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Terminalia mantaly leaves as a novel additive in water-based drilling MUD

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Abstract
In drilling processes, mud additives and cuttings comprise waste drilling fluids which end up being disposed into the environment. Naturally based mud additives that are eco-friendly, cheap and can improve the rheological properties and filtration loss of the drilling mud should be investigated. This research investigated the effect of *Terminalia mantaly* leaves in water-based mud as additive to improve drilling mud properties. Test and control mud were formulated and their properties determined using American Petroleum Institute (API) standard procedures. The obtained results showed that the plastic viscosity of the mud sample improved by 18% and 29% for the mud with 1% and 2 % *T. mantaly* plant concentration and were within the recommended values at standard temperature of 49 °C. However, PV values of the mud with *T. mantaly* leaves were affected by temperature, the value of 37cP was recorded by 4% concentration plant sample at 70 °C. The yield point of the formulated mud increased by 21% for 3 and 4% plant concentration. The pH of the drilling mud was basic for the C1 and C2 mud and mud with 1-3% concentration of *T. mantaly* except the mud of 4 % which recorded the pH of 6.9. The plant material did not alter mud weight at all concentrations. *T. mantaly* leaves reduced the filtration loss by 50%. Rheological properties of mud with *T. mantaly* leaves were within the recommended values after aging except that of gel strength at 10 seconds which recorded the value of 0.8 1b/100ft^2 after aging at 65° C and 93 °C. The drilling mud without *T. mantaly* leaves and surfactant showed high volume of filtration loss. Flat gel strength of the mud with *T. mantaly* leaves after all aging temperatures shows that the formulation was good and could be used to improve mud properties. *Terminalia* family has been reported to be having various phytochemicals which could have contributed to the improved properties of the drilling mud. This research is therefore encouraging the use of the leaves extract from *Terminalia mantaly* to improve the properties of the drilling mud. More research need to be done on the active component(s) in *Terminalia mantaly* plant to account for its activity in drilling mud formulation.

Keywords: Drilling mud, fluid loss, rheology, terminalia mantaly

1. Introduction

Drilling mud is a fluid that assist in enhancing drilling operations by cleaning the bore hole, carrying cuttings, cooling and lubricating the drilling tools (Enamul and Mohammed, 2016) [13]. It also assist in supporting the weight of the drill bit and drill pipe. There is a great need of conserving the environment globally and therefore use of toxic chemicals is being discouraged (Taleb and Mohamed, 2011 & Naleb *et al.*, 2012) [37, 28]. When formulating the drilling mud, many types of chemicals are used to design the drilling mud in order to meet the requirements of the hole specifications i.e. defoamers, emulsifiers, corrosion inhibitors, weighting agents, viscosifiers etc. (Caen *et al.*, 2011) [6].

Formation properties controls the selection of drilling mud and its additives making it complex because of the environmental factors (Joel *et al.*, 2012) [21]. Drilling mud can be chosen according to safety and logistics, productions concerns, environmental impact and overall well cost. In addition drilling muds are chosen based on the drilling conditions faced in the field and are classified according to the continuous phase they are using e.g. water, oil and gas. Some of the formulations used are oil based mud (OBM), synthesized based mud (SDM), emulsion based drilling mud (EDM) and water based mud (WBM). Water based mud is the most used formulation drilling fluid because it is considered to have high shear thinning, good bit hydraulic, high true yield and reduced circulating pressure losses (Putri *et al.*, 2015) [33] hence worth more investigation. However, water based mud system, fluid loss and rheological properties are not stable at high temperatures (Khodija *et al.*, 2010) [23]. Oil based mud has good wellbore stability, lubricity and high temperature resistance though its use is restricted due to the negative environmental impacts it poses (Demirdal *et al.,* 2007) [10].

