Analysis of Bio-enhancers for pH and Viscosity Control in Drilling Fluid Systems

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***Abstract*- This work was aimed at analyzing the suitability of Banana Peels Ash (BPA) and Plantain Peels Ash (PPA) as bio-enhancers to optimize pH and viscosity in Water-Based drilling Mud (WBM). It was recorded that PPA increased the pH of WBM from 9.00 to 10.00, 10.80, and 11.75 while BPA was 9.98, 10.66, and 11.42 compared to caustic soda of 13.42, 13.60, and 13.76, this corresponds to 2g, 4g, and 8g of the additives respectively. The result for all cases was greater than the API 13B standard requirement of 9.5.Furthermore, evaluating the effect of the bio-enhancers on viscosity of the drilling mud sample, it was verified that BPA increased the WBM viscosity from 7.00cP to 11.50 cP, 19.00cP and 32.50cP at 300RPM Rheometer speed. At 600 RPM, viscosity increased from 9.00cP to 12.50 cP, 20.50 cP and 35.00 cP for 2g, 4g, and 8g of BPA respectively. In a similar way, PPA increased the viscosity of WBM from 7.00cP to 13.00 cP, 16.00cP and 38.5cP for 300RPM, also from 9.00 cP to 14.00 cP, 18.00cP and 40.00 cP at 600RPM corresponding to 2g, 4g, and 8g of PPA respectively. These results show that both BPA and PPA additives are good viscosifiers and pH bio-enhancers for the formulation of water-based drilling mud.**

***Keywords*- Bio-enhancer, pH, Viscosity and Drilling mud.**

I. INTRODUCTION

Drilling fluid is a general term used to describe liquids, gases, foams and other liquids used for drilling operations. The three main categories of drilling fluids are Water-based mud, Oil-based mud, and Gaseous drilling fluid. Water-based mud is the most extensively used drilling fluids. They are generally easy to make, inexpensive to take care of, and may be formulated to solve most drilling problems[1]. Basic mud properties usually used to define the well program during drilling includes: Rheology, density, fluid loss, solid content, and chemical properties. For any typeof drilling fluid, these properties may to some extent, be manipulated using additive, however, the resulting chemical properties of a fluid depends largely on the type of mud chosen, and this choice rests on the types of well, the nature of the formation to be drill and the environmental circumstances of the well [2].As drilling muds are integral to the bore well drilling process, so also are additives that are very much a part of their composition, have a unique role to play. The use of locally generated additives will help to reduce the cost of drilling, and due to the organic nature of some additives, they are environmentally friendly having little or no effects on the subsurface formation and also in line with the new Nigerian Local Content Laws in the Petroleum Industry [3].There have been a substantial number of experimental researches to authenticate the pH enhancing abilities of some fruit peels[4],[5]. However, there has been no either experimental work to confirm that banana and plantain peel can improve rheological properties nor model developed to show the performance of banana and plantainpeels in water-based mud.

The aim of this study is to determine the effectiveness of processed Banana and Plantain peels ash as pH and viscosities enhancer in water-based mud as replacement forthe more commonly used caustic soda.

II. MATERIALS AND METHODS

To experiment and determine the effectiveness of Banana and Plantain peelsash for drilling mud modifications, samples of water-based mud per each bio-enhancers were prepared and another set for the control experiment using imported Caustic Soda (NaOH) as additive. It involves the procedures for the laboratory preparation of different samples of drilling mud using 350ml of water with 21.0g of local Bentonite clay, equivalent to 22.5Ib/bbl[6]. The materials and equipment used in this research include: Banana (*Musa sapientum*), Plantain (*Musa paradisiaca)*, Chemical balance, muffle furnace, mortar and pistol, standard sieve of 250 micron, tap water, bentonite clay, caustic soda (NaOH), barite, mixer, spatula, stirrer, Measuring cylinder, Porcelain crucibles, rheometer, mud balance, pH meter, beakers, conical flask, flat bottom flask, acetone and tissue paper.

