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Empirical Studies of the Effectiveness of Bio-enhancers (Food Waste Products) as Suitable Additives in Environmental Friendly Drilling Fluid Systems

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Abstract
Traditional chemical additives used in controlling the mud properties are non-biodegradable and constitute a source of environmental contamination from the oilfield drilling waste. The release of contaminants to the environment and fresh water aquifer have attracted increasing awareness and scrutiny therefore the need for environmental friendly biodegradable drilling fluid additives.

This paper presents an experimental investigation of the effectiveness of biodegradable food waste products such as; Banana Peel Powder (BPP), Gum Arabic Powder (GAP) and Potato Peel Powder (PPP) as suitable additives to control mud rheological properties such as; Plastic Viscosity (PV), Yield Point (YP), filtration loss, and corrosion control rate.

The effect of adding varying concentration of the biodegradable additives were measured using a standard API viscometer and filter press and compared with the properties of the base case water based mud.

The result showed that PPP and BPP improved the filtration characteristics by 78% and 43%, respectively, suggesting their applicability to be used as an excellent fluid loss control agent. Similarly, PPP and GAP additives resulted in an enhanced viscosity performance, improving the plastic viscosity by 38% and 25% respectively, signifying their suitability to be used in high viscosity sweeps to improve hole cleaning.

These experimental results show that food waste products have the potential to be used as bio-degradable drilling fluid additives replacing chemical additives and hence reducing amount of non-biodegradable waste disposed to the environment.

Introduction
The increasing global concerns for the protection of the environment from the detrimental effect of chemical and non-biodegradable derivative has continued to drive the drilling fluid optimization techniques towards safer and environmental friendly formulation. Drilling fluid consist of a base fluid and various solid and soluble additives that perform specific function to allow for good drilling performance. The performance of drilling fluid affects the overall drilling efficiency. Therefore, the selection of base fluid and additive are carefully chosen to fulfill the formation requirements, hydraulic considerations and hole cleaning efficiency. The factors that guide the selection of base fluid and the mud additives are complex and well discussed (Okorie 2009).

Environmental consideration led to increasing interest in the use of conventional water based drilling fluid over the oil based drilling fluids due to the high toxicity of the later especially in environmentally sensitive locations. Nonetheless, increased focus on economic and performance with little attention to environmental consideration have led to the use of toxic chemical additives in the formulation of conventional water based systems. These additives including; potassium chloride, potassium sulphate, polyamine, chromium containing thinners and fluid loss additives etc., have an overall negative environmental impact and are very expensive (Amanullah 2007).

Nowadays, strict environmental guidelines set by the environmental protection agencies on the discharge of water effluent to the sea and the disposal of drill cuttings have now motivated researchers to develop cost effective biodegradable additives that will deliver both performance and reduce environmental impact. Recent research efforts have examined the applicability of natural biodegrable waste as drilling fluid additives in order to reuse and reduce waste disposal and the toxicity to the environment.

Okon et al. (2014) examined the use the rice husk as an environmental friendly filtration control additive. The result showed that 20 ppb concentration of risk husk was able to reduce fluid loss by 65% when compared to performance of 10 ppb of Carboxymethyl Cellulose (CMC). However, the high concentration of rice husk might pose a risk to delicate Measurement While Drilling (MWD) tools and might result in undesirable effect on the plastic viscosity. Iheagwara (2015) in his study showed that banana peel exhibit an alkaline property on drilling mud as conventional caustic soda. Similarly, Adebowale and Raji (2015) examined the use of Banana Peel Ash (BPA) as a substitute additive for NaOH to enhance the pH of the drilling fluid and control corrosion. The study revealed a significant enhancement in pH from BPA. However, comparison of improvement from same concentration of BPA and NaOH showed an improvement in pH by 12 and 14, respectively.

Iranwan et al. (2009) studied the use of corncob and sugar cane as viscosifying agent. Although these additives showed an improvement in plastic viscosity but negatively affected the yield point and gel strength by reducing both values when the concentration of the additives were increased from 6 ppb to 10 ppb. In a similar vein, Nmeghu et al. (2014) examined the effect of using cellulose from corncob in improving the rheological properties of water-based mud. The experimental results showed that corncob was efficient in reducing fluid loss compared to Polyanonic Cellulose (PAC). The suitability of cashew and mango leaves extracts in improving the rheological properties of the mud were also investigated by Omotioma et al (2014) and showed that the extracts improved the rheological characteristics of the mud. The application of potato starch extracted from potato tubers in enhancing the rheological properties of mud was studied by Nyeche et al (2015). Their results showed that rheological and filtration properties were impacted negatively.

In this paper the applicability of the food waste products generated by the food industry, such as BPP, BPA and PPP as environmental drilling fluid additives to improve the rheological and the filtration properties is presented.

Materials and Methods

This section discusses the procedures used in preparing the various bio-enhancer additives and the different experimental procedures used in the laboratory evaluation. In addition, the reference mud sample properties as well as the conducted set of tests using different blends at different concentrations will be presented.

