International Journal of Petroleum Technology, 2025, 52-62

Published by Avanti Publishers

International Journal of Petroleum Technology

ISSN (online): 2409-787X

Formulation of a Water-Based Drilling Fluid with Natural Aloe Vera Additive for Enhancing Filtration Properties

Md. Siam Al-Mukit[1], Ahmed Elghoul[2], Mohammad Islam Miah[1,3,*] and Travis Wiens[3]

[1]Department of Petroleum and Mining Engineering, Chittagong University of Engineering & Technology, Chattogram 4349, Bangladesh

[2]Division of Economics and Business, Colorado School of Mines, Golden, CO 80401, United States

[3]Department of Mechanical Engineering, University of Saskatchewan, Saskatoon, S7N 5A9, Canada

ARTICLE INFO

Article Type: Research Article

Academic Editor: Meichun Li

Keywords:
Aloe Vera
Drilling fluid
Natural additive
Filtration properties

Timeline:
Received: July 10, 2025
Accepted: September 25, 2025
Published: October 21, 2025

Citation: Al-Mukit MS, Elghoul A, Miah MI, Wiens T. Formulation of a water-based drilling fluid with natural Aloe Vera additive for enhancing filtration properties. Int J Pet Technol. 2025; 12: 33-62.

DOI: https://doi.org/10.15377/2409-787X.2025.12.3

ABSTRACT

The search for natural additives to improve the performance of water-based drilling fluids (WBDF) has been fueled by the growing need for environmentally friendly and sustainable drilling processes. The objective of this study is to examine the potential utilization of Aloe Vera (AV) powder as a natural additive in WBDF through an experimental analysis of filtration properties. All experimental studies adhered to the American Petroleum Institute (API) standard procedure in order to accomplish the objectives mentioned above. In this experiment, a mixture of water phase volume of (350 ml) and chemical components like xanthan gum (0.8 gm), sodium hydroxide (0.8 gm), bentonite (13 gm), and barite (18 gm) were used to prepare base mud. Samples 1, 2, and 3 are created using 0.25%, 0.5%, and 0.75% weight of aloe vera powder (size less than 150 μm) in relation to water volume, while sample 4 was created using 0.5% weight of aloe vera powder (size less than 212 μm) in relation to water volume. The standard cell is used in the low-pressure mud filtration test, which was conducted for 30 minutes at room temperature with an API condition of 100 psi. Based on the laboratory analysis, this study suggests that AV powder has the potential to be an environmentally beneficial additive for usage in specialized drilling environments rather than generalized drilling operations. Specially, the 0.5% concentration of AV powder with particle size less than 150 μm demonstrated improved fluid loss management for water-based drilling fluid. This study offers a comprehensive evaluation of its influence on the fluid's behavior, with a focus on the drilling fluid's filtration performance. The outcome of the experiment indicates that WBDF containing aloe vera is an economical and environmentally beneficial additive for reducing filtration loss and preventing significant fluid loss during drilling operations.

---

*Corresponding Author

Email: islam.m@cuet.ac.bd
Tel: +(1) 306-491-7045

1. Introduction

Drilling fluid (DF), also called mud fluid, is an extraordinarily formed liquid fundamental for subsurface boreholes in oil and gas wells. This liquid carries out various basic roles that allow for effective and safe drilling activities. It transports rock cuttings from the bore to the surface, guarantees a clean wellbore. It stabilizes the wellbore walls, preventing collapse and maintaining structural integrity. It also helps manage pressure levels, maintaining density balance and preventing issues like piping collapses and other pressure-related induced problems. It cools and lubricates the bore and drilling assembly, lessening erosion and wear, which improves the life span of the hardware. Moreover, the fluid forms a cake on the wellbore walls, reducing fluid intrusion into the formation and protecting the reservoir. It also transmits data from downhole measuring tools to the surface, aiding in real-time decision-making [1-3].

The design of DF is critical to economically achieving the required rheological and filtration properties. For the fluid used for drilling to function effectively, thin mud cakes and lower fluid loss to the formation are required. In the petroleum and gas industry, unnecessary additional fluid loss throughout drilling operations has become a significant issue. This issue can be fixed by applying a thin layer of low-permeable mud cake to the borehole wall using the appropriate DF. In the event that the mud cake is highly permeable, there will be a considerable loss of fluid from the formation. Therefore, it is crucial to design and prepare a DF in a way that reduces the volume of fluid loss when drilling. In order to prevent excessive fluid loss, certain chemical additives are used as filtration loss controllers, including bentonite, carboxymethyl cellulose, low viscosity polyanionic cellulose, and starch [4]. Furthermore, at the laboratory scale, nanoparticles [5] and cellulose nanomaterials [6] have already demonstrated their potential for regulating fluid loss.