Fig.1: Fresh Banana Peels

Fig.2: Dried Banana Peels

Fig.3: Fresh Plantain Peels

Fig.4: Dried Plantain Peels

A. Bio-enhancers Preparation

The fresh peels were extracted from Banana and Plantain. The peels extracted were chopped with a knife into smaller sizes to provide a large surface area for effective drying. It was sun dried for 9 days until there were no traces of oil or water left. The dried peels were burned by heating to 700^0C in a muffle furnace forming dark ash, grinded with the aid of mortar and pestle and sieved with a set of standard mesh sieve of 250micron.

B. Water-Based Mud Preparation

21.0g of medium viscosity Bentonite clay was measured using chemical balance. The Bentonite clay was added to 350ml of tap water and was mixed in the mixer. The mixture was agitated until the clay was thoroughly mixed to create a homogenous drilling fluid. The prepared water-based mud was subsequently poured into different beakers and was properly labelled [7].

2.0g, 4.0g, and 8.0g of Banana ash, Plantain ash, and Caustic Soda (NaOH) were measured and added to the homogenous mixtures of the water-based mud prepared. The pH, viscosity and mud weight of the labelled samples were determined and recorded periodically.

C. Mud Weight Determination

The Fan Mud Balance was used to measure the mud weight or density. The lid of the cup was removed, and the cup was filled with a mud sample. The lid was replaced and rotated to firmness, to ensure no expulsion of mud through the hole in the cup. The balance arm was placed on the bottom, with the knife-edge resting on the fulcrum. The rider was moved until the graduated arm was level, as indicated by the level gauge on the beam. The mud weight was read at the left-hand edge of the rider, and its value was recorded. The same procedure was repeated for other mud samples and the readings were recorded. Barite, a foreign weighting material commonly used in drill muds to improve its weight, was used as one of the additives for the control mud sample.

D. pH Determination

The Jenway pH meter was used to determine the pH of the mud samples. The electrode of the pH meter was cleaned prior to use (this was done to prevent contamination) and was

E. Procedure for Viscosity Determination

A Rheometer was used for determining formulated drilling mud viscosity. The mud sample was poured into the Rheometer basin and the basin was raised up until the rotor sleeve was immersed in the mud. The gear was switched onto a speed of 600rpm and 300rpm respectively, the calibrated viscometer reading was allowed to stabilize and the reading on the screen was recorded. The same procedure was repeated other samples.

III. RESULTS AND DISCUSSION

A. Description of samples

Table 1 shows the summarized description of the samples used in this experiment.

Table 1: Mud samples and their descriptions

SAMPLE	DESCRIPTION
A	Control mud (no additives)
B1	A + 2 grams of Banana ash
B2	A + 4 grams of Banana ash
B3	A + 8 grams of Banana ash
C1	A + 2 grams of Plantain ash
C2	A + 4 grams of Plantain ash
C3	A + 8 grams of Plantain ash
D1	A + 2 grams of Caustic soda (NaOH)
D2	A + 4 grams of Caustic soda (NaOH)
D3	A + 8 grams of Caustic soda (NaOH)

E1	A + 2 grams of Barite ($BaSO_4$)
E2	A + 4 grams of Barite ($BaSO_4$)
E3	A + 8 grams of Barite ($BaSO_4$)

B. Effects of Additives on Mud Weight

The beginning of pressure control is the control of mud density. The weight of a column of mud within the hole necessary to balance formation pressure is the point of reference from which all pressure control calculations are based[8]. The needed weight of the mud column sets up the density of the mud for any specific case. Table2 shows the mud weights of the various mud samples. then inserted into the beaker of the drilling mud to be measured. The electrode was allowed to stabilize and reading on the digital monitor was recorded for each sample. This procedure was repeated on each sample every five (5) days to determine the change in pH value with time.

Table2: Mud weights of all mud samples

Mass of Additives	A (lb/gal)	B (lb/gal)	C (lb/gal)	D (lb/gal)	E (lb/gal)
(+2g)	8.55	8.60	8.61	8.58	9.25
(+4g)	8.55	8.65	8.67	8.60	9.37
(+8g)	8.55	8.75	8.79	8.60	9.54

Mud weight of control mud, A=8.55lb/gal.

