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Sesame Plant as a Green Additive in Enhancing the Performance of Drilling Mud

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Abstract
This research aims to investigate the use of additives created from two species of the dried sesame plant (sesamum indicum residue & sesamum radiatum leaves) as environmentally friendly additives to enhance water based drilling fluids. The study involved the formulation of water-based drilling mud using bentonite clay, the development of drilling mud formulations with four concentrations (2.5g,5g,7.5g & 10g) of the proposed green additives, laboratory tests to determine drilling fluid properties (Rheology, Density, Fluid loss control, and pH) and comparison of the performance of the additives with a reference mud. Energy dispersive X-ray fluorescence (EDXRF) analysis identified the presence of key elements such as Calcium, Iron, Potassium, Carbon, Silicon, and Magnesium in the natural additives, which are important for various drilling fluid functions. Based on the results, both Sesamum indicum and Sesamum radiatum act as density and pH reducers when added to the base mud. Both additives led to a decrease in mud density compared to the base mud, with Sesamum indicum being more effective. Sesamum radiatum was more effective in reducing fluid loss compared to Sesamum indicum across all concentrations, with the 10g concentration of Sesamum Radiatum showing the most significant reduction in fluid loss. The addition of both Sesamum Indicum and Sesamum Radiatum additives resulted in a reduction in mud cake thickness compared to the base mud. As concentration rises, Sesamum Radiatum increases plastic viscosity and exhibits high yield points and gel strengths. Sesamum indicum has lower yield points and lower gel strengths and minimally enhances plastic viscosity. Both natural additives (Sesamum indicum and Sesamum radiatum) have shown effectiveness in improving drilling mud performance, viscosity control, fluid loss reduction, optimizing mud cake thickness and pH reduction thus minimizing environmental impact and addressing both environmental concerns and the need for sustainable drilling practice.

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I. INTRODUCTION

Modern drilling fluids (muds) are complex heterogeneous fluids (water-based and oilbased) and are complex mixtures of more than 200 minerals and chemicals. It is used in a drilling operation and circulates from the surface, down the drill string, through the bit, and back to the surface via the annulus. To enhance the use of drilling fluids, numerous additives were introduced, and a simple fluid became a complicated mixture of liquids, solids, and chemicals. As the drilling fluids evolved, their design changed to have common characteristic features that aid in the safe, economic, and satisfactory completion of a well. (Paulauskiene, 2017).

1.1.1 GREEN ADDITIVES

The hazardous effects of additives such as defoamers, descalers, thinners, viscosifiers, lubricants, stabilizers, surfactants, and corrosion inhibitors on marine and human life have been reported. Effects range from minor physiological changes to reduced fertility and higher mortality rates. For example, Jonathan et al. (2002) reported that ferrochrome lignosulfonate (a thinner and defflocculant) affected the survival and physiological responses of fish eggs and fry. The filtration control additive CMC 24 (carboxymethylcellullose) causes the death of fish fry at high concentrations (1000–2000 mg/ml) and physiological changes start the level of at 12–50 mg/ml. On the other hand, corrosion inhibitors such as phosphoxit-7, EKB-2-2, and EKB-6-2 cause genetic and teratogenic damage in humans.