Rheology, filtration loss, pH and mud weight are among the properties of the mud which need to be monitored during drilling process to ensure success of the operation. The rheology of the drilling mud rely on the type and amount of clay in the shale and mud additives used which can be modified so that the mud gives optimum performance (Putri *et al.,* 2015) [33]. In drilling process, mud's viscosity and gel strength are among the main properties to be monitored and controlled (Busch *et al.*, 2018) [5]. One of the main function of drilling mud is removal of cuttings where viscosity and gel strength play an important role. The yield point of the drilling mud is dependent on the electro-chemical charges of the particles in the mud. When particles are attracted to each other, they result in high yield point and when they repel, the yield point is reduced (El-Sukkary *et al.,* 2014) [11]. pH of drilling mud symbolizes the hydrogen ion concentration in the mud and it tells the alkalinity or acidity of the drilling mud. Bicarbonate ions, carbonate ions and hydroxyl ions are chemicals involved alkalinity of the drilling mud (Omole *et al,* 2011) [30]. Factors that affect the pH of the drilling mud include contamination of water, carbonate or bicarbonate, anhydrite and acid gases. The fluid loss of mud is a measure of the capability of the contents in the drilling mud to form a filter cake which is thin and have low permeability. When permeability is low, and the filter cake is thin, the filtration loss volume will be lower (Hafiz *et al.*, 2018) [19]. Mud weight is another mud property and it should meet the requirements of the hole by matching the estimated density which is necessary to check formation pressure without fracturing or damaging the formation (Dwananto and Rachmat, 2015).) [41]. Depending on the type of the formation being drilled, cost can be saved when the conditions for drilling are good to facilitate fast penetration rates and good hydrostatic pressure (Akpabio *et al.,* 2015) [2]. In search of quality and environmentally friendly water based mud, it is important to consider bio source of mud additives from plants which can offer balance between cost and environment.

2. *Terminalia mantaly*

Terminalia mantaly belongs to the family of *Combretaceae* and commonly grows in savanna regions in Africa. Many parts of this tree has been utilized by the locals for various functions like medicines and it is known to have a variety of phytochemicals like saponins, alkaloids, tannins, terpenes and flavonoids among others (Tizhe *et al.*, 2016) [38]. Tannins from root of *T. mantaly* are used in leather preparation (Gunasena, 2007). The trunk of *Terminalia mantaly* acts as a source of gum which if treated well can be utilized in chemical industry. It is believed that a modified form of the gum from *T. mantaly* can be used to treat rheumatoid arthritis, osteoarthritis and ankylosing spondylitis (Michael *et al.,* 2017) [26].

Some studies have shown that *T. mantaly* supplements may support normal heart functioning, manage chest discomfort, manage blood clot by decreasing platelet activation, and that it exhibits antioxidant activities. Lately, herbalist prefer to utilize the bark of *Terminalia mantaly* as an alternative of *Terminalia catappa*. Coulibaly (2006) [7], found out that the roots of *Terminalia mantaly* are used to treat loss of voice. According to Kokora *et al.,* (2013) [24], it was seen that there was strong inhibition activity of aqueous and ethanolic extract of *Terminalia mantaly* on strains of *Styphylococcus aureus* and *Escherichia coli*. There is a possibility of employing the plant in green chemistry for probable application in petroleum industry. Its leaves drops frequently and so they provide good mulch hence leading to soil and small plants protection. As an umbrella shaped, it looks attractive. Because of the named contents and function of the plants, it is quite important to utilize the leaves from *T. mantaly* in petroleum industry since they fall out frequently and are reproduced easily.

3. Materials and Methods

3.1 Plant material

The plant leaves were collected in Port Harcourt, Rivers states, Nigeria. The geographical coordinates of Port Harcourt is 4° 54' 10.4724"North, 7° 0'4.5468" East. Fresh green leaves were taxonomically identified at the Department of Plant Science and Biotechnology, University of Port Harcourt, Nigeria.

3.2 Mud preparation

The formulated water based mud had the following ingredients: water as a base fluid, bentonite, barite, hydro polyanionic cellulose (PAC) LV, caustic soda, potassium chloride, arbreak (commercial surfactant) and plant material (*Terminalia mantaly* leaves). The samples were mixed in Hamilton mixer for 45 minutes with five minute interval after each additive.

The formulation of each mud is indicated in Table 1.

All the chemicals used were purchased from Scientific Laboratory Suppliers, U.K. They were all of analytical grade (AG).

Table 1: Water based mud formulation

Additives	Formulation 1 (C1)	Formulation 2 (C2)	Formulation 3 (MTL) / (Test mud)	Function
Water	318.74ml	318.74	318.74	Base fluid
Bentonite	17.50g	17.50	17.50	Viscosifier & Fluid loss control
Caustic Soda	0.25	0.25	0.25	pH control
KCl	10.70	10.70	10.70	Inhibitor
Hydro PAC LV	3.00	3.00	3.00	Fluid loss control & Viscosifier
Barite	68.72	68.72	68.72	Weighting agent
*Plant extract	-	-	1%, 2%, 3% and 4%	
Commercial surfactant (Arbreak)	-	1%, 2%, 3%, and 4%	-	

4. Experimental Procedures

4.1 Mud weight

Density of the drilling mud is measured as mass per unit volume of a drilling mud (b/gal) and it must match the density necessary to check formation pressure without fracturing or damaging the formation (Ogiriki & Ndienye, 2017) [29]. This was measured for all the mud formulated with and without different concentration of the *T. mantaly* leaves.

