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Effect of Banana Peels Waste on the Properties of Water Based Mud

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Abstract

This paper investigates the possibility of employing banana peels as eco-friendly waste material to water-based drilling mud to control different properties instead of the chemical additives. Banana peels are low cost and have no practical applications. Experiments were carried out on adding banana peels powder (BPP) after its preparation with increasing concentrations to the water-based drilling mud (0 wt%, 1 wt%, 2wt%,3 wt%, 4 wt%, and 5 wt%). The rheological properties, fluid loss and density tests were carried out at atmospheric pressure and room temperature. The results showed an increase in rheological parameters with an increase in BPP concentration, which led to increases in the efficacy of cleaning the well. Also, the decrease in the volume of fluid loss with the increase in the concentration of BPP, help to the protection of formations from contamination by drilling fluid. The increase in the concentration of the BPP also led to an increase in the density of drilling mud, which helps to provide sufficient hydrostatic pressure against the pressure of the formations.

Keywords: *Rheology; Density; Fluid loss; Eco-friendly materials; agricultural waste; Banana peels.*

1. Introduction

The operations of drilling oil wells are necessary operations to reach the oil reservoirs in the deep formations. Where oil is the world's primary industrial fuel. As a result, the rate at which wells are being drilled has grown in order to supply the ongoing demand for crude oil. Well drilling is an expensive operation due to its complexity and the risks involved. Drilling fluid is one of the most important elements needed to drill wells, and it accounts for a significant portion of the total cost of drilling a well [1]. Drilling fluid performs many important functions, such as cleaning the well from rocky cutting, cooling the drilling bit, suspending the cutting during a stop of circulation, and applying hydrostatic pressure by weighing the drilling fluid column [2]. Water-based drilling fluid and oil-based drilling fluid are the two main types of drilling fluid [3]. Water-based drilling fluid is the most widely used because of its ease of preparation and use, its suitability for most formations, in addition to its low environmental impact [2]. Water-based drilling fluid consists mainly of water and bentonite in addition to some industrial additives that are used to control the different properties of drilling fluid such as viscosity, density and fluid loss [4]. These additives include, for example, carboxymethyl cellulose, which is used to control fluid loss, and xanthan gum to control viscosity [5-6]. These industrial materials are considered expensive, which increases the cost of drilling fluid, which is directly reflected in the total cost of drilling a well [7]. Recently, studies have tended to use eco-friendly materials to replace them with these industrial additives and to test their ability to control the properties of drilling fluid. Among the most prominent of these materials are agricultural waste emanating from non-investable parts such as peels and seeds. [8] discovered that adding 15-20 wt % of Date Pit-Based to a water-based drilling fluid resulted in an optimum reduction of fluid loss. Increased concentration of rice husk and sawdust in the mud has also been proven to enhance the fluid loss-controlling properties of these materials [9].

Some studies also showed that adding orange peel and sunflower seeds in different particle sizes and increasing concentrations contributes significantly to reducing fluid loss [10-11]. Al-Khalaf *et al.* studied the effect of adding increasing concentrations of pinecone powder to water-based drilling mud, which led to the improvement of various properties, especially reducing the volume of fluid loss [12].

In this study, powders of banana peels are considered agricultural wastes were used as an additive to water based mud. The ability of these materials to control the different properties of the water-based drilling fluid was tested. The test results for this material were compared with the properties of the reference control fluid and the necessary recommendations and suggestions were made based on these results.

2. Experimental procedures

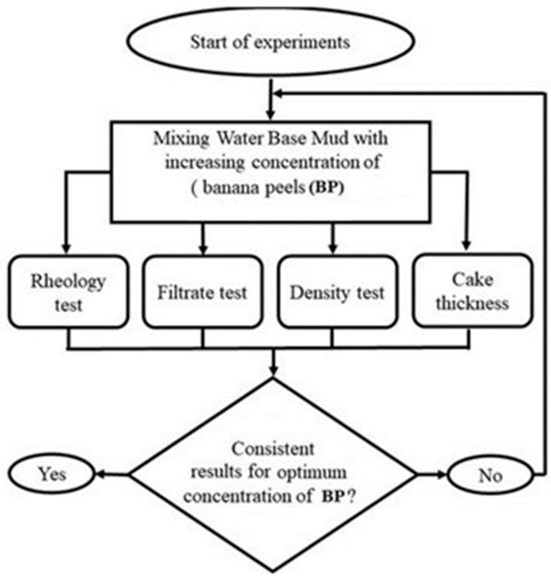

Figure 1. Workflow of the study

All the experiments that were conducted in this study were based on the (API-RP-13B-1 standards). Rheological measurements (plastic viscosity, apparent viscosity, yield point, and gel strength), the density of samples and fluid loss were carried out on six samples including one reference control mud sample, five samples with increasing concentrations of banana peel powder (BPP). Figure 1 shows a workflow for this study.

Waste banana peels were employed as additives to a water-based drilling fluid in this study. After being rinsed with clean water, the BP were dried under the sun for one week. An electric grinding machine was used to mill the peels after they had dried. Finally, the powder was sieved through mesh with a size of 450 µm or less. Figure 2 shows the manufacturing process of BPP. The microparticles' sizes range from 7 to 450 µm. Figure 3 shows the particle size distribution of BPP. The BPP was then dried in a 40° C oven for 4 hours to reduce the humidity. For this study, about 60 g of BPP was employed and added to the water-based drilling fluid at different concentrations (0 wt%,1 wt%,2 wt%,3 wt%,4wt%, and 5 wt%).

