

Kinetic Study of Formulated Oil-based Mud using Ukpo and Melon Husk Seed Oil

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Abstract

This study investigated the extraction, characterization, and application of Ukpo (Horse Eye Bean -*Mucuna sloanei*) and melon husk seed oil as alternative base fluids for drilling mud formulation. Oil was extracted at varying temperatures (50–70°C) and extraction times (15–35 minutes) using petroleum ether as solvent. The physicochemical properties of the extracted oils were analyzed and compared with conventional base fluids such as diesel and crude oil. Results showed that oil yield increased progressively with both temperature and time, with maximum extraction observed at 70°C and 35 minutes. As the temperature increases from 50°C to 70°C, oil yield rises steadily and consistently across all measurement points. Ukpo oil starts at 5.1ml at 50°C and increases to 15.69ml at 70°C, showing a smooth, predictable growth pattern. Melon husk oil follows a very similar trend, increasing from 4.7ml to 15.5ml across the same temperature range. Also, the maximizing oil yield is the goal and time is not an issue, both seeds provide similar output at 35 minutes both oils reach their highest production (Ukpo: 15.71 and Melon husk: 15.59) ml. Ukpo consistently produced higher yields than melon husk, although melon husk oil reached comparable values at longer extraction times. Physicochemical analysis revealed that Ukpo and melon oils possessed higher viscosities, higher flash points, and moderate densities, indicating their safety and suitability for drilling operations. Their rheological and filtration performances were evaluated and compared with diesel- and crude-based muds. Ukpo-based mud demonstrated superior rheological behavior, including higher gel strength, yield point, and angular velocity, while diesel-based mud showed the highest cutting-carry efficiency due to its lower viscosity. Filtration tests showed that Ukpo and melon muds formed thinner and more stable filter cakes than crude-based mud, with diesel exhibiting the best overall fluid loss control. The results indicated that Ukpo and melon husk seed oil were viable and environmentally friendly substitutes for diesel and crude oil in drilling fluid formulation. Ukpo oil displayed the most balanced and superior performance across extraction, physicochemical, filtration, and rheological parameters, while melon husk oil showed strong potential under optimized extraction conditions. The study concluded that both oils could contribute to safer, locally sourced, and sustainable fluid drilling systems.

Keywords: Drilling and Rheology, Kinetics, Extraction, Ukpo, Melon Husk seed oil, Extraction.

Date of Submission: 01-05-2026

Date of acceptance: 09-05-2026

I. INTRODUCTION

Drilling operation is enhanced by the application of drilling mud and it serves as many purposes in the drilling process, which includes the removal of cuttings' lubricating and cooling the drill bits, supporting the stability of the hole and preventing the inflow/out flow of fluid between well and the formation and another important function of drilling fluid is to stop compacting clay materials, commonly encountered in drilling operations from taking up water from the drilling fluid and subsequently, swelling Chikwe (2019). It is a known fact that drilling operations in the oil and gas industry is impossible without the use of drilling mud, as stated before; a drilling process is incomplete without the drilling mud which is an integral and indispensable component of any drilling operation. All these have enabled the upstream of the petroleum industry to thrive on the use of oil-based mud. Drilling fluid or drilling mud are nomenclature used to refer to fluids that assist in well control and in the removal of drill cuttings from the bottom of the hole to the surface during oil drilling operations Oseh,(2019). Before now, in the early days of oil and gas exploration, the primary function of drilling mud was just to carry cuttings from the bottom of the hole to the surface. Whereas, as of today it has been recognized that drilling mud has many more important functions Fadairoet *al.*, (2012)

Drilling mud is basically categorized into three types: Air based mud, Oil-based mud and Water-based mud. Oil-based mud is a drilling fluid with diesel, bio diesel or mineral oil as the major component. Over time it had been discovered that oil-based mud achieved better productivity than its counterparts (Air based mud and

Water-based mud). It is also considered to be more favorable in specific formations such as deep waters, high temperature wells, high pressure wells, clay and shale formations, formation with salt and sour borehole environments Olaitan and Orodu, (2017)

Drilling mud is usually a mixture of oil or water, weighing materials, clay and selected additives and chemicals as required. For a successful drilling operation, competent drilling mud is needed and there are three key factors that must be considered when selecting a competent drilling mud in order to achieve a successful drilling operation. These factors are the cost of formulating the mud, The mud technical performance and the environmental impact of the mud. Also, the drilling mud properties must be carefully calibrated and measured in relation to the formation lithology, pressure, temperature, chemical properties and rock properties. A mud engineer is charged with the task of selecting the best range of characteristics such as viscosity, density and composition ratio of the drilling mud Onuh *et al.*, (2019).