4.2 pH
This is the acidity or alkalinity of the drilling mud. Lower or high pH of drilling mud will result in more use of additives hence expensive in the long run (Fadairo *et al.*, 2012) [16] and thus make pH parameter very important to test. pH meter was used to measure the pH of the drilling muds formulated without and with different concentrations of *T. mantaly*.

4.3 Rheological properties
The rheological properties of the formulated mud was measured using American Petroleum Institute (API) standard procedure (Fugundes *et al.*, 2018) [18].
Plastic viscosity (PV), Yield point (YP) and gel strength were measured using FANN viscometer (Eshan *et al.*, 2016) [14]. Viscosity of the drilling mud is more of a function of temperature than pressure (Khabat *et al.*, 2018) [22]. Therefore, it is important to measure the viscosity at elevated temperatures to ascertain thermal stability. For gel strength testing, two readings were taken, gel strength after 10 seconds and gel strength after 10 minutes according to Mohmoud & Dadir, (2011) [27]. All the rheological properties were measured at all test temperatures (30 °C – 93 °C) and at all concentrations (1% - 4% of the plant sample and C2).

4.4 Filtration loss
Filtration loss of the drilling mud was determined by measuring the volume of the filter loss which was collected for 30 minutes in a measuring cylinder. This test was conducted at 65 °C and 500psi using high pressure high temperature (HPHT) fluid loss apparatus. The fluid lost was recorded using graduated cylinder at the end of the tested time (Putri *et al.*, 2017) [34].

4.5 Aging process
The thermal stability tests involved heating the drilling mud from ambient temperature to a testing temperature for 16 hours with roller oven and then cooling it to ambient temperature (Xian-yu *et al.*, 2015) [43] before testing the drilling mud properties.
Temperatures chosen for aging were 35 °C which is believed to be subsurface temperature, 65 °C is the temperature between surface temperature and bottom hole temperature and 93 °C was the maximum to perform rheological test so as to avoid degradation of polymers of the formulated water based mud (Putri *et al.*, 2015) [33]. Temperature of 49 °C was taken as standard temperature to measure rheological properties of the mud (Ahmed, 2017) [1] after aging.

5. Results and Discussion
5.1 Rheological properties
The rheological properties before aging were measured at four different temperatures ranging from 30 °C -70 °C where the standard temperature used was 49 °C for other drilling mud properties and to test rheology after aging. The rheological properties of the mud before aging are summarized in Table 1 below while the rheology after aging results are shown in Table 2. Other properties of the mud before and after aging are displayed in Figures 1 – 5.
Bingham model explains the performance of drilling fluid (Cussot, 2016) [8] and it calculates the plastic viscosity as:
Plastic viscosity (PV) cP = Dial reading at 600rpm – Dial reading at 300rpm (i)
Yield point (YP) 1b/100ft^2 = Dial reading at 300rpm – Plastic viscosity (PV) (ii)

Recommended values for rheological properties are shown in Table 1 below (Torsvik *et al.*, 2014).

Table 2: API Recommended values for Plastic viscosity (PV), Yield point (YP) and Gel strength

Property of the mud	Recommended value
Plastic Viscosity (Cp)	8- 35
Yield point (1b/100f2)	Minimum= 5 Maximum= $YP \leq 3 \times PV$
10sec gel strength (1b/100f2)	2- 5
10 Minute gel strength (1b/100f2)	2 -35