1.1.2 Plant Extracts

There is a growing global concern every day regarding protecting the environment from the harmful effects of chemicals and non-biodegradable products. These worries are driving the petroleum industry to produce drilling fluids from naturally occurring plant extracts that are safe, economical, sustainable, and environmentally benign. They contain a wealth of naturally occurring substances that can be extracted with ease and at a low cost, including amines, alkaloids, polyphenols, and tannins. conducted a study to determine whether okra powder can be used to decrease fluid loss and viscosity in drilling fluids. Okra powder was added at various weight percentages (0.25, 0.5, and 1) and was found to minimize fluid loss by 20%, performing similarly to traditional starch as a fluid loss control additive. In comparison to starch, okra has less of an effect on rheological properties, and its TGA investigation revealed strong thermal stability. Okra powder did not affect the pH of the solution, based on the pH test. Water-based drilling fluid samples with higher concentrations of okra powder were shown to be able to form a more stable microstructure using shear and loss modulus tests. Based on the findings, okra-containing drilling fluids may be utilized as a starch substitute without sacrificing the properties of other drilling fluids. [5] explored the potential of hibiscus leaf extract (HBLE) and henna leaf extract (HLE) as environmentally friendly additives to water-based drilling fluids (WBDFs). WBDFs were subjected to rheological and filtration characterizations at 78 and 300°F, and the results were compared with low-viscosity polyanionic cellulose (PAC LV). The findings demonstrated that HLE and HBLE considerably decreased filtrate loss and enhanced the WBDF system's rheological properties. Compared to the green additives, PAC LV had a stronger impact on rheological characteristics; however, it displayed fathigh and progressive gels. The addition of HLE and HBLE to the WBDF resulted in a reduction of the cake thickness by 30–32% (HLE), 32–33% (HBLE), and 24-27% (PAC-LV), respectively. These results demonstrate the exceptional filtration properties of the green additives. Compared to the Hibiscus product, the Henna extracts showed stronger inhibiting properties. Nevertheless, on the WBDF system, both compounds demonstrated outstanding inhibition properties and an excellent viscosity-enhancing effect. The green additives were found to be compatible with other base fluid additives and effective in inhibiting bentonite swelling. A study by explored the potential use of the leaves of the Moringa oleifera plant to enhance water-based drilling mud. Standard operating techniques were employed to measure the rheological characteristics of the mud. The concentration of M. oleifera leaves had no effect on the mud weight, and as the concentration increased, the mud's pH dropped by 28%. At 50 ºC, the mud containing 1% M. oleifera leaves had the highest plastic viscosity (33 cP). While the control mud had the lowest value (22 cP) at 70 ºC, the mud containing 4% M. oleifera leaves had the maximum yield point (57 1b/100 ft^2), whereas at 30 ºC and 49 ºC, the lowest yield point (91 b/100 ft^2) was obtained. At 70 ºC, gel strength increased with a 2% leaf concentration, while it was lowest at 49 ºC.

Sesamum indicum plant residue:

Figure 1 :Sesamum Indicum dried; a) hulls b) stalks c) leaves [3]

Sesamum radiatum plant:

Figure 2: a)Fresh Sesamum Radiatum b)rinsed plant c)dried plant [4]

1.2.1 Collection and Preparation of Sesamum Indicum Additive

Dried sesame (sesamum indicum) plant residue a byproduct of sesame seed harvesting was obtained from a local farm in Jigawa state, Nigeria. The dried plant stalks, deseeded hulls, and leaves were further dried at room temperature. The plant residue was manually picked to remove contaminants. The stalks were cut into smaller sizes. The residue (stalks, deseeded hulls, and dried leaves) in approximately the same ratio was pulverized in a grain milling machine and then sieved into a fine powder using a sieve shaker (0.25mm).

1.2.2 Collection and Preparation of Sesamum Radiatum Additive

The sesamum radiatum (Karkaashi) plant was obtained from a local market in Kano state, Nigeria. The plant was cleaned to remove dirt and other impurities and then dried under a shade.The leaves of the plant were picked and then spread to dry at room temperature. The dried leaves were pulverized in a food processor grain mill. Then sieved into a fine powder using a sieve shaker (0.25mm).

1.2.3 Elemental Composition Analysis

Energy-dispersive X-ray fluorescence (EDXRF) was carried out on samples of both
additives to determine elemental composition.

