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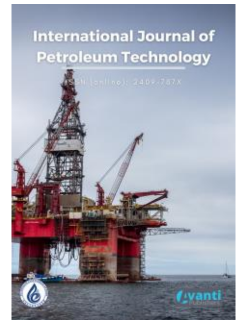

Determination of the Effect of *Moringa oleifera* Seed on the Rheological and Filtration Properties of Water Based Mud

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ABSTRACT

A cost-effective and environmentally friendly biodegradable locally sourced alternative will be sought to reduce drilling fluid cost drilling operations. *Moringa oleifera* seed is a cheap, locally obtainable, and environmentally friendly additive. This study aims to determine the effect and suitability of locally processed *Moringa oleifera* seed powder (MSP) as an additive to improve the performance of water-based mud. The seeds were collected, prepared, and pulverized to a particle size of 75 microns. Varying concentrations (2.0, 4.0, 6.0, 8.0, and 10.0 g) of the MSP were used to treat a simple mud sample, and their properties were determined at varying temperatures (26°C, 40°C, 50°C, 60°C, 70°C) using American Petroleum Institute (API) standard procedures. Mud samples treated with Carboxymethyl cellulose (CMC) served as control. From the result, it was observed that the pH and the mud weight were not affected by MSP concentration. The mud sample plastic viscosity improved by 18% as MSP concentrations increased. The YP/PV ratios show an enhancement at all *Moringa oleifera* seed powder concentrations relative to the control mud except for the sharp decrease at 70°C. The test sample processed a greater fluid loss volume and filter cake thickness for all concentrations. The physical examination of the mud filter cake of the additive depicted that they have slippery, smooth, and soft mud cakes. The results elucidated MSP suitability in some traditional chemical materials in the oil and gas industry.

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1. Introduction

In the search for hydrocarbons, drilling a successful hole is an essential part of the exploration process and is highly subject to the drilling fluid's performance. According to Udoh *et al*. [1], drilling creates a passage for the discovered hydrocarbon to be produced at the surface. The drilling fluids, called drilling muds, are often defined as liquid compositions to help drill petroleum wells. They depend on the particular requirements of each perforation [2].

Drilling fluid is generally seen as the "blood" of all drilling operations in the petroleum industry. Drilling fluids are the liquid composition that helps the process of drilling petroleum wells and are any fluids circulated through a well to remove cuttings from a wellbore. The fluid is pumped down the drill string, through the bit's nozzles, and returns up the annulus between the drill string and the wellbore walls, carrying the cuttings produced by the bit action to the surface. The prime use of the drilling fluid is to remove the formation cuttings within the well. The designed fluid should carry and suspend the cuttings while in circulation and transmitted securely through the annulus incurring minimum losses and environmental impact. Two vital parameters of drilling mud that need to be monitored and controlled to achieve successful drilling operations are the mud rheological properties [3] and the filtration properties [4].

Drilling fluids underwent significant technological evolution, from the first operations performed in the US, using a simple mixture of water and clays, to complex mixtures of various specific organic and inorganic products used nowadays. These products improve fluid rheological properties and filtration capability, allowing penetration into heterogeneous geological formations under the best conditions [5]. Drilling fluids are classified according to the base fluids under three distinct classes: Water-based, oil-based, and synthetic-based. Unlike oil-based drilling fluids, Water-based drilling fluids pose no threat to the environment and are easy to formulate [6]. Although the invasion of water into permeable formation weakens the wellbore stability resulting in severe drilling problems, such as tight holes, stuck pipes, and giving away of the wellbore, hampers the drilling program severely [7, 8].

Generally, two or three kinds of water-based drilling muds are used bentonite drilling mud, polymer drilling mud without clays that diminish shale formation hydration, and a drill-in fluid that prevents permeability damage as well as possesses inhibitory properties depending on the borehole's depth and the formations drilled at the time of borehole drilling. The main ingredient of bentonite drilling mud is bentonite, which is a structural building component. In order to improve the overall properties of the Water- Based Drilling Fluid system, additives such as cellulose derivatives, polymer starch, partially hydrolyzed polyacrylamide (PHPA), Carboxyl methylcellulose (CMC), guar gum, xanthan gum, added to the mud system [9]. This is possible due to the ability of the products to form a hydrogen bond with the molecules of water [10]. Kosynkin *et al*. [11], in their study, mentioned that reservoirs could be damaged and productivity can be reduced due to fluid invasion into porous media as this blocks hydrocarbon exit flow paths or causes wellbore collapse. As a result of all these, it can be seen that filtration control is significant for both well productivity and drilling performance [12, 13], and as such, polymer, such as polyanionic cellulose (PAC), acts as a fluid loss material which not only minimizes the loss of fluid into the formation but also forms a thin cake with low permeability on the wall of the wellbore [14]. The additive's molecular weight and chemical structure can also aid in improving the plastic viscosity of the mud [15].

The growing concern in the world on the side effect of the use of chemicals and non-biodegradable products on the environment is resulting in the drive in the oil and gas industry for products that are not only cheap but as safe, soluble in water, and environmentally friendly mud system [16, 17]. Drilling fluid treated with naturally occurring plant extracts is now rising. Many research works have been conducted in recent years on the use of natural, biodegradable, non-toxic, and eco-friendly green materials in drilling fluids to impart a specific function or several functions, with a particular focus on locally sourced materials as a means of reducing the drilling fluid cost and the impact of the toxic chemicals from the drilling industry on the ecosystem. These materials are frequently used to improve drilling fluid properties such as rheological properties and filtration control owing to appropriate properties, widespread availability, relatively low cost, and inherent biodegradability [18].