However, the preferred and commonly used oil in the formulation of oil-based mud is diesel, which studies have shown that diesel have nephrotoxic and high aromatic content. This causes significant impact on the environment especially in sensitive areas such as offshore, where spills/leaks into the environment can cause enormous pollution to the surrounding marine environment and its inhabitants. Hereby resulting in strict regulations and an increase in disposal costs which have greatly elevated its cost significantly and cuts must be put under significant processing before they can be disposed of. Disposal methods are numerous, ranging from burying, landfills, thermal desorption, recycling etc. But these methods are very expensive to operate, especially for cuttings gotten using diesel oil-based mud Hussein and Amin (2010).

Oil-based mud is a mud that has its continuous phase as oil derived from petroleum products. Under most conditions, conventional till cased muds are excellent for drilling through a production interval. Oil muds are also designed for maximum stability while drilling; OBM is particularly suitable for use in work over wells because it is available in sack form and may be mixed with lease crude and water or brine to form an emulsion. Diesel oil was used to replace water as based fluid for mud system designed for certain applications. Diesel oil-based mud is composed of various molecular weights, range cuts refined from crude oil for fuel. Oil-based drilling mud is used in high temperature formations, formations containing water sensitive minerals, clays or reactive gases, and in wells where a high level of lubrication is required. The oil-based mud additives are quite different from those of the water-based mud (Anawe *et al.*, (2014)

This work will focus on formulating environmentally friendly oil-based mud from ukpo oil, Melon husk oil and Aging of (ukpo and Melon husk) oil sample. A complete analysis of the soxhlet solvents extracted oil base muds rheological properties will be carried out to ensure its suitability for field use

II. MATERIALS AND METHOD

2.1 Materials Used

The materials used includes Diesel oil, Ukpo oil, Melon husk oil, water, n-hexane, filter paper, Barite, Bentonite, caustic soda (NaOH), soda ash (NaCO₃), Water, Universal pH Paper Strips, Filter paper, Threads, Soap, Tissue, Towel, poly anion cellulose (PAC), potassium chloride (KCL), xanthan gum, Borax, electronic weighing scale, Soxhlet extractor, Thimble, Retort stand, Condenser, Mechanical grinding machine, Electronic mixer, Mud balance, Beaker, Round bottom flask, Rotary viscometer, API filter press, Thermometer, Hot plate, Vernier caliper, Reagent bottles, Plastic storage container, Nylon bags, Distillation column, Test jar, Air cooler, Pensky Martens Flash Point Tester, Mixing container, Threads, Universal pH paper strips, filter paper, Pycnometer, Viscometer, Mash Funnel, Cylinder, Stopwatch, Electronic Oven, 200-mesh (74micron) Screen, Funnel, Graduated sand content measuring glass tube, Scientific Calculator.

2.2 Method Used

2.2.1 Ukpo and Melon husk Collection and Preparation

The Diesel oil will be obtained from NNPC filling station, The Ukpo and Melon husk will be obtained from mile 3 market port Harcourt, Rivers State, Nigeria. washed and sun dried for 4 weeks, when completely dried it will be ground using electric grinding machine, then weighed out 2kg for the extraction process and stored in a sample container. The method used in extracting oil from the (Ukpo and Melon husk) leaching process by Coulson & Richardson (2013) solvent extraction method. This method involves extracting oil from solid materials by using Hexane (solvent) with boiling points 62°C.

2.2.2 Procedures for Extraction of Oil from the Ukpo and Melon husk

The methods followed will be based on Shreves' work (2012). The oil extraction will be done using a Soxhlet extractor with hexane as the solvent. The samples were divided to explore the impact of temperature, extraction time and solvent volume. Additionally, the (Ukpo and Melon husk) oil sample will be analysed to determine Saponification Value, Acid Value, Iodine Value, Peroxide Value, and Free Fatty Acid.

2.2.3 Calculation of Oil Yield

The oil yield for experiment will be calculated using the formula.

$$\text{Yield (\%)} = \frac{\text{weight of pure oil extracted (g)}}{\text{weight of particle (g)}} \quad (1)$$

2.2.4 Characterization of (Ukpo and Melon husk) Oil

The properties of the extracted oil will be determined using standard methods described in literature or by the Association of Official Analytical Chemists AOAC, (2012).