5.1.1 Plastic viscosity (PV)
Friction between the fluid layers and the friction between the solid particles with the fluid layers is termed as plastic viscosity (PV) (Salaheldin, 2019) [35]. Table 2 – 4 show the dial readings which was used to calculate the plastic viscosity and yield point of the formulated drilling muds.
Referring to Tables 2-4 above, it can be seen that there was general decrease in plastic viscosity as the temperatures increased. It can also be noted that the control sample mud, C1 (without plant material), had lower viscosities at all the temperatures when compared with other plastic viscosities of the test samples with different concentrations of the plant and commercial surfactant. There was increase in plastic viscosity with increase in plant and commercial surfactant concentration in the formulated mud which was also observed by Saleheldin, (2019). The highest PV was 67cp recorded by TML mud sample with 4% plan concentration at 30 °C. For both muds (C1 and C2), at standard temperature (49 °C), all the PV were within recommended values of API except that of 3% and 4 %. This was also observed by Amosa *et al.*, (2010) [3] while investigating ferrous gluconate and synthetic magnetic as sulphide scavengers in oil. Improving the plastic viscosity of the drilling mud will improve the transportation of cuttings by the drilling mud and will reduce the complications linked with cuttings settling which can cause the sticking pipes (Hossain & Al-Majed, 2015) [20]. At all testing temperatures, PV values of C1 were lower than C2 and TML mud implying that the additives added improved the PV. At higher concentrations (4%) of the TML mud, the PV (37cP) value was still within the recommended value at higher temperature of 70 °C while that of C2 recorded 52cP which is considered higher according to API requirements.

5.1.2 Yield point (YP)
In Table 1, it is observed that the YP increased as the concentration of the plant sample increased. The YP decreased as the temperature decreased. It is also seen that at all concentrations and temperatures, the YP of the formulated mud were within the recommended values. At standard temperature (49 °C), YP (12,13 and 27 1b/100ft^2) for C2 at all concentrations was lower than the TML mud with 3% and 4% (45 and 49 1b/100ft^2 respectively) plant material but higher than the mud with 1% and 2% (12 and 13 1b/100ft^2) plant material. The highest YP was recorded by the C2 with 4% concentration (1771b/100ft^2) at 50 °C while the lowest YP was recorded by the C1 mud sample which gave 11 1b/100ft^2 at same temperature.
The effect of temperature and concentration on YP of the drilling mud sample has similar trend which was also noticed by Omotioma *et al.*, (2014) [42]. Addition of plant extract and commercially available surfactants to the drilling mud showed improvement of YP of the drilling mud.

5.1.3 Gel strength

The concentration of the colloidal clays affects the gel strength of the drilling mud. Measuring the gel strength of a drilling mud guide on the ability of the mud to hold the cuttings (Caen, 2011) [6]. In Table 1, it can be seen that gel strength at 10 seconds was high (7.91b/100ft^2) in the mud with 3 % concentration at temperature of 30 °C. At 49 °C, C1 mud sample recorded the lowest gel strength at 10 seconds of 1 1b/100ft^2 while the mud with 1% plant material recorded the same gel strength but at temperature of 70 °C. There was same trend at 10 minutes gel and that of 10seconds at temperature of 30 °C which recorded higher gel strength of 20.21b/100ft^2 in the mud having 3% of the plant material. The lowest gel strength was recorded by the mud with 1% of the sample at 49 °C which gave 4.1 1b/100ft^2. It was also observed that the 10minute gel strength was higher than that of 10 seconds gel strength which was in agreement with the work of Saleheldin (2019). High concentration of the *T. mantaly*, (3 and 4%) led to high 10 seconds gel strengths which were above the recommended values but all the 10 minutes gel strengths were within agreeable values. At lower concentration (1%), and higher temperature at 3% concentration and higher temperature (70 °C), C2 recorded values (4-27 1b/100ft^2) permitted by API. High gel strengths will require high pressures to overcome the gel strength and to start the circulation hence they are not preferred during drilling process (Lyons *et al.*, 2012) [25]. At 1 % concentration, MTL mud had lower values compared to the C1 mud. The values of the gel strength increased with increase in concentration of *T. Mantaly* leaves. The drilling mud with *T. mantaly* leaves had good gel strength compared with C2 mud which recorded relatively high gel strengths (12-45.71b/100ft^2) even at lower concentrations of the surfactant.