Some naturally occurring materials are used in drilling fluids directly without modification [19, 20] while applying quebracho (a plant tannin) as a drilling fluid additive, Qi *et al*. [21] from the result of their study concluded that the excellent properties of this plant make it suitable even for ultra-deep drilling operations. Perez [22] examined tannin as a thinner in reducing the viscosity in a water-based mud; the study shows that tannin performed excellently as a deflocculant and did not require any modification. Hossain *et al*. [23] studied the effect of powdered grass as a sustainable drilling fluid additive in a simple water base mud. The result from the study shows that with varying particle sizes and concentrations, the mud sample's viscosity, gel strength, and filtration showed some improvement. Oseh *et al*. [24] investigated using Henna Leaf Extracts as a viscosity modifier. In contrast, the side effect of applying Henna extract as an additive in a water-based mud was carried out by Moslemizadeh *et al*. [25]. Investigation into the use of Henna leaf extract and Hibiscus leaf extract in a sodium bentonite mud, and their result shows that both extracts had a positive influence on the mud filtration properties and also reduced the swelled volume of the mud sample [26] and also the study on the use of potato starch in improving the rheological properties of a drilling mud [27]. The effect of Terminalia mantaly leaves on the properties of drilling mud was also studied [28]. The use of banana peel ash as a substitute additive for NaOH to enhance pH properties for drilling fluids and to control corrosion was examined. In the study, it was concluded that banana peel ash was a pH control material [29].

Others were chemically modified to meet the requirements of water-based drilling fluids. The study of the use of poly (oxyethylene)-amidoamine-based Gemini cationic surfactant with hydrophilic spacers in water-based drilling Fluids by [30] shows secondary amine spacer surfactant performing well like the conventional KCl and dodecyl trimethylammonium bromide (DTA). Due to their shear-thinning and thixotropic behavior, xanthan gum, scleroglucan, guar gum, diutan, and welan gum are typically viscosifiers [31, 32]. Starch derivatives like carboxymethyl starch (CMS) and hydroxypropyl starch (HPS), cellulose derivatives like V carboxymethyl cellulose (CMC), hydroxyethyl cellulose (HEC), and polyanionic cellulose (PAC), modified tannins and lignins are classic products that have been widely used for rheological modification and filtration control [33].

Cellulose obtained from corn cob was used to improve the rheology of a water–based mud. The results showed that the corncob reduces fluid loss and is effective compared to polyanionic cellulose (PAC) [34]. Several other natural materials and their modifications have also been investigated as potential drilling fluid additives, including waste products. Some of them include the use of pistachio shell powder [35], mandarin peel powder [36], and potato peel powder [37]. The availability of Moringa seeds in most parts of Nigeria makes it a cost-effective material for drilling fluid additives. In this study, the interaction of water-based mud and Moringa Seed Powder (MSP) was investigated under the varying concentration of MSP and increased temperatures for the possible application of MSP in enhancing the rheological and filtration properties of the mud. Also, it will be examined to confirm its possible use as a replacement for the conventional viscosity and fluid loss additive in the bid to reduce the overall cost of drilling.

2. Materials and Methodology

The materials used for the study are distilled water, bentonite, barite, carboxymethylcellulose (CMC) -low viscosity (lv), and plant material (*Moringa oleifera* Seed Powder), while the apparatus used was weighing balance, measuring cylinder, beakers, multimixer and cup, pH indicator strip, thermometer, sieving mesh, bucket, bowl, Fann 35A, stopwatch, API filter press, sieve, spatula, and a Soxhlet apparatus.

This study is divided into six sections, namely:

1. Collection and processing of the Moringa seeds into powder form
2. Characterization of the Moringa seed powder
3. Drilling mud formulation
4. pH and density determination
5. Evaluation of the drilling mud's Rheological properties and
6. Filtration properties of the mud samples

2.1. Collection and Processing of Plant Material (Moringa Seed Powder)

The Moringa seed pods were harvested from Moringa trees at the Abadina area, University of Ibadan, Ibadan, Nigeria, and taxonomically identified at the Department of Botany, University of Ibadan. The seeds were manually removed from their pods (Fig. **1A**) and seed kernels (Fig. **1B**). The seeds (Fig. **1C**) were first dried at room temperature for five days, then roasted using a sand bath method (Fig. **1D**) which ensures the seeds roast evenly. After roasting evenly, the seeds were pulverized using a pulverizer to obtain a smooth powdery sample (Fig. **1E**). The pulverized sample was dried at room temperature for three days before being stored in air-tight containers.

A B C D E

Figure 1: Drying and preparation of the Moringa seed sample using a sand bath method.

2.2. Sample Characterization

The FTIR (Fourier Transform InfraRed Spectroscopy) and proximate analysis tests were carried out to characterize the Moringa seed powder.

A) Fourier Transform InfraRed Spectroscopy (FTIR)

FTIR offers quantitative and qualitative analysis for organic and inorganic samples. Fourier Transform Infrared Spectroscopy (FTIR) identifies chemical bonds in a molecule by producing an infrared absorption spectrum. FTIR is an effective analytical instrument for detecting functional groups and characterizing covalent bonding information.

B) Proximate Analysis of Moringa Sample

The proximate composition of the *Moringa oleifera* seed powder was determined with slight modifications using the method described by Pearson [38] and [39]. The sample was analyzed for Moisture content, Dry matter, Crude protein, Ash, Crude Fat, and Carbohydrates. The difference determined carbohydrate.

i) Determination of Moisture Content Using the Oven Method

Aluminum dishes were washed thoroughly and kept in the moisture oven to dry, after which they were left to cool in a desiccator. Each dish was weighed, and individual weight was taken down. Representative macerated Moringa seed powder sample portions were placed in the already-weighed dish. The weight of the sample in the dish was then weighed and noted. The samples were left to dry in the moisture oven at 80ºC for 20 hours and then at 105ºC for another 4 hours until a constant weight was achieved. The sample was then cooled in a desiccator, and the dry weight of the sample and the dish were determined. Moisture content was calculated using equation the 1.0.

$$\%\, moisture = \frac{wet\ weight - dry\ weight}{wet\ weight} \times 100\% \qquad 1.0$$

ii) Determination Moisture of Moisture as Dry Matter (%)

Dry matter of the sample was obtained by calculating the difference in the weight of the sample before drying in the moisture oven and after drying in the moisture oven. It can easily be obtained using equation 1.1.