1.2.3 Mud Rheology Test

The sample was placed in a container and the rotor sleeve immersed exactly to the scribed line. The temperature of the sample was recorded. With the sleeve rotating at 600 r/min, the viscometer dial reading was waited for to reach a steady value (the time required is dependent on the drilling fluid characteristics). The dial reading for 600r/min was recorded. The rotor speed was reduced to 300 r/min and the viscometer dial reading was waited
for to reach a steady value. The dial reading for 300 r/min was then recorded and this was repeated at 200 and 100 r/min. The 'Mud' option on the viscometer was selected, drilling fluid sample was stirred for 10 s at 600 r/min. Then, the rotor was stopped. The drilling fluid sample had been allowed to stand undisturbed for 10 seconds. The maximum reading was taken as the initial gel strength (10-second gel) and recorded in pounds per 100 ft^2. The drilling fluid sample was then stirred at 600 r/min for 10 s, the rotor was stopped, and the drilling fluid was allowed to stand undisturbed for 10min. The measurements had been repeated as in the measurement for initial gel strength, and the maximum reading was reported as the 10-minute gel in pounds per
100 ft2 . The values for plastic viscosity and yield point were displayed on the viscometer screen along with the initial and final gel strengths.

II. RESULT AND DISCUSSION

The results obtained are as discussed below

1.3.1 ENERGY DISPERSIVE X-RAY FLUORESCENCE (EDXRF) ANALYSIS

The elemental composition of the two additives was analyzed using an EDXRF analyzer. The results identified the various elements contained in the natural additives and their concentrations. The Sesamum Indicum additive (SIA) was found to contain Calcium (Ca), Iron (Fe), Potassium(K), Copper(Cu), Carbon(C), Sulfur (S), Aluminum (Al), Magnesium (Mg), Sodium (Na), Phosphorous(P), Chlorine (CL), Tungsten(W), Tantalum (TA), Silicon (Si) and traces of other elements in varying concentrations consistent with the organic nature of the additive. (Fig 3) below presents a graph of the results of the analysis.

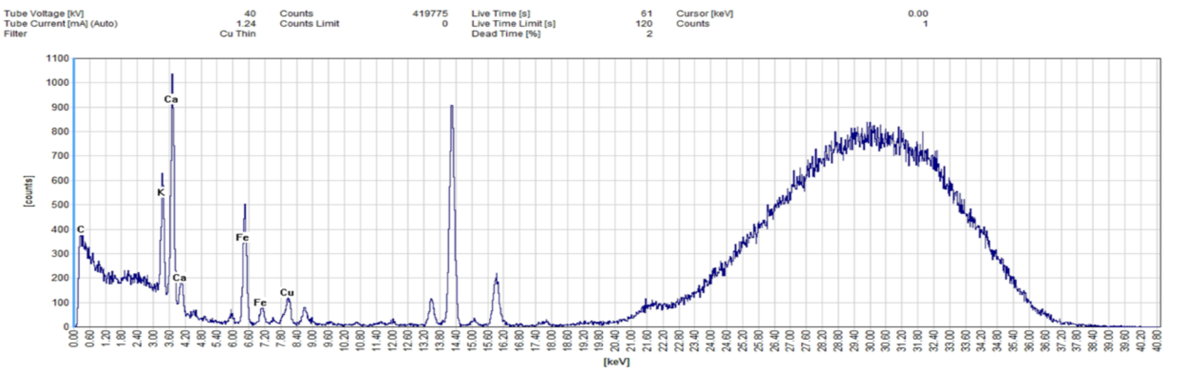

Figure 3:ED-XRF Sesamum Indicum

The Sesamum Radiatum Additive (SRA) was found to contain Calcium (Ca), Iron (Fe), Potassium (K), Carbon (C), Sulfur (S), Aluminum (Al), Magnesium (Mg), Sodium (Na), Phosphorous (P), Chlorine (Cl) ,Tungsten(W), Tantalum (Ta) and traces of other elements in varying concentrations consistent with the organic nature of the additive.(Fig 4) below presents a graph of the results of the analysis.