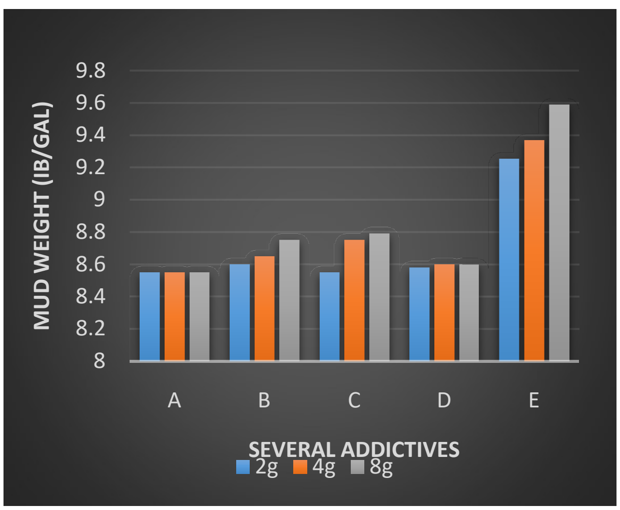

Fig.5 Effect of Additives on Mud weight

***A** represent samples without additives, **B** represent sample blended with banana ash, **C** represents samples blended with plantain ash, **D** represents samples blended with Caustic soda while **E** represents samples blended with barite. Blue, Orange and gray represents 2g, 4g and 8g of additives respectively*

As illustrated in Fig.5, the control mud, A has a weight of 8.55lb/gal with no additives. On the addition of 2g of Banana ash, the mud weight increases from 8.55 to 8.60 lb/gal. An additional 2g increased the mud weight to 8.65 lb/gal. It was further increased by 0.10 lb/gal when the ash content was doubled to 8g. This shows that Banana peels ash (BPA) has little increasing effect on the weighting of the mud.2g of Plantain peels ash (PPA) was added to the mud, and this increased the mud weight by 0.06 lb/gal. Additional concentrations of plantain peels ash (4g and 8g) to the mud increased the mud weight to 8.67g and 8.79g respectively. This implies that an increase in PPA concentrations, like BPA, also has a little increasing effect on the weight of the mud. For D samples, on the addition of 2g of caustic soda, the mud weight increased to 8.58 lb/gal. This increase was not much due to the light density of caustic soda. 2g more was added and it increased by 0.02 lb/gal. On doubling this, no change was noticed. Hence, caustic soda has very little effect on mud density. Samples E show the addition of different concentrations of barite, a foreign weighting material. 2g increased the mud weight to 9.25 lb/gal. 4g increased it to 9.37 lb/gal and 8g caused an increment of 0.17 lb/gal. This confirms the highly significant effect of barite on mud weight.

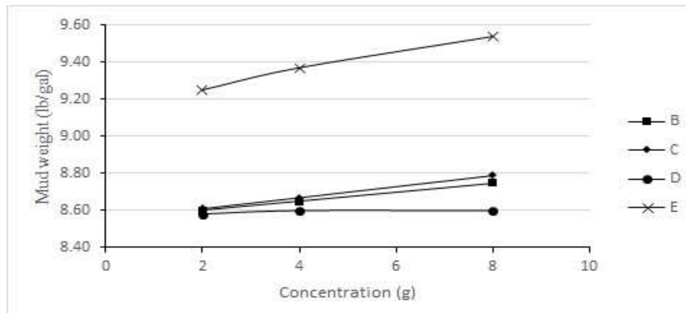

Fig.6: Plot comparing Selected Mud Weights

Fig.6 above shows a plot comparing the resultants weights of WBM. It could be inferred thus, that mud weight increases with increasing concentrations of additives. With samples E (control sample containing Barite having the highest incremental effect on the mud weight, and then sample C (control sample containing PPA), sample B (control sample containing BPA) and finally sample D (control sample containing Caustic Soda) in that order. Thus, BPA and PPA containing samples perform better as weighting material than caustic soda.

C. Effects of Additives on pH determination

The pH values of the mud samples were taken every five days for fifteen (15) days for different concentrations of the various additives in order to determine the effect of ageing on the WBM and was as presented in Table4.