$$dry\ matter = 100 - \%\, moisture\ (wet\ basis) \qquad 1.1$$

iii) Determination of Ash Using Muffle Furnace

Using 5g of finely ground MSP, the weight of ash was obtained using the equation 1.2.

$$\% \, Ash = \frac{Ash \; weight(g)}{Sample \; weight(g)} \times 100 \qquad 1.2$$

iv) Fat Determination Using Soxhlet Extraction Method

A 250ml clean boiling flask was dried in an oven at 105-110ºC for about 30 minutes. It was then kept in the desiccator to cool, and 2.0g of samples were weighed into labeled thimbles. The corresponding flasks were also weighed and labeled accordingly. The boiling flask was filled with about 300ml petroleum ether with a boiling point of 40-45ºC. The extraction thimble was plugged lightly with cotton wool. The Soxhlet apparatus was assembled and refluxed for about 6 hours. The thimble was afterward unplugged carefully, and the petroleum ether was collected at the top. The flask was removed when almost free of petroleum ether and dried at 105-110ºC for one hour. It was then transferred from the oven to a desiccator, where it was cooled and later weighed using equation 1.3.

$$\% \, Crude \text{ fat} = \frac{\text{Weight of fat}}{\text{weight of sample}} \times 100 \ldots \qquad 1.3$$

v) Total Carbohydrates Determination % (CHO)

This was determined by subtracting the % Moisture, % Protein, % Ash, % Crude Fat from 100 as presented in equation 1.4.

$$Total \; Carbohydrate = 100 - (\% \text{ Moisture} + \% \text{ Protein} + \% \text{ Ash} + \% \text{ Crude Fat}) \qquad 1.4$$

2.3. Preparation of Mud Samples

The water-based drilling mud is freshwater formulated using distilled water and sodium bentonite clay as recommended [40]. A Hamilton mixer was used with an electric weighing machine to measure the various additives.

Ten (10) fresh water-based drilling mud samples were formulated with a weighting material. Five (5) of the mud samples were treated with varying concentrations of the MSP, while the reminding with CMC served as a control. The Hamilton mixer was used in mixing the mud samples until a homogenous mixture was obtained. The mud samples were labeled as presented in Table **1**.

2.4. Determination of pH and Density

Immediately after the preparation of the base mud, the mud samples' pH was determined using a pH meter, and a pH paper was used to confirm the accuracy of the result. The mud weight was determined using a Bariod Mud balance and calibrated using distilled water.

2.5. The Rheological Properties of the Mud Samples

The mud rheological properties were determined using a Fann 35A viscometer. After thorough agitation of the mud samples for 15 mins., each sample was poured into the viscometer cup. Dial readings 30rpm, 60rpm, 100rpm, 200rpm, 300rpm, and 600rpm were recorded at different temperatures (26ºC, 40ºC, 50ºC, 60ºC, and 70ºC) and varying concentrations (2.0g, 4.0g, 6.0g, 8.0g, and 10.0g). The 10 seconds and 10 minutes of gel strength readings were also recorded.

The Bingham model was used to explain the behavior of fluid and the plastic viscosity and yield point calculated using the equation 1.5 and 1.6.

$$\text{Plastic Viscosity (PV) cp} = \theta_{600} - \theta_{300} \qquad 1.5$$

$$\text{Yield Point (YP) lb/100ft}^2 = \theta_{300} - \text{PV} \qquad 1.6$$

Table 1: Composition of the water-based mud treat with the different concentrations of additives.

	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	Sample G	Sample H	Sample I	Sample J
Distil Water	350ml	350ml	350ml	350ml	350ml	350ml	350ml	350ml	350ml	350ml
Bentonite	21.5g	21.5g	21.5g	21.5g	21.5g	21.5g	21.5g	21.5g	21.5g	21.5g
Barite	9.5g	9.5g	9.5g	9.5g	9.5g	9.5g	9.5g	9.5g	9.5g	9.5g
CMC	2.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g
CMC	0.0g	4.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g
CMC	0.0g	0.0g	6.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g
CMC	0.0g	0.0g	0.0g	8.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g
CMC	0.0g	0.0g	0.0g	0.0g	10.0g	0.0g	0.0g	0.0g	0.0g	0.0g
MSP	0.0g	0.0g	0.0g	0.0g	0.0g	2.0g	0.0g	0.0g	0.0g	0.0g
MSP	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	4.0g	0.0g	0.0g	0.0g
MSP	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	6.0g	0.0g	0.0g
MSP	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	8.0g	0.0g
MSP	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	0.0g	10.0g

2.6. The Filtration Properties of the Mud Samples

A) The API Filter Press

The LTLP filter press was used to determine the filtration rate through a standard filter paper and the rate at which the mud cake is deposited, as indicated by an increase in thickness on the standard filter paper under standard test conditions.

B) Mud Filter Cake Characteristic

API qualitatively describes a drilling fluid filter cake as firm, slippery, smooth, soft, sticky, etc. [41]. The mud cake is deposited as indicated by increased thickness on the standard filter paper under standard test conditions. The filter paper contains a layer of mud cake, and the cake thickness was measured with a ruler and recorded as the drilling fluids' cake thickness in centimeters (cm). This was then converted to 1/32 of an inch.

3. Results and Discussion

The FTIR spectrum of Moringa seed powder is depicted in the Fig. (**1**). Based on the distinctive absorption bands displayed by the spectrum, the main functional groups in Moringa seed are identified as hydroxyl (OH), carboxylate (COO), methylene (CH_2) and methene (=CH-). The vibration bands at 3797.03–3690.15 and 3295.08-3007.01cm^{-1} were observed due to the CH_2 and OH vibrations, respectively. Multiple variations occurred for OH and CH_2 functionalities. This was believed to result from the polymeric nature of Moringa seed, causing different chemical environments. The absorption band at 2923.87cm^{-1} was due to the =CH functionality, while the absorption band at 1710.92cm^{-1} was due to the OH bonding vibration mode. Moreover, the absorption bands with peaks around 1700 and 1624cm^{-1} showed the existence of C=O. Peaks above the 3000cm-1 baseline indicated the double bond functionality in Moringa seed.

