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# Performance Evaluation of the New Environmentally Friendly Additive for Enhanced Fluid Loss and Rheological Properties of Drilling Fluid

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**ABSTRACT**

Environmental protection during drilling is necessary for onshore oil and gas development. With the available additives, it is impossible to design a drilling fluid system that is both efficient and environmentally friendly. Nevertheless, due to their high cost and complicated manufacturing procedure, several environmentally friendly drilling fluid additives cannot be utilised widely. This study used broad bean peel powder (BBPP) as a drilling fluid additive to improve drilling fluid performance. All the necessary experimental tests for rheology and filtration were conducted in an ambient condition. According to the results, BBPP reduced the drilling fluid's alkalinity by 10–39% and enhanced its rheological characteristics (plastic viscosity, gel strength). However, the BBPP had a negligible effect on other properties, including mud weight and yield point. Furthermore, adding fine (FBBPP) and Medium (MBBPP) broad bean peel powder improved the filtration properties of the reference mud. However, FBBPP was more effective in reducing the filter cake thickness and fluid loss from 1.75 mm and 20.4 mL to 1.0 mm and 13.3 mL, respectively. The ability of BBPP to improve rheological properties and decrease filtration properties makes them beneficial to a successful drilling operation.

## Introduction

In the oil and gas industry, drilling fluid is an essential component of the drilling process. It is constituted of a liquid phase (water or oil) and a blend of synthetic and natural components,

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such as chemical additives or/and clay. Drilling fluid is used for different purposes, including formation pressure control, wellbore stabilisation, cuttings removal, bit cleaning and cooling, reducing friction between the drilling string and the hole's sides, creating a filter cake to seal pores, facilitating data interpretation and collection, and accelerating penetration [1-3].

A current regulation states that in addition to drilling mud, consideration should be given to borehole design, environmental impact, cost, rock strength, and formation damage. Additionally, due to the negative environmental effects of drilling mud, it requires finding and using new additives that can help regulate the drilling fluid's properties and enhance their performance with the minimum adverse environmental impact [4].

Okorie [5] used burnt palm head sponge powder and "Trona" powder (Akaun or Kaun powder) as two local additives to modify pH. The analysis revealed that both additions might be used as a fine powder or in solutions to improve pH values from 7.0 to 13.0. However, burnt palm head sponge powder added a higher mud pH than Trona powder. Irawan et al. [6] assessed the effectiveness of sugar cane and corncobs as viscosifiers. When the quantity was increased from 6 to 10 pounds per barrel, the results revealed a negative effect on the drilling fluid's rheological properties. Okon et al. [7] investigated the application of rice husk as an eco-friendly separation control additive. According to the study's findings, a risk husk concentration of 20 ppb might minimise fluid loss by 65% compared to a concentration of 10 ppb of carboxymethyl cellulose. Banana peel ash was studied by Adebowale and Raji [8] as an alternate addition to raise pH and prevent corrosion. The results revealed that the pH of the mud significantly improved. The usage of potato starch derived from potato tubers to enhance the properties of mud was investigated by Nyeche et al. [9]. They combined their additive with 2 ppb of polyanionic cellulose. According to their findings, potato starch can be employed in drilling mud as a viscosifier and fluid loss agent. Hossain and Wajheeuddin [10] examined the rheological properties of mud and separation control in water-based mud by adding powdered grass. Their findings revealed a slight increase in gel strength (at higher concentrations). However, when grass powder was present in sufficient quantities, the filtering abilities revealed reductions of up to 25% compared to the base mud. The use of henna extract in water-based muds as a biodegradable shale inhibitor was studied by Moslemizadeh and Shadizadeh [11]. Their findings demonstrated that the henna could enhance the lubricity of the mud and decrease shale swelling. Biodegradable grass powder (GP) was found to be more effective at controlling fluid circulation loss than starch by Al-Hameedi et al [12]. According to the authors, Grass Powder enhanced the filter cake and reduced fluid loss by 44% when 7 grams of grass powder was added to the base mud. Mandarin peel powder (MPP) was used in experiments by Al-Hameedi et al. [13] to study mud's rheological properties and filtration. Their research demonstrated that MPP could decrease fluid loss and improve the rheological properties of mud. Al-Hameedi et al. [14] looked at the viability of employing food waste products as an eco-friendly drilling fluid additive. They found that fibrous food waste material (FFWM) and potato peel powder (PPP) improved plastic viscosity, reduced fluid loss and lowered yield point. The usage of corn starch as an additive to control filtration loss and drilling mud rheology was examined by Novrianti et al. [15]. According to the study, corn starch significantly reduced mud cake and drilling mud filtration loss while also increasing plastic viscosity and gel strength.