Preparation of Additives

The raw waste and non-waste materials collected from different sources were sliced into small pieces to accelerate the drying process and kept under the sun for 4-5 days to dry (**Figure 1**). Once dried, the materials were grinded into very fine powder (**Figure 2**).To create the BPA, the grinded BPP powdered was heated in the oven at 100°C until the content was completely oxidized(**Figure 2b**).

(a) **(b)** **(c)**

Figure 1. (a) Drying Banana Peels, (b) Drying Gum Arabic, and (c) Drying Potatoes Peel

(a) **(b)** **(c)** **(d)**

Figure 2. (a) Banana Peels Powder (BPP), (b) Banana Peels Ash (BPA), (c) Gum Arabic Powder (GAP), (d) Potato Peels Powder (PPP)

Mud Sample Preparation.

The reference mud sample referred as the base mud was prepared using 7% bentonite. The composition of the mud includes; 36 grams of bentonite mixed with 500 ml of fresh water and 4.0 grams of sodium hydroxide pellet. The reference mud properties are as shown in **Table1**.

Table 1. Reference Mud Sample Properties

Plastic Viscosity (cP)	Yield Point (lb/100 ft^2)	Gel 10s (lb/100 ft^2)	Fluid Loss (ml/30 min)	Mud Cake Thickness (inches)	pH
8	15	12	59	0.283	12.5

Four test samples of drilling fluid were created by mixing 1% concentration (5 grams) of each of the corresponding bio-enhancer additives to the reference mud sample to have the following samples:

- Base Mud + 5 grams of BPP
- Base Mud + 5 grams of BPA
- Base Mud + 5 grams of GAP
- Base Mud + 5 grams of PPP

Laboratory Measurements.

To evaluate the effectiveness of the drilling fluid additives on the reference mud sample, the filtration properties including the fluid loss in ml/30 and the filter cake characteristics were measured using the standard API filter press at 100 psi. The rheological properties including; the PV, YP and gel strength were also measured using the standard API rotary viscometer and the sample mud weight was obtained using the mud balance.

Results and Discussion

The summary of the experimental results obtained are presented in **Table 2.** The results include fluid sample weight, PV, YP, Gel strength and filtration properties including fluid loss (FL) and filter cake thickness (FCT).

Table 2. Summary of results with addition of 5 grams of additives

Fluid Sample	Mud Wt.	PV	YP	Gel 10s	FL	FCT	pH
	(ppg)	(cP)	(lb/100 ft^2)		(ml/30 min)	(inches)	
Ref (BM)	**8.6**	**8**	**15**	**12**	**59**	**0.283**	**12.50**
BM +BPP	8.6	7.5	9	11	22	0.150	12.5
BM +BPA	8.6	7.5	9	8	23	0.141	12.7
BM +GAP	6.7	11	6	8	30	0.196	12.3
BM +PPP	7.8	10	16	13	13	0.162	12.5

Effect of Additives on Mud Weight

Based on the results presented in Table 2, it is clearly seen that that both the BPP and BPA blends had no effect on the mud weight, however, GAP and PPP blends significantly reduced the mud weight compared to the reference mud due to foaming. The addition of 1% concentration of GAP and PPP results in mud weight reduction of 22% and 9%, respectively.

Effect of Additives on the Rheological Properties

The effect of the addition of 1% concentration (5 grams) of the different bio-enhancer additives on the rheological properties of the reference mud was evaluated by comparing the measured values with the reference mud readings. The plastic viscosity, which defines the resistance of the fluid to flow, the yield point, the fluid intrinsic property that determine cutting lifting capability and the gel strength measured after 10 seconds which indicates the effectiveness of the fluid to suspend cuttings at pump off condition are presented in **Figure 3.**

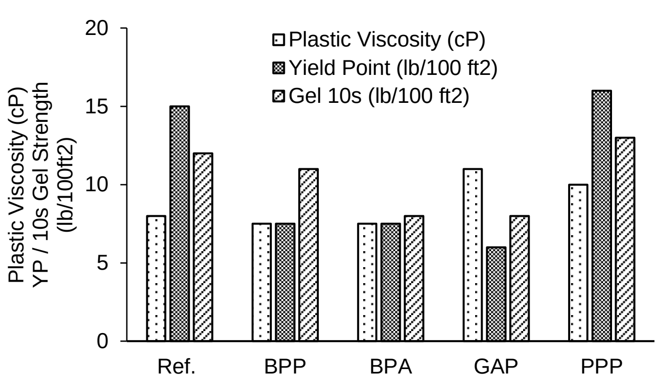

Figure 3. Effect of different additives at 1% concentration on the rheological properties

Figure 3 shows that Banana Peel Powder (BPP) and Banana Peel Ash (BPA) blends have negligible effect on plastic viscosity, however both blends resulted in decrease in both the yield point and the 10s Gel strength. GAP and PPP blends however increases the plastic viscosity by 38% and 25% respectively at 1% concentration, suggesting applicability to be used as high viscosity pills.