Table 3: Dial readings, PV and YP of the control (C1) drilling mud at different temperatures

RPM	30 °C	49 °C	50 °C	70 °C
600	76	65	55	54
300	46	43	33	33
200	35	25	24	25
100	20	15	14	15
6	2	1	1	2
3	1	1	1	2
PV	30	22	22	21
YP	16	21	11	12

Key: RPM= Rotation per minute

Table 4: Dial readings of the control (C2) drilling mud at different temperatures and concentrations of commercially available surfactant

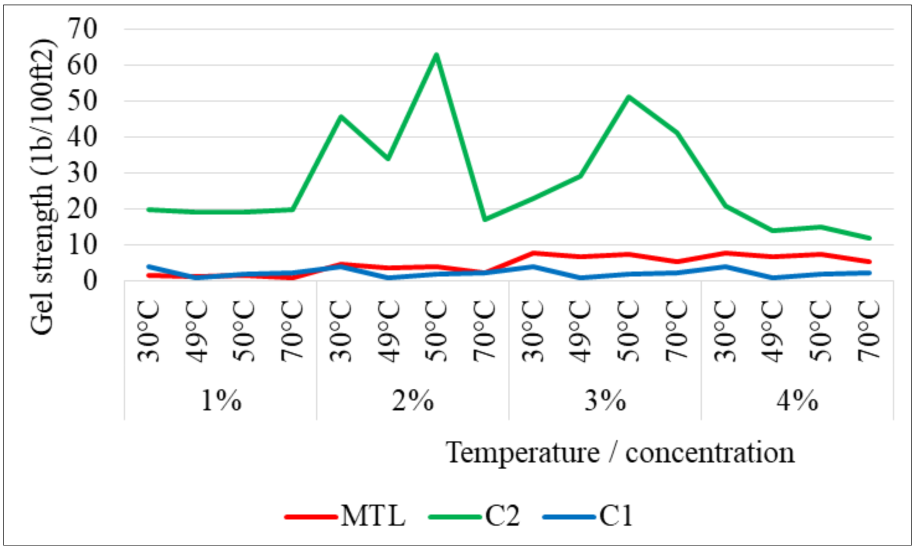
RPM	Concentration / Temperature															
	1%				2%				3%				4%			
	30 °C	49 °C	50 °C	70 °C	30 °C	49 °C	50 °C	70 °C	30 °C	49 °C	50 °C	70 °C	30 °C	49 °C	50 °C	70 °C
600	98	66	69	35	157	126	130	65	210	184	193	99	268	243	253	132
300	85	47	45	25	116	100	102	46	149	143	159	61	181	191	215	80
200	64	42	40	22	101	87	92	43	141	125	145	58	180	164	194	77
100	50	32	30	18	82	70	67	32	111	107	102	49	142	144	139	64
6	16	13	12	7	35	26	26	13	55	39	40	18	75	52	14	24
3	14	11	11	7	34	25	25	12	37	39	40	18	74	52	14	24
PV	14	19	24	10	41	25	29	20	61	40	33	38	87	51	38	52
YP	71	28	21	15	75	75	73	24	88	103	126	23	94	140	177	28

Table 5: There was increase in PV (22-64 cP) and YP (7- 64 1b/100ft^2) of the C1 mud after aging

RPM	1%				2%				3%				4%			
	30 °C	49 °C	50 °C	70 °C	30 °C	49 °C	50 °C	70 °C	30 °C	49 °C	50 °C	70 °C	30 °C	49 °C	50 °C	70 °C
600	98	66	69	35	157	126	130	65	210	184	193	99	268	243	253	132
300	85	47	45	25	116	100	102	46	149	143	159	61	181	191	215	80
200	64	42	40	22	101	87	92	43	141	125	145	58	180	164	194	77
100	50	32	30	18	82	70	67	32	111	107	102	49	142	144	139	64
6	16	13	12	7	35	26	26	13	55	39	40	18	75	52	14	24
3	14	11	11	7	34	25	25	12	37	39	40	18	74	52	14	24
PV	14	19	24	10	41	25	29	20	61	40	33	38	87	51	38	52
YP	71	28	21	15	75	75	73	24	88	103	126	23	94	140	177	28

