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Comparative Analysis of Used/Heated Edible Oil as Oil-Based Mud in Drilling Operations

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ABSTRACT

Oil based mud is formulated with the used and heated edible oil which can be collected from various sources like fast food makers and restaurants. The oil collected should be analysed based on the tests, i.e. yield point, gel strength, mud density, filtration loss properties.

The result obtained will show whether the oil used will exhibit similar properties to that of OBM and be used more efficiently by reducing the cost for the drilling fluid.

The need to drill a usable hole with minimal environmental impact and with a low cost imprint has been a dream long held by drillers and industry operators. One major component of the oil well drilling operation which is often referred to as "the blood of the drilling process'' is the drilling fluid. The drilling fluid plays a few invaluable roles. These roles include transporting the drill cuttings from the bottom of the hole to the surface, cooling and lubricating the drilling bit as well as the drill string to minimize its wear, sealing off permeable formations by forming an impermeable, relatively thin mud cake at the borehole wall of the permeable formations creating a buoyancy force to partly support the weight of the drill string and casing string, reduction of formation damage of various horizons penetrated, transmission of hydraulic horsepower to the bit and allowing maximum penetration rates, carrying downhole information from the drilled well in form of signals to the surface for interpretation, and so forth.

By formulating the drilling mud with heated/used edible oil, and by running certain analysis on the sample will show whether we can use it as efficient OBM thus reducing the cost and increase the ease of availability.

Key Words: oil, oil-based mud, soybean, diesel, drilling, temperature,pressure

1. OBJECTIVE

The primary objective of using soybean oil in OBM is to provide an eco-friendly alternative to conventional mineral oil-based drilling fluids, which can be harmful to the environment and human health.

Other objectives of using soybean oil as an OBM include:

1. Lubrication: Soybean oil has excellent lubricating properties that help reduce friction and heat during drilling operations. This property helps to extend the life of drilling equipment and reduce the risk of damage to the wellbore.
2. Stability: Soybean oil has good thermal and oxidative stability, which means it can withstand high temperatures and resist degradation over time. This stability helps to maintain the properties of the drilling fluid during the drilling process.
3. Biodegradability: Soybean oil is biodegradable, which means it can break down naturally in the environment without causing harm to ecosystems. This property makes it an eco-friendly alternative to mineral oil-based drilling fluids.
4. Low toxicity: Soybean oil is non-toxic and poses no health risks to humans or wildlife. This property makes it safer to handle and use than conventional mineral oil-based drilling fluids.

Overall, the objectives of using soybean oil as an OBM are to provide a safe, effective, and eco-friendly alternative to traditional mineral oil-based drilling fluids.

2. INTRODUCTION

Oil-based drilling muds (OBMs) and water-based drilling muds (WBMs) have been the two main types of drilling fluids used by the oil well drilling industry across time. On the one hand, water-based mud is the most often utilized drilling fluid since it is less expensive and simpler to formulate. On the other hand, oil-based muds, despite being more expensive than their water-based counterparts, are preferred because of their superior lubricating properties, good rheological characteristics at temperatures as high as 500°F, and effectiveness against all types of corrosion. The ability to drill through formations containing clays that may swell in water is another benefit of oil-based drilling fluids. Due to its low flammability, limited solvent capacity for rubber, and high viscosity, diesel oil is generally employed as the basis fluid to create these oil-based muds.

All of these petroleum-based oils that are used to make drilling mud have n-olefin concentrations that are at least moderately high and aromatic concentrations that may be poisonous or damaging to plant and animal life. Because of this, the drilling industry has throughout time created different types of oil-based muds that are officially referred to as synthetic-based muds. In this study, two oil-based muds are created and compared; one is made from leftover cooking oil, the other from diesel oil. The rheological parameters and filtration traits of the drilling muds serve as the foundation for the comparison.

3. RESOURCES AND TECHNIQUES

3.1 Preparation of samples

The used culinary oil is gathered from stores located on Peddapuram's neighbourhood streets. Wastes will be present in this used oil, which will cause it to have a lot of contaminants.

Therefore, we must sanitise. For that, we imply the filtration technique, which allows us to separate the oil from the waste or impurities. The gasoline then followed must be collected as required for mud formation, and the oil must be kept in a container.

Fig 3.1: Soyabean Oil

Fig 3.2: Collection Of Soyabean Oil From Local Areas

3.2 Characteristics of Oil-Based Fluids

The characteristics of the basic fluids used in the OBM's formulation were examined. These factors can be used to predict mud composition and behavior.There for the parameters that were examined are,

(a) Specific gravity: it shows the weight of the fluid that will indicate density of mud.

(b) Pour point: it shows the lowest temperature of fluid flow at base level .

(c) Flashpoint: it shows the temperature at which the fluid begins to burn.

(d) Kinematic viscosity: it shows flow under the influence of gravity force by its resistance.

(e) Cloud point: temperature at which dissolved solids are no longer completely soluble.