According to XRF analysis, the majority of the organic additives had calcium, potassium, chlorine, sulfur, silicon, iron, phosphorus, and manganese as their primary elements. In the drilling mud, calcium compounds serve as weighting and bridging agents. Both calcium carbonate ($CaCO_3$) and calcium chloride ($CaCl_2$) are utilized as clay dispersion additives and inhibitors to control active shale, respectively. Alkalinity control agents (KCl), acidity control agents (KOH) are all employed with potassium compounds in drilling mud. Silica is used in drilling fluids to perform a variety of functions, including stabilizing shale and controlling downhole pressure. In addition, silica is added to a drilling fluid to change the density, ionic strength and charges [10]. It is believed that the presence of these components in the proposed organic additive may help them mimic the effects of their potentially harmful counterparts when used in drilling fluid.

This study examined the interaction between broad bean peel powder (BBPP) and water-based drilling fluid. The primary goal of this study is to use an alternative environmentally friendly additive to enhance the drilling fluid's properties. Additionally, it provides a valuable guide for lowering drilling fluid costs and reducing the volume of a non-biodegradable waste landfill in the environment.

## Methodology

This part will discuss the methods used to collect and prepare the environmentally friendly Broad Beans Peel Powder (BBPP) additive and the experimental procedures employed in the laboratory. The characteristics of the reference fluid sample and the tests performed with various BBPP combinations at different concentrations will also be shown.

### Preparation of broad bean peel powder (BBPP)

The process of making broad bean peel (BBP) into a powder is shown in Figure 1. First, the broad bean peel was collected at home. Then, it was sliced into little cuts to speed up the drying process and quickly remove the moisture. The little cuts of broad bean peels were put in the oven for one hour at 70–80 °C (158–174 °F). After that, they were stored in a dry environment with typical laboratory requirements for 14 days. Following that, the broad bean peels were again placed in the oven at 100–120 °C (284–302 °F) to ensure a thorough drying process. After being dried, the broad bean peels were processed into fine dust in a food processor. A sieve analysis test has determined the size of the peel powder. The test results suggested that the broad bean peel powder (BBPP) has a size of approximately 300 to 2000 μm (50 US Mesh size to 10 US Mesh size).