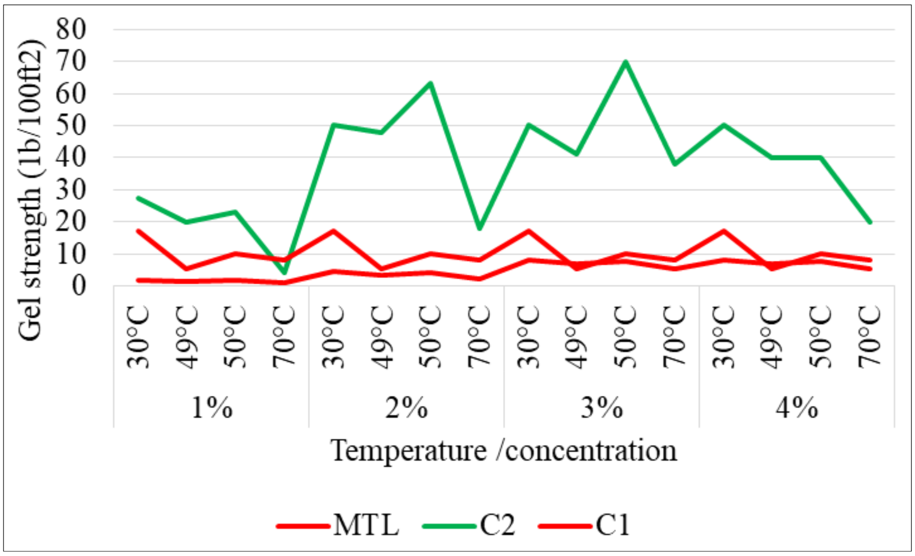
Table 6: Dial readings of the drilling mud with *T. mantaly* leaves at different temperatures and concentrations

RPM	1%				2%				3%				4%			
	30 °C	49 °C	50 °C	70 °C	30 °C	49 °C	50 °C	70 °C	30 °C	49 °C	50 °C	70 °C		49 °C	50 °C	70 °C
600	100	66	64	49	114	75	73	57	166	125	118	102	166	125	118	102
300	60	39	37	29	69	44	42	34	99	76	73	65	99	76	73	65
200	45	28	28	20	50	32	31	24	74	55	54	51	74	55	54	51
100	26	16	15	11	30	19	18	14	47	35	23	34	47	35	23	34
6	3	2	2	1	4	2	2	2	9	6	5	12	9	6	5	12
3	2	1	1	1	3	2	2	2	8	6	6	11	8	6	6	11
PV	40	27	26	20	45	31	31	23	67	49	45	37	67	49	45	37
YP	20	12	10	9	23	13	11	11	32	27	27	28	32	27	28	28



Key: C1=Mud without surfactant and plant material
C2= Mud with commercial surfactant (arbreak)
MTL: Mud with *T. mantaly* leaves

Fig 1: Gel strength at 10 seconds versus concentration of *T. mantaly* leaves and temperature



Key: C1=Mud without surfactant and plant material
C2= Mud with commercial surfactant (arbreak)
MTL: Mud with *T. mantaly* leaves

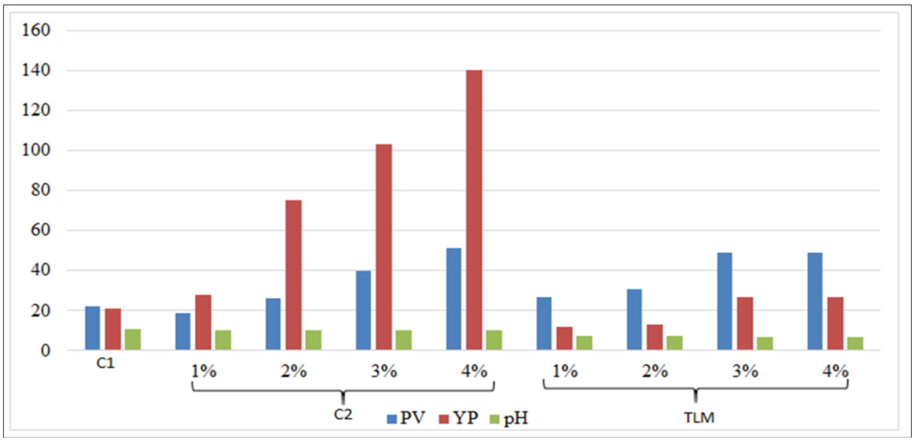
Fig 2: Gel strength at 10 minutes versus concentration and temperature

5.1.4 pH

When pH of the drilling mud is altered, the rheological values will be affected, especially PV, YP and gel strength and therefore, it is quite important to maintain the pH within the recommended range e.g. 7.5-11 (Aremu *et al.*, 2017) [4]. As it can be seen from Figure 1, as the concentration of *T. mantaly* was increasing, there was decrease in pH and may be this could account for high values of PV's on the drilling muds. The highest and lowest value of pH was that of C1 and mud with 4 % *T. mantaly* which recorded 10.5 and 6.5 respectively. At low pH (below 7.5), the PV of the mud was too high and this could be due to increase in concentration of the *T. mantaly* in the drilling mud. I has been noted that study on effect of pH on particle association and chemical interaction which give rise to change in rheological behavior is complex (Vassilios *et al.*, 2007) [40]. It was observed that pH was within the range at the concentration of 1, 2 and 3 %, suggesting that it is the optimum concentration of *T. mantaly* leaves which might not give problems during drilling operations. The effect of low pH on the drill pipe is corrosion and can be minimized my raising the pH of the mud (Dardir *et al.*, 2017) [9].

