CHEMICAL ENGINEERING TRANSACTIONS
VOL. 106, 2023
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Peck Loo Kiew, Hon Huin Chin

ISBN 979-12-81206-05-2; **ISSN** 2283-9216
DOI: 10.3303/CET23106156

An Eco-Friendly Fluid Loss Control Additive for Water-Based Bentonite Drilling Fluid: Orange Peel Waste

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Drilling fluid performs a crucial function in petroleum drilling operations. This functional fluid improves the performance of the drilling process by controlling bottom hole pressure, wellbore stability, and cleaning the hole. Circulation fluid loss frequently occurs during drilling, leading to several costly problems, such as formation damage and wellbore instability. This study investigates the potential of utilizing orange peel waste as an environmentally friendly and cheap additive to enhance the characteristics of the bentonite drilling fluid. Laboratory experiments were conducted to evaluate the impact of orange peel powder addition into the filtration fluid of drilling fluid with various concentrations (0, 0.1, 0.15, 0.2, 0.25, and 0.5 % by weight). Following American Petroleum Institute (API) guidelines, their rheological and filtration characteristics were measured at room conditions. The results stated that adding orange peel powder significantly improves the fluid loss control ability. By increasing the orange peel powder amount, the API filtration volume decreased up to 18.18 % as compared to the bentonite drilling fluid without orange peel powder addition.

1. Introduction

To meet the growing demand for hydrocarbon energy, the search for new resources in unexplored regions and deeper geologic structures has increased in the oil and gas industry. The efficiency of the drilling fluid plays a crucial role in hydrocarbon exploration, and the success of drilling a well is crucial to the overall process (Akpan et al., 2020). Drilling fluid is an essential component in drilling wells and contributes significantly to drilling costs. Drilling fluid serves numerous functions, including removing rock cuttings from the wellbore, cooling the drilling tool, holding cuttings during circulation stoppage, and applying hydrostatic pressure to the wellbore via the fluid column (Caenn et al., 2011). There are two major categories of drilling fluid: water-based and oil-based (Ibrahim et al., 2022). Water-based drilling fluid is the most common in the oil and gas industry due to its simplicity of preparation and use, compatibility with most formations, and low environmental impact (Parate, 2021). Typical water-based drilling fluid consists of water, bentonite, and various chemical additives that control the fluid's properties, such as rheology, specific gravity, and filtration fluid loss (Murtaza et al., 2022). Widespread additives include carboxymethyl cellulose and xanthan gum (Akpan et al., 2020). These commercial additives are frequently considered expensive, raising the price of drilling fluid, and directly affecting the total expense of drilling a well (Prakash et al., 2021). The oil and gas drilling industry aims to identify appropriate additives that are both effective and environmentally friendly, in accordance with the strict environmental regulations that govern the industry (Ismail et al., 2017). The latest studies have examined sustainable alternatives for industrial drilling fluid additives (Ghaderi et al., 2020).
In this work, the utilization of orange peel powders (OPP), classified as agricultural waste products, was examined as an additive for water-based bentonite drilling fluid. The base drilling fluid was prepared by mixing distilled water and 5.0 wt% bentonite. A series of experiments were conducted to evaluate the performance of

Paper Received: 15 July 2023; Revised: 07 August 2023; Accepted: 25 August 2023
Please cite this article as: Le N.N.H., Hau D.P., Hieu L.T., Quang H.T., Tam T.N.T., Dung T.T., Khanh D.Q., 2023, An Eco-Friendly Fluid Loss Control Additive for Water-Based Bentonite Drilling Fluid: Orange Peel Waste, Chemical Engineering Transactions, 106, 931-936 DOI:10.3303/CET23106156

the orange peel powder as a fluid loss control additive in bentonite drilling fluid at various concentrations. The results revealed that orange peel powder decreased fluid loss and positively impacted rheology.

2. Materials and methods

2.1 Materials

Bentonite powder, distilled water, and orange waste powder were used as drilling fluid additives in this study. Raw orange peel wastes were collected from the local supermarket and washed with distilled water to remove impurities. To create an orange waste powder, a dry grinding procedure was employed. Figure 1 shows the flowchart of OPP production. The orange waste was cut into small pieces and dried for 48 h at a temperature of 80 °C. The dried peels were ground into powder by using a grinder (Model SEKA SK200, China). An illustration of the dry grinding process can be seen in Figure 1(b). Finally, the powder was sieved through 45 to 100 μm meshes (Figure 1 (c)). Figure 2 presents the appearance of brown bentonite powder and a scanning electronic microscope (SEM) image.