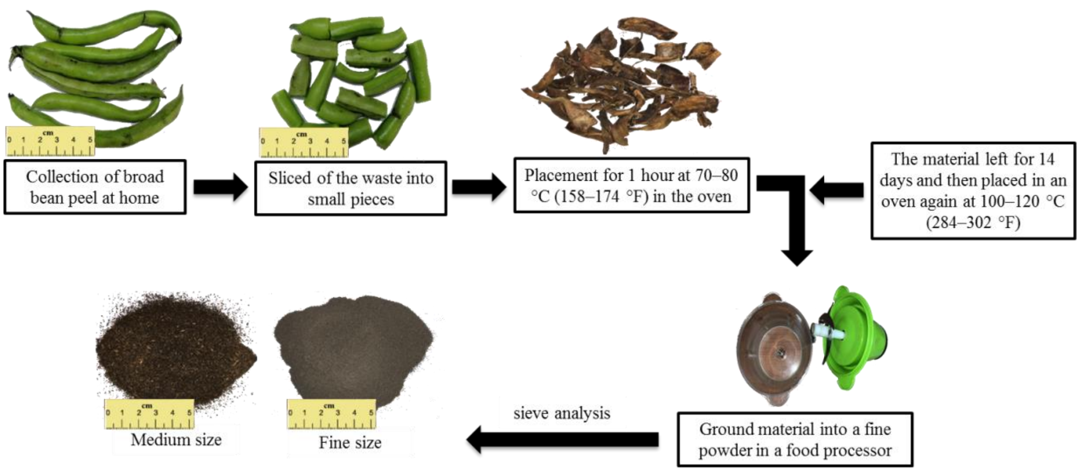


**Fig. 1**. Illustrates the process for preparing broad bean peel powder

### Preparation of a Mud Sample

This experimental study used water-based mud (WBM) as the reference mud (RM). It was made using only NaOH and Bentonite as typical chemical materials. The reference mud comprised 40 grams of Bentonite, 1 gram of caustic soda, and 700 cc of water. Various BBPP concentrations were added to the reference mud, ranging from 1% to 3% by weight (Table 1). Full-set measurements were then made for each concentration to evaluate the effect of BBPP concentration on the rheological and filtration properties of the reference mud.

**Table 1**. Composition of drilling fluids

| Drilling Fluid | Sample | Material | | | |
|---|---|---|---|---|---|
| | | Water (cc) | Bentonite (g) | NaOH (g) | BBPP (g) |
| Reference Mud (RM) | WBM | 700 | 40 | 1 | - |
| Adding fine BBPP | FBBPP1 | 700 | 40 | 1 | 7 |
| | FBBPP2 | 700 | 40 | 1 | 14 |
| | FBBPP3 | 700 | 40 | 1 | 21 |
| Adding Medium BBPP | MBBPP1 | 700 | 40 | 1 | 7 |
| | MBBPP2 | 700 | 40 | 1 | 14 |
| | MBBPP3 | 700 | 40 | 1 | 21 |

### Rheological and Filtration Measurements

The term "rheology" describes the properties of how drilling fluid flows and deforms when subjected to an external force. This property is typically explained by the apparent viscosity (AV), plastic viscosity (PV), yield point (YP), and gel strength. Rheology is a basic characteristic of drilling fluids that is crucial for assessing their effectiveness. Equations 1, 2, and 3 were used to determine apparent viscosity, yield point and plastic viscosity, respectively. In addition, the drilling fluid's filtration loss performance is determined by the quality of the mud cake that is formed and the volume of the filtered drilling fluid. In this study, the filtering loss performance of the drilling fluid with various BBPP particle sizes was evaluated under API conditions (100 psi and ambient temperature) using the API filtrate volume tester.

$$\mathrm{V} = \emptyset_{600} \mathrm{x}\ 0.5 \quad (1)$$
$$\mathrm{YP} = \emptyset_{300} - \mathrm{PV}\ (\mathrm{Ib}/100\ \mathrm{ft}^2) \quad (2)$$
$$\mathrm{PV} = \emptyset_{600} - \emptyset_{300}\ (\mathrm{cp}) \quad (3)$$

where the dial reading a 600 rpm is $\emptyset_{600}$, and the dial reading at 300 rpm is $\emptyset_{300}$.

## Results

The experimental readings for the reference mud and various BBPP concentrations and sizes are presented in detail in this section. Results included filter cake thickness, fluid loss, gel strength, plastic viscosity, pH and mud weight. Tables 2 show the experimental findings for the reference fluid (RF) and reference mud with a fine and medium size broad bean peel powder (FBBPP) (MBBPP).

**Table 2**. The effects of different FBBPP and MBBPP concentrations on the reference mud's properties

| Properties | RF | FBBPP | | | MBBPP | | |
|---|---|---|---|---|---|---|---|
| | | 1% | 2% | 3% | 1% | 2% | 3% |
| Density (ppg) | 8.6 | 8.6 | 8.5 | 8.25 | 8.8 | 8.7 | 7.8 |
| Apparent viscosity | 10 | 7.5 | 9 | 10.5 | 7.5 | 7.5 | 11 |
| Plastic Viscosity (cp) | 4 | 5 | 6 | 7 | 6 | 5 | 4 |
| Initial Gel Strength ($\mathrm{Ib/100ft^2}$) | 9.3 | 4.5 | 6.5 | 7 | 4 | 6 | 10 |
| Final Gel strength ($\mathrm{Ib/100ft^2}$) | 15 | 7.5 | 8 | 8.5 | 6 | 8 | 12 |
| Yield Point ($\mathrm{Ib/100ft^2}$) | 12 | 5 | 6 | 7 | 3 | 5 | 14 |
| Thickness of the Filter Cake (mm) | 1.75 | 1.5 | 1.25 | 1 | 1.75 | 1.5 | 1.25 |
| Filtration 7.5 min (cc) | 10 | 7.3 | 6.6 | 6.4 | 8.6 | 7.8 | 6.6 |
| Filtration 10 min (cc) | 11.6 | 8.5 | 8 | 7.5 | 10.1 | 9 | 7.8 |
| Filtration 30 min (cc) | 20.4 | 15.3 | 13.9 | 13.3 | 17.8 | 15.6 | 14 |
| pH | 11.33 | 7.91 | 7.11 | 7.85 | 10.21 | 9.15 | 6.9 |