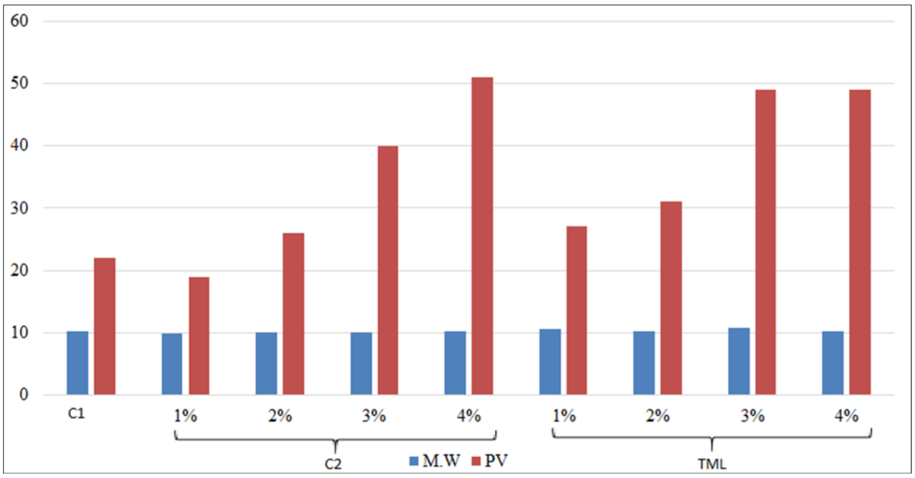
5.1.5 Mud weight

From Figure 2, mud weight of all the formulated mud was steady. It also shows that the mud weight of the drilling mud did not change significantly after increase in concentration of the *T. mantaly* leaves but there was increase in plastic viscosity. When there is an increase in plastic viscosity and constant weight of the mud, it implies that there is solid increase in the drilling mud (Paiaman *et al.*, 2015) [32].



Key: C1=Mud without surfactant and plant material
C2= Mud with commercial surfactant (arbreak)
MTL: Mud with *T. mantaly* leaves

Fig 3: Relationship between the pH, PV and YP of the formulated mud at 49 °C temperature.



Key: Plastic viscosity (PV): Cp,
Mud weight (M.W):1b/gal
C1=Mud without surfactant and plant material
C2= Mud with commercial surfactant
MTL: Mud with *T. mantaly* leaves

Fig 4: Relationship between PV and mud weight of the formulated mud

5.2 Effect of Aging

5.2.1 Rheology

Most polymers fail to maintain their rheological properties because of the degradation at high temperatures (Ahmed, 2017) [1]. As it can be seen from Table 5, there was increase in PV (22-64 cP) and YP(7- 64 1b/100ft^2) of the C1 mud after aging. The PV and YP of the C2 mud reduced after aging (25 to 5 cP and 75 to 2 1b/100ft^2) respectively. After adding 2% *T. mantaly*, the PV and YP decreased from 31 – 6Cp and 13 – 6 Ib/100ft^2 respectively. It is also observed that the PV and YP of the test mud increased after aging the mud at 38 °C. It is anticipated that at 38 °C, the activity of the mud additives including the plant material had their optimum performance (Evelyn *et al.*, 2018) [15].