The physiochemical characteristics of used food oils and diesel oil are shown in Table 1.

Property	Diesel oil	Soyabean oil
Physical form	Liquid	Liquid
Melting point	-30°C to -18°C	-16°C
Boiling Point	282°C to -338°C	257°C
Density	830kg/m^3 at 20°C	920kg/m^3 at 20°C
Water solubility	Immiscible	Immiscible
Flash point	70°C	330°C
Cloud point	-9°C	-4°C
Kinematic Viscosity	6 Cst at 20 °C	61 Cst at 20°C
Pour point	-18°C	-20°C

Table 3.1: properties of Diesel oil and Soyabean oil

Diesel and soybean oil's chemical stability

Howell, Erhan, and Perez, for instance, all concur that soybean oil and other vegetable oils are safe for the earth, renewable, and biodegradable. From the perspective of chemical stability, some of the properties that support the advantages of soybean oil as a feasible substitute for the use of diesel oil.

The specifications for use as the oil basis in OBM formulation are shown in the table. In contrast to soybean oil, which has a high flash point and low volatility, diesel oil displays high volatility and low flash points, which could pose a safety risk. Therefore, using diesel as an OBM would be hazardous to both the environment and the health and welfare of its users. Additionally, the difference between the pour and fire points of diesel oil and soybean oil suggests that the former would be chemically unstable at low and high temps, as it becomes challenging to maintain fuel oil flow rate at 18 C. Additionally, a fire point of diesel oil is 108° C that catch fire in high-temperature, high-pressure (HTHP) wells. low aniline point of soybean oil, which could harm rubber components on the drilling platform, is the only drawback.

Property	Aniline point (°C)	Pour point (°C)	Flash point (°C)	Fire point (°C)	Kinematic viscosity at 40°C,Cst	Aromatic content (%)
Base oil required properties	>65	Ambient temperature	>66	>80	2.3 - 3.5	4 - 8
Diesel oil	145	-18	66	108	2.7 - 3.4	25% v/v
Soyabean oil	60	-20	330	342	31.8	N/A

Table 3.2: Base properties of oil for use as OBM

4. MEASUREMENT OF MUD PROPERTIES

4.1 Estimations of Rheological Characteristics

The Fann V-G viscometer was used to determine the rheological properties of the mud samples. The equipment was switched on and allowed to stabilize, after which the viscosity of distilled water was tested to check the integrity of the equipment. The rheogram (shear stress-shear rate profile) for the readings is presented in Figure below. Consequently, the apparent viscosity (AV), plastic viscosity (PV), and yield point (YP) of the mud samples (presented in Table 5) were calculated based on two data point approach from the viscometer (Fann V-G) dial readings presented in Table 4 using,

$$PV = \square 600 - \square 300$$

$$YP = \square 300 - PV,$$

$$AV = 1\ 2 * \square 600,$$

where AV is apparent viscosity, PV is plastic viscosity, □600 is dial reading at 600 revolutions per minute, □300 is dial reading at 300 revolutions per minute, and YP is yield point.

Fig 4.1: Fann V-G viscometer

Mud component	Diesel oil	Soyabean oil	Mixing durations (mins)	Mixing order
Oil (mL)	245	245	-	1
Primary emulsifier (mL)	6	6	5	2
Secondary emulsifier (mL)	4	4	5	3
Filter loss agent HEC (g)	0.35	0.35	5	4
Water (mL)	105	105	15	5
Bentonite (g)	25	25	5	6
NaOH (g)	0.25	0.25	5	7
Barite (g)	10	10	10	8

Table 4.1: Composition of Soyabean oil and Diesel oil mud

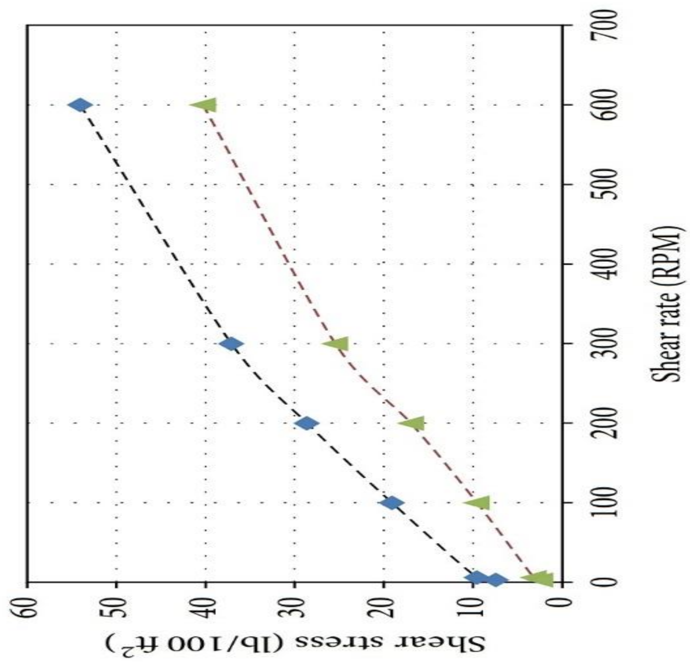

Fig 4.2: Shear Stress-Shear Rate profile

Viscometer speed (rpm)	Diesel oil		Soyabean oil	
	Dial reading	Shear stress (lb./ftx^2)	Dial reading	Shear stress (lb/ftx^2)
600	51	54.06	38	40.28
300	35	37.1	24	25.44
200	27	28.62	16	16.96
100	18	19.08	9	9.54
6	9	9.54	3	3.18
3	7	7.42	2.3	2.438