# Discussion

## Effect of Adding BBPP on the Mud Weight

Figure 2 demonstrates that both FBBPP and MFBBPP had no effect on MW at 1% concentration, a negligible reduction of the mud weight (MW) at 2% concentration, and a moderate impact at 3% (21 g) concentrations on MW. The mud weight decreased due to the formation of foams in the mud rather than the BBPP on its own, and this issue was evident throughout laboratory testing. Anti-foam additives are suggested that can be used pre- or post-treatment to prevent or reduce the influence of foaming on MW.

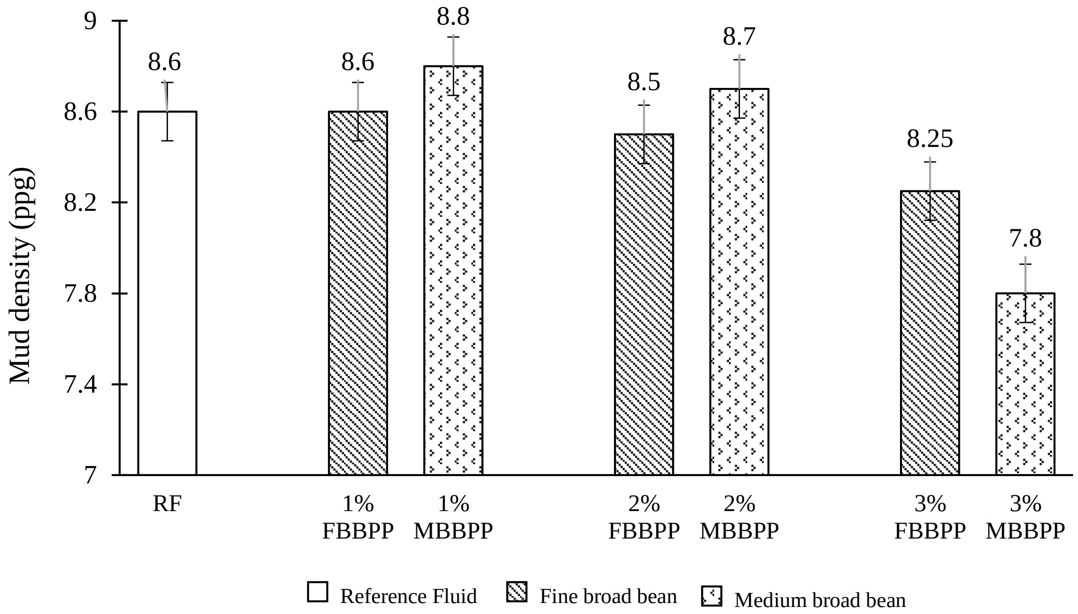


**Fig. 2**. FBBPP and MBBPP effects on the mud weight

## Effect of Adding FBBPP and MBBPP on Rheological Properties

The rheological characteristics of the drilling muds, including apparent viscosity (AV), yield point (YP), plastic viscosity (PV) final and initial gel strength, were assessed and are shown in Table 2. As concentration rises, apparent viscosity (AV) rises noticeably, as depicted in panel A of Figure 3. A certain range of apparent viscosity is needed for cuttings circulation. An appropriate viscosity range is necessary for cuttings circulation. When the shear rate is high, a low viscosity inside the pipe is required; however, cuttings uplift under low-shear conditions requires a slightly higher annulus viscosity. The experimental findings demonstrated that increasing the FBBPP and MBBPP additive concentrations increased plastic viscosity. When 1%, 2% and 3% of FBBPP additive was added to the reference mud, the plastic viscosity increased by 25% (4cp to 5cp), 50% (4cp to 6cp) and 75% (4cp to 7cp), respectively (Figure 3b). These results suggest that 1%, 2%, and 3% concentrations of the FBBPP can be used as viscosity modifiers during typical drilling operations. On the other hand, adding 1% and 2% of MBBPP additive to the drilling mud resulted in a modest increase in the plastic viscosity. However, the plastic viscosity was unaffected by the 3% concentration (Figure 3b). In terms of yield point, MBBPP and FBBPP had a significant impact on mud properties. Figure 3c demonstrates that the yield point decreased by 58%, 50%, and 42%, respectively, compared to the reference fluid, at concentrations of 1%, 2%, and 3% of FBBPP. In addition, when 1%, 2%, and 3% concentrations of MBBPP were added to the reference mud, the yield point was lowered by 75%, 58%, and 45%. Additionally, FBBPP and MBBPP provided excellent gel strength behaviour. The initial and final gel strengths differed by no more than 3 (Ib/100ft$^2$) (Figure 3d). This will help drilling operations since it won't be necessary to apply more pressure while changing from pump-off to pump-on situations.