The majority of the twenty-first-century oil and gas industries are concerned with sustainable technologies. In order to lessen the impact of hazardous chemicals on the environment and the cost of DF, the drilling industry has introduced organic additives. Several studies have also recommended that certain locally available agro-waste materials can be substituted as beneficial additives in the creation of DF that provide results that are either better or on par with those of their toxic and chemical counterparts [7, 8]. Based on the literature survey, a list of some selective studies on eco-friendly DF additives are explained as follows:

Pistachio shell powder (PSP) was used in a novel field-applicable DF formula that Davoodi *et al*. [9] successfully applied to an Iranian oil field. The primary reason for concern was the replacement of polyanionic cellulose polymer with pistachio shell in two distinct fine sizes of particles. The comparatively small particle size (less than 75 microns) produced thin and fine mud cakes and showed its extreme usefulness as a filtration loss control additive by reducing fluid loss up to 44%. Furthermore, the PSP mud showed excellent rheological properties, and the cost analysis indicated that DF made with PSP is 13% less expensive.

It was determined whether grass powder (GP) could be used to enhance fluid qualities [10], and the results were compared with those obtained using conventional starch. To evaluate the experimental findings of the mud samples performed with 0.5%, 1%, and 1.5% GP, exactly the same starch quantities were used. The authors concluded that starch more effectively improved rheological qualities at all concentrations than GP. For instance, it was more successful than starch as a filter loss control additive. It also found that mud weight was unaffected by GP or starch.

As a potential prospect of environmentally friendly drilling fluid additive, Mandarin peel powder (MPP) was utilized to improve the performance to enhance drilling fluid properties [11]. The experimental findings of their studies, it was demonstrated that MPP decreased the DF alkalinity by 20–32% while improving the fluid's rheological characteristics, such as plastic viscosity (PV), yield point (YP), and gel strength (GS). Al-Hameedi *et al*. [12] found that the maximum concentration of MPP was 4% by water volume; however, in their investigation, the maximum tested concentration was 2% MPP. They concluded that concentrations greater than 2% led to a notable gelation of the DF, which inhibited mixing. Additionally, they suggested that the ideal ratio of powdered mandarin peel to water volume should not exceed 1.5%. A follow-up experimental study on MPP aimed to ascertain whether the size of the MPP particles affected DF's properties [13]. They came to the conclusion that better results in enhancing fluid properties were shown by smaller particle sizes. Bagum *et al*. [14] attempted an investigation to assess the performance of aloe vera gel as a drilling fluid additive. They claimed that this additive is environmentally friendly for water-based drilling fluid preparation.

Furthermore, Shuvo *et al*. [15] investigated the performance of sawdust (SW) additives to make water-based drilling fluid (WBDF). Based on their experimental studies, it was found that SW improves the DF filtration properties by reducing fluid loss and mud cake thickness while increasing the fluid's rheological characteristics, such as PV, YP, and GS. They concluded that 0.5% concentration of SW exhibited the optimum performances in laboratory tests. Also, Fato and Rahmani [16] listed different additives-based drilling fluid formulation to control the fluid density, filtration properties and rheological properties for sustainable drilling operations. They claimed that biodegradable waste additives are most cost effective and eco-friendly to improve the drilling fluid properties of oil and water-based drilling operations. Notably, Khan *et al*. [17] comprehensively reviewed and summarized the performance of cellulose additives in WBDFs for rheological modifiers, fluid loss reducers, and shale inhibitors as environmentally friendly additives. Moreover, Khan *et al*. [18] investigated the effects of high temperature and salt content into rheological and filtration properties of WBDFs. It is concluded that tempo-mediated oxidized cellulose nanofiber (CNF)-based mud exhibited better resistance to salt contamination compared to hot rolling, whereas mechanically disintegrated-CNF or bentonite (BT)-WBDFs performed more robust against hot rolling than salt contamination. Recently, Khan *et al*. [19] performed an experimental study at HPHT environments to enhance the filtration performance with additives of CNF-WBDF and BT-WBDF. Based on the mechanistic findings, it is concluded that maintaining the uniform dispersion of BT- and CNFs is critical for reducing fluid loss, with amalgamation of acrylamide, 2-acrylamide-2-methylpropane sulfonic acid, and dimethyl diallyl ammonium chloride revealing proficiency to preserve colloidal stability.

However, due to the growing tendency by different scholars to develop drilling fluid with different additives, Aloe vera (AV) is one of the additives for drilling fluid preparation which can be found from the local area. In this study, AV powder is used as natural additive that could take the place of chemical additives to reduce drilling costs while also minimizing adverse environmental effects. The major objective of this study is to examine the potential utilization of AV powder as a natural additive in WBDF through an experimental analysis of mud filtration properties.

2. Materials and Methods

The definition of eco-friendly additives includes the characteristics of being natural, biodegradable or non-toxic. These additives are used to improve the operational performance without harming the environment. Aloe vera (AV) is a plant-based additive that is safe, organic, and biodegradable that is well-known for its gel-filled leaves. As it has gel formation ability it could be a potential additive for WBDF for reducing fluid loss as well as improving rheological properties and that’s why AV has been selected for investigation in this study as a natural additive. The working procedures followed in this study are presented in Fig. (**1**).

