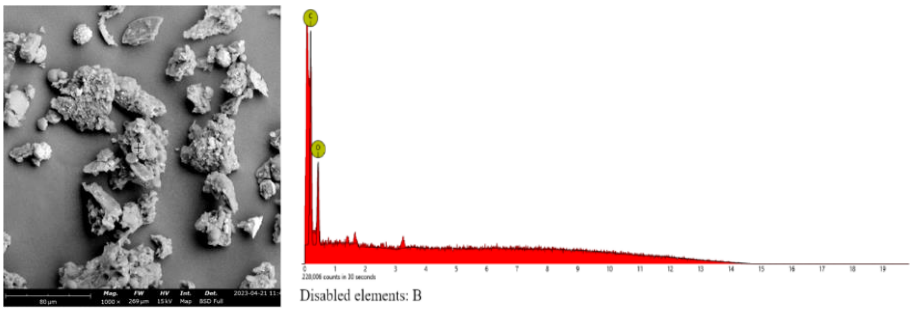


(a) (b)

Figure 10. a. Spot 2 EDX. b: EDX image of the distribution of Spot 2.

Table 2*. EDX characterization result for Spot 2.*

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
8	O	Oxygen	36.29	20.51
14	Si	Silicon	20.06	19.91
19	K	Potassium	14.10	19.48
20	Ca	Calcium	12.53	17.74
12	Mg	Magnesium	6.34	5.45
26	Fe	Iron	5.96	11.76
15	P	Phosphorus	4.71	5.16



(a) (b)

Figure 11*. a. Spot 3 EDX. b: EDX image of the distribution of Spot 3.*

Table 3*. EDX characterization result for Spot 3.*

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
8	O	Oxygen	72.34	77.70
6	C	Carbon	27.66	22.30

2.3. Drilling Fluid Preparation

Drilling muds samples were prepared based on the composition given in Table 4 according to the API 13A recommended practice [12]. The mud samples were allowed to hydrate for 16 hours before been treated with PKSP at varying concentration (0.5g, 1.0g, 1.5g, 2.0g, and 2.5g) and varying temperature (27 ℃, 40 ℃, 60 ℃, and 80 ℃) underwent aging period of 24 hours, 48 hours, and 72 hours.

Table 4*. WBM Composition.*

Additive	Quantity
Distil water, ml	350
Bentonite, g	21.5
Barite, g	25
PKS, g	0.5 – 2.5
PAC Hv, g	0.5

Rheological Measurements

Several additives are employed to enhance the rheological parameters of drilling fluids such as viscosifiers, polymers, thinners, and deflocculants. In this work, the mud rheological parameters were determined using Fann model 35A rotational viscometer. The mud samples apparent viscosity, plastic viscosity and yield point were determined using the equations 1, 2 and 3, respectively.

$$\text{Apparent Viscosity, } \mu_a = \theta_{600}/2 \quad (1)$$

$$\text{Plastic Viscosity, } \mu_p = \theta_{600} - \theta_{300} \quad (2)$$

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

where, θ_{300} and θ_{600} are the dial reading at 300 and 600 rpm, respectively.

For gel strength determination, the API recommended procedure was followed by stirring the mud sample at 600 RPM for 10 s to ensure proper dispersion. Then, the sample was brought to static conditions for 10 s followed by stirring at 3 RPM. The 10 s-gel strength was measured by the highest defection on the viscometer.

2.4. Filtration Measurements

The filtration experiments at static conditions were performed through a conventional Fann API filter press with a controlled nitrogen pressurizing system. The standard API filter with pore size varying from 25 to 30 µm was used as filter media to accumulate the mud cake. The measurements were performed at room temperature and 100 psi pressure according to the API recommended standard procedures to examine the filtrate control capability of PKSP containing drilling muds. The filtrate volume against standard time (30 min) was measured, and finally, the mud cake thickness of each sample was measured after completion of experiments using a digital vernier caliper.

3. Results and Discussion

3.1. Density and pH of the Mud

The mud weight of the studied samples for the different aging duration is given in Figure 12. It is observed that the density at 24 hours, a high density was observed but as aging increased to 48 and 72 hours, a decrease in density was observed for all the mud samples containing the PKSP additive. The mud sample with 0.5g and 2.0g concentration was constant for the different aging time while there were fluctuations for the other concentrations. While mud samples treated with PAC HV, had a relatively constant density at 8.9ppg for aging time of 24 and 48 hours.