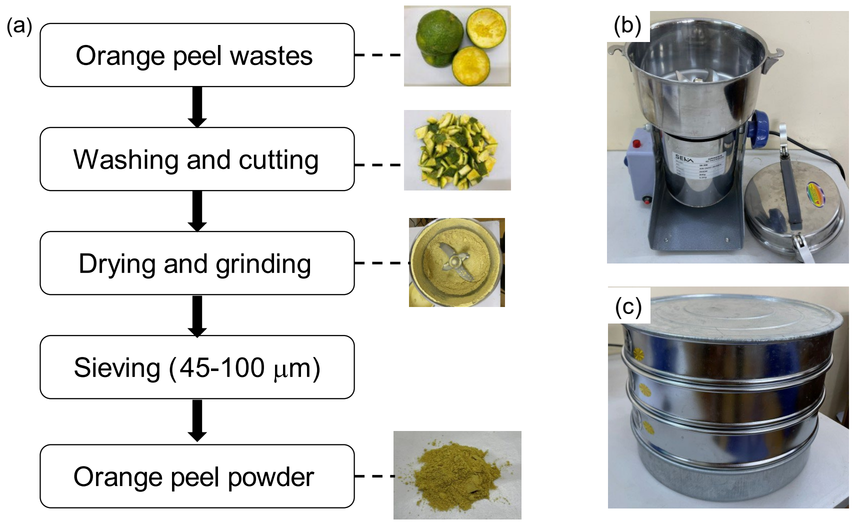

Figure 1: (a) The production process of OPP, (b) Grinder, and (c) Sieve

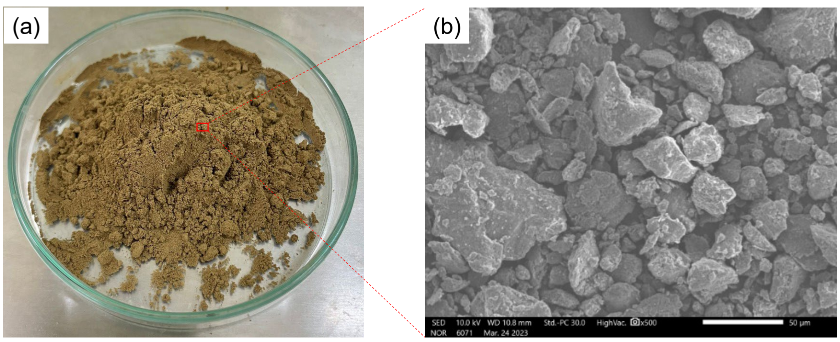

Figure 2: (a) Appearance, and (b) SEM image of bentonite powder

2.2 Drilling fluid preparation

In this work, six drilling fluid samples were prepared. The control sample was labeled “base fluid”. Five other samples were labeled as A, B, C, D and E. The base fluid sample contains water and bentonite as the viscosity agent, while the other samples were prepared using orange waste powder in addition to the bentonite. Table 1 presents the additives and dosages used in this study. 400 mL of distilled water and 5.0 wt% bentonite (Barry et al., 2015) were mixed at high stirring speed of 21,000 rpm by using Hamilton Beach mixer for 20 min. A certain amount of OPP with size distribution from 45 to 100 μm was added to the mixer container to stir continuously for 10 min for each fluid sample. A mixture of distilled water and bentonite was stirred by using Hamilton Beach mixer for 20 min. A certain amount of OPP was added to the mixer to stir continuously for 10 min. Rheology and filtration characteristics were measured in the following section. Figure 3 presents the apparatuses used in this work.