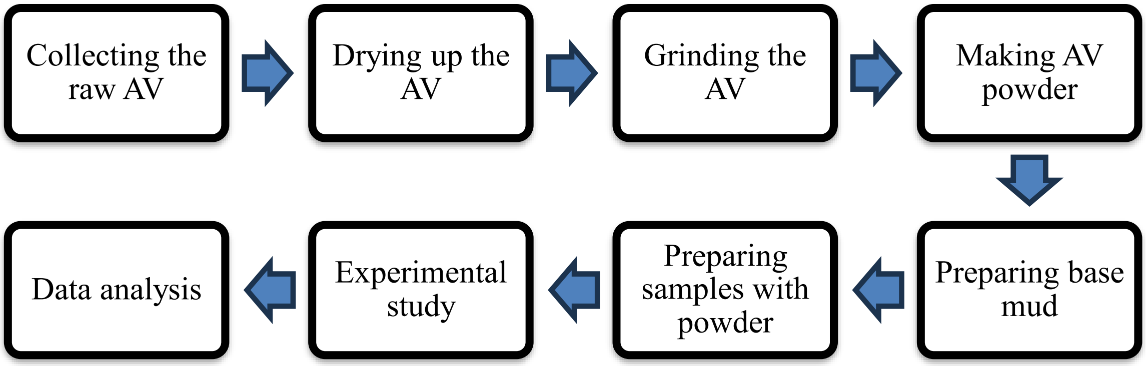

Figure 1: Working steps for sample preparation to conduct experimental study.

2.1. Raw Material Collection

Aloe vera, a natural plant as a drilling fluid additive is utilized in this study to accomplish the research objective. It may be grown indoors in pots in tropical regions all over the world. For this study, AV is procured from a nearby nursery. We picked AV leaves that were mature and healthy and avoided any leaves that exhibit damage or disease in any way. Collected raw AV leaves are shown in Fig. (**2**).

Figure 2: Collected Aloe vera for sample preparation.

2.2. Drying the Sample

To dry Aloe vera, we must take the moisture out of the gel in order to turn it into a powder. Steps to dry AV are given below:

i. Using a sharp knife carefully peel away the green outer skin of the AV leaves so that clear gel can be seen. The yellow sap (aloin), which was right under the skin, should be avoided because it could cause irritation to skin. Also, take care not to make too deep of a cut.

ii. The gel was taken out of the stems using a metal spoon or other blunt appliance and thoroughly rinsed with running water to get rid of any dirt or debris. Then the gels were collected in a clean pot as shown in Fig. (**3a**).

iii. To give the powder a smoother texture, the extracted gels were blended in a food processor until it forms a smooth paste.

iv. We spread the gel onto a clean, non-stick surface, such as parchment paper or a dehydrator tray. To achieve even drying, the gel layer should be thin and evenly distributed. It is shown on Fig. (**3b**).

v. The tray was kept in a well-ventilated area at room temperature, away from the sun to maintain a homogeneous drying of the paste. It took 60 hours to dry fully, and the gel paste turned brittle (Fig. **3c**). There was no gummy or gel-like structure anymore. Dried AV gel is preserved in an air tight container before further processing.

vi. Finally, produce a powder from the dried aloe vera gel using a ball mill and mortar and pestle. The prepared AV powder and mortar and pestle are shown in Fig. (**3d**) to obtain aloe vera powder (Fig. **3e**).