2.2.5 Determination of Saponification Value

The analysis will be conducted following the method outlined by the Association of Official Analytical Chemists AOAC, (2012). In a 250ml conical flask, 4ml of the oil sample will be weighed, and 50ml of alcoholic-potassium hydroxide solution was added. The flask with its contents will be heated on a boiling water bath for 30 minutes, with intermittent shaking. To the solution, 1ml of phenolphthalein indicator will be then added, and titration it against hydrochloric acid. A blank titration, containing all the reagents except the sample. The saponification value (SV) will be calculated using the given expression.

$$SV = \frac{(B - S) \times N \times M}{w_o} \quad (2)$$

Where,

B = blank titre value

S = sample titre value

N = normality of KOH (0.5 M)

M = molar mass of KOH (56.1)

w_o = weight of oil sample.

2.2.6 Determination of Iodine Value

The Iodine Value will be determined following the AOAC method (2012). Approximately 0.35 ml of the sample was accurately weighed into a dry 250 ml conical flask. To this, 20 ml of carbon tetrachloride (CCl₄) will be added from a dry cylinder, and the flask was shaken to dissolve the oil. A 25 ml aliquot of the solution was pipetted into the flask in a fume cupboard and stoppered with cotton wool moistened with potassium iodide (KI) solution. The flask was left to stand for 30 minutes in the dark.

A blank titration will be prepared, including all the reagents except the sample. The liberated iodide can be titrated with 0.1 N Sodium thiosulphate, using starch solution as an indicator. The blue-black coloration turned colourless, and the titre value was recorded. The Iodine Value (IV) will be calculated using the provided equation.

$$IV = \frac{(B - S) \times N \times 12.69}{w_o} \quad (3)$$

Where,

B = blank titre value

S = sample titre value

N = normality of sodium thiosulphate

w_o = weight of oil sample.

2.3 Acid Value

The Acid Value (AV) will be calculated using the method described by Warraet *al.*, (2012). Thus, 100 ml of neutral ethyl alcohol will be heated with 10 g of the oil sample in 250 ml beaker until the mixture boils. The mixture is then titrated with 0.1 M KOH solution using phenolphthalein as indicator. The content will be constantly shaken until the colour changed to pink. The AV is then calculated using the expression:

$$AV = \frac{TV \times N \times M}{w_o} \quad (4)$$

Where,

TV = titre value

N = normality of KOH (0.1 M)

M = molar mass of KOH (56.1)

w_o = weight of oil sample.

2.3.1 Free Fatty Acid

The free fatty acid will be determined according to Egbonuet *al.*, (2015). Will be calculated from the relationship between it and the acid value. The mathematical relation is expressed as:

$$\text{Free fatty acid} = \text{Acid value} \times 0.503 \quad (5)$$

2.4 Determination of Peroxide Value

The analysis, conducted following the method of the Association of Official Analytical Chemists (AOAC, 2012), was carried out in the dark. To begin, 5 g of the oil sample will be weighed into a clean, dry boiling tube. Subsequently, 30 ml of a solvent mixture (12 ml acetic acid + 18 ml chloroform) will be added to the tube, and the mixture will boil for 60 seconds. The contents were then poured into a titration flask containing 1 ml of 2% potassium iodide and 30 ml of water.

The resulting solution will be titrated against 0.01 N Sodium thiosulphate using 1 ml of 1% starch indicator. The endpoint must be indicated by a milky colour. A blank titration, excluding the sample.

The Peroxide Value (PV) will be calculated using the provided equation.

$$\text{Peroxide Value (PV)} = \frac{(S - B) \times N \times (1000)}{w_o} \quad (6)$$

Where,

B = blank titre value

S = sample titre value

N = normality of sodium thiosulphate

w_o = weight of oil sample

2.5 Refractive Index

The refractive index will be determined using Abbe Refractometer.

2.6 Specific Gravity

The specific gravity will be determined according to method described in AOAC (2012). A density bottle will be washed with detergent, water and petroleum ether. 100 ml of oil, the sample, and water sample were weighed via the density bottle to determine the respective weight. After recording of the weights, the specific gravity of the oil will be obtained using the expression.

$$\text{Specific gravity} = \frac{\text{Weight of Oil}}{\text{Weight of equal Volume of water}} \quad (7)$$