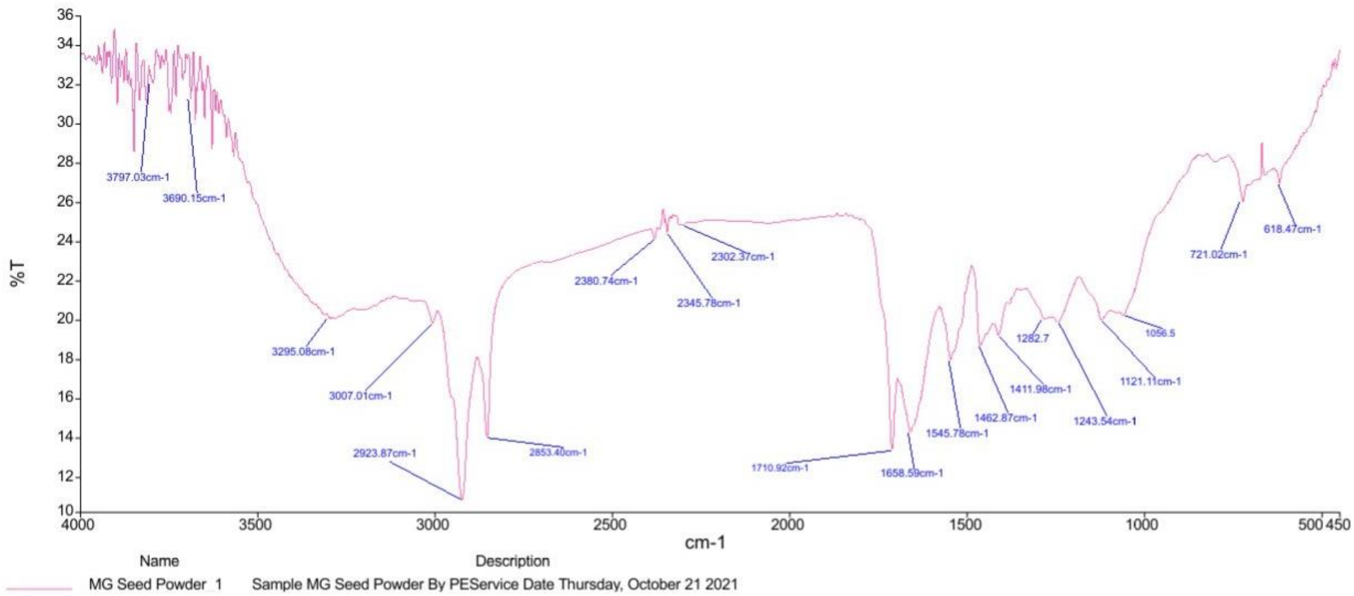

Figure 1: FTIR spectrum for Moringa seed powder.

From Table **2**, the result of the proximate analysis, moringa seed powder is low in ash content. This indicates that it has little concentration of inorganic materials. The high amount of crude fiber indicates a high amount of cellulose in the seed. The increased viscosity of the drilling mud sample with increased additive concentration further evidenced this. Also, the low moisture content shows that the activity of the microorganisms in the sample would be reduced, and this corresponds to an increase in the shelf life of the MSP. MSP can have a long shelf life without microbial action. This, however, changed after about 7 weeks of storing the additive in an air-tight container. Hence there is a need to investigate the possible means of increasing the shelf life of Moringa should it show commercial viability.

Table 2: Results of the proximate analysis for the Moringa seed powder.

Parameters (mg/100g)	Raw Seed Powder Samples (%)
Moisture Content	6.43
Dry matter	93.57
Crude protein	35.97
Ash	4.45
Crude Fat	41.23
Carbohydrates (by difference)	11.92

3.1. The Mud Samples pH and Density

After adding the bentonite only to the water, the measured mud density was 8.6lb/gal. Barite was added to the mix to weigh it up to the industry standard of 8.75lb/gal. The measured pH of the mud was 9.4 using the pH meter. This falls within the acceptable range for water-based drilling fluids. The pH paper confirmed this value and gave a color range between 9 and 10. After aging the mud for 24 hours, the pH remained the same. The additives were added, and the pH and mud weight was checked immediately after mixing. The resulting mud weight remained at 8.75lb/gal while the pH also gave the same reading of 9.4. Therefore, MSP does not affect visible differences in the mud weight and the pH of drilling mud. After aging the mud for 24 hours, the mud weight remained the same, and no reduction was observed.

3.2. The Mud Samples Rheology

Some measured mud rheological properties are plastic viscosity (PV) and yield point (YP). Moreover, gel strength and Viscosity is a property of the fluid to resist motion; it is one of the important rheological properties of drilling fluids. The plastic and apparent viscosities are important, while a yield point measures stress to start a fluid movement.

According to the API standards, water–based drilling fluids should have a viscosity of 15cp at least [42].

A) Plastic Viscosity

The effect of temperature on the water-based drilling mud with the MSP at atmospheric pressure of 70°C is presented in Fig. (**2-6**). From the figures, it can be seen that there was a general decrease in the plastic viscosity for each concentration with a change in trend at higher temperatures (60°C and 70°C). It is also noted that the control sample mud (with CMC-lv) had higher plastic viscosity at all temperatures when compared with those of the mud samples treated with MSP, whose plastic viscosity fell within the recommended range of API [28]. A decrease in viscosity is observed as flocculation increases. This results in the general reduction in solid volume, which allows the free movement of aggregates in the aqueous phase causing a reduction of internal friction [43]. Thus, an improvement in the plastic viscosity of the plant material (Moringa) was observed.