Table 1: Formulation of drilling fluid samples

Material	Base fluid	Sample A	Sample B	Sample C	Sample D	Sample E
Distilled water	400 mL	400 mL	400 mL	400 mL	400 mL	400 mL
Bentonite	5.0 wt%	5.0 wt%	5.0 wt%	5.0 wt%	5.0 wt%	5.0 wt%
Orange peel powder (OPP)	-	0.1 wt%	0.15 wt%	0.2 wt%	0.25 wt%	0.50 wt%

2.3 Rheology measurement

The rheological properties of the drilling fluid were evaluated, following the procedure based on the API standard (API 13B for field testing) (American Petroleum Institute, 2017). An 8-speed rotational viscometer (OFITE, USA) was used to measure the plastic viscosity (PV), yield point (YP), and gel strength of five different fluid samples. The samples were introduced into the rheometer cup. measurements were taken at several speeds (600, 300, 200, 100, 60, 30, and 6 rpm) to determine the rheological properties. Gel strength was assessed at two time points: 10 s and 10 min. Eq(1) and Eq(2) were utilized to calculate the PV and YP parameters.

$$PV\ (cP) = \Phi_{600} - \Phi_{300} \quad (1)$$

$$\mathrm{YP\ (Pa)} = 0.4788(\Phi_{300} - \mathrm{PV}) \quad (2)$$

where Φ_{600} is dial reading at a speed of 600 rpm, Φ_{300} is dial reading at a speed of 300 rpm.

2.4 Filtration fluid loss measurement

The filtration properties of drilling fluid samples were evaluated using an API filter press following API specifications (American Petroleum Institute, 2017). Filtrate volume, a measure of water loss from fluid to the formation, was determined during the filtration test to simulate fluid loss in the wellbore. The filter cake was built from solid particles in the sample. It helps prevent excessive fluid loss. A thick filter cake can lead to a decrease in effective hole diameter and an increase in the risk of striking. Effective fluid loss control is typically achieved by minimizing the amount of water filtrate and maintaining a thin filter cake. In this test, a Whatman 50 filter paper was positioned in the API cell and filled with drilling fluid. The sample was subjected to a pressure of 689,476 Pa (100 psi), and the amount of fluid lost was measured at 7.5 and 30 min.

2.5 Filter cake permeability

The permeability of the filter cake can be determined by analyzing the correlation between the amount of filtrate loss and the duration of time. The formula for permeability is presented by K in Eq(3) as follows.

$$\mathrm{K} = (\mathrm{Q} \times \mathrm{l} \times \mu) \times \frac{1}{2\mathrm{P}\times\mathrm{F}\times\mathrm{t}} \quad (3)$$

where the parameters Q (cm^3), l (cm), m (cP), P (atm), F (cm^2), and t (s) represent the volume of filtrate, the thickness of the cake, the viscosity of the filtrate, the filtration pressure, the filter surface, and the time. This formula enables the precise calculation of the filter cake's permeability, which is a crucial parameter for evaluating the filtration properties of drilling fluid (Elkatatny et al., 2012).

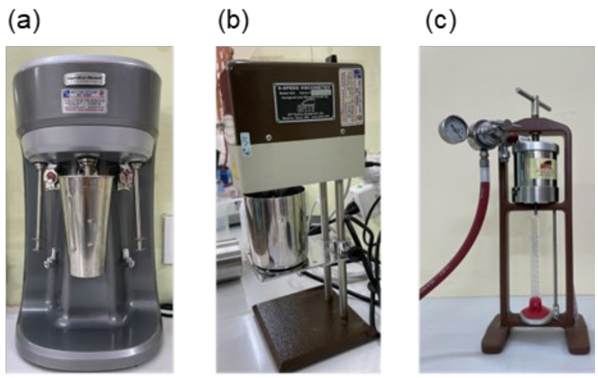

Figure 3: Experimental equipment: (a) Hamilton beach mixer; (b) 8-speed viscometer; (c) API filter press

3. Results and discussion

3.1 Rheological properties of drilling fluids

The rheological characteristics of drilling fluids are crucial in both flowing and stationary situations. PV is an indicator of the interactions between solid particles as well as the interactions between solids and liquids in the fluid, it should be kept as low as possible. The pressure of the fluid pumps may increase as PV increases, raising the overall cost of drilling. The results presented in Figure 4 (a) reveal that adding OPP had significant effect on the PV. 0.1 wt% concentration of OPP increased PV by 10 % compared to the base fluid sample. Increasing the concentration of OPP to 0.25 % and 0.5 % increased the PV by 30 % and 40 %. This makes OPP a potential candidate additive for transporting solid cuttings by improving PV parameter of drilling fluid.