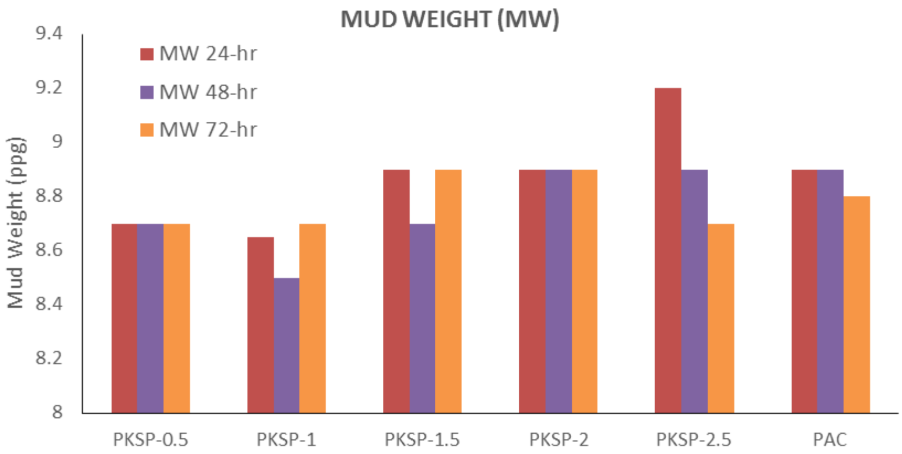


Figure 12. *Mud Weight of the mud samples.*

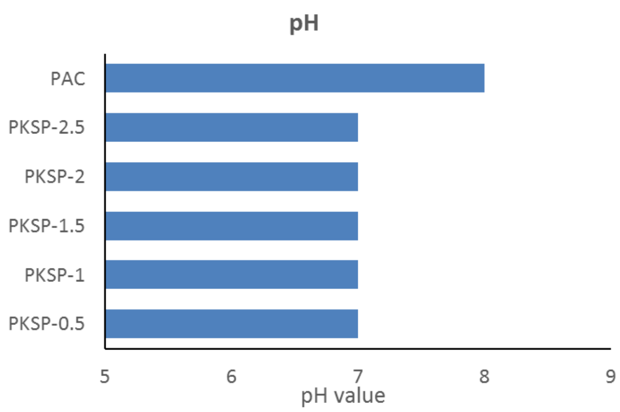


Figure 13. *pH of the mud samples.*

The pH results of the mud samples are presented in the Figure 13. From the results, it was observed that all the PKSP muds samples showed pH values of 7.0, while that PAC Hv showed pH values of 8.0. The pH values were relatively constant for all the different aging times.

3.2. Rheological Properties

The varying conditions of concentration, aging duration, and temperature were investigated to understand how PKSP affects the rheological properties of water-based mud.

3.2.1. Effect of Temperature

The study was carried out at 27 ℃, 40 ℃, 60 ℃, and 80 ℃. The effect of temperature on all the rheological properties can be seen in Figure 14. The Plastic Viscosity (PV) of the mud with PKSP decreased with increasing temperature and concentration. However, there was a sharp increase in PV at the concentration of 2.0g across all temperatures with 27 ℃ being the optimal temperature, making this the best result when compared with other concentrations. It was also observed that the Apparent Viscosity (AV) had the best results at the concentration of 2.0g of PKSP with 27 ℃ being the optimal temperature. There was a slight difference in the results for the yield point with the best results being at the concentration of 2.5g of PKSP and 60 ℃ being the optimal temperature. Lastly, the highest gel strength was observed at a concentration of 2g which outperforms the results for PAC HV across all temperatures except for 80 ℃. This could be as a result of the increased concentration of the sample. However, having a very high gel strength could result in a very high pump pressure to resume circulation of the drilling fluid.

Comparison of the best results from PKSP with PAC HV shows that the results from PAC HV for all the rheological properties outperformed PKSP across all concentrations and temperatures.