Table 4.2: Viscometer readings of the formulated mud samples

4.2 Mud Density Measurement

According to the table mentioned below, soybean mud without barite has a greater density than diesel mud (7.50 lb./gal), a result of the soybean oil's density (920 kg/m3, or 7.66 lb./gal) as shown in Table above. The density variation of the mud at a 10 g barite concentration is further shown in Table below.

The formulated soybean OBM has a greater density value than diesel OBM, according to the table. According to the findings, diesel and soybean sludge density increased to 8.10 lb./gal and diesel mud density at 10 g barite concentration to 7.98 lb/gal. According to these findings, the abundance of soybean and diesel OBMs has increased by 3.58 percent and 6.40 percent, respectively. According to this claim, barite can be used to increase the density of soybean OBMs to suit any drilling operation, particularly when a heavy amount of mud is required.

The main purpose of mud density in the drilling fluid system is to control formation pressure. Additionally, a rise in mud density enhances the mud's capacity to carry drilled cuttings due to the associated buoyancy impact of the suspending fluid on the cuttings.

Because soybean oil has a higher density than diesel mud (920 kg/m3, or 7.66 lb/gal), as indicated in the chart below, soybean mud without barite has a higher density than diesel mud (7.50 lb/gal). The table below further illustrates the density variation of the mud with a 10 g barite content.

The table shows that the density value of the formulated soybean OBM is higher than that of the diesel OBM.

Barite (g)	Diesel Oil	Soybean Oil
0	7.50	7.82
10	7.98	8.10

Table 4.3: Mud Density values with Barite Content

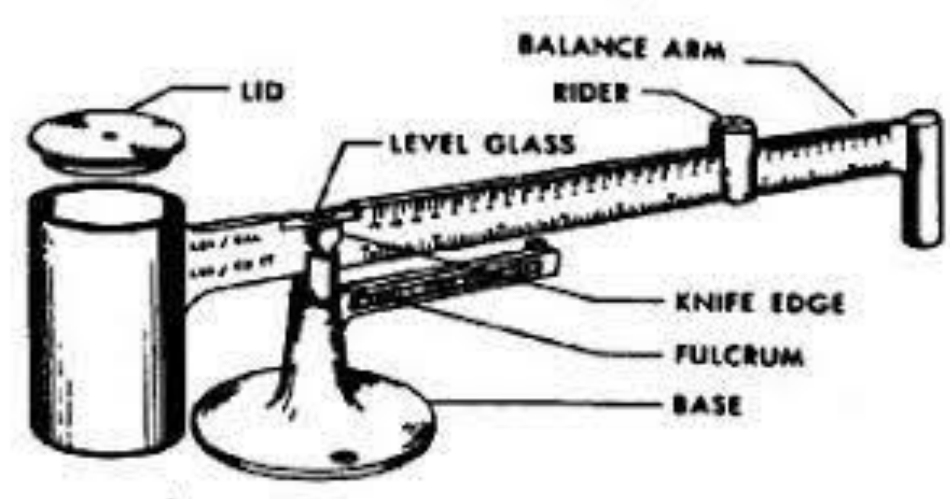

Fig 4.3: Mud Balance Diagram

4.3 Measurement of Mud Filtration Properties

Using a normal cell and an API condition of 100 psi differential pressure at room temperature, the filtration test was conducted. The press used for testing was made up of six separate filter cells mounted on a single frame, into which the test mud was then inserted. The mud cup assembly was clamped to the frame with the air pressure valve closed, and the filtrate outlet end was held finger taut. The pressure valve was opened to allow gas to enter from an air compressor pump, and the timing was initiated at the same time. A graduated cylinder was put underneath to collect filtrate.

The vacuum valve was closed after 30 minutes, and the filtrate measured in milliliters (mL) and the filter cake, measured in millimeters, were both measured.Figure below shows the test's findings.