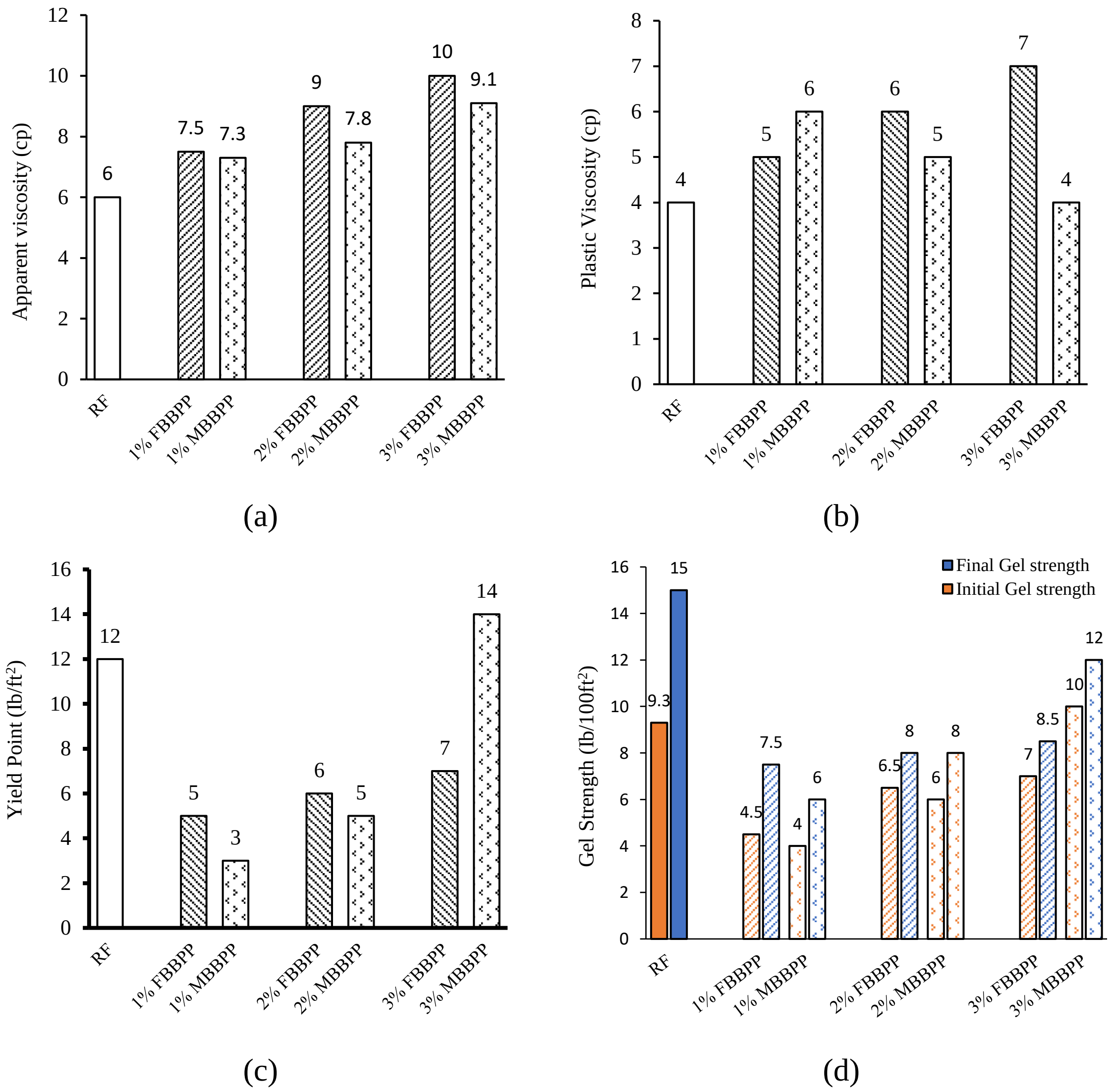


**Fig. 3**. FBBPP and MBBPP effects on rheological properties

## Effect of Adding FBBPP and MBBPP on the pH

Drilling fluid that is acidic (has a pH value below 7) typically pollutes the environment and corrodes drilling equipment. Therefore, it is crucial for engineers to control the pH level of a drilling fluid. In high alkaline mud, pH reducers are often added, and pH enhancers are added to acidic mud to control pH. From an environmentally point of view, it is deemed more convenient if the same result can be obtained using an organic additive.

Figure 4 shows the impact of FBBPP and MBBPP additives on the alkalinity of the reference mud. According to the laboratory results, both sizes of BBPP decreased the alkalinity compared to the reference fluid, with pH being reduced by 30%, 37%, and 31% at 1%, 2%, and 3%

concentrations of FBBPP, respectively. However, concerning the reference fluid, MBBPP concentrations of 1%, 2%, and 3% reduced pH by 10%, 19%, and 39%, respectively. Thus, both BBPP sizes can be utilised as a pH reducer, mainly at elevated concentrations.