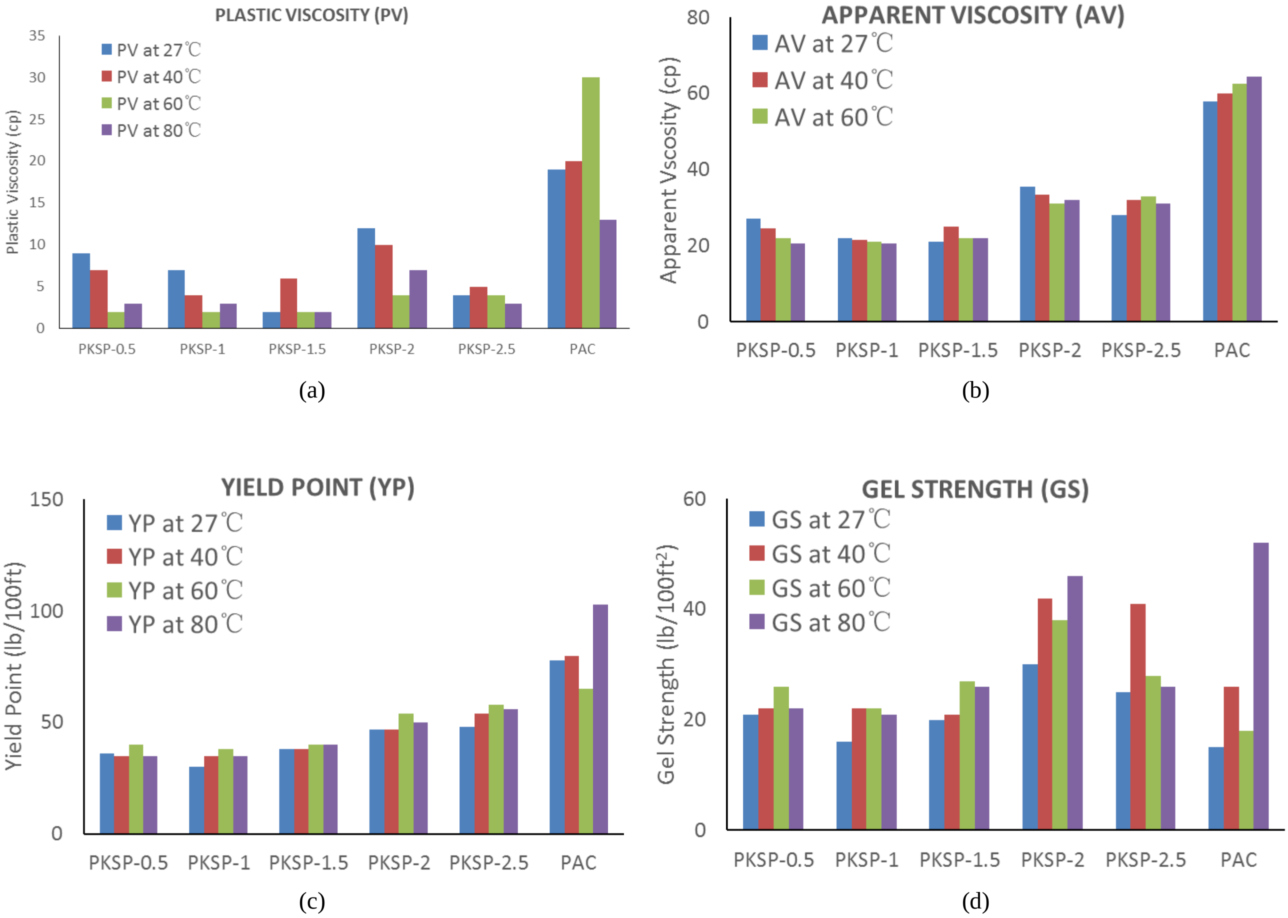


Figure 14. *Effect of temperature on the Rheological Properties (a) Plastic Viscosity (b) Apparent Viscosity (c) Yield Point (d) Gel Strength.*

3.2.2. Effect of Aging

For aging considerations, the study was carried out on drilling muds with different aging duration of 24, 48 and 72 hours. The effect of aging on all the rheological properties can be seen in the Figure 15. The results for the plastic viscosity (PV) of the mud with PKSP varied with increasing concentrations and aging duration. However, where compared with other concentrations, the best results were observed at a concentration of 2.0g and aging duration of 24 hours. It was also observed that the Apparent Viscosity (AV) had the best results at the concentration of 2.0g of PKSP and aging duration of 24 hours. There was a slight difference in the results for the yield point with the best results being at the concentration of 2.5g of PKSP and aging duration of 24 hours. Lastly, the gel strength was best at a concentration of 2.0g and aging duration of 24 hours. Comparison of the best results from PKSP with PAC shows that the results from PAC across all the rheological properties outperformed PKSP across all concentrations. However, aging the mud for PKSP did not yield better results as aging time increased.