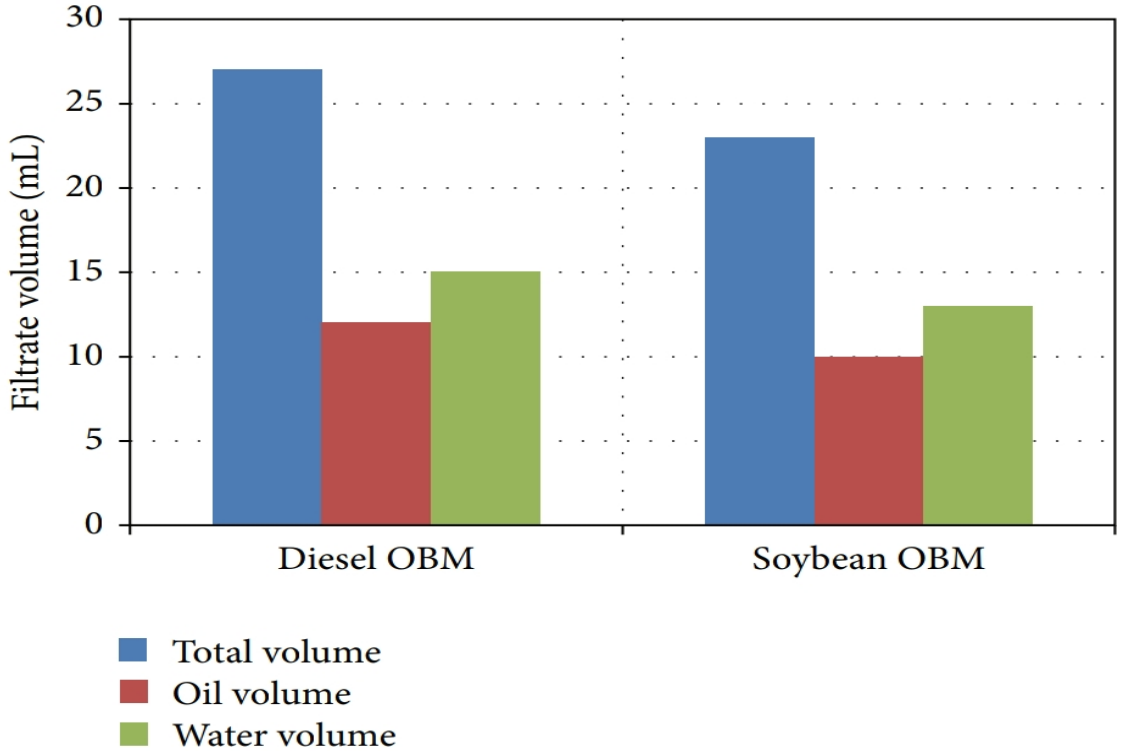

Fig 4.5 : Filtration Volume plot for Diesel and Soyabean OBM

The expanded equation,

$$f_1 = f \times \left(\frac{\sqrt{T_1}}{\sqrt{T}} \right),$$

where f_1 is an unknown filtrate at a time interval of T1, and f is a known filtrate at a time interval of T, can also be used to predict the calculation of filtrate loss at variable time intervals relative to known filtrate loss and time interval. As a result, Table 8 and Figures 5 and 6 show the computed values for filtration volume at times of 1, 5, 7.5, 10, and 15 minutes.