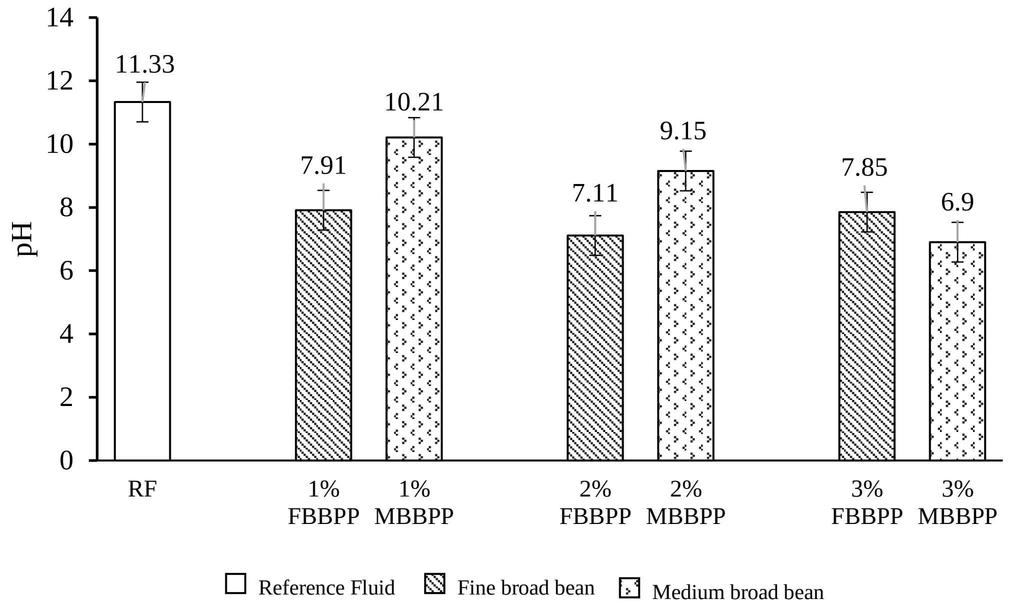


**Fig. 4**. FBBPP and MBBPP effects on the alkalinity

## Effect of Adding FBBPP and MBBPP on the Filtration Characteristics

A typical API filter press was used to measure fluid filtration loss at 100 psi to assess the effectiveness of FBBPP and MBBPP as eco-friendly filtration chemical control. A significant improvement was seen after measuring the fluid loss at 7.5 and 30 minutes. Additionally, compared to the reference fluid, adding BBPP produced a thin and impermeable mud layer; nevertheless, FBBPP was noticeably more effective than the reference fluid and MBBPP in reducing mud cake thickness. According to Figure 5, at the concentrations of 1%, 2%, and 3% of FBBPP, the mud filtrate volume (30 min) was reduced by 25%, 32%, and 35%, respectively, as compared to the reference fluid. While the filtrate volume (30 min) was decreased by 13%, 24%, and 31%, respectively, by adding MBBPP at concentrations of 1%, 2%, and 3%.

For the mud cake thickness, the experiment's results demonstrated that FBBPP was more effective than MBBPP in producing a thin, impermeable filter cake. Figure 6 demonstrates that adding a 3% concentration of FBBPP resulted in a 43% (1.75 to 1.0 cc) reduction in filter cake thickness compared to the reference mud.

It is crucial to note that the dried broad bean peels were ground in a simple food processor. As is well known, finer particles effectively reduce filtration loss. As a result, controlling the filtering would be easier if a more powerful grinder was used to grind broad bean peels.