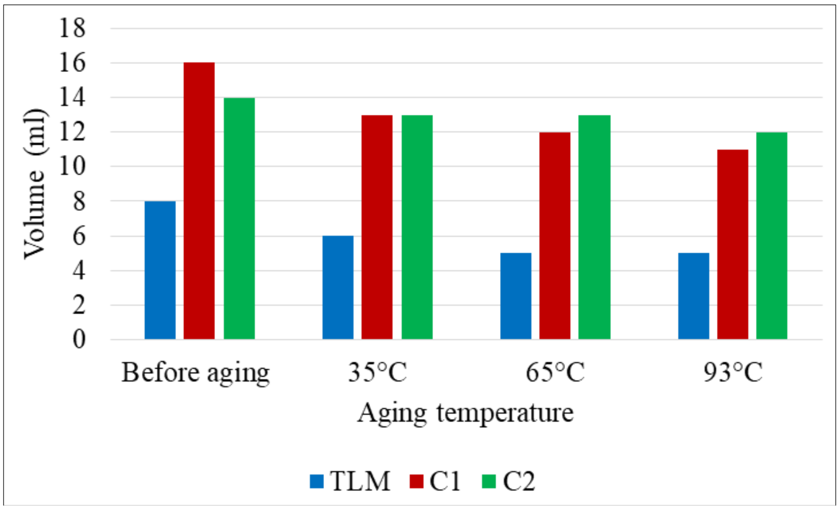
Gel strength is an important parameter and shows the capacity of muds to suspend the solids in drilling process. In Table 3, it can be seen that there was a decrease in gel strength at 10 seconds and 10 minutes for all the temperatures except for the control mud after aging at 65 and 93 °C where the gel strength increased significantly. The increase in gel strength of control mud could be attributed to the flocculation of bentonite clay as mentioned by Hafiz *et al.*, (2018) [19]. Gel strengths after 10 minutes were too low for C2 mud (0.11b/100ft^2) while the C1 mud (55.8 1b/100ft^2) had too high gel strengths after aging at 65 and 93 °C. Higher gel strengths are not desired because separation of cuttings might be delayed while on the other hand, too low gel strengths will not be able to suspend the cuttings (Putri *et al.*, 2015) [33]. There was flat gel strength in the mud with *T. mantaly* leaves after aging for 38, 65 and 93 °C which may be due to the phytochemicals in the leaves that made gel strength of the mud stable towards high temperatures (El- Sukkary *et al.*, 2014) [11].

5.2.2 Filtration loss

Figure 2 shows the results of filtration loss before and after aging the samples. After aging the sample at different temperatures for 16 hours, there was decrease in the volume of the filtrate. Comparing the filtrate between the C1, C2 sample and the sample with *T. mantaly*, control sample lost significantly higher value than the test mud. Drilling mud should reduce the fluid loss to the formation as much as possible and avoid highly thick filter cake (Skalle, 2015) [36]. There was decrease in filtration loss with increase in temperature which was also observed by Ogiriki & Ndienye, (2017) [29] in their research. This could be attributed to the fact that the aging encourages the dehydration of the drilling mud hence leading to low filtration loss (Oriji & Joel, 2012) [21]. Terminalia family is known to be having various phytochemicals which include lignin derivatives, flavonoids, tannins and phenolic acids among others which could have contributed to the behavior of the drilling mud with *T. mantaly* as mud additive (Fahmy *et al.*, 2015) [17].

Table 7: Effect of aging in rheological properties of drilling mud with 2% concentration of *Terminalia Mantaly*

Samples	Aging Temperature	Plastic viscosity (Cp)	Yield point (Ib/100ft^2)	Gel strength 10 sec (1b/100ft^2)	Gel strength 10 min (1b/100ft^2)
C1	Before aging	22	7	6	8
	After aging 38 °C	28	35	4	6
	After aging 65 °C	36	64	26.8	55.8
	After aging 93 °C	64	64	26.8	55.8
C2	Before aging	25	75	34	48
	After aging 38 °C	6	2	0.1	0.1
	After aging 65 °C	5	3	0.1	0.1
	After aging 93 °C	5	2	0.1	0.1
TLM	Before aging	31	13	3.5	10.7
	After aging 38 °C	33	30	4	5
	After aging 65 °C	17	7	0.8	5
	After aging 93 °C	6	6	0.8	5



Key: TLM. Mud with *Terminalia mantaly* leaves powder.
C1=Mud without surfactant and plant material
C2= Mud with commercial surfactant

Fig 5: Graph showing the effect of aging of 2% concentration of TL on fluid loss

6. Conclusion

The study compared the properties of water based mud formulated with leaves from *T. Mantaly* plant with mud formulated without the leaves. The research concludes that *Terminalia mantaly* leave extracts are suitable for production of water based mud formulations and that different concentrations of the *Terminalia mantaly* leaves have varied effects on the drilling mud properties. The phytochemicals present in *Terminalia mantaly* leaves could be responsible for improvement of the mud properties.

7. Recommendation

This research encourages the use of *Termianlia mantaly* leaves as drilling mud additives because it has shown to improve rheological properties and filtration loss and to some extent, it can be used at high temperatures. However, further research work need to be done to isolate and characterize the active component(s) in *Terminalia mantaly* plant to account for its activity in drilling mud formulation.

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