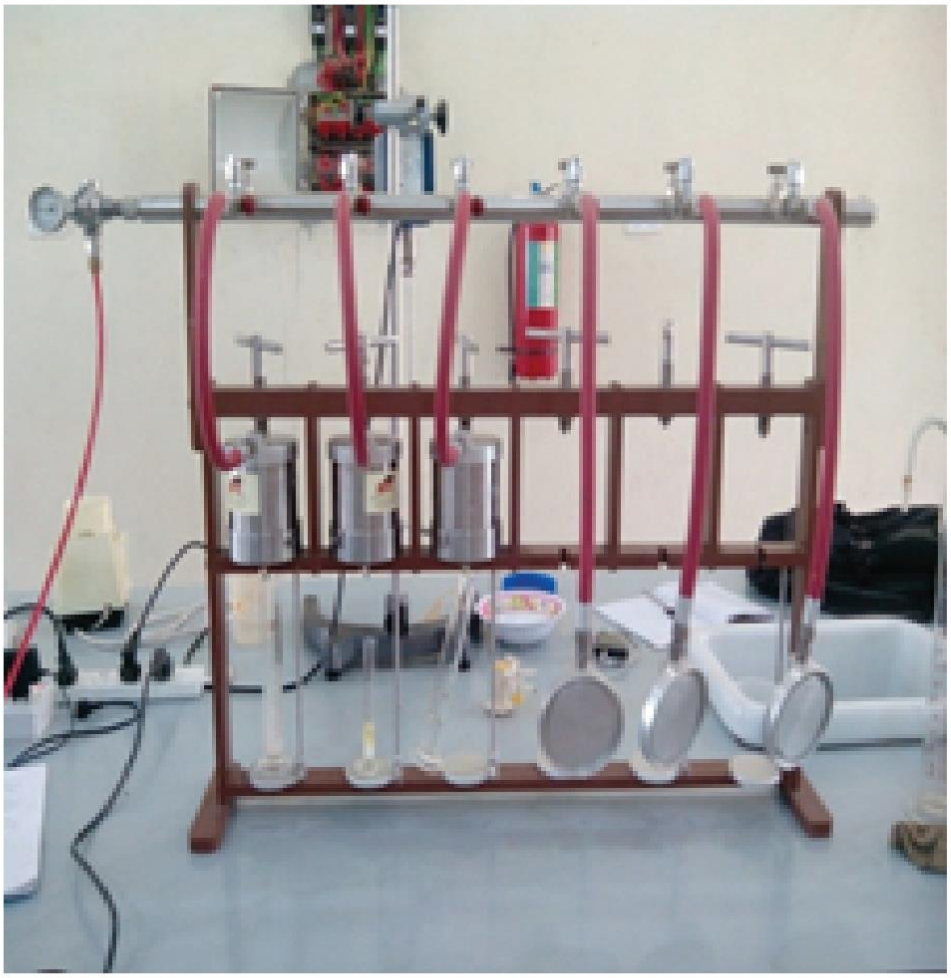

Figure 4.6 : API Filter Press

5. RESULTS

5.1 Rheological Characteristics

The significance of the rheological, plastic viscosity, yield point, gel strength, filtration, fluid loss, and filter cake characteristics of the two oils is the main driver behind the decision to use these characteristics as the foundation for comparison. The yield point (YP) is a measurement of a mud's capacity to raise cuttings from the annulus. A fluid with a high YP is not Newtonian and will carry cuttings more effectively than a fluid with a lower YP but comparable density. It is crucial to note that when the drilling mud is being circulated, overly high YP causes high pressure losses. Shear rate and shear stress were calculated from the dial measurements and viscometer speeds, respectively.

Using the Fann V-G viscometer, the gel strength of the mud samples was also measured. The power was quickly turned off after the speed selector knob had been turned at 3 rpm for ten seconds to stir the mud sample. The power was switched on at 3 rpm after 10 seconds and 10 minutes, respectively, after the sleeve stopped rotating. For each instance, the highest dial was noted as the gel strength of the mud samples at 10 seconds and 10 minutes.

The shear stress-shear rate curve (rheogram) of the formulated mud is shown in Figure 1 based on the results. The two mud samples' rheological models are shown in this image. The rheology of both mud samples, as depicted in the image, is comparable. This suggests that the rheological behavior of the dirt samples is comparable. In this regard, it is clear that the two OBMs that have been developed show a rheological model that is almost identical to the Bingham plastic model. Until the shear stress exceeds a specific minimum number known as the yield point, or YP, a Bingham plastic fluid will not flow. Variations in shear stress are proportional to variations in shear rate after the yield point (YP), with the plastic constant serving as the constant of proportionality.

This suggests that diesel OBM has a higher viscosity, which would provide more fluid flow resistance and lead to higher circulating pressures that could result in circulation loss and higher pumping expenses. beans therefore

OBM that has a low viscosity is a good candidate for drilling because it will give less resistance to fluid flow, which will result in a turbulent flow at low pump pressure and good hole cleaning.

5.2 Mud Density

The mud density of an oil-based mud can vary depending on the specific formulation and the drilling conditions. Generally, the mud density of an OBM ranges from 8.5 to 20 ppg (1.02 to 2.4 kg/L).

soybean oil has a density of 920 kg/m3, or about 7.66 lb./gal, as shown , soybean mud without barite has a greater mud density (7.82 lb./gal) than diesel mud (7.50 lb./gal), as shown in Table. It also shows the variance in mud density at a 10 g barite content.

According to the table, diesel OBM has a lower density number than soybean OBM. The outcomes show that soybean soil density increased to 8.10 lb./gal and diesel mud density at 10 g barite concentration is 7.98 lb./gal. According to these findings, the abundance of soybean and diesel OBMs has increased by 3.58 percent and 6.40 percent, respectively. This claim demonstrates Barite can be used to increase the density of soybean OBMs to suit any drilling operation, particularly when a heavy mud weight is needed.

5.3 Filtration Loss

The filtrate volume from the formulated OBMs that was recovered after 30 minutes is shown in Figure 3 and Table 7. The findings show that the water volume obtained from diesel mud (15 mL) was greater than the water volume obtained from soybean mud (13 mL).

This might be explained by the possibility that the water was only partially emulsified in the diesel sludge, creating an unstable emulsion. However, the amounts of oil obtained from the two samples were 12 mL and 10 mL, respectively Similarly, gasoline and soybean mud. The estimated filtrate loss volumes are also shown in Figure 5 for time intervals of 1.0, 5.0, 7.5, 10.0, 15.0, and 30.0 minutes. Given that the diesel OBM exhibits higher filter loss capacities than the soybean OBM, the figure demonstrates that the filter loss values increased over time.

The filtrate volumes are plotted in Figure 6 against the square root of the duration in minutes. This action was taken to measure the OBMs' spurt reduction. Consequently, the spurt loss readings for the two mud samples were the same, with a spurt loss volume of approximately 0.01 mL.