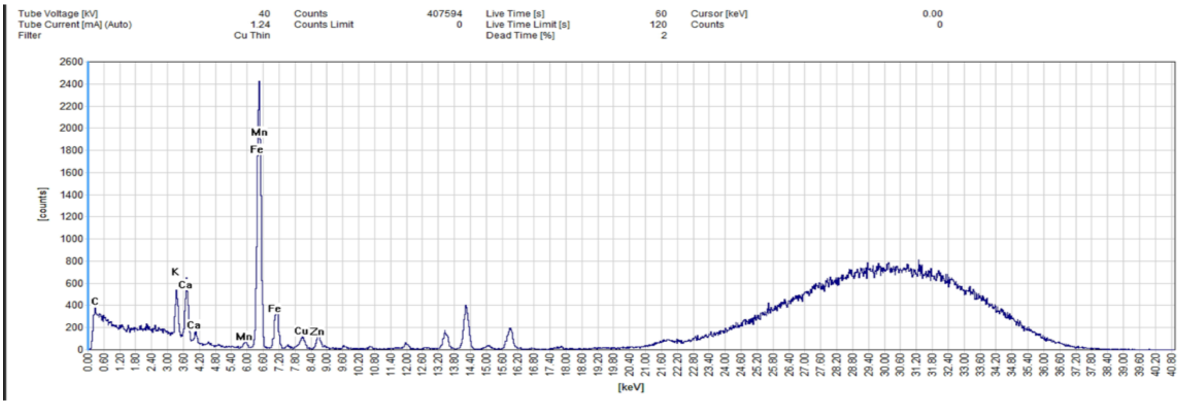

Figure 20:ED-XRF Sesamum Radiatum

1.3.2 MUD DENSITY (ppg)

The results of the mud density test on the two natural drilling fluid additives, Sesamum indicum and Sesamum radiatum, at varying concentrations of 2.5g, 5g, 7.5g, and 10g respectively, provide insights into their impact on the performance of drilling mud compared to a base mud with a density of 8.7 pounds per gallon (ppg).

Sesamum indicum: The density values obtained at different concentrations indicate that as the concentration increases, the density of the mud decreases. This additive appears to have a significant impact on reducing the density of the mud.

Sesamum radiatum: The density values with a very narrow range of variation obtained at different concentrations are slightly lower than those of Sesamum indicum. This additive significantly reduces mud density when added to base mud and shows a negligible density increase as concentration increases.

indicating that Sesamum radiatum also contributes to reducing the density of the mud, although not as effectively as Sesamum indicum.

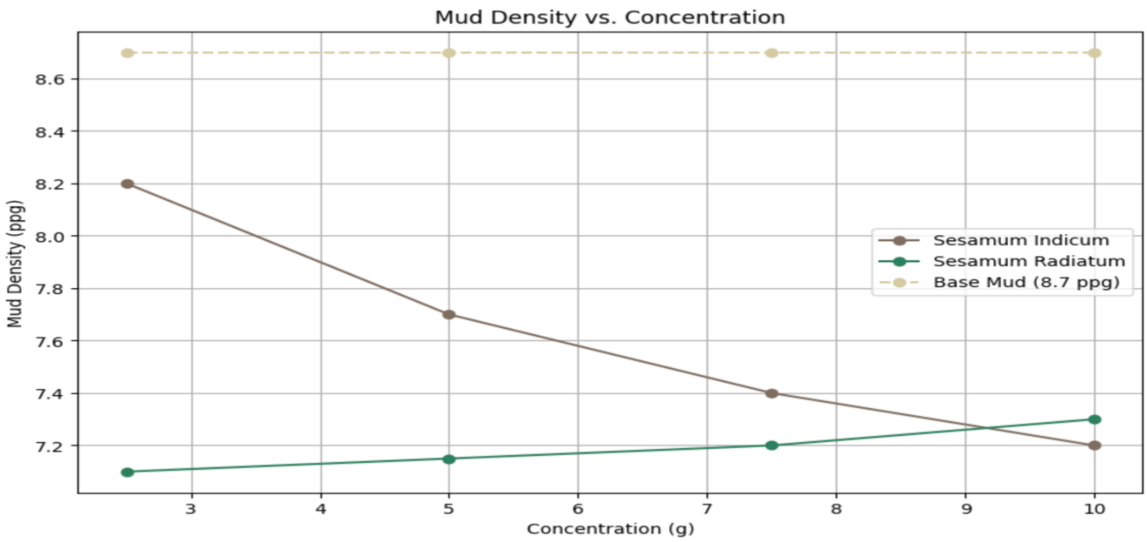

Figure 5:Graph showing Mud density results against concentrations.