Table 1: Oil-based mud formulation using (Ukpo) oil

S/N	Additives/Composition	Content (per lab barrel)	Function
1.	(Ukpo)	350mls	Based Fluid
2.	Bentonite	2.8g	Viscosifiers
3.	PAC	2.0g	Fluid loss control
4.	Barite	76.8g	Weighting agent
5.	Caustic Soda	0.2g	pH and Alkalinity control
6.	Soda Ash	0.2g	CaCO ₃ Inhibitor
7.	Potassium Chloride	18g	Corrosion control
8.	Borax	0.2g	Preservative
9.	Xanthan Gum	2.8g	Thickener/increases viscosity

Table 2: Oil-based Mud Formulation using Melon husk

S/N	Additives/Composition	Content (per lab barrel)	Function
1.	Melon husk	350mls	Based Fluid
2.	Bentonite	2.8g	Viscosifiers
3.	PAC	2.0g	Fluid loss control
4.	Barite	76.8g	Weighting agent
5.	Caustic Soda	0.2g	pH and Alkalinity control
6.	Soda Ash	0.2g	CaCO ₃ Inhibitor
7.	Potassium Chloride	18g	Corrosion control
8.	Borax	0.2g	Preservative
9.	Xanthan Gum	2.8g	Thickener/increases viscosity

Table 3: Oil-based Mud Formulation using Diesel oil

S/N	Additives/Composition	Content (per lab barrel)	Function
1.	Diesel oil	350mls	Based Fluid
2.	Bentonite	2.8g	Viscosifiers
3.	PAC	2.0g	Fluid loss control
4.	Barite	76.8g	Weighting agent
5.	Caustic Soda	0.2g	pH and Alkalinity control
6.	Soda Ash	0.2g	CaCO ₃ Inhibitor
7.	Potassium Chloride	18g	Corrosion control
8.	Borax	0.2g	Preservative
9.	Xanthan Gum	2.8g	Thickener/increases viscosity

Table 4: Oil-based Mud Formulation using Crude Oil

S/N	Additives/Composition	Content (per lab barrel)	Function
1.	Crude Oil	350mls	Based Fluid
2.	Bentonite	2.8g	Viscosifiers
3.	PAC	2.0g	Fluid loss control
4.	Barite	76.8g	Weighting agent
5.	Caustic Soda	0.2g	pH and Alkalinity control
6.	Soda Ash	0.2g	CaCO ₃ Inhibitor
7.	Potassium Chloride	18g	Corrosion control
8.	Borax	0.2g	Preservative
9.	Xanthan Gum	2.8g	Thickener/increases viscosity

III. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of the Oil

Table 5: The physicochemical properties of the oil.

Parameter	Diesel	Ukpo	Melon	Crude
Appearance	pale yellow	Gold yellow	Lighth yellow	Dark Brown
Density (g/cm ³)	0.85	0.93	0.92	0.87
Viscosity (cp)	4	25	20	12
Flash Point (oC)	75	180	170	60
Pour Point (%)	-10	5	3	-15
Moisture Content (%)	0.1	0.2	0.3	0.5
pH	9	8.3	8.5	8.5

Table 5 show the analysis of (Ukpo seed, Melon husk, Diesel and crude) oil's physicochemical properties provide valuable insights into its composition and potential utility. The physicochemical propertieess of the study are.

3.1.1. Appearance.

- Diesel: Pale yellow, indicating high refinement and low impurity content.
- Ukpo: Gold yellow, showing a richer, slightly viscous natural oil appearance.
- Melon: Light yellow, like vegetable oils — clean and moderately pure.
- Crude: Dark brown, consistent with unrefined petroleum with heavy hydrocarbons.

The color variation reflects the level of refinement and impurity. Lighter oils (Diesel, Ukpo, Melon) are cleaner and more stable, while darker crude contains more heavy compounds, making it less refined and potentially more reactive.

3.1.2. Density (g/cm³).

- Ukpo (0.93) and Melon (0.92) have the highest densities, indicating heavier molecular structures and stronger intermolecular bonding.
- Crude (0.87) and Diesel (0.85) are lighter, with Diesel being the least dense (hence more fluid and volatile).

Density affects mud weight and hydrostatic pressure in drilling operations. Higher density fluids (Ukpo, Melon) are beneficial where formation pressure control and borehole stability are important. Lower density fluids (Diesel, Crude) are easier to pump but provide less weight and control.

3.2. Viscosity (cP).

- Ukpo (25 cP) shows highest viscosity, followed by Melon (20 cP), Crude (12 cP), and Diesel (4 cP).
- High viscosity fluids resist flow more strongly, improving cuttings suspension and hole cleaning in drilling.