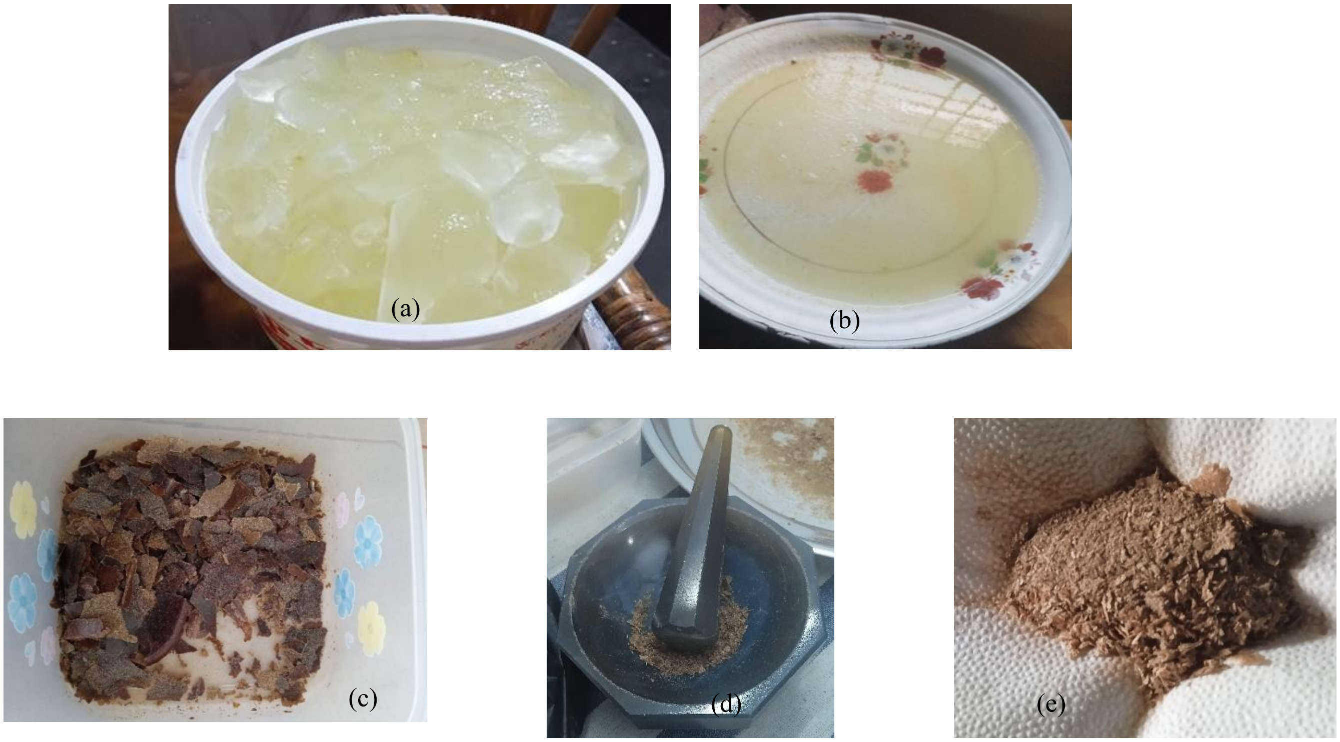

Figure 3: Powder preparation from raw AV: **a**) extracted AV gel, **b**) blended gel, **c**) dried gel, **d**) mortar and pestle for power making, and **e**) AV powder.

2.3. Formulation of Drilling Fluid

Barite, bentonite, xanthan gum, and sodium hydroxide are combined with water to create base mud, shown in Fig. (**4**). A bottom mixer cup and a standard Hamilton Beach commercial high-speed mixer were used to mix the ingredients. While the impeller was mixing, 350 milliliters of clean water were gradually mixed with each solid additive, which was first weighed using an electronic balance. To avoid spilling the fluid, each sample was mixed carefully for ten minutes.

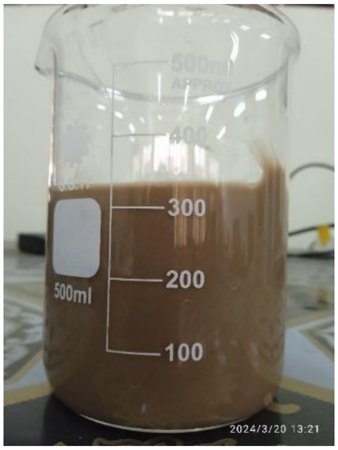

Figure 4: Formulated bas mud with different ingredients for the study.

Table **1** lists the functions of the reagents along with their mixing order. After the base mud was leveled, three fluid samples were made by adding aloe vera (AV) powder with a particle size of less than 150 μm at concentrations of 0.25%, 0.5%, and 0.75%, respectively. The names Sample-1 (S-1), Sample-2 (S-2), and Sample-3

(S-3) refer to these samples. AV powder with a particle size of less than 212 μm and a concentration of 0.5% is used to prepare Sample-4 (S-4). Prepared samples are listed below for the function of fluid loss control (FLC):

- S-1: BM + 0.25% weight of AV powder (< 150 μm) in water volume
- S-2: BM + 0.5% weight of AV powder (< 150 μm) in water volume
- S-3: BM + 0.75% weight of AV powder (< 150 μm) in water volume
- S-4: BM + 0.5% weight of AV powder (< 212 μm) in water volume

Table 1: Preparation of base mud and different samples.

Ingredient	Quantity	Mixing Order	Mixing Time	Functions of the Materials
Fresh Water	350 ml	---	---	Base fluid
Bentonite	13 gm	1	10	Viscosity
Barite	18 gm	2	10	Weighting agent
Xantham Gum	0.8 gm	3	10	Rheology control
NaOH	0.8 gm	4	10	p^H control
S-1	0.875 gm (0.25%)	5	10	FLC
S-2	1.75 gm (0.5%)	5	10	FLC
S-3	2.625 gm (0.75%)	5	10	FLC
S-4	1.75 gm (0.5%)	5	10	FLC

2.4. Laboratory Measurement

Laboratory tests were performed on each drilling fluid (DF) sample to evaluate its mud filtration properties and the findings of the tests were recorded. Each laboratory measurement was completed in accordance with the guidelines provided in “API Recommended Practice 13B-1”, a handbook for the field analysis of water-based drilling fluids [1]. The numerous filtration qualities of the mud samples were estimated using the OFI testing equipment (OFITE) API low-temperature low-pressure filter press. At ambient temperature and 689.5 kPa pressure, the DF sample's filtration characteristics were measured. After that, any extra fluid that wasn't a part of the mud cake was carefully removed from the mud cake by carefully washing it with the base fluid (water). A millimeter scale was dipped into the mud cake to measure its thickness before the cakes dried. Their textures were also examined physically. The mud cakes utilized in this study were examined right away after any excess fluids that weren't required for the cakes to form were removed, and this was done prior to the cakes' thickness being measured. Mud cakes are essential to coring operations because they reduce the chance of formation damage, preserve core integrity during retrieval, maintain wellbore stability, manage filtration, and provide data for assessing the formation. Notably, rotational viscometer is used to determine the viscosity of the base mud and the samples which are examined in the experiment at 6-600 rpm, consequently.