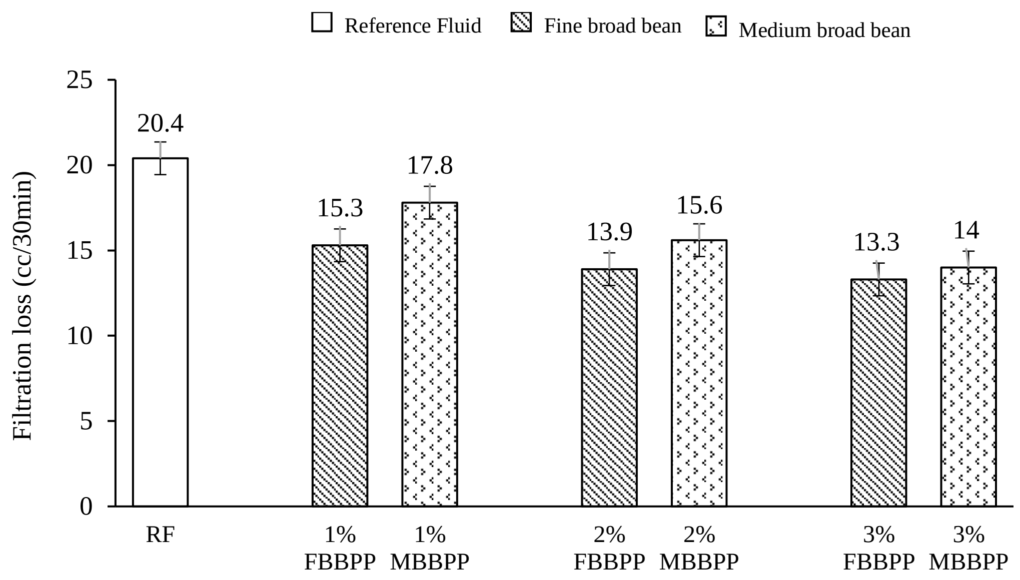


**Fig. 5**. The effect of FBBPP and MBBPP on the filtration loss

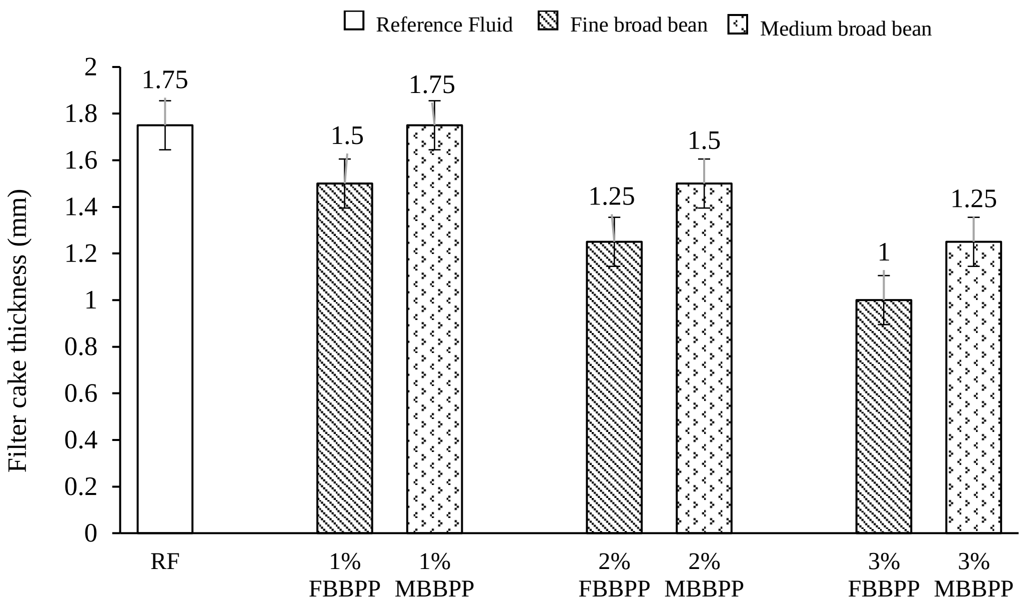


**Fig. 6**. The effect of FBBPP and MBBPP on the filter cake thickness

## Economic Value

The policy of drilling mud was changed in recent years, drilling mud is no longer a choice by only considering the mud performance, but additional factors such as borehole design, environmental impact, costs, rock strength, and formation damage are also significant in the selection of drilling mud. However, it might seem like a simple operation; using drilling fluid to complete a well involves careful technical and economic planning, making the process more complicated. According to Al-Hameedi et al. [16], the costs for drilling mud might range from one million dollars to nearly half a million dollars. Additionally, 8.2% of greenhouse gas emissions come from food waste and loss products [17]; however, these materials can be used better, like additives in drilling fluid. Furthermore, the consequences on health, safety, and the environment must also be considered while handling drilling fluid additives. Employees must wear personal protective equipment (PPE) when handling drilling fluid to prevent health and safety issues. Hence, this study aims to provide new substitutes or supporting materials for drilling fluid additives. Waste foods are generally accessible and offered everywhere. Therefore, they make great candidates for more study. The cost of accumulating and processing food waste is significantly lower than the cost of conventional chemical additives [16].

## Conclusions

This study examined the effect of adding BBP at different concentrations on the characteristics of drilling fluid. Different results were obtained from the measurements of the alkalinity, rheological properties, filtration characteristics, and weight of the drilling mud. The major findings are presented as follows:

- The development of mud foams made it so that the weight of the mud was only a little affected by the addition of BBPP. Anti-foam additives are suggested that can be used pre- or post-treatment to prevent or reduce the influence of foaming on MW.
- Plastic viscosity and yield point were improved by adding more FBBPP and MBBPP additives. Thus, BBPP demonstrated its ability to be used as a viscosity modifier during normal drilling operations. Excellent gel strength behaviour was also seen. Because the initial and final gel strengths did not differ by more than 3 (Ib/100ft$^2$).
- The laboratory results for the BBPP additive indicate that it can be used as a pH reducer, particularly when drilling through cement, because it may effectively precipitate the calcium content and lower the pH.
- The potential for BBPP to be applied as a fluid loss control agent was demonstrated by the fact that it significantly enhanced the filtering properties, especially at a 3% concentration of FBBPP, by decreasing mud cake thickness and fluid loss.

## Nomenclature

| | |
|---|---|
| API | American Petroleum Institute |
| BBPP | Broad bean peels powder |
| BPP | Banana Peels Powder |
| FBBPP | Fine Broad bean peels powder |
| FFWM | Fibrous Food Waste Material |
| GP | Grass Powder |
| MBBPP | Medium Broad bean peels powder |
| MW | Mud Weight |
| NaOH | Sodium Hydroxide |
| Ø 300 | Dial Reading at 300 rpm |
| Ø 600 | Dial Reading at 600 rpm |
| pH | Potential of Hydrogen |
| ppb | Pound per barrel |
| PPP | Potato Peels powder |
| PV | Plastic Viscosity |
| RF | Reference Fluid |
| WBM | Water based mud |
| YP | Yield Point |

## Declaration of Interests

The authors state that they have no known competing financial interests or personal relationships that could have influenced the research presented in this paper.

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