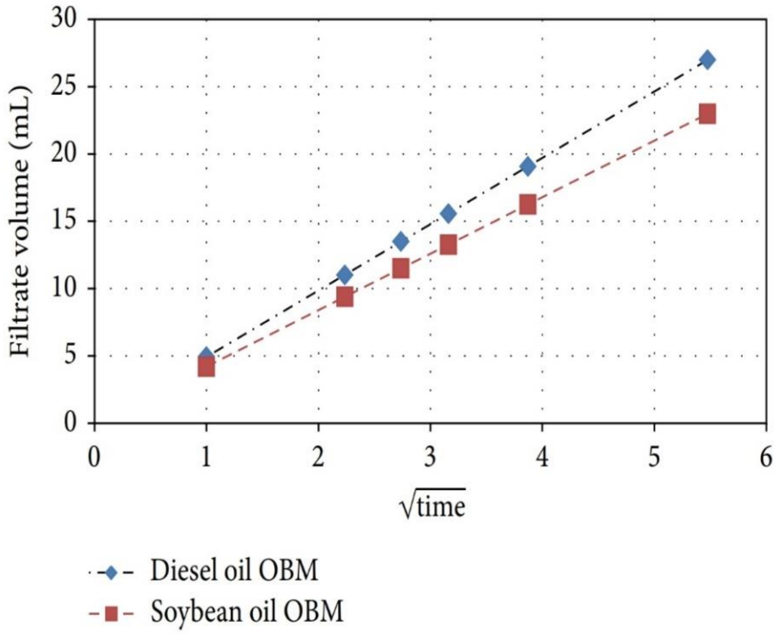

Fig 5.2: Comparison of Filtrate volume Vs Square root of time

The volume of filtrate that is lost to the formation is an important parameter that can affect drilling performance, wellbore stability, and the quality of the mud. When the volume of filtrate is plotted against the square root of time, the resulting graph can provide insight into the rate of penetration of the mud, the permeability of the formation, and the efficiency of the mud in sealing the formation. Typically, the graph will have a characteristic shape that reflects the behavior of the mud.

At the beginning of the test, the volume of filtrate will increase rapidly, indicating that the mud is losing fluid to the formation at a high rate. As time progresses, the rate of fluid loss will decrease, and the volume of filtrate will begin to level off. This is because the mud has formed a filter cake on the formation face, which is preventing further fluid loss. The rate of fluid loss will continue to decrease until it reaches a steady state, which indicates that the filter cake has reached a stable thickness and is no longer allowing fluid to pass through.

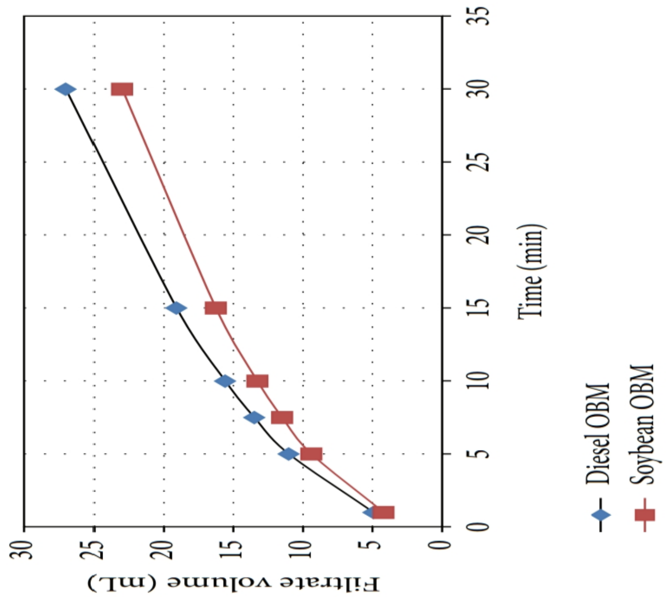

Fig 5.3: Comparison of Filtrate loss with time

5.4 Mud Cake Thickness

As was previously mentioned, the diesel OBM filters more effectively than the soybean-based formulations. High filtrate levels are typically linked to thick filter cake because the cake is made when filtrate is lost to formation and clay fragments are deposited on the hole's walls. Therefore, the filter cake will be thicker and the drilling mud will be less effective the greater the filter volume. As shown in Figure 4, diesel OBM has a thicker mud layer (2.5 mm) than soybean OBM (2.0 mm) due to its high filtration rate. This results in a thick mud cake that decreases the drilled wellbore's useful diameter, raising the region of the drill pipe's contact with the cake, increasing the risk of incidents involving stuck pipes. According to this finding, the soybean OBM formulation has excellent filtration properties that will be useful for drilling because they would stop occurrences involving stuck pipes. As shown in Figure 8, the soybean OBM has a soft physical characteristic, whereas the diesel OBM filter cake has a hard and rubbery physical characteristic. Considering this, it is preferable for drilling operations to use the thin but soft mud cake that was produced in the case of the soybean oil OBM.