3. Results and Discussions

The filtration data for a base mud and four distinct samples (S-1, S-2, S-3 and S-4) over a given time (measured in minutes) for filtrate volume is listed in Table **2**. Understanding the fluid loss characteristics of drilling fluid (DF) is crucial for preserving wellbore stability and reducing formation damage, and filtration data plays a key role in this process.

Table 2: Obtained filtration data from the experiment.

Time (min)	Base mud (ml)	Sample-1 (ml)	Sample-2 (ml)	Sample-3 (ml)	Sample-4 (ml)
0	0	0	0	0	0
2	4	4.7	4	4.9	4.7
4	6	6	5.5	6.5	6
6	7	7	6.5	7.9	7
7.5	8	8	7.2	8.4	8
10	9	9	8.1	9.5	9
12	10	10	9	10.3	10
14	10.7	10.9	9.9	11	10.9
16	11.4	11.5	10.5	11.9	11.5
18	12	12	11	12.4	12.1
20	12.5	12.7	11.6	13	12.7
22	13	13.2	12.1	13.5	13.2
24	13.6	13.7	12.5	14	13.7
26	14.1	14.2	13	14.5	14.4
28	14.8	15	13.5	15	15
30	15.1	15.5	13.9	15.5	15.5

By minimizing fluid loss and preserving wellbore stability, an understanding of these filtration properties aids in the selection of the proper DF for a given set of circumstances, ensuring drilling operations are efficient and stable.

Aloe vera powder was tested as a potential filtration control additive by measuring the filtrate volume at 100 psi using a standard API filter press. Based on the tabulated results in Table **2**, the amount of fluid lost is greatly reduced by adding AV powder. The sample 2 concentration for both 7.5 and 30 minutes showed the lowest filtration loss compared to other samples. Reduced filtrate volume indicates a useful filtration property because it prevents formation damage and borehole instability. Data on filtration loss at various time intervals for a base mud (BM) and four distinct samples (S-1, S-2, S-3 and S-4) are shown in Fig. (**5**).

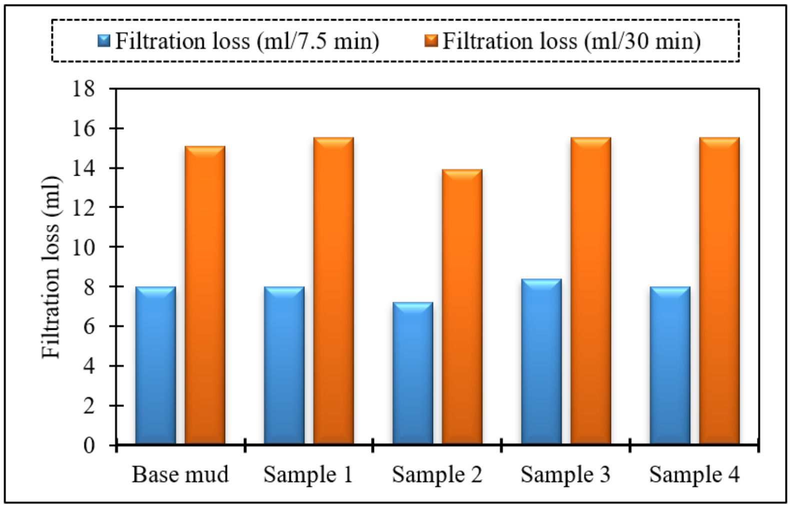

Figure 5: A graphic representation of filtration properties of the studied mud samples.

These characteristics are essential for assessing how well drilling fluid performs in terms of controlling fluid loss and mud cake formation on the wellbore wall. Sample 2 exhibits superior long-term fluid loss control, as evidenced by its consistently lowest filtration loss of 13.9 ml. Similar higher filtration losses of 15.5 ml are seen in Samples 1, 3, and 4, indicating less successful long-term fluid loss control than in Sample 2. Out of all the samples, Sample 2 exhibits the best fluid loss control, as evidenced by its lowest filtration loss at both 7.5 minutes and 30 minutes. Sample 3 has the highest initial loss and all three have comparable long-term losses. Samples 1, 3, and 4 exhibit higher filtration losses.

In order to prevent problems with drilling and completion, the build-up characteristics and quality of the mud cake are essential. The addition of AV increased the thickness of the mud cake for all concentrations studied. Mud samples containing AV produced a thicker mud cake than base mud (BM). The volume of water preserved in the mixture and the percentage of solids in the mud determine the overall thickness of the mud cake; this thickness is assumed to correspond to filter loss. The cake volume increases, and the filter loss decreases as the concentration of solids increases [20]. The mud cake thicknesses of four distinct samples (S-1, S-2, S-3 and S-4) and a BM are shown in Fig. (**6**).