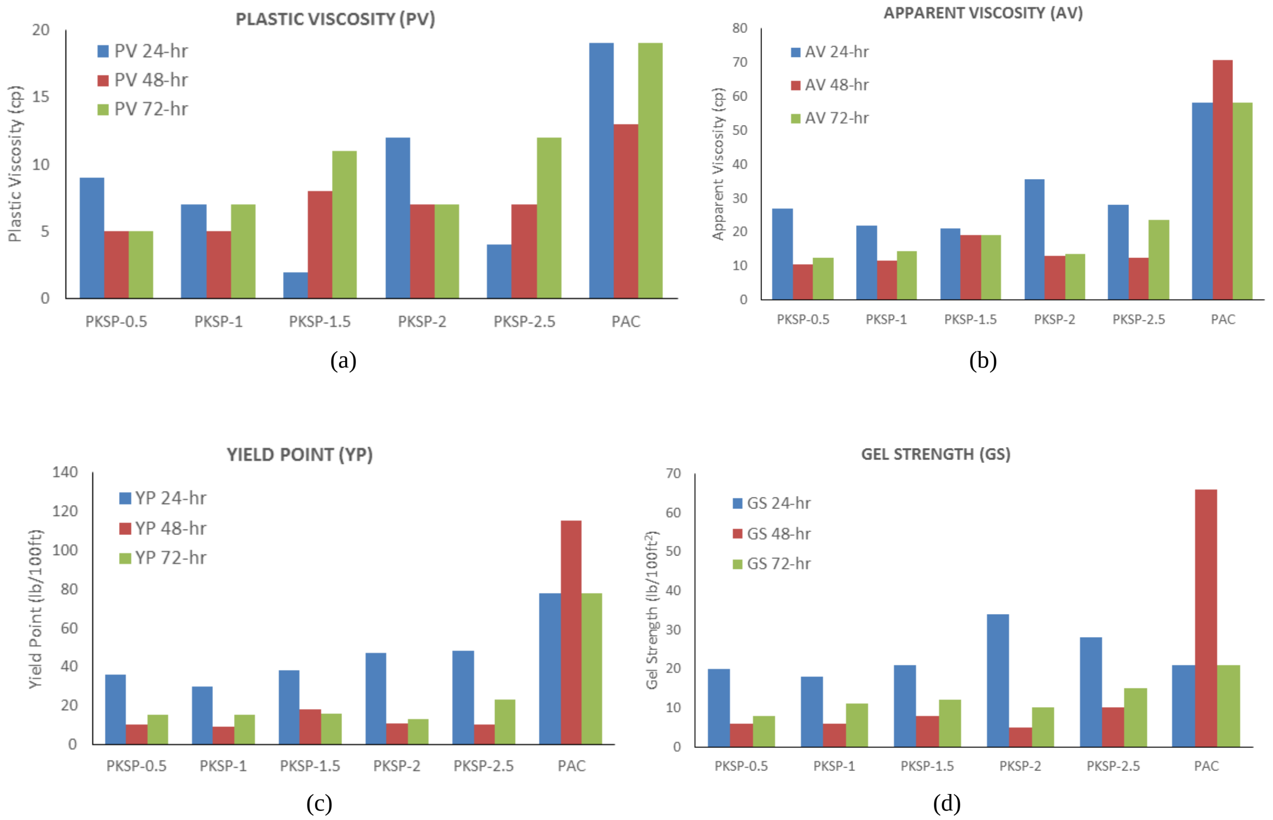


Figure 15. *Effect of aging on the Rheological Properties (a) Plastic Viscosity (b) Apparent Viscosity (c) Yield Point (d) Gel Strength.*