Table 4: pH values of mud samples at various concentrations for different days

Sample	DAY 0 (Initial)	DAY 5	DAY 10	DAY 15
A	9.00	8.42	8.28	8.19
B1	9.98	9.50	9.11	8.88
B2	10.66	10.34	10.14	10.02
B3	11.42	10.93	10.38	10.09

C1	10.00	9.80	8.80	7.90
C2	10.80	10.0	9.75	8.50
C3	11.75	11.25	10.50	9.50
D1	13.42	13.35	13.22	13.17
D2	13.60	13.52	13.46	13.37
D3	13.76	13.67	13.58	13.51

A represents sample with no additives, B1, B2 and B3 represent sample blended with 2g, 4g and 8g of Banana peel ash. C1, C2 and C2 represent samples blended with 2g, 4g and 8g of Plantain peel ash while D1, D2 and D3 represent samples blended with 2g, 4g and 8g of Caustic soda

Over the 15 days of testing, the pH of the control mud went from 9.00 to 8.19. This decrease occurred with time, as depicted in normal drilling operations. The pH shows the Hydrogen ion concentration of the mud. A pH of 7, for pure water, is neutral. A decrease in pH below 7 shows a rise in acidity (hydrogen ions), while an increase in pH above 7 shows a rise in alkalinity (hydroxyl ions).For B samples (BPA), the pH of the samples increased from the control pH of 9.00 to 9.98, 10.66 and 11.42, with the doubling of the additives. But, over the days, the pH reduced greatly with the final readings at 8.88, 10.02 and 10.09, which are low compared to the initial readings.

2g, 4g, and 8g of PPA were added to the mud for C samples, and this increased the pH to 10.00, 10.80 and 11.75 respectively. However, from days 0 to day 15, the pH reduced significantly, like in the case of BPA. Their final pH readings further buttress this decrease; 7.90, 8.50 and 9.50 respectively, which are low when compared with their respective initial readings. This shows that the increased pH effect of PPA on WBM decreases greatly over time. Caustic soda is the commonly used foreign additive for pH enhancement and is highly alkaline in nature. This fact causes a great increase in the pH of the D samples, from 13.42 to 13.60 and 13.76, on concentrating them with 2g, 4g, and 8g respectively. Also, the reducing difference over time left off the pH readings at 13.17, 13.37 and 13.51, which is a close range. Hence, caustic soda has a very significant effect on mud pH.

As shown in Table4 that both BPA and PPA have a similar effect (pH reduction rate with time) on WBM, the pH value of the various test mud samples reduced as the time progressed indicating that capacity for all mud samples to inhibit corrosion, when used over a short period of time rather than a longer time frame. It could be inferred that PPA or BPA can be used to substitute caustic soda, the common foreign additive for pH enhancement in the Oil and Gas industries.

D. Effects of additives on viscosity

Table 1.5 shows the variation of additives concentration which was used to determine the viscosity of the mud samples, with the viscosity of the mud sample monitored and measured by Rheometer. The changes in viscosity of the test samples by adding grams of BPA, PPA, and caustic soda additives were studied, to demonstrate that improved rheology performance of the mud samples that is obtainable by using Banana and Plantain peels (both being biodegradable biological inhibitors). A good mud should have viscosities that can be optimized for performance in formation downhole conditions [9].

Table 5: Viscosity measurements of mud samples

Samples	Viscosity (cP)	
	300 RPM	600 RPM
A	7.00	9.00
B1	11.50	12.50
B2	19.00	20.50
B3	32.50	35.00
C1	13.00	14.00
C2	16.00	18.00
C3	38.5	40.00
D1	9.50	11.00
D2	12.50	14.50
D3	16.00	17.00

The viscosity readings were all taken at room temperature of 25°C (77°F).Table 5 showed that the viscosity of the original test mud sample with no additive is 7.00cP for 300rpm and 9.00cP for 600rpm, while the increase of the BPA concentration to 2g resulted in a mud viscosity increase to 11.50cP for 300rpm and 12.50cP for 600rpm. With a further increase in the concentration of BPA to 8g, an exponential increase in the mud viscosity to 32.50cp for 300rpm and 35.00cP for 600rpm was observed. Similarly, for the case of PPA, an increase in its concentration also showed a considerable increasing effect in the mud viscosity from 7.00 to 13.00cP for 300rpm and 9.00 to 14.00cP for 600rpm at 2g and maximum of 40.00cP at 8g for 600rpm. The results from Table.5 above confirm that BPA and PPA are better viscosifiers compared to caustic soda additive, signifying better rheology and drilling performance of the mud. Thus, BPA and PPA combine the benefits of standardizing the mud for pH control, corrosion inhibition in the scale of caustic soda and optimizing mud viscosities for different downhole drilling conditions.