Comparing these results to the base mud density of 8.7 ppg, shows that both additives lead to a decrease in mud density. In the case of the sesamum radiatum additive, this could be due to the slimy, foamy consistency of the mud. This reduction in density is essential for controlling wellbore pressure during drilling operations. Lower density mud helps prevent blowouts and fluid loss into the formation while drilling through porous formations and can contribute to improved drilling performance by reducing hydrostatic pressure, which may enhance penetration rates and overall drilling efficiency.

The base mud has a higher density than both sesamum indicum and sesamum radiatum at all concentrations. The lower densities of the additives may result in reduced carrying capacity for cuttings and a higher risk of wellbore instability. However, the lower densities of the additives may be beneficial in certain situations, such as when drilling in shallow wells or when trying to reduce the overall weight of the drilling fluid, they may also provide other benefits, such as improved lubricity and reduced wear on drilling equipment.

Compared to conventional additives used for mud density reduction, such as lignite, asphalt, and lightweight additives (e.g., hollow glass microspheres, cenospheres, or polymer beads), Sesamum indicum and Sesamum radiatum are natural additives, which are advantageous in terms of cost, biodegradability and reduced environmental impact. Utilizing natural additives can contribute to reducing the reliance on synthetic chemicals and minimizing energy and resource intensive processes as well as potential environmental contamination. Using plant-based additives could be more sustainable, especially if sourced responsibly. They might reduce the reliance on mined materials like barite and help in reducing the carbon footprint of drilling operations.

1.3.3 FLUID LOSS (ML)

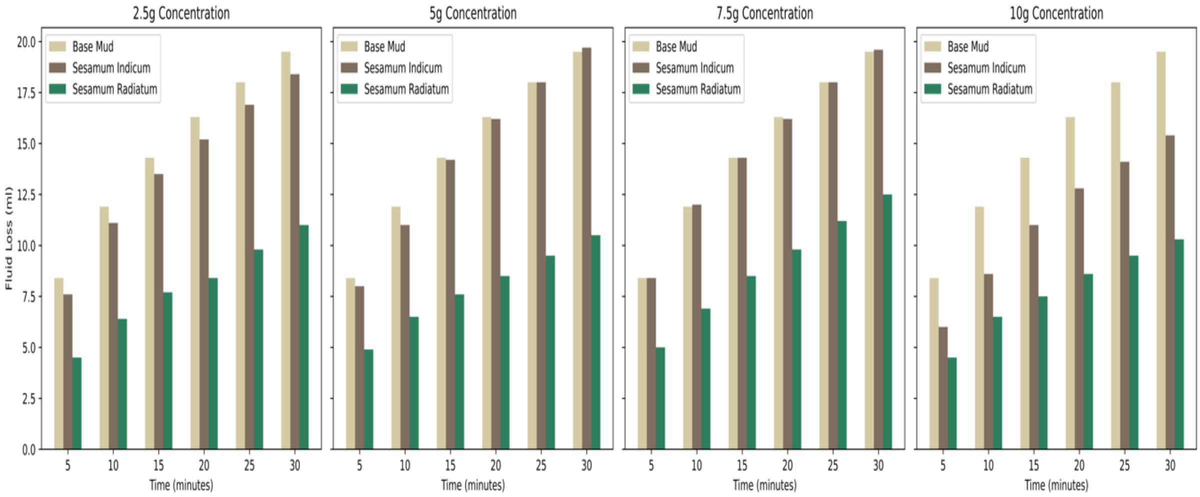

Figure 6:Chart showing fluid loss results of various concentrations against time.