3.3. Filtration Properties

The filtration characteristics of the drilling muds with additives at different concentrations are given in Figure 16a. The addition of PKSP showed improved performance in terms of reducing the filtrate volume as well as the cake thickness with increasing concentration of the additives. It is a key factor to be considered because the filtrate can cause numerous irreversible changes in the exposed rocks. The PKSP showed promising results when added as a filtrate control agent in bentonite-based mud system. At 24 hours aging duration, the highest fluid loss was recorded at 1.5g of PKSP, while the lowest volume was recorded at 2.5g. Similarly, after 48 hours, the concentration with the highest and lowest volumes were at 1g and 1.5g respectively. After 72 hours, the filtrate volume did not reduce further when compared with the 24-, and 48-hours aging duration except for concentrations 2.0g and 2.5g. The lowest fluid loss volume was recorded at 2.5g. The concentration that gave the best results across all aging duration was 2.5g.

Another important factor in mud filtration is the formation of filter cake on the borehole wall. In all the mud blends containing PKSP, the filter cake thickness was decreasing relatively with the addition of PKSP in increasing concentration and aging duration as shown in Figure 16b.

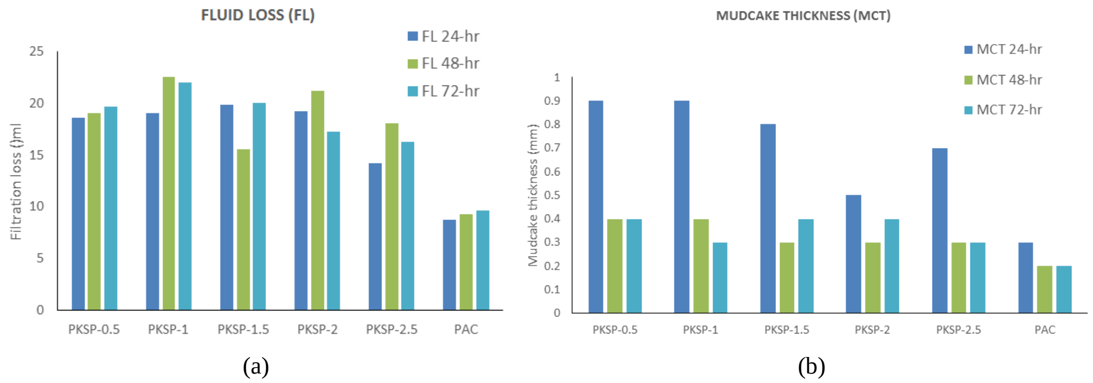


Figure 16. *Filtration Properties at Different Aging Duration (a) Filtration Loss (b) Mud Cake Thickness.*

However, PAC HV showed better results in all the cases of fluid loss and mud cake thickness. It could be due to the soluble contents in the PAC HV which increased the viscosity significantly and thus, kept the solid particles in suspension.

4. Conclusion

From the comparative analysis of the results obtained for all samples, the following conclusions were made: Palm kernel shell powder is a good rheology enhancing additives for water-based mud as it meets the API standards for rheological properties. It was also observed that palm kernel shell powder (PKSP) at the different concentrations did not outperform PAC HV because it is a low viscous additive since the plastic and apparent viscosities of PKSP are way lower than that of PAC HV. For the 24-hour aged mud, there were no significant changes in the rheological properties of the mud samples with PKSP as additives at varying temperature conditions except for plastic viscosity and gel strength, hence plastic viscosity and gel strength are dependent on temperature. Increasing aging time of mud samples with PKSP as additives to 48 hours and 72 hours did not yield better results as the optimal result with respect to aging time was at 24 hours. This shows that aging time has an impact on the rheological properties of drilling mud. Increasing aging time yielded higher filtration volume and lower mud cake thickness respectively showing the significant impact of aging in drilling mud.

In conclusion, though the palm kernel shell powder exhibited good properties as rheology enhancing additives, but when compared with the control additive, PAC HV, it is not the adequate substitute. This gap can be bridged by either increasing the concentration to a degree by which the properties can match that of PAC HV. It is also recommended that low viscosity polyanionic cellulose (PAC LV) is used and compared with PKSP at the concentration used in this study to investigate the performance of PKSP as a low viscosity additive, to see if it is a good substitute for PAC LV.