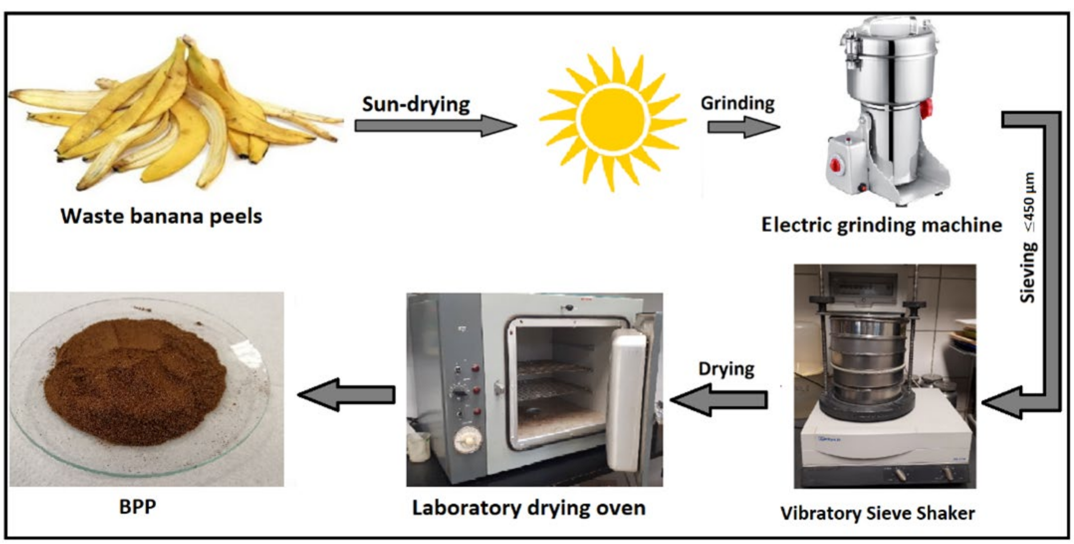

Figure 2. The manufacturing process of BPP

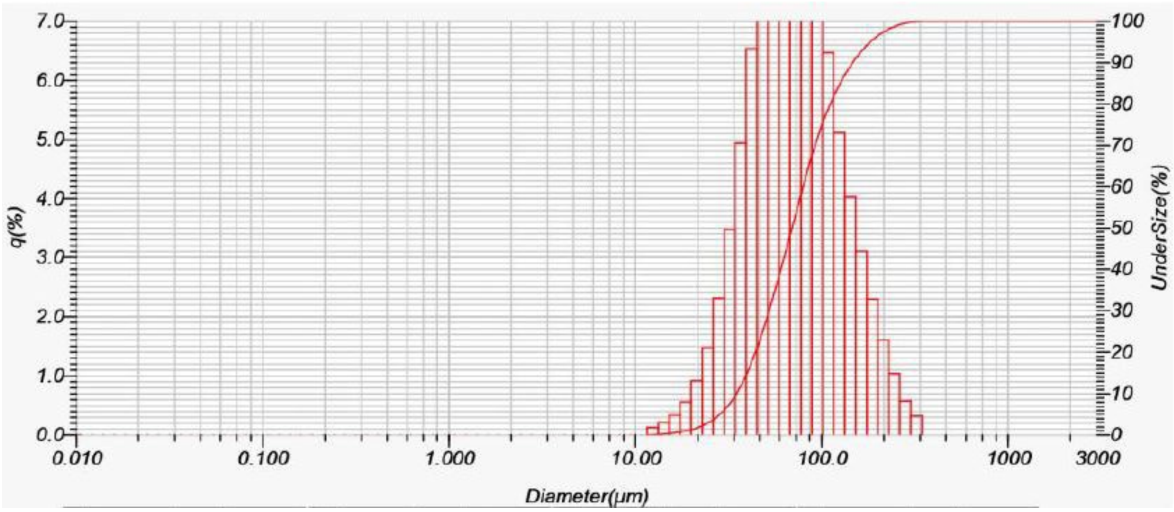

Figure 3. Particle size distribution of BPP

2.1. Mud formulation materials

All the experiences were carried out according to the American Petroleum Institute standard (API RP 13B-1, 2003). Table 1 lists the ingredients and dosages used to prepare the water-based mud which used in this study.

Table 1. The materials and dosage used to formulate the water-based mud

Additives	Function(s)	Dosages
Water	Base fluid	350 [mL]
Bentonite	Viscosifier agent	22.5 [g]
CMC	Fluid loss control	1 [g]
Xanthan gum (XG)	Viscosifier agent	0.5 [g]

2.2. Preparation of water-based mud

Six samples of water based mud were prepared for the experimental measurements. Water was first poured into the Hamilton beach mixer, then bentonite, xanthan gum (XG), and carboxymethyl cellulose (CMC) were gradually added during the mixing process, and the mixture was stirred for 20 minutes to achieve perfect homogeneity. The mixture was then left for 24 hours to ensure that the bentonite was fully hydrated before being used in the measurements. After that, measurements were conducted on the first water-based drilling fluid sample without the addition of peels powder, which was used as the control mud in this study. The increasing concentrations of BPP (0 wt%,1 wt%,2 wt%,3 wt%,4 wt% and 5 wt%) were added to the 5 samples of water-based drilling fluid and mixed for 10 minutes with a Hamilton mixer until homogeneity was achieved. Following that, rheology, density, a fluid loss test, and mud cake thickness were all done, then the results were analysed.

2.3. Rheological properties measurement

A multi-speed Fann 35 viscometer was used to perform rheological experiments such as measuring plastic viscosity (PV), apparent viscosity (AV), yield point (YP), and gel strength at 10 seconds, 1 minute, and 10 minutes [13]. After ensuring that the clean and dry rotor was fitted in the correct spot, the device cup was filled with a particular volume of water-based drilling fluid and then installed on the device. At six different rotating speeds (600, 300, 200, 100, 6, and 3) [rpm], the viscometer was operated and reading values were recorded. The difference between readings at 600 [rpm] and readings at 300 [rpm] measured in the [cP] unit was used to calculate the plastic viscosity (PV). The apparent viscosity (AV) is calculated by multiplying the reading at 600 [rpm] by the number 2 measured in [cP] units. The difference between the reading at 300 [rpm] and the plastic viscosity measured in [lb/100ft^2] unit is used to calculate the yield point. The viscometer was switched on at 600 [rpm] for 10 seconds to measure the gel strength, then turned off for ten seconds. In the next steps restart the viscometer at 3 [rpm], and the maximum value that the viscometer index reached was recorded; this value indicates the initial gel strength. The same steps were repeated when the viscometer was stopped for 1 minute and 10 minutes, respectively to measure the final gel strength value by using [lb/100ft^2] units.