Sesamum Radiatum is more effective in reducing fluid loss compared to Sesamum Indicum across all concentrations, with the 10g concentration of Sesamum Radiatum showing the most significant reduction in fluid loss. For Sesamum Radiatum, even lower concentrations (2.5g and 5g) are very effective, suggesting that less of this additive is needed to achieve significant fluid loss control.
However, there is an exception to the reduction at the concentrations of 5g and 7.5 g SIA, as well as 7.5g SRA where the decreasing trend of the filtrate loss does not hold. The Base Mud shows the highest fluid loss, indicating the effectiveness of both additives in fluid loss control.

1.3.4 RHEOLOGY

I. Plastic Viscosity

Sesamum Indicum: the PV starts higher than the base mud at 2.5g, matches the base mud at 5g, and remains slightly above the base mud for higher concentrations. This indicates a moderate increase in viscosity, which can help in improving the carrying capacity of the drilling fluid without significantly affecting the pumpability.
Sesamum Radiatum, shows a significant increase in plastic viscosity with increasing concentration, indicating that it acts as a thickening agent. This could be beneficial in situations where higher viscosity is needed to suspend and carry cuttings from the drill bit to the surface. Increased Plastic Viscosity is Useful in stabilizing the wellbore, preventing the collapse of unstable formations, and improving the carrying capacity of the drilling fluid.

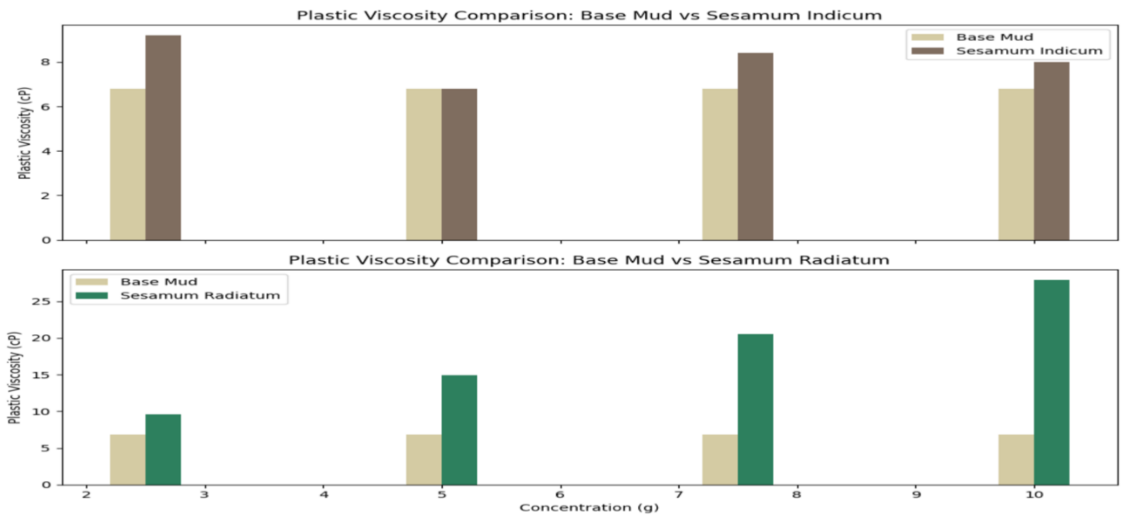

Figure 7:Chart showing plastic viscosities of Sesamum Indicum, Sesamum Radiatum, and base mud at different concentrations.

II. Yield Point

The YP values for Sesamum Indicum are consistently lower than the base mud. This suggests that Sesamum Indicum while increasing the plastic viscosity slightly, does not significantly enhance the yield point. This could mean that while the fluid's ability to suspend cuttings is slightly improved, it may not be as effective in maintaining cuttings in suspension under static conditions.

