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Hydrated aluminum silicate and *Musa paradisiaca* L. bio-waste as fluid loss additives in an aqueous mud system

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ABSTRACT

Fluid loss control is critical in drilling operations to prevent filtrate invasion into permeable formations, which can compromise wellbore stability and increase operational costs. This study evaluates the potential of kaolin (hydrated Aluminum silicate) and bio-waste (*Musa paradisiaca*) materials as fluid loss control additives in aqueous-based drilling fluids. Hydrated Aluminum silicate, a naturally occurring clay, and green sun/oven-dried bio-wastes (*Musa paradisiaca*) peels were investigated to test their effectiveness in reducing fluid loss. The additives were incorporated into water-based mud formulations at varying concentrations. Carboxymethyl cellulose was used as the fluid loss agent in the base or control sample. Compared to the control sample with an observed density of 8.9 ppg and filter cake thickness of 2/32-in. (1.59 mm), the proposed combined additives each showed a density of 8.8ppg and filter cake thickness of 3/32-in. (2.38 mm). Sun-dried *Musa paradisiaca* mixtures showed a slightly higher 30 mins. average fluid loss value than the oven-dried samples, with 13.2 ml and 12.9 ml, respectively. Results indicate that the proposed combined additive materials exhibited understandable fluid loss control properties, in accordance with the American Petroleum Institute (API) specifications. This research highlights the benefits of using environmentally friendly and green materials as sustainable alternatives in drilling fluid designs.

Keywords: Aluminum silicate, *Musa paradisiaca*, carboxymethyl cellulose, fluid loss test, aqueous mud

1. INTRODUCTION

The exploration of eco-friendly drilling fluid additives has gained significant attention due to the environmental and operational benefits they offer. Various materials, including clays, synthetic polymers, and organic waste products, have been studied for their efficacy in fluid loss control. Drilling fluids, or drilling muds, are crucial to oil and gas exploration. They serve various functions, including stabilizing the wellbore, cooling and lubricating the drill bit, and removing cuttings from the wellbore (Skalle, 2011, Caenn *et al.*, 2011). Fluid loss occurs when water from the drilling fluid is absorbed into permeable formations, which can destabilize the wellbore, increase the risk of well control problems, and cause formation damage.

Carboxymethyl cellulose (CMC) is a fluid loss control material commonly used in water-based muds. In addition to other conventional materials, it is a vital polymer in aqueous-based drilling fluids due to its dual role as a viscosifier and fluid loss control agent. CMC's unique structure enables it to enhance the viscosity of drilling fluids and create a low-permeability filter cake on the wellbore wall, effectively reducing fluid loss (Darley & Gray, 1988). Moreover, CMC is biodegradable and environmentally friendly, aligning with industry efforts to minimize the ecological impact of drilling operations. The effectiveness of CMC in drilling operations is enhanced when used with materials like bentonite, barite, kaolin, and plantain peel powder. Bentonite, a clay mineral with strong swelling properties, works synergistically with CMC to enhance the viscosity and gel strength of the drilling fluid. Together, they improve the fluid's carrying capacity and contribute to the stability of the wellbore. Kaolin, another clay additive, interacts favorably with CMC by forming a cohesive structure within the fluid, which aids in forming a stable filter cake for fluid loss control.



Plate 1. Raw Kaolin clay.

Kaolin (Plate. 1) is increasingly studied for its potential in fluid loss control due to its fine particle size, stability, and ability to support filter cake formation. Kaolin, a naturally occurring clay mineral, has been used in a variety of industrial applications due to its favorable properties, such as high surface area, fine particle size, and good adsorption capacity (Wilson, 2007, Uwaezuoke *et al.*, 2024).

It is particularly advantageous when used in conjunction with other materials like bentonite and CMC, as it enhances the cohesiveness and effectiveness of the filter cake. Kaolin's abundance and affordability also make it a cost-effective alternative or supplement to conventional fluid loss agents, particularly in regions where kaolin deposits are locally accessible. Recent research focuses on using natural and sustainable resources, such as kaolin and bio-waste materials, to develop environmentally friendly and cost-effective drilling fluids.