Removing rock cutting from the annular space of the well during the drilling operations is the most important function of the drilling fluid. It is necessary to keep the borehole clean of cuttings. If the drilling fluid is unable to transfer the cuttings to the surface, they will gather and deposit inside the wellbore, causing a number of serious problems such as stuck the pipes. Many factors may affect this function, such as the diameter of the wellbore, the velocity of the drilling fluid flow, (size, type, shape and quantity) of cutting, the speed of rotation of the drill pipes...etc [14]. So, it is important to get a clear idea about the efficiency of cleaning the wellbore by drilling fluid. This can be done by using the Cutting Carrying Index (CCI) method. It is an experimental method for evaluating the ability of drilling fluid to clean a wellbore using equation (1) that shows the relationship between several factors. In the drilling operations, the average annulus drilling mud velocity (V) accepted to get effective well cleaning in both vertical and near-vertical inclined wells is stated as 100 ft/ min [15]. if the value of CCI ≤ 0.5, this indicates the hole clean efficiency is low. Also, if the value of CCI ≥ 1.0, this indicates the hole clean efficiency is high.

$$CCI = \frac{\mathrm{V\alpha} \times \mathrm{K} \times \mathrm{\rho m}}{400000} \qquad (1)$$

where Vα is the annular velocity [ft/min]; ρm is the mud density [lb/gal]; and K is the Power Law flow consistency index [mPa-s], and it can be calculated by using the following equation (2):

$$K = \frac{510 \times \ \Theta 300}{510^{n}} \qquad (2)$$

where n is the flow behaviour index; and it can be calculated by using the following equation (3):

$$n = 3.32 log\frac{\Theta 600}{\Theta 300} \qquad (3)$$

2.4. Density property measurement

A mud balance is used to determine the density of the water-based drilling fluid. The cup was filled with the water-based drilling fluid that need to measure, and a cup cover was placed on top, and let the extra drilling fluid pass through a hole in the middle of the cup cover. After cleaning the cup from the outside, trying to achieve the balance between the device's cup and the moving weight on the device's arm was performed. The density value was then recorded in [ppg] using the arm's ruler.

2.5. Filtration property measurement

Filtration tests were performed with an API LT-LP filtration apparatus (Multiple-unit filter press) at 100 [psi] pressure and room temperature. The measurements took 30 minutes to complete. The water-based drilling fluid sample was placed in the device cell, followed by the sealing ring and filter paper (Whatman No. 50), and finally, the cell was fully closed. A pressure of 100 [psi] from the nitrogen gas cylinder was applied to the cell after it was placed on the manifold. A graduated cylinder (size 50 ml) was positioned underneath the cell to collect the filtrate liquid, and the volume of the filtrate liquid was measured using the [ml] unit at various times (1,3,5,7.5,10,15,20,25, and 30) minutes. The filter paper was then removed after the pressure was released.

2.6. Mud cake characteristics measurements

Because there is no standard scientific procedure for determining the characteristics of mud cakes, there is a wide range of findings between researchers [16]. A mud cake can be classified according to its texture (soft or gritty). Using the ruler, the thickness of the mud cake was measured in three distinct locations on the filter paper, and the average thickness was recorded in the [mm] unit. These factors play an important role to determine the likelihood of differential drilling pipe sticking during the drilling operation [9].

3. Results and discussion

3.1. Analysis of the rheological results

Based on the data obtained by Model 35A viscometer, the apparent viscosity, the plastic viscosity, the yield point, the gel strength (10s, 1min, and 10 min) were measured and calculated at room temperatures (75°F).

Figure 4 shows the results of the apparent viscosity, plastic viscosity, and yield point of water-based bentonite drilling fluid systems formulated with increasing concentrations of BPP. The addition of BPP in the water-based drilling fluid improves the apparent viscosity of the mud, as seen in Figure 4. The apparent viscosity of all samples containing BPP had a higher apparent viscosity compared with the base drilling fluid without BPP. When a 5 %wt concentration of BPP was added to the fluid, the apparent viscosity increased by 67%. As a result, adding BPP to the water-based drilling fluid increases the apparent viscosity, which improves the drilling fluid's ability to suspend cuttings and effectively clean the well.