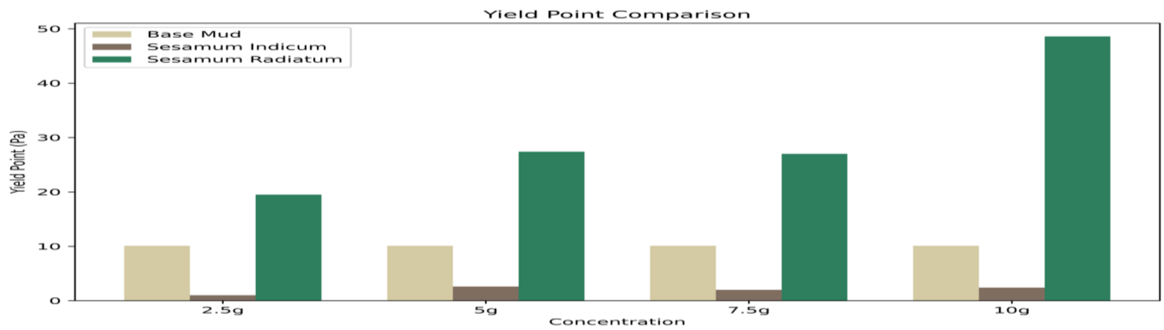

Figure 8:Chart showing yield point of additives, and base mud at different concentrations.

In contrast, Sesamum Radiatum shows a significantly higher yield point than the base mud, especially at higher concentrations. This suggests that Sesamum Radiatum acts as a thickening agent, increasing the yield point which can be advantageous in stabilizing the wellbore and preventing fluid loss into the formation.

The choice between these additives would depend on the specific requirements of the drilling operation. If a lower yield point is desired for easier pumping and better fluidity, Sesamum Indicum would be the preferred additive. Alternatively, if a higher yield point is needed for better hole cleaning and wellbore stability, Sesamum Radiatum would be more suitable.

III. Gel Strength

Gel Strength at 10 Seconds

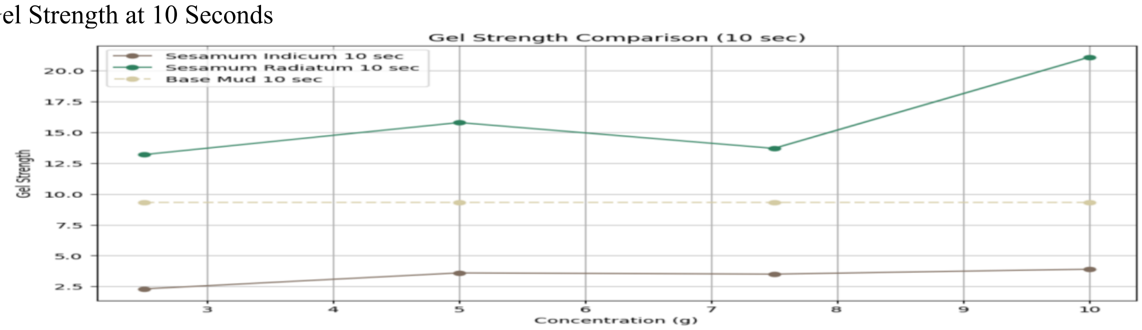

Figure 9:Graph plotted showing 10 sec gel strength levels of additives, and base mud at various concentrations.

Sesamum Indicum shows lower gel strength compared to the base mud across all concentrations. This indicates that it might not be as effective in initially stabilizing the mud.
Sesamum Radiatum exhibits significantly higher gel strength than both the base mud and Sesamum Indicum, suggesting a stronger initial gelation which could be beneficial for preventing the settling of cuttings.

Gel Strength at 10 Minutes
Sesamum Indicum continues to show lower gel strength compared to the base mud, although the difference narrows slightly at higher concentrations. This might indicate some degree of time-dependent stabilization but not as pronounced as the base mud.
Sesamum Radiatum shows lower gel strength than the base mud at all concentrations, with the strength peaking at the 5g concentration. Sesamum Radiatum appears to be a better additive in terms of enhancing both initial and final gel strength, which can improve the mud's ability to suspend and carry cuttings effectively.