Effect of Additives on Filtration Properties

Measured fluid filtration loss at 100psi with standard API filter press was used to evaluate the effectiveness of the additives as an environmental friendly filtration control agent. The fluid loss measured at 10 minutes and 30 minutes are shown in **Figure 4**.

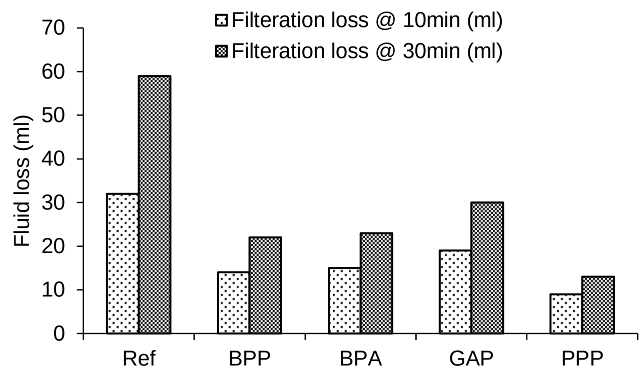

Figure 4. Effect of additives on Filtration loss

It can be clearly seen that all the blends resulted in a reduction in fluid loss. However, the best filtration control additive was the PPP blend, which resulted in an improvement in fluid loss by 78% compared to the reference mud followed by the Banana Peel additive (BPP and BPA) and Gum Arabic blends with an improvement of 61% and 49%, respectively.

In regards to the filter cake thickness, the resultant mud cake thicknesses were within acceptable range as shown in **Figure 5**, where the mud cake thickness was also reduced by all the biodegradable drilling fluid additives.

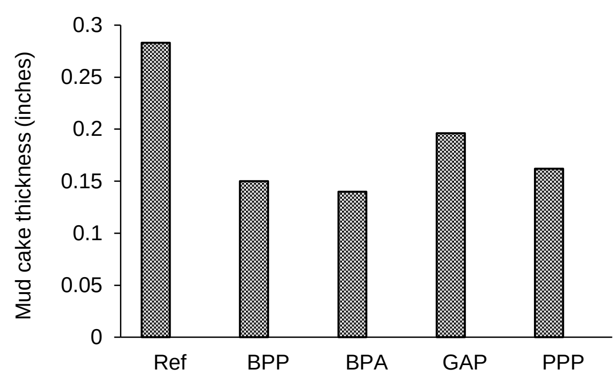

Figure 5. Effect of additives on Mud cake Characteristics

Effect of Concentration Variation

Further experiments to investigate the effect of increasing the concentration of the additives from 1% (5 grams) to 2% (10 grams) and 3% (15 grams) were evaluated. The rheological and filtration properties were also evaluated. The results of the variation in the concentration of the BPA and BPP additives are presented in **Table 3.** It is clear that increasing the concentration does not affect the rheological properties of the mud.

Table 3. Effect of variation in the concentration of the BPP and BPA on rheological properties of water based mud

Additives	BPP			BPA		
Concentration	5g	10g	15g	5g	10g	15g
PV (cP)	7.5	7.5	8	7.5	7.5	9
YP (lb/100ft2)	9	9	10	9	9	10
10sGel (lb/100ft^2)	11	11	11	8	8	8
FL(ml/30min)	22	21	20	23	20.5	20
FCT (inches)	0.15	0.12	0.10	0.14	0.101	0.10

The results show that increasing the concentration of the BPA and BPP by 2% and 3% does not result in a proportionate improvement in the fluid loss control properties and therefore suggesting a lower concentration of the additives to be considered for optimal performance.

Conclusions

Three independent experimental studies to measure and validate the results of the effect of biodegradable additives and their effectiveness in optimizing the performance of water-based mud have been performed. The following conclusions are reached from the study:

1. Potatoes Peel Powder (PPP) is a multifunctional bioenhancer additive, with significant improvement of the rheological and filtration properties of water based mud.
2. PPP exhibited an excellent fluid loss control performance in water based mud, as the addition of 1% concentration of the additive, resulted in reducing fluid loss and filter cake thickness by 78% and 43%, respectively.
3. Banana Peel Powder (PPP) and Banana Peel Ash (BPA) also improved the filtration characteristics by reducing the fluid loss and the mud cake thickness by 70% and 50%, respectively, suggesting their applicability to be used as fluid loss control agents.
4. Higher concentration of the BPP and BPA did not result in a proportionate improvement in the filtration properties suggesting a lower concentration of 1% - 2% to be used for optimal performance.
5. Both Gum Arabic Powder (GAP) and PPP reduced the mud weight dramatically by 22% and 9%, respectively due to foaming by the addition of 1% concentration compared to the reference point drilling fluid, suggesting their applicability as mud weight control and filtration control additives.
6. BPA was found to increase the pH of the reference point fluid, whilst BPP does not. The alkalinity property of the BPA is a result of the production of potassium oxide when oxidized by combustion suggesting their suitability to serve as a pH modifier and corrosion control agent.

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