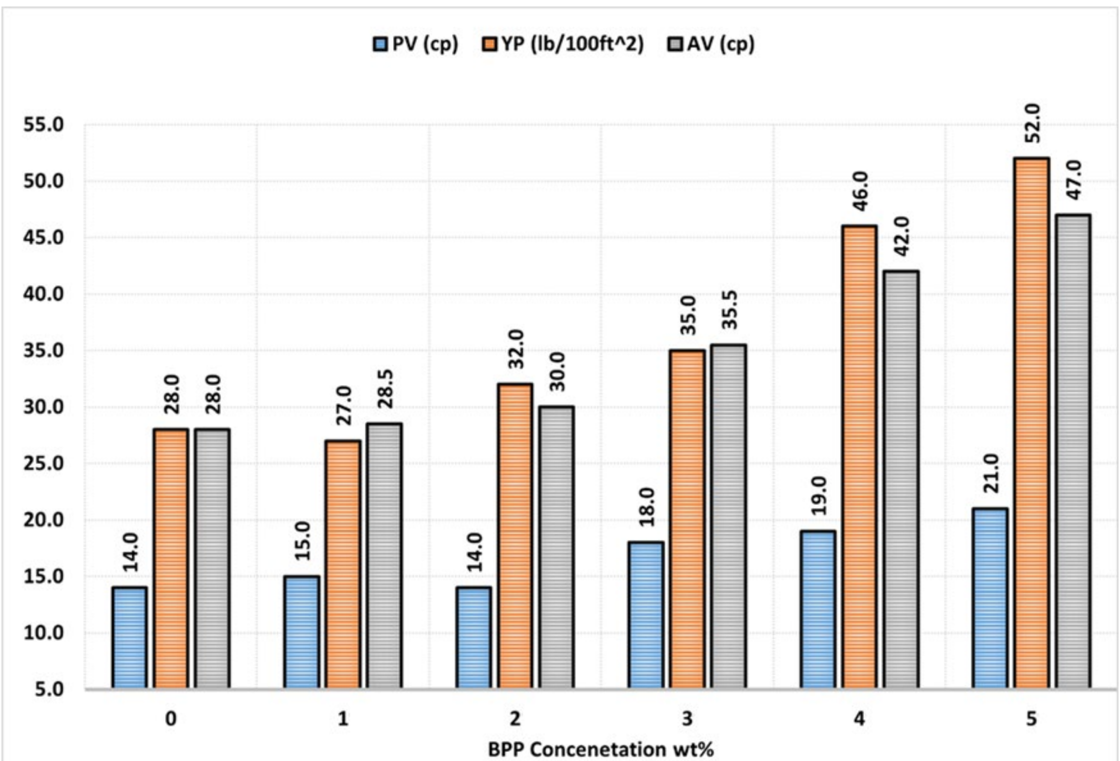

Figure 4. Plastic viscosity, yield point, and apparent viscosity at different concentrations of BPP

The results showed an increase in the plastic viscosity compared to the base water-based drilling fluid. The addition of 5 %wt of BPP led to an increase the plastic viscosity by 50%. This increase may be due to the increased solid content in water-based drilling fluid, which leads to an increase in friction pressure loss during the circulation of the drilling fluid during drilling operations. The increase in plastic viscosity leads to several problems, especially in the early stages of drilling. As the surface formations are weak and undesirable fractures may occur due to the increase in equivalent circulating density (ECD) that occurred as a result of the increase in the plastic viscosity of the water-based drilling fluid. The increase in the plastic viscosity also leads to an increase in the pressure of the mud pumps, which increases the total cost of drilling.

Similar to the apparent and plastic viscosity results, the yield point data showed that as the concentration of BPP increased, the yield point increased as well. The yield point was enhanced by 86 % when 5 wt% of BPP was added. This means that the water-based drilling fluid carrying capacity has increased, which has a favourable impact on the hole cleaning efficiency during drilling operations.

Figure 5 represents the shear stress versus the shear rate of water-based drilling fluid samples containing increasing concentrations of BPP. Water-based drilling fluid is a non-Newtonian fluid. There are three rheological models for non- Newtonian fluids (Bingham plastic model, power-law model, and Herschel–Bulkley model). It was found that the best rheological model to explain the behaviour of the water-based drilling fluid with the addition of BPP with increasing concentrations is the power-law model by comparing the measured and calculated results. The consistency index (k) and the flow index (n) in the power-law model show the apparent viscosity and the degree of non-Newtonian behavior in the water-based drilling fluid, respectively. Figure 5 also shows that increasing the concentration of BPP resulted in higher shear stress versus shear rate.

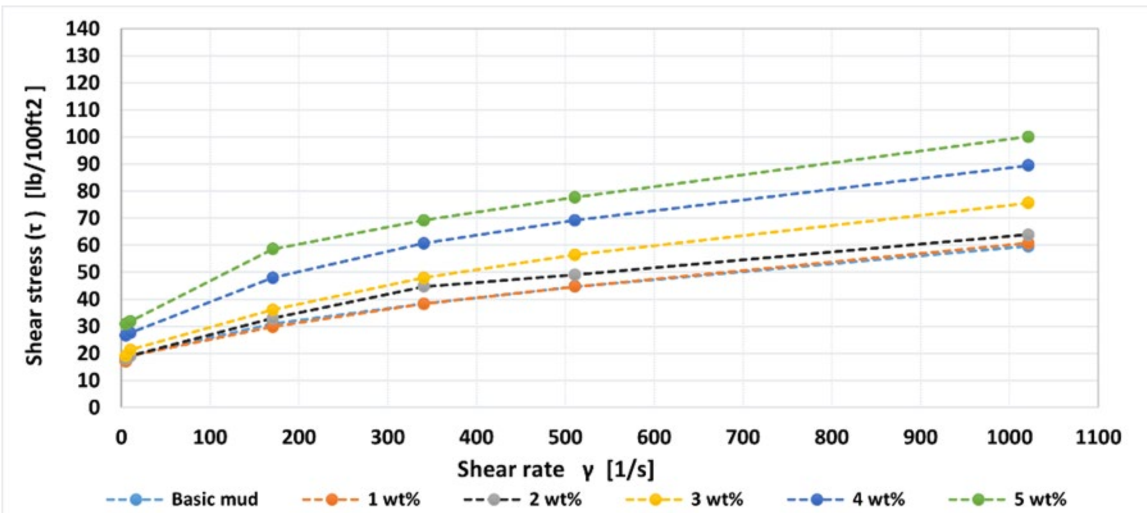

Figure 5. Shear stress via shear rate at different concentrations of BPP

Table 2. Rheological parameter of water based drilling fluid at different concentration of BPP

wt%	n	k [mPa-s]	Va [ft/min]	CCI
0	0.415046	1612.685	28.84	3.47
1	0.440582	1375.271	33.62	2.97
2	0.383337	2152.489	21.31	4.69
3	0.421836	1950.688	23.46	4.26
4	0.369958	3306.232	13.80	7.25
5	0.364772	3835.192	11.87	8.43