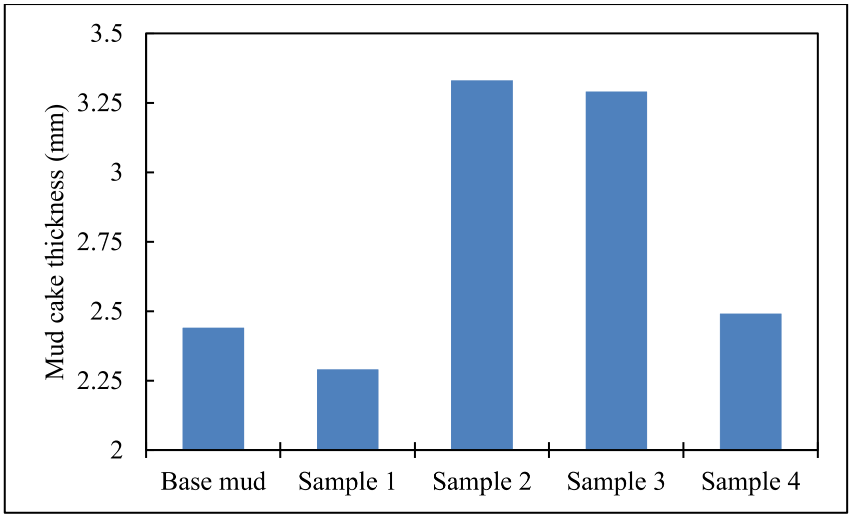

Figure 6: A comparison of the thickness of the mud cake for different samples.

At 2.29 mm, Sample 1 has the thinnest mud cake, indicating less solid deposition but possibly less effective sealing. The thickest mud cakes are found in Samples 2 and 3, measuring 3.33 mm and 3.29 mm, respectively. This may indicate increased solid depositing, which could result in improved sealing as well as other issues like differential sticking. The moderate mud cake thicknesses of Sample 4 and BM are 2.46 mm and 2.44 mm, respectively. The thickest mud cakes are formed by samples 2 and 3, which may improve sealing but also increase the possibility of issues like differential sticking. Sample 1 creates the thinnest mud cake, which is perhaps less successful in sealing the wellbore but simpler to remove and move the drill bit through. The likelihood of pipe sticking, inadequate well-log data, formation damage, lost circulation through fines, and filtrate invasion into the permeable zone is increased by thick mud cakes and excessive filtration loss [21]. As AV powder containing mud samples developed thick mud cakes compared to base mud, it could be problematic. In that case, finer particles of AV powder may reduce the thickness of mud cakes. Notably, as a scope of future study, comprehensive study is required related to the balance between improved filtration and thicker mud cakes scenarios with high-pressure environments for sustainable drilling operations.

It is noteworthy that the plastic viscosity (cp) is 4.5, 7, 8, 4 and 3 for S-1, S-2, S-3, S-4 and Base mud, while the yield point ($lb_f/100\ ft^2$) is 65, 66, 71, 83.5 and 78, respectively. These rheological characteristics are essential for comprehending how drilling fluid (DF) behaves in various scenarios. Because the base mud has the lowest plastic viscosity, shear stress can be applied to it more easily. Sample 3 exhibits the highest plastic viscosity, indicating a higher flow resistance. This could be advantageous in specific drilling conditions where thicker fluids are required. The moderate plastic viscosities of both samples make them appropriate for striking a balance between carrying capacity and flowability. Sample 4 is a good choice for difficult drilling conditions because of its high yield point, which shows that it is very effective at suspending and transporting solids. Compared to other samples, Sample 1 may be less effective at transporting solids due to its lower yield point. These offer an excellent compromise between robust suspension and fluidity thanks to their comparable yield points. To maximize performance, various samples can be chosen based on the requirements of the drilling operation (e.g., higher or lower viscosity, solid carrying capacity). Sample 4 might be the best choice for operations that need a strong, solid suspension because of its moderate plastic viscosity and high yield point. Sample 1 might work well in less demanding circumstances because of its moderate viscosity and lower yield point. Knowing these characteristics makes it easier to choose the right DF for the job, ensuring stability, effectiveness, and little formation damage.