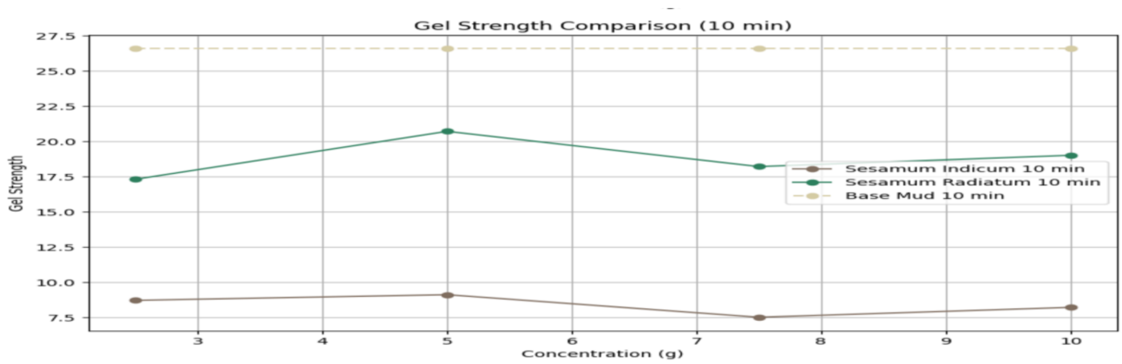

Figure 10:Graph plotted showing 10 min gel strength levels of additives, and base mud at various concentrations.

The numerical deviation between initial and final gel strengths being less than 10 (lb/100ft2) indicates that additional pressure will not be required when switching between pump-on and pump-off conditions.
Synthetic polymers e.g. polyacrylamide, and clay minerals are widely used for viscosity control and fluid loss reduction in drilling fluids. However, their extraction and production can result in habitat destruction and soil erosion as well as the release of harmful byproducts due to the use of petrochemicals. Disposal of used drilling fluids containing these additives can lead to long-term environmental impacts, including soil and water contamination, sedimentation, and alteration of aquatic ecosystems.
Natural additives derived from plant sources pose advantages in terms of biodegradability and reduced environmental impact, their extraction and production processes are generally less environmentally impactful compared to conventional additives.

III. CONCLUSION

It was observed that Sesamum radiatum exhibited a concentration-dependent thickening effect, while Sesamum indicum had a less pronounced impact on viscosity. Therefore, further research may be required to establish a definitive trend. Sesamum indicum displayed lower yield points and gel strengths than the base mud as compared to Sesamum radiatum. Sesamum radiatum's higher yield points enable improved cuttings suspension and higher gel strengths, preventing settling during static periods. Results suggest that both Sesamum indicum and Sesamum radiatum have varying effects on the gel strength of the drilling mud, with Sesamum radiatum showing a more variable impact across different concentrations.

The addition of Sesamum Radiatum improves drilling mud performance by reducing fluid loss and optimizing mud cake thickness, leading to more efficient drilling operations, cost savings, and minimized environmental impact. The choice of additive and its concentration can be adjusted based on specific drilling conditions. Both additives were found to significantly reduce pH, making them potential pH reducing agents. However, further investigation and testing are necessary to ensure that these additives do not compromise mud performance.

Natural additives like Sesamum indicum and Sesamum radiatum offer several environmental advantages over conventional additives in drilling fluid applications. These plant-based additives support sustainability by enabling local cultivation, reducing transportation emissions, and promoting local agriculture. Their biodegradability minimizes the risk of long-term contamination at drilling sites, and their lower toxicity levels minimize the harm to wildlife and aquatic life in case of spills or leaks. Additionally, natural additives typically have a lower carbon footprint than conventional additives, contributing to overall environmental sustainability in the oil and gas industry. However, further research and field testing are needed to fully evaluate their performance and environmental benefits in real-world drilling operations.

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