Table 2 shows that the flow index (n) is less than 1 for each water-based drilling fluid containing different concentrations of BPP. A fluid with a value of (n) less than 1 (n≤1) has a pseudoplastic flow behaviour, according to [17]. It can also be observed from the table that both the flow index (n) and the consistency index (k) increased with the increase in the viscosity of the materials but decreased with the increase in temperature at the same concentration of BPP. This is because the viscosity of the water-based drilling fluid increases the resistance to flow, causing the flow index (n) to increase. As well, increasing the overall thickness of the water-based drilling fluid led to increasing the consistency index (k) and vice versa. From Table 2, it is also clear to say that the cutting carrying index of the water-based drilling fluid enhanced with the addition of BPP. The cutting carrying capacity continuously increased up to a BPP concentration of 5 wt% at room temperature (75°F).

Figure 6 shows the results of measuring the gel strength of water-based drilling fluid (10 s,1 min, and 10 min) when increasing concentrations of BPP were added at room temperature. The results reveal that the gel strength increases with time in general when the concentration of BPP increases. Figure 6 also shows that heat has a negative effect on gel strength.

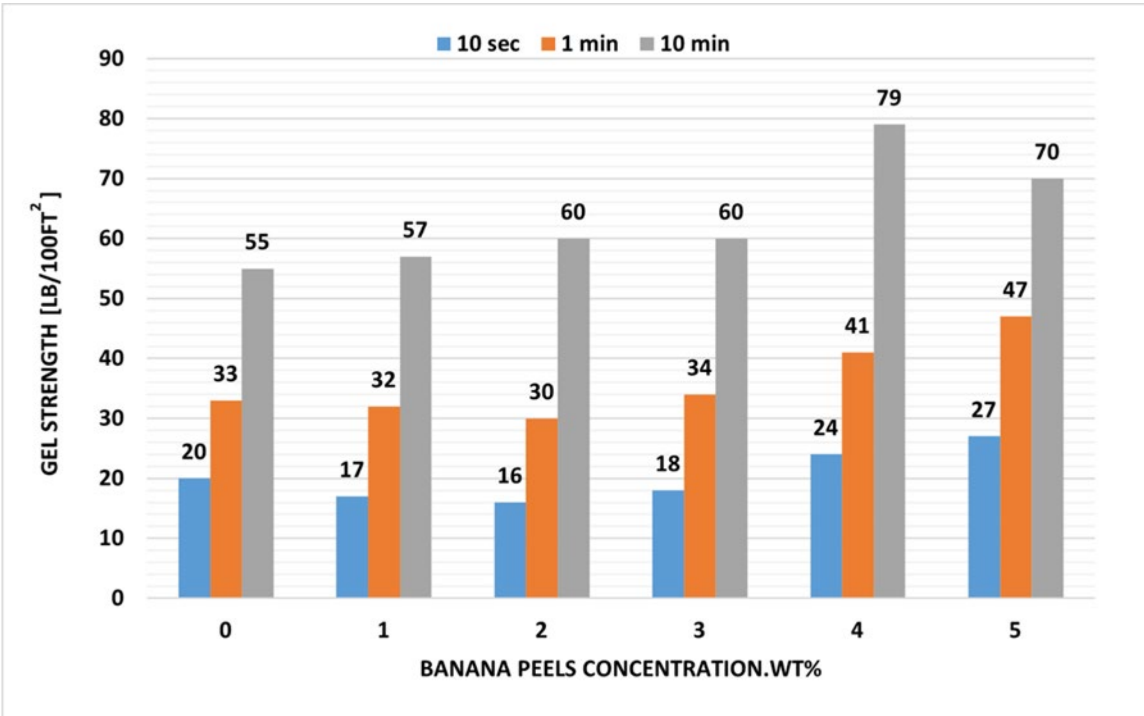

Figure 6. The gel strength of water based mud at different concentrations of BPP

The water-based drilling fluid with 4 wt% of BPP had the highest differential gel strength value at room temperature (75 °F), as can be observed from Figure 6. The initial gel strength was 24 lb/100 ft^2, but after 10 minutes of rest, it increased to 79 lb/100ft^2. Nonetheless, the gel strength for the base water-based drilling fluid sample was increased from 20 lb/100ft^2 to 55 lb/100ft^2. Meanwhile, the differential gel strength was 40 lb/100ft^2, 44 lb/100ft^2, 42 lb/100ft^2, and 43 lb/100ft^2 with the addition of 1 wt%, 2 wt%, 3 wt %, and 5 wt % of BPP, respectively.

3.2. Analysis of the filtration results

The fluid loss volume, the mud cake thickness, and the mud cake permeability of water-based drilling fluid samples prepared in the absence and presence of BPP were compared to the reference mud in this section. The loss of fluid means that the liquid phase of drilling mud penetrates the porous and permeable formations, leaving behind a mud cake on the wellbore as a result that the pressure of the hydrostatic water-based drilling fluid column is higher than the pressure of the formations. Figure 7 shows the results of the fluid loss test. It can be seen from Figure 7 that the addition of BPP up to a 5 %wt has a positive effect on a decrease in the volume of fluid loss. The water-based drilling fluid prepared with a 4 wt% concentration of BPP had the smallest fluid loss volume, which was reduced by about 17%. Thus, the addition of BPP helps to avoid many drilling problems caused by a fluid loss that increase the cost and time required for drilling, such as formation damage, stuck pipes, etc. It should be mentioned that the fluid loss values for all drilling systems formulated in the absence and presence of BPP showed acceptable fluid loss values according to the American Petroleum Institute, which set a limit of 15 mL for the maximum volume of fluid loss.