Studies by Adogbo and Mohammed (Adogba & Mohammed, 2012) expanded on kaolin's application and showed that it does not function well as a fluid loss control agent. Some properties include that kaolin particles are extremely fine, with an average size ranging from 0.5 to 4 microns. This small particle size is advantageous for forming a dense, low-permeability filter cake in drilling operations, which limits the fluid loss into porous formations. The plate-like shape of kaolin particles further contributes to a compact and cohesive filter cake, which enhances its sealing capabilities. Also, kaolin has a plastic, thixotropic nature, meaning it can undergo viscosity changes under shear stress and return to its original viscosity when stress is removed. It is chemically inert and does not easily react with other components in the drilling fluid.



Plate 2. (a) Sun-dried and (b) Oven-dried plantain peels powder

The potential of bio-waste materials in drilling fluids, showing that agricultural residues like plantain peels can provide effective fluid loss control is due to their fibrous nature and presence of cellulose. The application of waste biomass for several purposes in drilling mud has been presented (Azam *et al.*, 2024, Al-Saba *et al.*, 2018). However, other biomaterials have been used in mud formulations for different purposes (Uwaezuoke *et al.*, 2017, Uwaezuoke *et al.*, 2020, Igwilo *et al.*, 2021). Plate. 2 shows the sun and oven dried samples.

They decompose naturally and reduce the environmental impact of drilling operations, hence, aligning with regulatory pressures to reduce the use of synthetic polymers and non-biodegradable additives. *Musa paradisiaca* (plantain peel powder), represents an innovative approach to fluid loss control that aligns with sustainable drilling practices. This bio-based additive can enhance the fluid's ability to form a robust filter cake, minimizing fluid invasion into the formation.

The incorporation of *Musa paradisiaca* powder with kaolin in a drilling fluid system could provide synergistic effects, with the plantain fibers enhancing the structural integrity of the kaolin-based filter cake. Bioproducts have been shown to support improvement in mud properties as well as cost-effective (Bichaksham & Borkha, 2021).

The use of kaolin in the same filter press for fluid loss yielded fluid loss volumes and filter cake thicknesses with values of 14 ml to 25ml after 15 minutes. and 3/32-in. to 4/32-in, respectively (Uwaezuoke *et al.*, 2024). The combination of kaolin with plantain peel powder in this project offers a sustainable approach to fluid loss control. While kaolin provides the fine particles needed to create a dense filter cake, plantain peel powder (*Musa paradisiaca*) contributes fibrous content that reinforces the cake's structural integrity.

Significant advancements have been made in the development of environmentally friendly and cost-effective fluid loss control additives. Materials like kaolin, bentonite, barite, carboxymethyl cellulose (CMC), and bio-waste products such as *Musa paradisiaca* (plantain peel powder) have been studied for their effectiveness in aqueous-based systems. Although kaolin and bio-waste materials, such as plantain peel powder, have individually demonstrated potential in fluid loss control applications, there is limited research on their combined use in aqueous-based drilling systems.

This work investigates the potential of using kaolin in combination with plantain peel powder as fluid loss control additives in an aqueous-based drilling fluid system. The addition of *Musa paradisiaca* peel powder brings bio-based fibers and polysaccharides, which complement the filter cake properties of CMC, potentially improving its sealing and plugging capabilities.

The research represents an eco-friendly approach to fluid loss control, reducing reliance on synthetic and non-renewable materials.

2. MATERIALS AND METHODOLOGY

2. 1. Sources of materials used

The kaolin which can be found in some states in Nigeria was harvested from a town in Abia State, Nigeria (Uwaezuoke *et al.*, 2022), with known characteristics. Similarly, the dried *Musa paradisiaca* peels were sourced from Owerri market in Imo State, Nigeria. The bentonite, barite, CMC, and NaOH were obtained from the laboratory. The mud compositions and their functions and laboratory equipment functions are given in Tables 1 and 2.