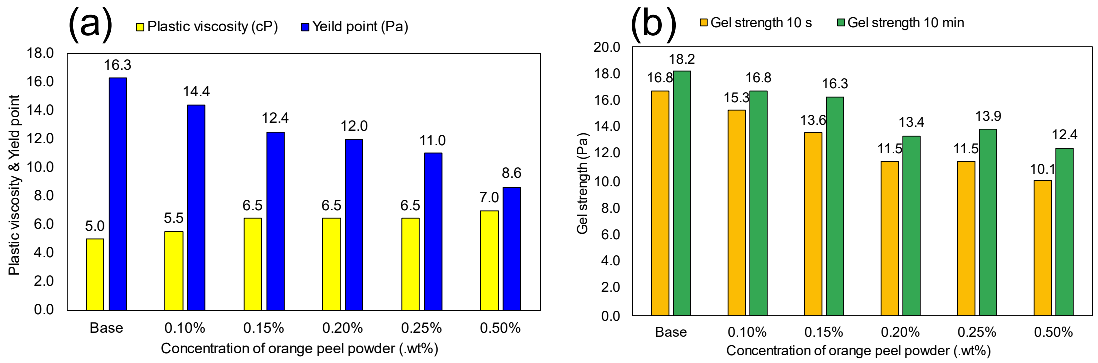

Figure 4: (a) PV and YP of OPP drilling fluids; (b) Gel strengths of OPP drilling fluids

Figure 4 (a) depicts that the YP decreased when the OPP was added to the drilling fluid compared to the base sample. The YP decreased by 32 % and 47 % at concentrations of 0.25 wt% and 0.5 wt% of OPP. A drilling fluid's yield point is essential to its capacity to be pumped, and higher values may result in greater pressure losses during drilling operations. The optimal yield point range for drilling operations is typically considered to be between 5 and 12 Pa (Kulkarni et al., 2014). The drilling fluid with OPP outperformed the base fluid in terms of yield point results.

Figure 4 (b) displays the drilling fluid's gel strengths as a result of the gel 10 s and gel 10 min parameters. These parameters are crucial for keeping drilled cuttings suspended under static conditions. By incorporating OPP into the drilling fluid, it was possible to see an increase in gel strength over time. It could be good to hold the cuttings in drilling fluid. Gel strength increased by 1.4 Pa from 16.8 Pa at 10 s to 18.2 Pa at 10 min for base fluid without OPP. On the other hand, after 10 min of static conditions, the gel strengths of drilling fluids containing 0.15, 0.2, 0.25, and 0.5 wt% OPP increased by 2.7, 1.9, 2.4, and 2.3 Pa. Figure 3 (b) also shows a decrease in gel strength when increasing the amount of OPP in the bentonite drilling fluid. It results in lower circulation pressure to break the gelation of the drilling fluid after remaining static.

3.2 Filtration properties of drilling fluids

In this section, samples of water-based drilling fluid made with the addition of OPP are compared to the base sample in terms of fluid loss volume, filter cake thickness, and filter cake permeability. Fluid loss occurs when the liquid phase of drilling fluid penetrates through permeable formations due to the differential pressure, forming a mud cake along the wellbore. Figure 5 illustrates that adding BPP has a favorable impact on minimizing fluid loss volume. After 30 min of the test, the drilling fluid sample with 0.5 wt% orange peel powder showed the lowest fluid loss volume, which decreased by over 18 %. Using OPP can help reduce the number of costly drilling problems caused by fluid loss, such as formation damage and drill-pipe sticking. It is important to highlight that the sample contained 0.25 wt% of orange peel powder, which demonstrates an acceptable fluid loss value according to API criteria (the maximum value of the fluid loss is 15 mL) (API-13I, 2009). The observed decrease in fluid loss indicates the capacity of orange peel powder to restrict the filtrate flow. Figure 6 depicts the SEM photos of OPP captured with a magnification of 2,000 and 10,000. It can be seen the OPP particles had roughly irregular surfaces. This compact texture could be helpful in plugging the pore space on the bentonite filter cake. This tendency was also reported by (Murtaza et al., 2021).

Filter cakes play a vital role in the drilling process as they are formed by accumulated bentonite particles under pressure. Numerous studies have demonstrated that concerns, including fluid loss and wellbore stability, are related to the quality of filter cakes (Yao et al., 2014). Figure 7 visually illustrates the filter cake produced after

30 min of filtration tests. The pictures demonstrate that the cake with more OPP displays enhanced smoothness and slipperiness. It may mitigate the problem of drill pipe sticking.