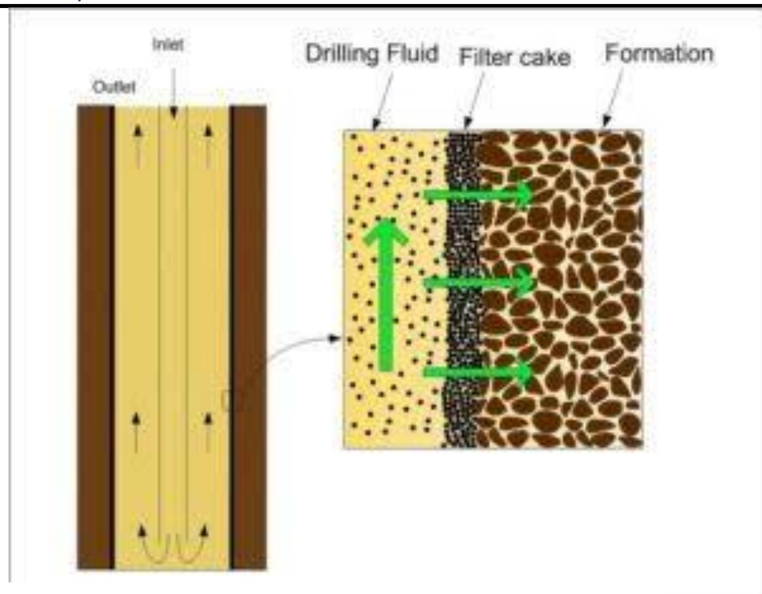

Fig 5.5: Mud Cake Thickness

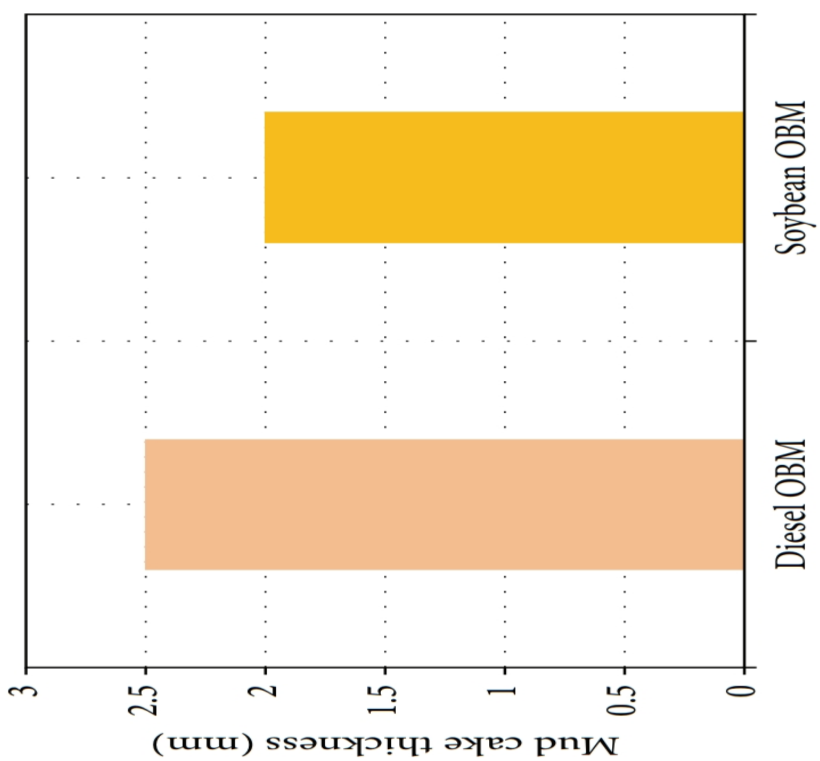

Fig 5.6: Comparison of Mud cake thickness

6. COMPARISON METHODS

6.1: Edible (Soybean) Oil Mud compared to other Oil Base Fluids.

Compared to other oil-based drilling fluids, soybean oil mud has several advantages. First, it is more environmentally friendly since it is biodegradable and non-toxic. This means that it has a lower impact on the environment and can be disposed of more easily. Second, soybean oil mud is a renewable resource, which means that it can be produced sustainably without depleting finite resources. Third, soybean oil mud has excellent lubricating properties, which can help reduce friction during drilling and prevent damage to the drilling equipment. Soybean oil mud is less expensive than other oil-based drilling fluids, which can help reduce drilling costs.

Soybean oil mud is a viable alternative to traditional oil-based drilling fluids, especially in environmentally sensitive areas. Its advantages in terms of environmental impact and cost make it an attractive option for companies looking to reduce their environmental footprint and drilling costs. However, its limitations in high-temperature environments and viscosity should be taken into consideration when selecting a drilling fluid for a particular well.