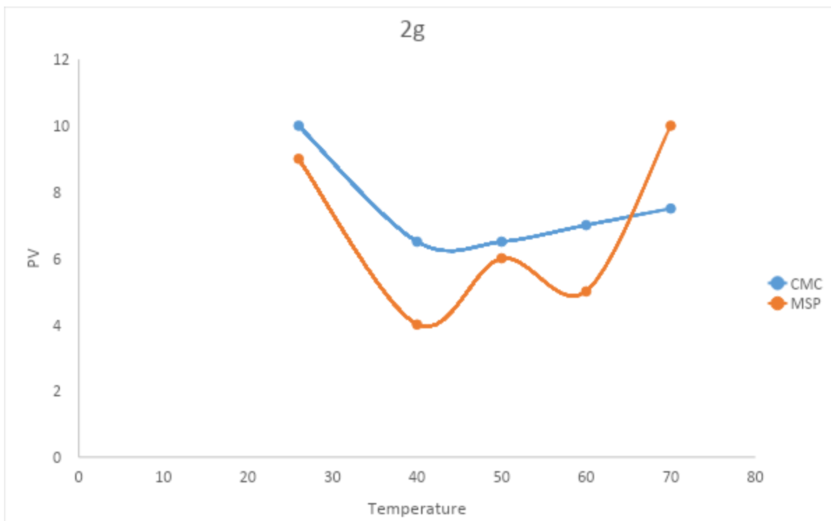

Figure 2: PV (cp) of 2.0 g MSP and CMC- lv against increasing temperature (°C).

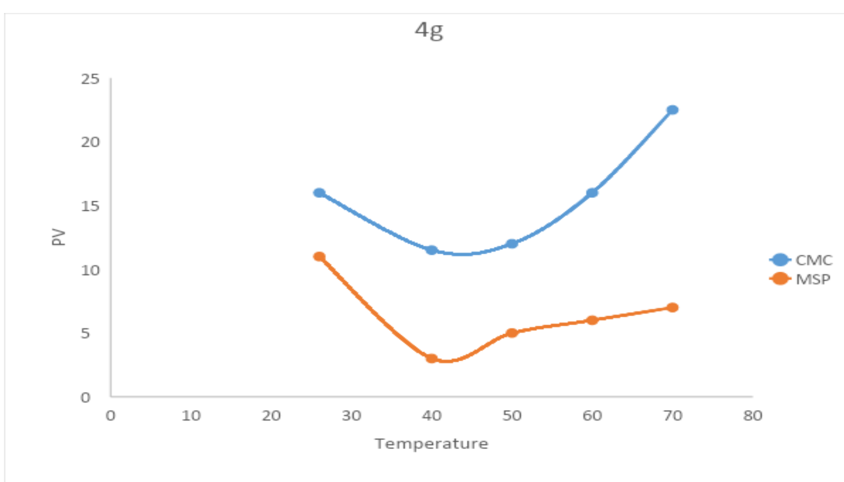

Figure 3: PV (cp) of 4.0 g MSP and CMC- lv against increasing temperature (°C).

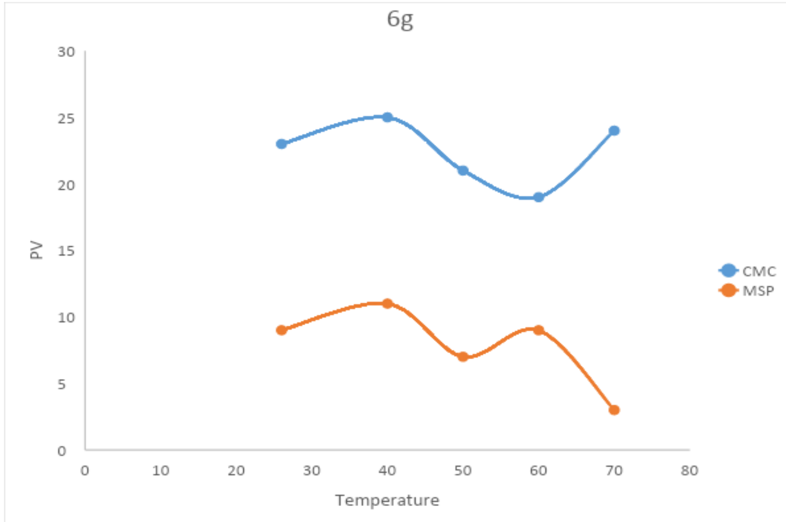

Figure 4: PV (cp) of 6.0 g MSP and CMC- lv against increasing temperature (°C).

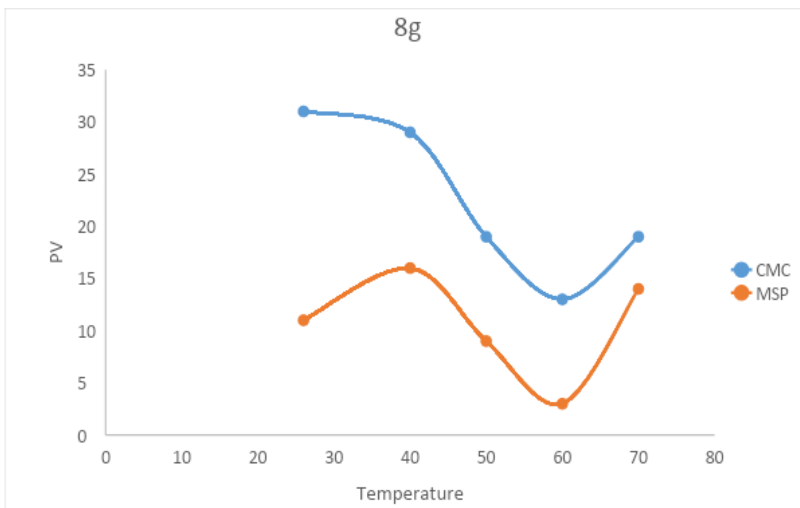

Figure 5: PV (cp) of 8.0 g MSP and CMC- lv against increasing temperature (°C).