4. Significance and Limitation of the Study

This study holds significant importance in the field of drilling fluid (DF) technology and environmental sustainability within the petroleum industry. It's significance can be outlined in the following ways:

- Advancing eco-friendly drilling practices: The research investigates the use of eco-friendly natural additives in water-based drilling fluid (WBDF). By demonstrating their potential to enhance DF performance, the study contributes to the advancement of eco-friendly drilling practices. This aligns with the industry’s growing emphasis on minimizing environmental impact and adopting sustainable approaches.
- Environmental responsibility: The importance of environmentally friendly DF formulations is becoming more and more evident as the world turns its attention to environmental conservation. The study discusses the pressing need to lessen drilling operations' negative environmental effects in order to encourage ethical resource extraction.
- Sustainable resource utilization: The use of natural additives derived from renewable resources represents a shift towards sustainable resource utilization. By exploring the viability of such additives, the study encourages the industry to embrace environmentally responsible practices that can be sustained in the long term.
- Enhanced drilling fluid performance: The investigation into the effect of the natural additive on the rheological and filtration properties of WBDF can lead to improves fluid performance. Drilling operations can be made more efficient and successful overall by improving filtration control, and strengthening wellbore stability.
- Practical application: The study findings hold practical implications for drilling engineers and operators. The insights gained from the experimental investigation can guide the formulation of drilling fluids, facilitating the adoption of eco-friendly additives in real-world drilling scenarios.
- Industry relevance: Given the importance of drilling fluid in drilling operations, the study holds direct relevance to the petroleum industry. The research addresses a current and pressing need, making it valuable to companies and professionals seeking sustainable drilling solutions.

As a future study scope, the effect of common contaminants such as salts and clays on the AV found in drilling environments, such as salts or clays, on the performance of AV powder could be investigated by scholars. Notably, a comprehensive study is required related to the balance between improved filtration and thicker mud cakes scenarios with high-pressure environments. Considering this study outcome, additional research can be conducted to enhance mud quality and other aspects. These are included below:

- Because the study was carried out in carefully regulated lab environments, real drilling operations might not have been perfectly replicated.
- Because the results are unique to the tested aloe vera concentrations and drilling mud formulation, they are not applicable in other situations.
- The study focused on immediate effects rather than carefully examining long-term performance or durability; contaminants commonly found in geological formations were not specifically examined.

5. Conclusions

This study tried to evaluate the applicability of Aloe vera (AV) powder as a biodegradable additive in WBDF. To assess the efficacy of AV powder, API recommended laboratory tests were conducted where rheological and filtration properties were investigated. The key findings of our study are:

- AV powder containing mud samples could be advantageous in specific drilling conditions where thicker fluids are required to suspend and transport solids.
- Sample 2 (0.5% AV powder) exhibits superior long-term fluid loss control compared to other samples as evidenced by its consistently lowest filtration loss of 13.9 ml.
- For the same concentration of AV powder, comparably finer particles of AV powder showed greater filtration control.
- In case of mud cake thickness, AV powder containing mud samples developed slightly thicker mud cakes compared to base mud.

Based on these experimental findings, this study concludes that AV powder can be a potential environment-friendly additive to be used in specific drilling conditions rather than generalize drilling operations. Specifically, 0.5% concentration of AV powder with particle size less than 150 μm showed better performance in fluid loss control as well as maintaining a balanced rheological characteristic.

The stability of the suggested mud formulation in the presence of possible contaminants such as anhydrite, calcium, magnesium, salts, and clays that are frequently present in geological formations needs to be further investigation. In addition, AV powder particle size less than 100 μm should be examined for improving filtration properties. Furthermore, by considering the effect of wall slip on the rheometer, future research can investigate wall slippage's effect on yield strength and measured viscosity at reduced shear rates as well as rheological properties at HPHT. These additional studies will enable a deeper understanding of the AV powder system and the recommended water-based drilling fluid, as well as potential industrial applications. In addition, scholars could attempt to assess the effects of AV power mixtures with additives of bentonite or carboxymethyl cellulose for sustainable WBDF. Also, there is a scope to provide a deeper insight into its effectiveness by performing a comprehensive evaluation of AV gel versus power.

Conflict of Interest

The authors declare that they have no known competing financial interests that could have appeared to influence the work reported in this paper.

Funding

The study received no financial support.

Acknowledgement

The authors would like to acknowledge the personals who supported to accomplish this experimental study at the ‘Drilling Fluid Analysis Laboratory’ of the Petroleum and Mining Engineering Department, Chittagong University of Engineering & Technology, Bangladesh.

References

[1] Bourgoyne AT, Millheim KK, Chenevert ME, Young FS. Applied drilling engineering. Vol. 2. Richardson: Society of Petroleum Engineers; 1986. p. 514. https://doi.org/10.2118/9781555630010

[2] Encyclopaedia Britannica, Editors. Drilling mud. Encyclopedia Britannica. 2017 Jun 6 [cited 2025 Oct 2]. Available from: https://www.britannica.com/technology/drilling-mud

[3] Bridges S, Robinson L. A practical handbook for drilling fluids processing. Houston: Gulf Professional Publishing; 2020. https://doi.org/10.1016/B978-0-12-821341-4.00011-7

[4] Shakib JT, Kanani V, Pourafshary P. Nano-clays as additives for controlling filtration properties of water-bentonite suspensions. J Petrol Sci Eng. 2016; 138: 257-64. https://doi.org/10.1016/j.petrol.2015.11.018

[5] Bayat AE, Moghanloo PJ, Piroozian A, Rafati R. Experimental investigation of rheological and filtration properties of water-based drilling fluids in presence of various nanoparticles. Colloids Surf A Physicochem Eng Asp. 2018; 555: 256-63. https://doi.org/10.1016/j.colsurfa.2018.07.001