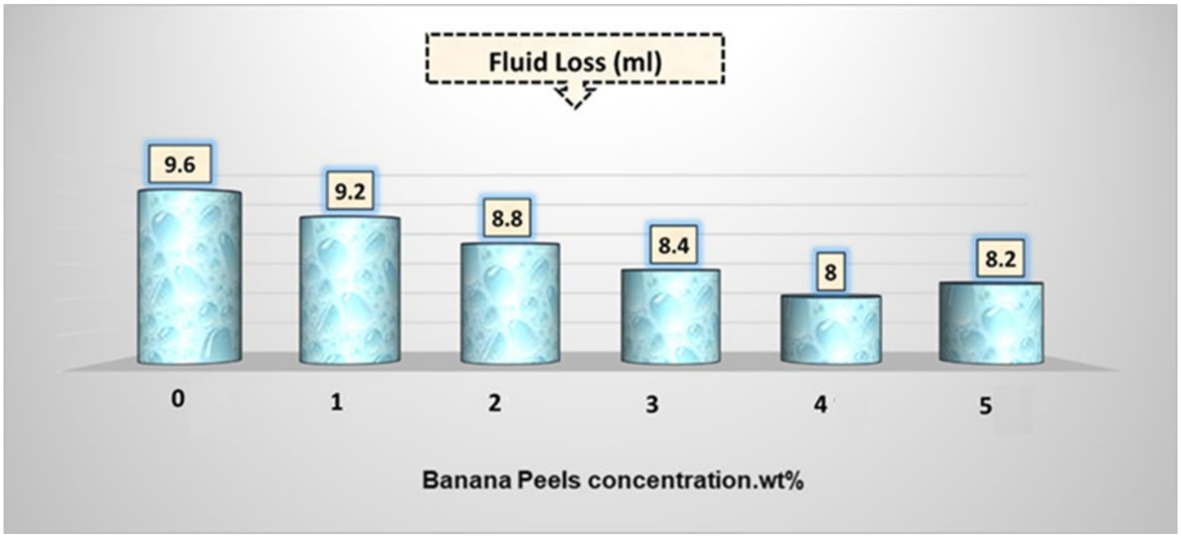

Figure 7. Fluid loss volume at different concentrations of BPP

The mud cake thickness resulting from 30 min fluid loss test was measured by caliper and the results are shown in Figure 8. It is preferable that the mud cake be thin and impermeable to prevent many drilling problems such as damage of the formations, stuck pipe, fluid loss…. etc. The results show a decrease in the thickness of the mud cake when adding a 1 %wt. concentration of BPP, which resulted in a mud cake with a thickness of 0.6 mm. However, the situation changed with the increase in the concentration of BPP, which led to an increase in the thickness of the mud cake again. It should be noted that the addition of a 4%wt concentration of BPP resulted in the biggest mud cake with a thickness of 1.2 mm, which is near the mud cake thickness of the base mud. This indicates that the addition of BPP does not have a significant negative effect on increasing the thickness of the mud.

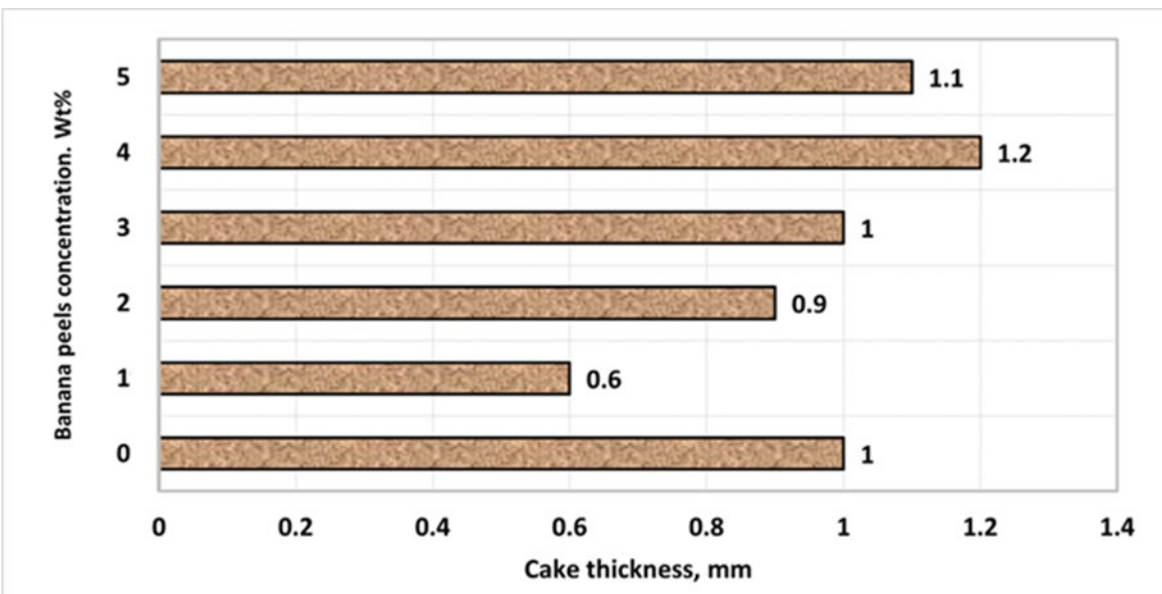

Figure 8. Mud cake thickness at different concentration of BPP

As mentioned previously, the drilling mud cake should be impermeable in order to prevent the fluids from entering into the formations to protect them**.** Table 3 shows the results of changing mud cake permeability with the addition of BPP at increasing concentration. The results display that the water-based drilling fluid formulated with BPP had a detrimental influence on the mud cake permeability of the drilling mud at all concentrations except 2 wt% and 5 wt%. The mud cake permeability ratio was found to be more than one and rose continuously as the concentration of BPP increased due to increased mud cake thickness. However, compared with the base drilling mud, the drilling mud prepared with a 2 wt% and 5 wt% concentration of BPP resulted in a lower mud cake permeability ratio.