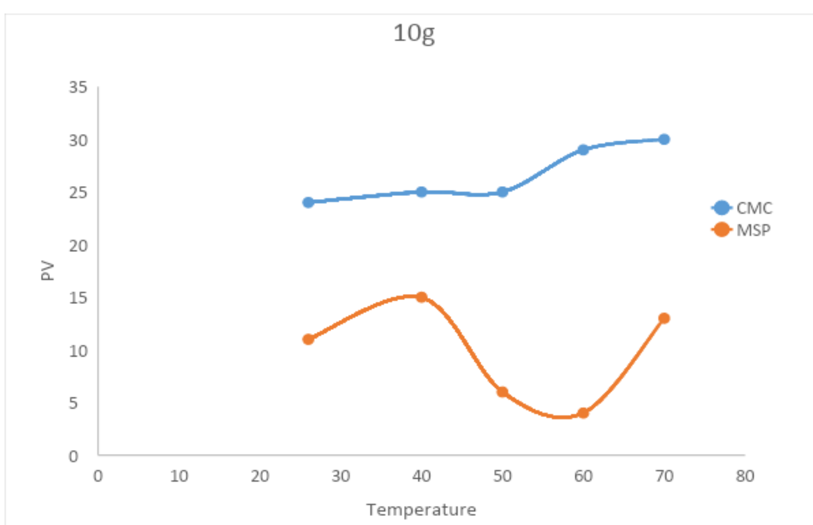

Figure 6: PV (cp) of 10.0 g MSP and CMC- lv against increasing temperature (°C).

B) Yield Point

From the Fig. (**7-11**), it is observed that at all concentrations and temperatures, the YP of the control mud were within the recommended values Although, the YPs of the sample mud (with MSP) were higher than that of the control mud all through, there was a general decrease in the YP when the temperatures were increased. The sample recorded the highest YP with a 10.0g concentration of MSP; this can be attributed to the interaction of active additives that can lead to a reduction in electrostatic forces between the additives [44]. The effect of temperature and concentration on the YP of the drilling mud sample has a similar trend [45]. A high yield point enhances the drilling fluid's solids-carrying characteristics and increases the good bore's pressure drop [46].

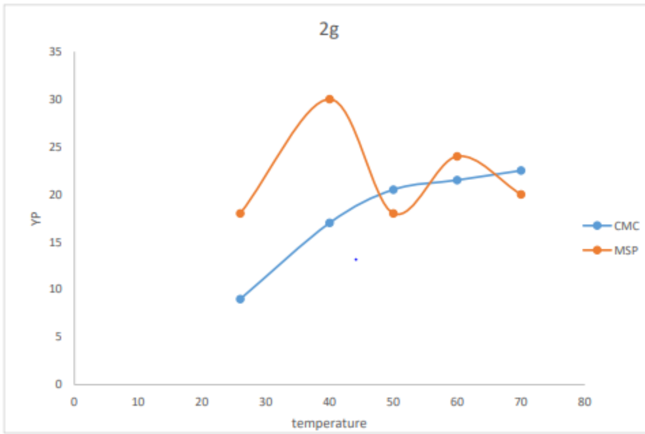

Figure 7: YP (lb/100 ft ^{2}) of 2.0g MSP and CMC- lv against increasing temperature (°C).

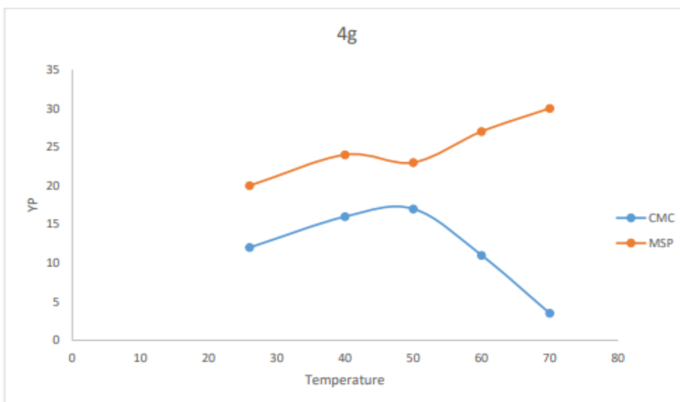

Figure 8: YP (lb/100 ft ^{2}) of 4.0g MSP and CMC- lv against increasing Temperature (°C).

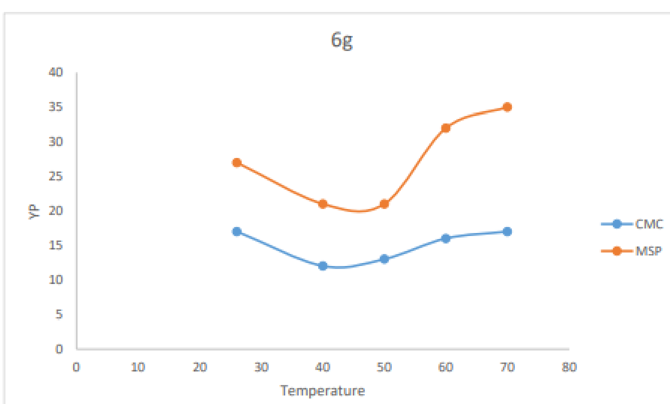

Figure 9: YP (lb/100 ft ^{2}) of 6.0g MSP and CMC- lv against increasing temperature (°C).

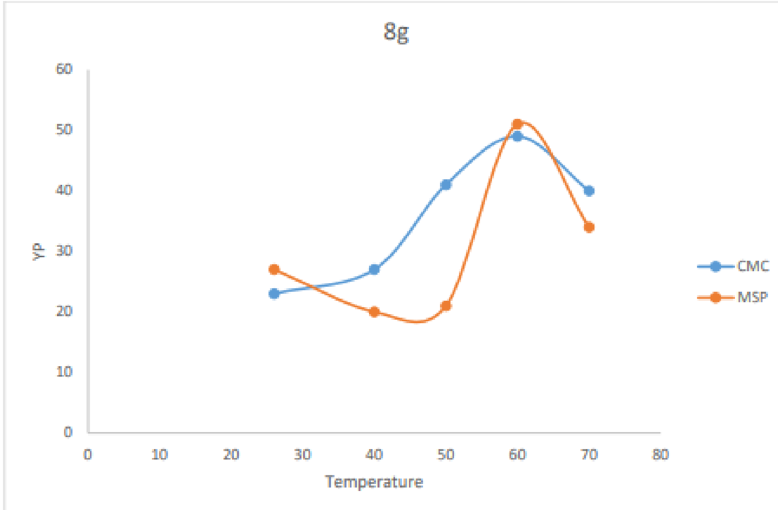

Figure 10: YP (lb/100 ft^2) of 8.0 g MSP and CMC- lv against increasing temperature (°C).