Limited or no direct comparisons of the rheological characteristics of soybean oil with those of other vegetable oils as the basic fluid in oil-based drilling mud have been made in the literature.

However, the literature compares various vegetable oils as an option to diesel oil in the formulation of oil-based mud. As a result, Adesina et al. proposed algae, moringa, canola, and jatropha oils as substitutes for diesel oil in the creation of oil-based mud.

The results of their research, which are shown in table below, showed that the different oils they looked at had the following mud properties.

Mud Properties	**Diesel Oil**	**Canola Oil**	**Jatropha Oil**	**Algae Oil**	**Moriga Oil**
Density,lb/gal	8.26	8.47	8.32	7.81	8.30
pH	8.00	9.50	9.00	9.00	9.00
Rheological Properties					
Plastic Viscosity,cP	13.0	12.0	8.0	8.0	11.0
Apparent Viscosity,cP	92.5	64.0	77.0	61.0	84.5
Yield Point,lb/100ft^2	155	112	112	106	147
Gel Strength,lb/100ft^2	50/51	60/72	54/55	52/43	52/53
Filtration Property					

Water Volume,mL	4.60	5.00	5.20	5.10	4.70
Cake Thickness,mm	1.00	0.90	0.89	0.90	0.90

Table 6.1: Comparison of Edible oil with previous works on oter oil based fluids

6.2 Cost Comparison between edible (Soybean) Oil and Diesel Oil

In the same manner, it is crucial to consider the price of these oils when conducting a comparison study of the use of soybean oil as a diesel oil substitute in drilling mud formulation. Thus, the prices of both fuels over the previous six years are shown in table.

These show that the price per barrel of soybean oil remained higher than that of the No. 2 diesel oil over the course of the preceding five years (i.e., 2009 through 2013). It's interesting to note that in 2014, the price per barrel of soybean oil decreased marginally. compared to diesel oil as output rose. Although the price of soybean oil would undoubtedly increase the cost of creating OBMs with it, the superior rheological properties of the soybean oil would ultimately offset this high cost. Soybean oil is also less risky in the event of spills and ecologically friendly (biodegradable) in terms of cuttings disposal.

Year	Edible Oil (Soyabean)	Diesel oil
2018	119.58	92.22
2019	135.39	126.33
2020	177.98	30.76
2021	168.61	126.66
2022	147.98	124.46

Table 6.2 : Comparison of edible (soyabean) oil and diesel oil

The cost of making OBMs with soybean oil would surely go up with its price, but in the end, this high cost would be mitigated by the oil's excellent rheological qualities. Additionally, soybean oil is less dangerous in the event of spills and environmentally benign (biodegradable) when it comes to the disposal of cuttings.

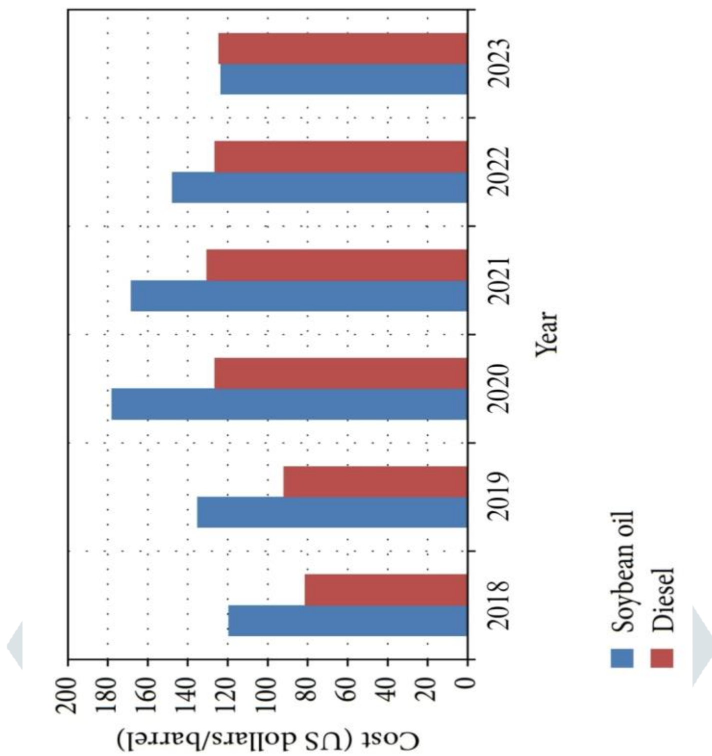

Fig 6.3: Trend of price of soyabean oil and Diesel oil

7. SCOPE

The future scope of using edible oil as OBM is promising, as researchers continue to explore new ways to improve its performance and overcome its limitations. Some of the ongoing research in this area includes developing new additives and surfactants to enhance the properties of edible oil-based muds, and optimizing the formulation and application of these muds in different drilling environments.

Overall, the use of edible oil as OBM is a promising area of research and development, with the potential to provide a more sustainable and environmentally friendly alternative to traditional oil-based muds.

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