Abbreviations

BPP: Banana Peel Powder
EDX: Energy Dispersive X-Ray Spectroscopy
FTIR: Fourier-Transform Infrared Spectroscopy
PAC HV: Polyanionic Cellulose High viscosity
PAC LV: Polyanionic Cellulose Low viscosity
PKSP: Palm Kernel Shell Powder
SEM: Scanning Electron Microscopy

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Ismail A., Aftab A., Ibupoto Z. H., Zolkifile N., The Novel Approach for the Enhancement of Rheological Properties of Water-Based Drilling Fluids by Using Multi-Walled Carbon Nanotube, Nanosilica and Glass Beads, Journal of Petroleum Science and Engineering, 139: 264-275 (2016).

[2] Al-Hameedi, A. T.; Alkinani, H. H.; Dunn-Norman, S.; Alkhamis, M. M.; Alshammari, A. F.; Al-Alwani, M. A.; Mutar, R. A. Controlling Drilling Fluid Properties Using Bio-Degradable Environmentally Friendly Additives: Comparison Between Conventional (2019).

[3] Ismail, A. R., Rashid N. M., Jaafar M. Z., Wan Sulaiman W. R., Buang N. A.,, Effect of Nanomaterial on the Rheology of Drilling Fluids, Journal of Applied Sciences, 14(11): 1192-1197 (2014).

[4] Bayan Qadir Sofy, Khalid Mahmood Ismael Sharbazheri, Nabil Adiel Tayeb Ubaid,. Comparison between the Effect of Local Katira Gum and Xanthan Gum on the Rheological Properties of Water-based Drilling Fluids. UHD Journal of Science and Technology. vol 4 issue 2(2020).

[5] Al-Hameedi, A. T.; Alkinani, H. H.; Dunn-Norman, S.; Hamoud, Z. A. Investigation Study of the Effectiveness of Eggshells Powder as a Multifunctional Eco-Friendly Additive in Water-Based Fluid. In Proceedings of the 54th US Rock Mechanics/Geomechanics (2020).

[6] J. A Ali, K. Kolo, S. M. Sajadi, K. H. Hamad, R. Saliman, M. Wanli and S. M. Hama. Modification of rheological and filtration properties of Water Based Mud for drilling Oil and Gas wels Using green SiO_2 ZNO Xanthan nanocomposite. IET Nano Biotechnology, Vol 13, no 7 pp 748-755, (2019).

[7] Asma Nour El Houda Sid, Hichem Tahraoui, Mohammed Kebir, Mohammed Amin Bezzekhami, Benalia Kouini, Amel Hind Hassein-Bey, Toumi Selma, Abdeltif Amrane, Ali Imessaoudene and Lotfi Mouni. Comparative Investigation of the Effect of Eggshell Powder and Calcium Carbonate as Additives in Eco-Friendly Polymer Drilling Fluids. Sustainability 2023, 15(4), 3375; https://doi.org/10.3390/su15043375

[8] Imtiaz Ali, Maqsood Ahmad and Tarek Al-Arbi. Experental study on water -based mud: investigate rheological and Filtration properties using Cupressus cones powder. Journal of Petroleum Exploration and Production Technology. Volume 12, pp 2699-2709 (2022).

[9] Igor Medved, Nediljka Gaurina-Međimurec, Karolina Novak Mavar and Petar Mijić. Waste Mandarin Peel as an Eco-Friendly Water-Based Drilling Fluid Additive. Energies 15(7), 2591; 2022.

[10] Siti Aishah Azalan Evaluation on The Performance of Palm Oil Fuel Ash (Pofa) As Fluid Loss Reducing Agent. Faculty of Chemical and Energy Engineering Universiti Teknologi Malaysia (JUNE 2018).

[11] Nagham Alhaji Mohammed, Hani Al Khaif, Gabriella Federer, Enime Yalman and Tolga Depci. Effect of Banana Peel Wastes on the properties of a Water Base Mud. Petroleum and Coal (2022).

[12] American Petroleum Institute. 13A Specification for Drilling Fluid Materials. 15th ed. American Petroleum Institute, Washington, DC.