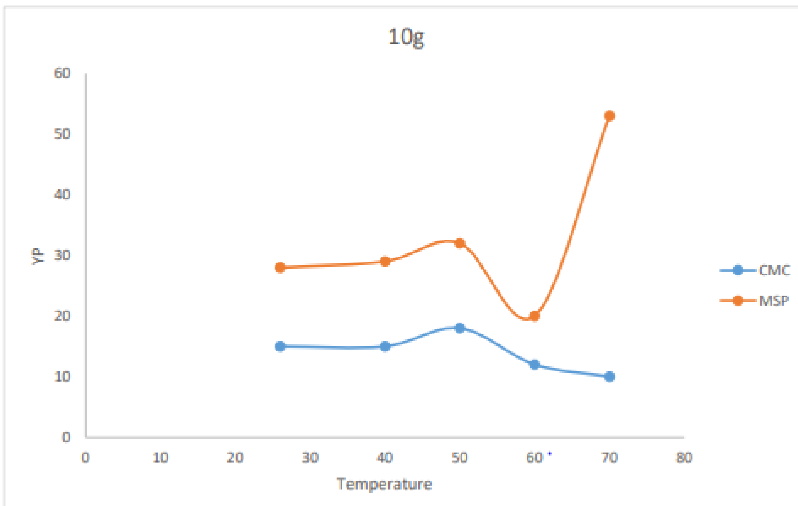

Figure 11: YP (lb/100 ft^2) of 10.0 g MSP and CMC- lv against increasing temperature (°C).

C) Gel Strength

The gel strength, an important rheological property, comes into play when there is no circulation.

The 10s and 10min gels are measured by taking the mud shear stress at 3rpm after the fluid has been allowed to stand for 10s after being exposed to high shear rates and further tested after 10 minutes when at rest. Fig. (**12-13**) presents the 10s and 10min gel strength data, respectively. It can be observed that gel strengths indicated that control mud had progressive gel strength for 10 seconds gel strength and 10-minutes gel strength which is undesirable [47], while the mud with MSP had flat 10-min gel strength and was progressive at the 10-sec before being flat and drop at 10g concentration. The drilling mud should form a gel at rest as it helps to suspend the cuttings and prevent them from settling out and following to the bottom of the well. A too-strong gel is undesirable as it can lead to a reduced penetration rate. However, a strong gel is not a problem for a fluid with shear thinning characteristics since it will quickly break as the fluid gets thinner due to shearing, resulting in an increased penetration rate [48].

3.3. Filtration Results

Mud samples were prepared and subjected to 100 psi pressure for 30 minutes at room temperature using the API filter press.

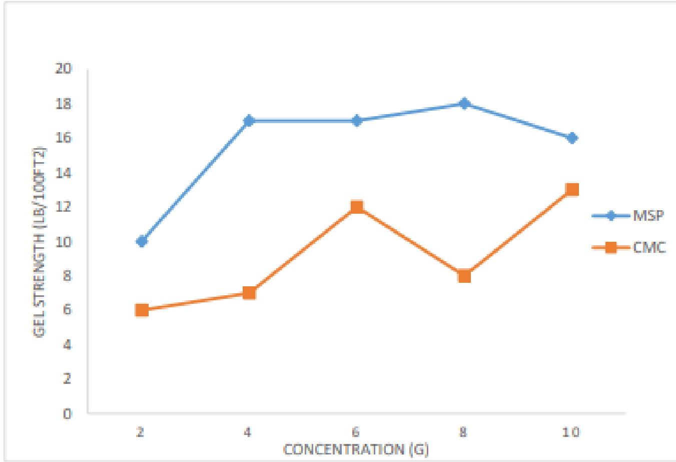

Figure 12: 10-sec Gel strength against varying concentration.

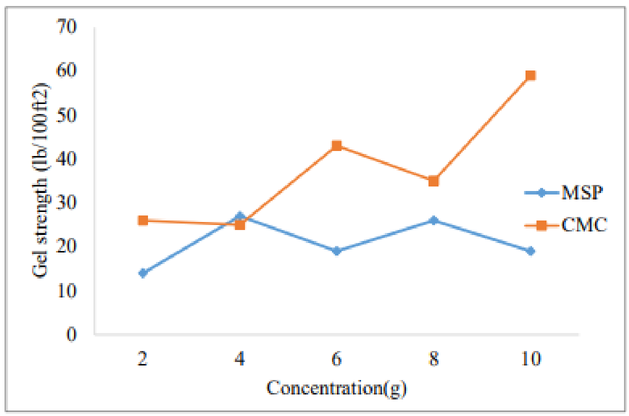

Figure 13: 10-min Gel strength against varying concentrations.

The filtrate volume follows the same trend for all times of the filter loss experiment. The lowest filtrate volume was observed at an additive concentration of 20g. The volume of the obtained filtrate followed an upward trend and increased from the initial additive concentration of 2.0g to the final additive concentration of 10g. However, there was a decrease in filtrate volume when the additive was increased from 4g to 6.0g before it then increased from 6.0g onwards.

From Fig. (**14**), it is noticed that an increase in additive content of the MSP from 4g to 8g led to a decrease in filter loss volume, which is a desirable filtration loss control property. The reduction of fluid loss with increasing concentration of MSPs can be attributed to its high affinity to water and the ability to absorb and hold water [49].

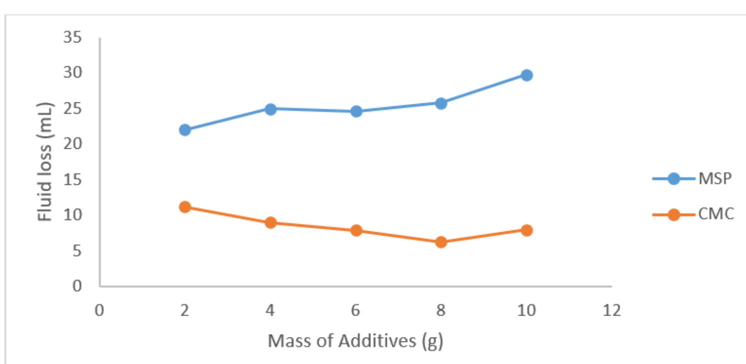

Figure 14: MSP and CMC filtrate loss (mL) at 30 mins.