[6] Zhou G, Qiu Z, Zhong H, Zhao X, Kong X. Study of environmentally friendly wild jujube pit powder as a water-based drilling fluid additive. ACS Omega. 2021; 6(2): 1436-44. https://doi.org/10.1021/acsomega.0c05108

[7] Agwu OE, Akpabio JU. Using agro-waste materials as possible filter loss control agents in drilling muds: A review. J Petrol Sci Eng. 2018; 163: 185-98. https://doi.org/10.1016/j.petrol.2018.01.009

[8] Agwu OE, Akpabio JU, Archibong GW. Rice husk and saw dust as filter loss control agents for water-based muds. Heliyon. 2019; 5(7): e02038. https://doi.org/10.1016/j.heliyon.2019.e02059

[9] Davoodi S, Abdi RS, Jamshidi S, Jahromi AF. A novel field applicable mud formula with enhanced fluid loss properties in high pressure-high temperature well condition containing pistachio shell powder. J Petrol Sci Eng. 2018; 162: 378-85. https://doi.org/10.1016/j.petrol.2017.12.059

[10] Al-Hameedi ATT, Alkinani HH, Dunn-Norman S, Al-Alwani MA, Alshammari AF, Albazzaz HW, *et al*. Insights into the application of new eco-friendly drilling fluid additive to improve the fluid properties in water-based drilling fluid systems. J Petrol Sci Eng. 2019; 183: 106424. https://doi.org/10.1016/j.petrol.2019.106424

[11] Al-Hameedi ATT, Alkinani HH, Dunn-Norman S, Al-Alwani MA, Alkhamis MM, Alshammari AF, *et al*. Experimental investigation of environmentally friendly drilling fluid additives (mandarin peels powder) to substitute the conventional chemicals used in water-based drilling fluid. J Petrol Explor Prod Technol. 2020; 10: 407-17. https://doi.org/10.1007/s13202-019-0725-7

[12] Al-Hameedi ATT, Alkinani HH, Dunn-Norman S, Al-Alwani MA, Al-Bazzaz WH, Alshammari AF, *et al*. Experimental investigation of bio-enhancer drilling fluid additive: Can palm tree leaves be utilized as a supportive eco-friendly additive in water-based drilling fluid system? J Petrol Explor Prod Technol. 2020; 10: 595-603. https://doi.org/10.1007/s13202-019-00766-7

[13] Medved I, Gaurina-Međimurec N, Novak Mavar K, Mijić P. Waste mandarin peel as an eco-friendly water-based drilling fluid additive. Energies. 2022; 15(7): 2591. https://doi.org/10.3390/en15072591

[14] Bagum M, Ahammad JM, Husain T, Hossain ME. An experimental study to develop an environmental friendly mud additive of drilling fluid using Aloe Vera. J Petrol Sci Eng. 2022; 211: 110135. https://doi.org/10.1016/j.petrol.2022.110135

[15] Shuvo MAI, Sultan MZB, Ferdous AR. Applicability of sawdust as a green additive to improve the rheological and filtration properties of water-based drilling fluid: an experimental investigation. J Petrol Explor Prod Technol. 2024; 14(1): 303-15. https://doi.org/10.1007/s13202-023-01706-2

[16] Fato DA, Rahmani O. Enhancing drilling fluid properties using biodegradable waste additives: A comprehensive study on water- and oil-based systems. J Environ Manage. 2024; 370: 123007. https://doi.org/10.1016/j.jenvman.2024.123007

[17] Khan MA, Li MC, Lv K, Sun J, Liu C, Liu X, *et al*. Cellulose derivatives as environmentally-friendly additives in water-based drilling fluids: A review. Carbohydr Polym. 2024; 342: 122355. https://doi.org/10.1016/j.carbpol.2024.122355

[18] Khan MA, Lv K, Sun J, Shen H, Zhang Y, Noor AA, *et al*. Influence of salt and temperature on the rheological and filtration properties of cellulose nanofiber/bentonite water-based drilling fluids. Geoenerg Sci Eng. 2025; 244: 213524. https://doi.org/10.1016/j.geoen.2024.213524

[19] Khan MA, Lv K, Sun J, Liu F, Shen H, Ding Y, *et al*. Enhanced filtration performance of cellulose nanofiber/bentonite water-based drilling fluids with temperature- and salt-resistant polymers for extreme conditions. SPE J. 2025; 1-23. https://doi.org/10.2118/228402-PA

[20] Caenn R, Darley HC, Gray GR. Composition and properties of drilling and completion fluids. Houston: Gulf Professional Publishing; 2011.

[21] Aftab AARI, Ismail AR, Ibupoto ZH, Akeiber H, Malghani MGK. Nanoparticles based drilling muds a solution to drill elevated temperature wells: A review. Renew Sustain Energy Rev. 2017; 76: 1301-13. https://doi.org/10.1016/j.rser.2017.03.050