The treatment of the mud with additives was done to increase the viscosity in order to improve the ability of the mud to suspend cuttings when drilling is stopped. This phenomenon is known as *Gel Strength*. Fig.7below shows the effect of additives (BPA and PPA and) on mud viscosity. It is observed that increase in additives concentration resulted in increased viscosity of mud samples. The usage of BPA will improve hole cleaning capacity suspension at lower shear rates [4]. This experiment shows that BPA and PPA are good viscosifiers.

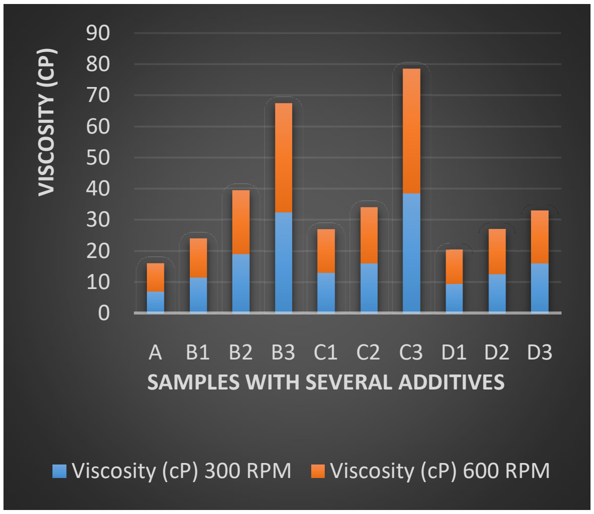

Fig.7: A chat showing the effects of additives on mud viscosity

E. Plastic Viscosity (PV) and Yield Point (YP)

Plastic viscosity, PV, is an absolute flow property indicating the flow resistance of different reservoir fluid types. Its unit is centipoise (cP). The plastic viscosity is an indicator of high shear rate viscosities even though it is calculated from measurements at relatively low shear rates. Consequently, it tells us something about the expected behavior of the mud at the bit. One of our design criteria was to reduce the high shear rate viscosity. To accomplish this, we must minimize the plastic viscosity. A decrease in plastic viscosity should signal a corresponding decrease in the viscosity at the bit, resulting in a higher penetration rate. Increasing the plastic viscosity isn't a desirable means of increasing the hole-cleaning ability of a mud. In general, high plastic viscosity isn't desirable and it should be maintained as low as practical [9]. The plastic viscosity can be calculated using this equation:

$$\text{Plastic Viscosity} = \theta 600 - \theta 300 \qquad (1)$$

Where ($\theta 600$ and $\theta 300$) are the dial readings at 600rpm and 300rpm, respectively

Yield point, YP, is the resistance to the initial flow of a fluid or stress required to start fluid moving. The yield point, calculated from the Bingham equation, is not the true yield stress necessary to maintain flow but is a value that is somewhat higher. It is normally near to the value of the shear stress at annular shear rates. Anything that causes changes within the low shear rate viscosities is going to be reflected within the yield point. For this reason, it is a good indicator of flow behavior in the annulus and compositional changes that affect the flow behavior in the annulus. Its unit is lb/100ft2.The yield point can be calculated using this equation:

$$\text{Yield Point} = \theta 300 - \text{Plastic Viscosity} \qquad (2)$$

Table 6: Effect of Additives on Plastic Viscosity and Yield Point

Samples	Viscosity (cP)		PlasticViscosity(cP)	Yield Point (lb/100ft2)
	600 RPM	300 RPM		
A	9.00	7.00	2.00	5.00
B1	12.50	11.50	1.00	10.50
B2	20.50	19.00	1.50	17.50
B3	35.00	32.50	2.50	30.00
C1	13.00	14.00	3.00	15.00
C2	16.00	18.00	4.00	22.00
C3	38.5	40.00	4.50	37.50

As presented in table 6, the plastic viscosity (PV) and yield point (YP) for all the mud samples differ. Plantain Peel Ash (PPA) has a higher yield point than Banana peel ash (BPA). Since the yield point describes the suspension properties of the mud, it could be inferred that both BPA and PPA are good viscosifiers compared to conventional caustic soda.