Table 1. Mud compositions and their function(s).

Materials	Function(s)
Bentonite	Viscosifier and mild fluid loss control
Barite	Densifier
CMC (Carboxymethyl cellulose)	Fluid loss control
Kaolin	Fluid loss control
Musa paradisiaca peels	Fluid loss control
NaOH (Sodium Hydroxide)	Used to adjust and maintain the pH
Water	Base fluid

Table 2. Laboratory apparatus and equipment used.

Equipment	Function(s)
General Lab Oven	Heating and drying of the plantain peels
Weighing Balance	Weight measurement
Mud Mixer	To mix the various components
pH Paper	pH measurement
Mud Balance	Density measurement
Filter Press	Measurement of fluid loss control

2. 2. Preparation of materials used

The plantain peels were divided into two parts, one part was oven-dried in the general laboratory oven at 127.4 F (53 °C) for 4-8 hours, while the other part was sun-dried at 31 °C for 40 hours. Then both were crushed and ground to powder. They were stored in glass containers at ambient temperature. The kaolin was stored in a ceramic container with a tight seal and kept in a cool, dry, and dark place in the laboratory. Using a weighing balance, 20g of bentonite was measured into 7 places and 10g of barite into 7 places. 1g of CMC was measured for the control. Both sun-dried and oven-dried plantain peel powder (Tables 3 and 4) were measured into 0.5g, 1g, and 2g each. The kaolin powder was also measured into 0.5g, 1g, and 2g as well then 0.25g of NaOH was measured in 7 places. These increased concentrations were

to show the effects of increased amounts of those materials in the formulations. All the formulations were prepared by ANSI/API (ANSI/API, 2017).

2. 3. Drilling mud formulations

Table 3. Drilling mud Sample formulations.

Sample No	Common/Peculiar compositions	Item	Density (g/cm ³)	Volume (ml)	Weight (g)
	Common	Bentonite	2.6	7.69	20
	Common	Barite	4.48	2.23	10
1	Peculiar	CMC	1.6	0.625	1
2	Peculiar	Kaolin	2.65	0.1887	0.5
		Dried plantain peels powder (sun-dried)	0.6	0.833	0.5
3	Peculiar	Kaolin	2.65	0.1887	0.5
		Dried plantain peels powder (oven-dried)	0.6	0.833	0.5
4	Peculiar	Kaolin	2.65	0.3774	1
		Dried plantain peels powder (sun-dried)	0.6	1.6667	1
5	Peculiar	Kaolin	2.65	0.3774	1
		Dried plantain peels powder (oven-dried)	0.6	1.6667	1
6	Peculiar	Kaolin	2.65	0.7547	2
		Dried plantain peels powder (sun-dried)	0.6	3.3333	2
7	Peculiar	Kaolin	2.65	0.7547	2
		Dried plantain peels powder (oven-dried)	0.6	3.3333	2
	Common	NaOH	2.13	0.117	0.25
	Common	Water	1	340	
Note: The common compositions are used in all the mud formulations, whereas the peculiar compositions distinguish the mud					

Table 4. Summary of the amount of additives in the samples (formulations).

Sample No.	Fluid loss materials and quantities		
1	Control Sample	1g CMC	
	Hydrated Aluminum silicate	<i>Musa paradisiaca</i> peel	
		Sun-dried (31 °C)	Oven-dried (53 °C)
2	0.5	0.5	
3	0.5		0.5
4	1	1	
5	1		1
6	2	2	
7	2		2

3. RESULTS AND DISCUSSION

The mud weight of the samples demonstrated a slight difference of 0.1ppg compared to the control sample (Sample 1), which contained CMC. This variation might be attributed to the addition of Kaolin with its slight expansion property which affected the density. Moreover, the slight decrease in mud weight (Table 5) indicates that kaolin and the plantain additives have a minimal impact on the density of the drilling fluid. Maintaining an optimal mud weight is crucial for balancing formation pressures and preventing wellbore instability.