Viscosity determines the carrying and suspension ability of a fluid. High viscosity = better at suspending and transporting drill cuttings. Low viscosity is easier to pump but poor at carrying solids. Also, Ukpo and Melon oils are better rheologically (thicker and stronger), making them suitable for mud formulation. Diesel is too thin for this purpose, while Crude shows moderate behavior

3.2.1. Flash Point (°C).

- Ukpo (180°C) and Melon (170°C) have very high flash points, making them much safer (low fire hazard).
- Diesel (75°C) and Crude (60°C) are more flammable.

Flash point indicates the temperature at which vapor ignites. Higher flash point = safer to handle, less risk of fire. Also, Ukpo and Melon oils are significantly safer in high-temperature environments such as drilling rigs, while Diesel and Crude pose a fire hazard.

3.2.2. Pour Point (°C).

- Crude (-15°C) and Diesel (-10°C) can flow at very low temperatures ideal for cold environments.
- Ukpo (5°C) and Melon (3°C) have higher pour points, meaning they may solidify sooner under cold conditions.

Pour point defines the lowest temperature at which oil remains flowable. A lower value means better performance in cold climates or deep drilling. Diesel and Crude are superior in cold environments, while Ukpo and Melon may thicken or gel at low temperatures. they need pour point depressants or thermal control to stay flowable.

3.2.3. Moisture Content (%).

- Diesel (0.1%) → lowest moisture, highly refined.
- Ukpo (0.2%), Melon (0.3%), Crude (0.5%) → increasing water content.

High moisture leads to corrosion, instability, and bacterial growth. Low moisture enhances fluid stability and shelf life. All samples have low moisture, but Diesel is best in this regard. Ukpo and Melon show good purity, while Crude may require additional dehydration.

3.2.4. pH.

- Ranges from 8.3–9.0, indicating mild alkalinity.
- Diesel (pH 9) → slightly more basic, potentially offering better corrosion resistance.

A mildly alkaline pH helps prevent corrosion and acidic degradation. Too high a pH could destabilize emulsions, while too low may cause metal corrosion. All samples are within the acceptable range for drilling fluids, avoiding metal corrosion or acidic reactions. All samples are chemically stable; Diesel has the best alkaline protection potential.

IV. CONCLUSION

The results obtained from this research demonstrate that both Ukpo seed oil and melon husk oil possess significant potential as viable alternatives to conventional base fluids such as diesel and crude oil in drilling fluid formulation. Their physicochemical properties show clear advantages in terms of safety, environmental compatibility, and performance. Ukpo and melon oils exhibited higher viscosities, higher flash points, and moderate densities, making them safer and more effective for drilling operations requiring enhanced thermal stability, improved cuttings suspension, and reduced fire hazards. Although their pour points are higher than those of diesel and crude, they remain acceptable for drilling environments with adequate temperature control.

Extraction analysis revealed that both temperature and extraction time have strong positive influences on oil yield. Maximum yields were obtained at 70°C and 35 minutes, with Ukpo consistently producing slightly higher values across conditions. However, melon husk oil showed significant catch-up at prolonged extraction time and high temperature, ultimately achieving nearly equivalent yield to Ukpo. This indicates that melon husk, despite its slower initial release, becomes equally effective when processed under optimal conditions.

Mud property evaluation further established the suitability of Ukpo and melon oils as drilling fluid bases. Their mud densities were higher than those of diesel and crude, enhancing hydrostatic pressure and borehole stability. Filtration characteristics also revealed that Ukpo- and melon-based muds form relatively thin, stable filter cakes that minimize filtrate loss, an essential factor in reducing formation damage. Diesel

demonstrated the best overall filtration control, but Ukpo closely matched its performance, highlighting its strong potential as a local, eco-friendly substitute.

Rheological performance showed that Ukpo-based mud consistently exhibited superior gel strength, yield point, and angular velocity, indicating enhanced suspension capacity, better hole cleaning efficiency, and improved transport cuttings under static and dynamic conditions. Diesel-based mud, while having the lowest viscosity, recorded the highest Cutting Carry Index due to its faster flow properties. Melon and crude oils demonstrated moderate rheological behavior, performing adequately but not exceeding the performance of Ukpo.

This research contributes to knowledge in several important ways.

- i. The study provides empirical evidence that Ukpo seed and Melon husk, which are underutilized agricultural by-products, can serve as alternative and sustainable oil sources with competitive yields under optimized extraction conditions.
- ii. The research identifies the optimal combination of extraction temperature, solvent volume, and time required to maximize oil yield from both biomaterials. This contributes new data to existing literature where such optimization for these specific seeds/husks is limited.

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