Table 3. Mud cake permeability at different concentration of BPP

BPP concentration [wt%]	K1/K2	BPP concentration [wt%]	K1/K2
0	1	3	1.0606
1	0.9583	4	1.1429
2	1.4348	5	0.9396

Figure 9 shows the mud cake resulting from the addition of BPP powder, noting the change in the colour of the mud cake with increasing concentration. Also, it had become more slippery and smooth which helps to reduce the problem of differential sticking of the drill pipes.

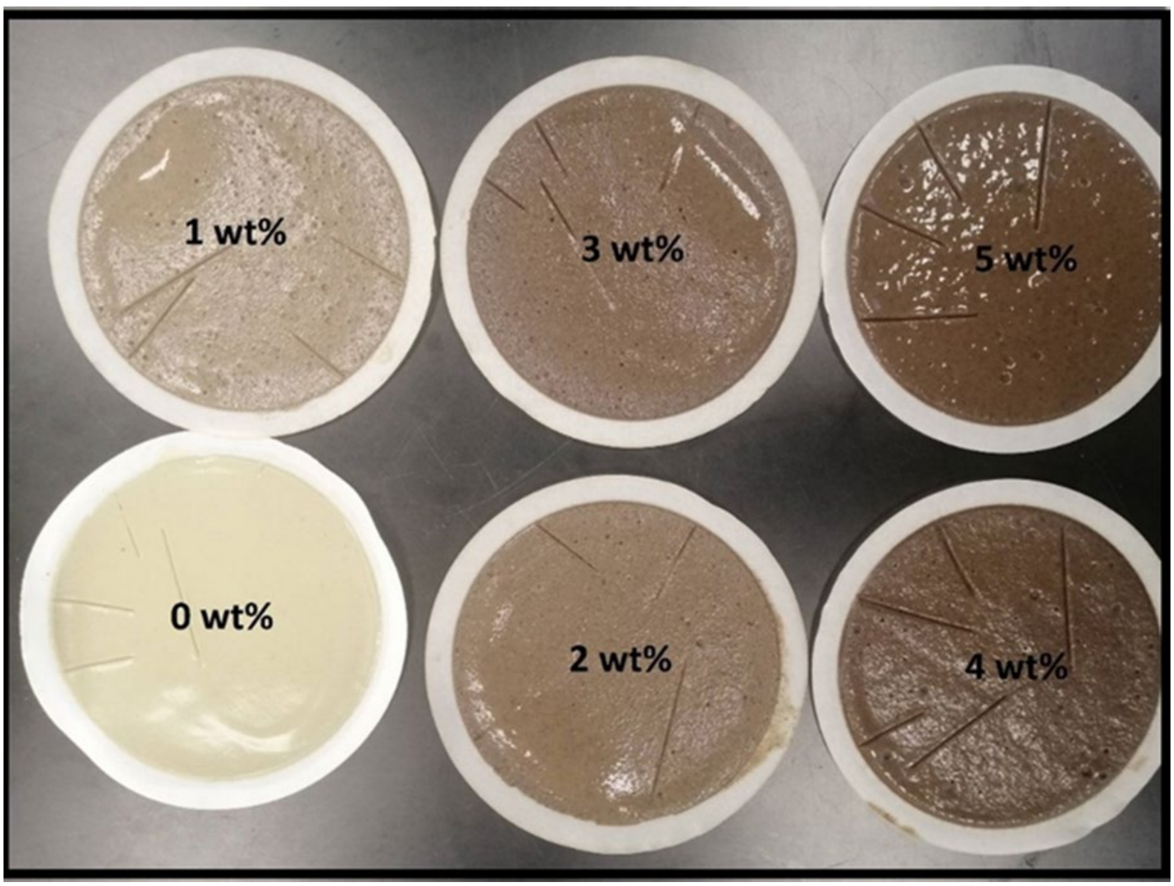

Figure 9. Mud cake with different concentrations of BPP

3.3. Analysis of the density results

The density of water-based drilling fluid is one of the most important properties because it provides the hydrostatic pressure necessary to control the pressure of formations and prevent blowout during drilling operations. Figure 10 shows the density test results of water-based drilling fluid systems formulated with increasing concentrations of BPP. The results show a slight increase with the increase in the concentration of BPP, and the reason for this is due to the increase in the solid mass in water-based drilling fluid.