Fig. (**15**) shows that MSP did not compete favorably with CMC as a fluid loss additive. However, when compared with PAC, MSP showed a better filtration control property, with fluid loss content from below the API fluid loss specification for PAC, the best result being at an additive concentration of 2.0g. Generally, an increase in the concentration of the MSP leads to a decrease in filtration control capabilities.

Fig. (**16**) compares the filter cake thickness of the various mud samples. The figure shows that all the filter cake thicknesses exhibited the same trend for both MSP and CMC; that is, the filter cake thickness increases with an increase in the additive content in the drilling mud samples. The filter cake thickness of all the additive concentrations met the API specification for filter cake thickness of fluid loss control additive. Furthermore, the results from the various filter loss volume and the filter cake thickness showed that the mud filter loss volume decreased as the filter cake thickness increased from 2.0 to 8.0g of additive content, after which there is an increase in filter loss volume on increasing the additive concentration to 10.0g.

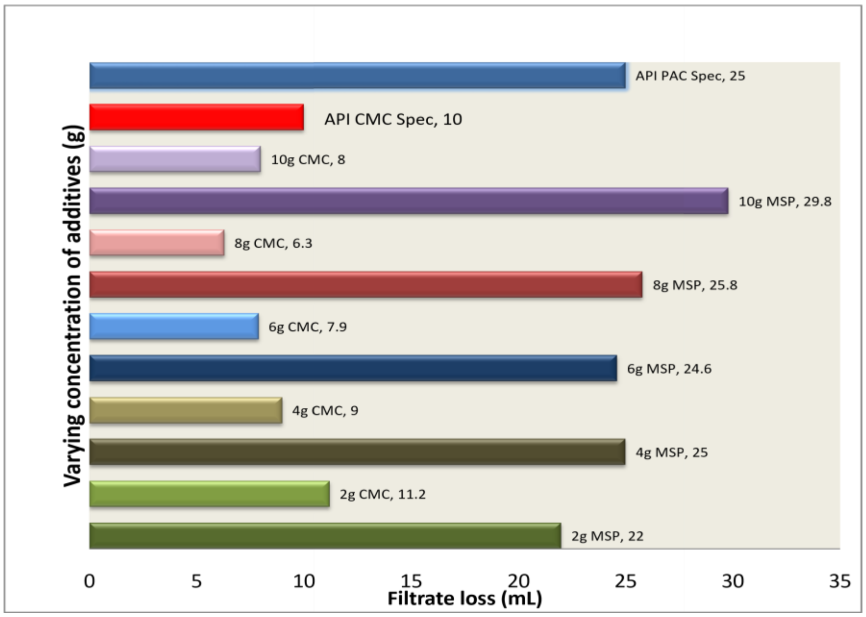

Figure 15: All samples' filtrate loss (mL) compared with API standards.

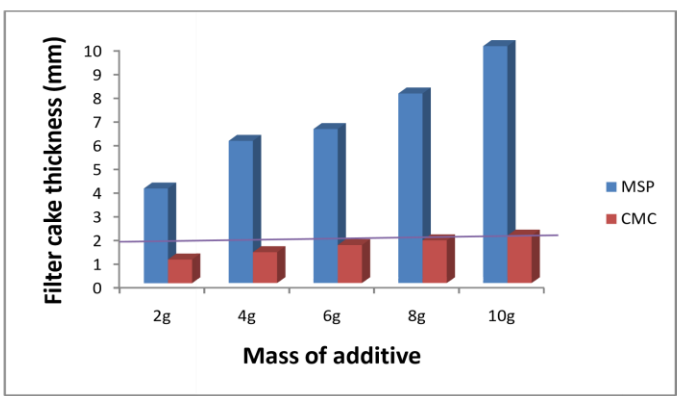

Figure 16: Filter cake thickness of MSP against CMC.

Assessment of the mud cakes for the Moringa sample showed that their texture was slippery, smooth, and soft, and these same characteristics were observed for the control additive. It is eminent to state here that the smooth and slippery characteristics of the mud are some of the requirements of a good mud filter cake. This is because the slippery, smooth, and soft characteristics of a mud cake prevent the differential pipe from sticking as opposed to a mud cake which is near dry and solid, which can also cause excessive torque and frictional drag when the drill pipe comes in contact with the wellbore walls. Based on the preceding, MSP exhibits good mud filter cake characteristics.

4. Conclusion

In summary, from the study, we can conclude that MSP has a significant effect on the properties of the drilling mud as a result of the following:

The Characterization of *Moringa oleifera* seed powder showed that this seed powder could be utilized successfully as a source of edible oil for human consumption and, therefore, human and environmentally friendly.

Adding MSP to water-based drilling fluid significantly affects the PV, YP, and YP/PV ratio comparable with CMC - lv. The cutting transport properties of the drilling fluid also enhance upon adding *Moringa oleifera* seed powder to the drilling fluid. The study shows that MSP cannot compete favorably with CMC as a fluid loss additive since it gives a higher fluid loss volume than CMC, which could be a better quality for filtration control. The sticking tendency is also reduced for the drilling fluid with *Moringa oleifera* seed powder as an additive.

After carefully observing all the properties, it can be concluded that *Moringa oleifera* seed powder can be used in water-based mud as a mud thickener to improve the rheological properties of the drilling fluid.

Further study can be carried out to check the effect of temperature on the filtration property of MSP since this formulated fluid will be used in downhole conditions at high temperatures and pressure. Thermal aging can also be carried out to mirror downhole conditions to a reasonable extent, thereby determining the effect of high temperatures and pressures on the integrity of MSP as an additive. Also, since the additive being used is organic, after aging the mud, there is a need to check if the microbial action of the additive has any effect on the mud.

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