Table 5. Measured densities and pH of the samples.

Items	Sample 1 (Control)	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
Mud weight (ppg)	8.9	8.8	8.8	8.8	8.8	8.8	8.8
pH	9.0	8.1	8.0	8.1	8.0	8.0	8.0

The results suggest that these additives can be used without significantly altering the drilling fluid's density, ensuring effective pressure control. Also, the pH readings of the mud

samples were fairly similar to those of the control sample, all falling within the alkaline range. The alkaline nature of the samples is beneficial for drilling fluid stability and corrosion prevention. The similarity in pH between the samples containing kaolin and bio-waste additives and the control sample indicates that these materials do not introduce significant acidity or alkalinity to the fluid.

Table 6. Filtrate and Mud Cake Readings.

Samples	Filtrate reading at 5 mins (mL)	Filtrate reading at 10 mins (mL)	Filtrate reading at 15 mins (mL)	Filtrate reading at 20 mins (mL)	Filtrate reading at 25 mins (mL)	Filtrate reading at 30 mins (mL)	Mud cake (in)	Mud cake (mm)
1	6	8.5	10	11.8	12.8	13.8	2/32	1.59
2	5.8	8.3	10.7	11	11.9	12.5	3/32	2.38
3	6.5	9	10.5	11.7	12.5	13	3/32	2.38
4	6.2	7.8	9.5	11.2	11.7	12.4	3/32	2.38
5	7.8	8.5	9.8	10.6	11.3	12	3/32	2.38
6	8.6	9.2	10	11.8	13.8	14.8	3/32	2.38
7	6.2	8.5	10	11.8	12.8	13.8	3/32	2.38

This compatibility ensures the additives' suitability for maintaining the chemical balance of drilling fluids, reducing the risk of equipment damage and enhancing fluid performance. Furthermore, the fluid loss of the samples at 30 minutes (Table 6) was almost the same as the control sample containing CMC. This indicates that the addition of kaolin contributes significantly to reducing fluid loss, though the values are slightly higher than the API recommended value of a maximum of 12 ml.

The good performance observed could also be attributed to the presence of nano-sized particles present in the kaolin clay used. The study was presented by Uwaezuoke *et al.*, (Uwaezuoke *et al.*, 2022), and the impact of nanoparticles in drilling fluids has been highlighted (Uwaezuoke, 2022).

This is in addition to the cellulose found in plantain peels which could help in plugging the pores to reduce fluid loss, and the pH control capability (Ohia *et al.*, 2022). Plantain peels could contain up to 46.5% cellulose. Lower fluid loss is critical in preventing lost circulation, a common issue in drilling operations that can lead to operational delays and increased costs. The ability of the kaolin/plantain peel mixture to form a thin filter cake, within the API range (<2 mm) is an advantage. The fluid loss and filter cake thickness values are better than when kaolin alone was used (Uwaezuoke *et al.*, 2024). These positive results highlight the potential application of the materials as additives in aqueous mud formulations.

4. CONCLUSIONS

Based on the study, the effectiveness of kaolin and bio-waste materials as fluid loss control additives in water-based drilling fluids was comprehensively evaluated. The results demonstrated that kaolin clay mixed with plantain peel product significantly reduces fluid loss, primarily by improving the filtration behavior and forming a thin mud cake acceptable based on API specifications. The addition of the bio-waste materials provided supplementary benefits, with minimal impact on mud weight and pH levels, ensuring compatibility with standard drilling fluid formulations. The additives proved to be effective fluid loss control agents, offering stability under various conditions. Their performances were comparable to those of conventional additives like carboxymethyl cellulose (CMC), highlighting its potential as a cost-effective and sustainable alternative. The study confirms that kaolin and bio-waste materials can enhance drilling fluid performance while minimizing environmental impact, making them viable candidates for improving wellbore stability and general drilling efficiency due to the observed thin mud cake.

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Abbreviations

ANSI – American National Standards Institute
API – American Petroleum Institute
CMC – carboxymethyl cellulose

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