F. Effects of BPA on Plastic Viscosity and Yield Point

As presented shown in fig.8below, it was observed that the yield point of the mud experienced a sharp and continuous rise with increasing concentrations of BPA. Also, the plastic viscosity varied slightly and maintained an almost constant (dashed) level. This shows that using banana peel ash, BPA, the flow resistance of the mud is minimal-to-insignificant. Hence, BPA will improve the suspension property and cutting-carrying capability of the mud.

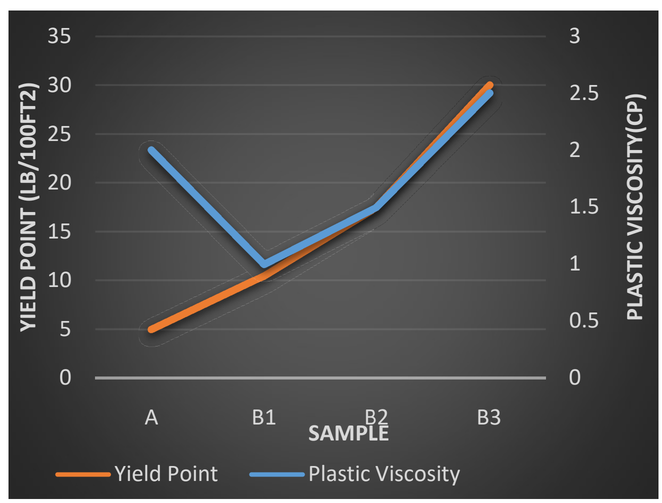

Fig.8: A plot showing the effect of BPA on yield point and plastic viscosity

G. Effects of PPA on Plastic Viscosity and Yield Point

Fig.9shows the effect of PPA differs slightly from that of BPA. The yield point also increased but the increment rate is higher. This shows the effectiveness of PPA as a viscosifier, just like BPA. From the results in table 6, it is observed that PPA is a better viscosifier than BPA, although both are good viscosifiers. Table7 below shows the standard specification for WBM by EGASPIN

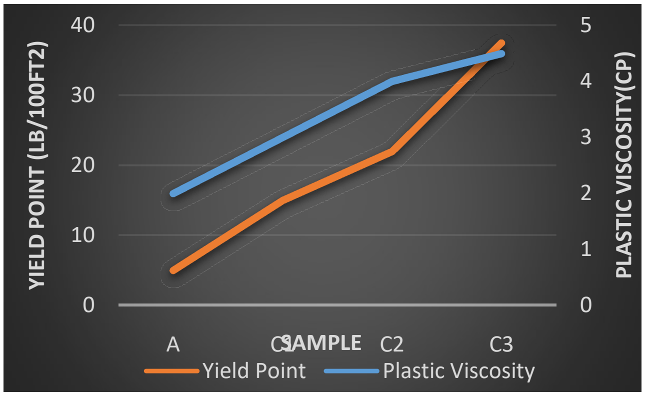

Fig.9: A plot showing the effect of PPA on yield point and plastic viscosity

Table 7: Standard specification for WBM [10]

Sea water / Fresh Water L-al Mud	
Attapilgite or Bentonite	10 – 50
Barite	0 – 50
Caustic Soda	0.5 – 3
Cellulose Polymer	0 – 2
Drilled Solids	20 – 100
Lime	0 – 2
Seawater or Fresh Water	1
Soda Ash / Sodium Bicarbonate	0 – 2

IV. CONCLUSION

The use of locally made bio-products helps in cost reduction, and due to the organic nature of the additives, it makes it environmentally friendly having little or no effects on the subsurface formation. This aligns with the Nigerian Local Content Laws in the Petroleum Industry.This study was done to ascertain the effectiveness of indigenous Bio-enhancers for pH, Viscosity and other rheological properties control in drilling fluid. It was established from the experiment carried out on the water-based mud (WBM) that locally prepared additives, Banana and Plantain Peels Ash, had great effect on the mud pH and viscosity. Hence, it was confirmed that both the dried banana and plantain peels additive are good bioenhancers for improving rheological properties of drilling mud to acceptable ranges stipulated by the American Petroleum Institute (API). There is a great prospect for locally sourced materials and it is hoped that this research encourages the readers and industries to explore them.

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