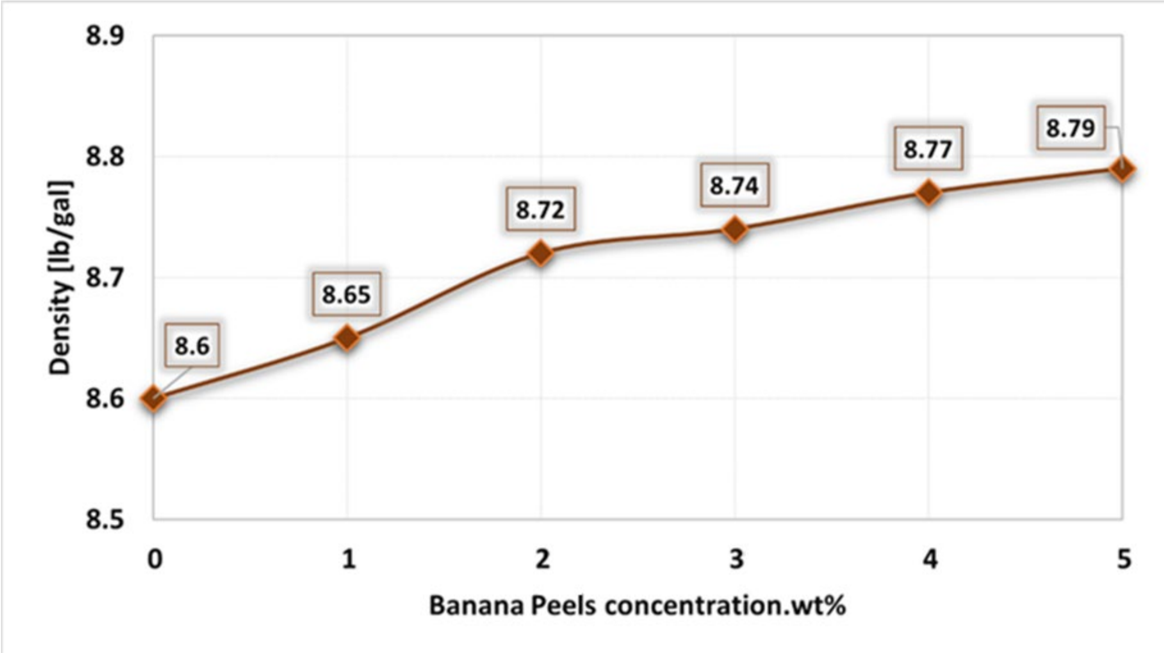

Figure 10. Density of water based mud at different concentration of BPP

4. Conclusions

Based on the previous results, the BPP showed great effectiveness as an additive to the water-based drilling fluid. The addition of BPP with increasing concentrations led to an increase in the rheological parameters such as the plastic viscosity, the yield point, and the apparent viscosity, which leads to an increase in the pressure required by the pumps to circulate the drilling fluid. It also led to an increase in the gel strength, which increases the effectiveness of the drilling fluid on suspending the cutting when the drilling fluid circulation stops.

The addition of BPP increased the cutting carry index, which increased the effectiveness of water-based drilling fluid in cleaning the well from cuttings. BPP showed good efficacy in reducing the volume of fluid loss. The addition of BPP resulted in a mud cake with thickness and permeability within acceptable limits. The addition of BPP led to an increase in the density of the drilling fluid, which helps to provide sufficient hydrostatic pressure for the water-based drilling fluid column to overcome the formation pressure.

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References

[1] Hossain ME. Drilling Costs Estimation for Hydrocarbon Wells. J. Sustain. Energy Eng.,2015; 3(1): 3–32.

[2] Fink J. Ed., Chapter 1 - Drilling muds. in Petroleum Engineer's Guide to Oil Field Chemicals and Fluids (Second Edition), Boston: Gulf Professional Publishing, 2015, pp. 1–61. doi: 10.1016/B978-0-12-803734-8.000011.

[3] Caenn R, Darley HCH, and Gray GR. Chapter 1 - Introduction to Drilling Fluids. in Composition and Properties of Drilling and Completion Fluids (Sixth Edition), R. Caenn, H. C. H. Darley, and G. R. Gray, Eds. Boston: Gulf Professional Publishing, 2011, pp. 1–37. doi: 10.1016/B978-0-12-383858-2.00001-9.

[4] Dong W, Pu X, Ren Y, Zhai Y, Gao F, and Xie W. Thermoresponsive Bentonite for Water-Based Drilling Fluids. Materials, 2019; 12(13): 2115.

[5] Navarrete RC, Himes RE, and Seheult JM. Applications of Xanthan Gum in Fluid-Loss Control and Related Formation Damage. presented at the SPE Permian Basin Oil and Gas Recovery Conference, Mar. 2000. doi: 10.2118/59535-MS.

[6] AN Okon, JU Akpabio, and KW. Tugwell Evaluating the locally sourced materials as fluid loss control additives in water-based drilling fluid. Heliyon, 2020; 6(5): e04091.

[7] Iscan AG, and Kok MV. Effects of Polymers and CMC Concentration on Rheological and Fluid Loss Parameters of Water-Based Drilling Fluids. Energy Sources Part Recovery Util. Environ. Eff., 2007; 29(10). 939–949.

[8] Adewole JK, and Najimu MO. A Study on the Effects of Date Pit-Based Additive on the Performance of Water-Based Drilling Fluid. J. Energy Resour. Technol., 2017; 140(5): 052903.

[9] Agwu OE, Akpabio JU, and Archibong GW. Rice husk and saw dust as filter loss control agents for water-based muds. Heliyon, 2019; 5(7): e02059.

[10] Idress M, and Hasan ML. Investigation of different environmental-friendly waste materials as lost circulation additive in drilling fluids. J. Pet. Explor. Prod. Technol., 2019; 10:, 233-242.

[11] Olaitan O, Orodu O, and Ehinmowo A. Experimental Investigation of Limonene-based Environmental-Friendly Emulsion Drilling Mud. Am. J. Eng. Appl. Sci., 2017; 10: 611–621.

[12] Al Khalaf H, Alhaj Mohammed N, and Kovacsne GF. Evaluation of using waste pinecones as an eco-friendly additive to water-based mud. Rud.-Geol.-Naft. Zb., 2022; 37(2): doi: 10.17794/rgn.2022.2.1.

[13] Tomlin M. Model 35 Viscometer Instruction Manual.- p. 45, 2016.

[14] Yassin AM, Daud MZ, and Daud MA. Experimental Study of Drilling Cutting. Removal in Inclined Annuli. Univ. Teknol. Malays., 1989, https://doi.org/10.2118/12123-PA .

[15] Bourgoyne AT. Ed., Applied drilling engineering. Richardson, TX: Society of Petroleum Engineers, 1986.

[16] Tan CP. Embedment Modulus of Mudcakes - Its Drilling Engineering Significance. p. 15, 2001.

[17] Rapp BE. Fluids. in Microfluidics: Modelling, Mechanics and Mathematics. Elsevier, 2017, pp. 243–263. doi: 10.1016/B978-1-4557-3141-1.50009-5.

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