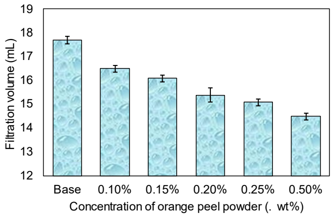

Figure 5: Fluid loss after 30 min of OPP drilling fluids

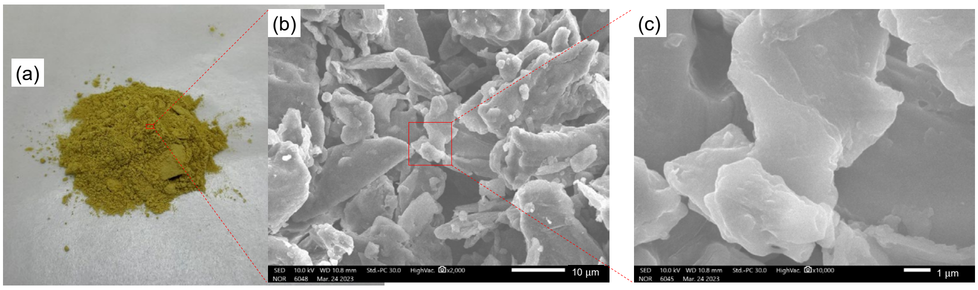

Figure 6: (a) Sample of dried OPP, (b) SEM images of dried OPP with magninfication of 2,000 times, and (c) 10,000 times

Figure 8 shows that the presence of orange peel waste in the drilling fluid leads to a significant decrease in the thickness of the filter cake. The filter cake thickness for the base sample (0 %wt OPP) was 2.3 mm, corresponding to a permeability of 2.19×10^{-3} Darcy. Once OPP was introduced to fluids, the thickness and permeability of the cake decreased significantly. Notably, the addition of OPP at a concentration of 0.25 wt% resulted in a remarkable reduction of filter cake thickness by 43 % compared to the base mud. At the higher concentration of 0.5 wt%, the thickness and permeability of the filter cake do not have a significant change at 1.3 mm and 1.01×10^{-3} Darcy. It indicates that the presence of orange peel not only strengthens the filter cake to avoid fluid loss but also reduces its thickness, minimizing any adverse effects on the formation during drilling. In this study, the results confirm that the highest concentration of OPP (0.5 %) could significantly improve the fluid loss control ability of bentonite drilling fluid. It makes bentonite drilling fluid suitable for the oil and gas industry with a low environmental impact.

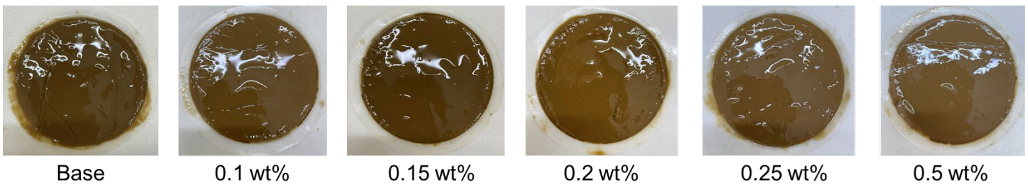

Figure 7: Filter cake with different concentration of OPP

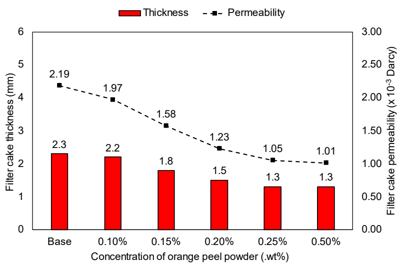

Figure 8: Effect of OPP concentration on the filter cake's thickness and permeability

4. Conclusions

In summary, the addition of OPP to drilling fluids has shown promising results in improving rheological characteristics and reducing friction pressure loss. The plastic viscosity increased with higher concentrations of OPP. The yield point decreased with the addition of OPP, which is beneficial for pumping capacity. OPP showed a OPP helped minimize fluid loss volume and reduce filter cake thickness, which can prevent drilling problems and improve wellbore stability. The reduction in fluid loss demonstrates that OPP can prevent the escape of filtrate by plugging the pore space on the filter cake. The results showed that 0.5 % OPP had the best filtration fluid control. OPP is a potential candidate additive for enhancing drilling fluid performance.

Acknowledgments

We acknowledge Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for supporting this study.

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