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Analysis of Selected Fiber-Rich Agricultural Waste as Water-Based Drilling Mud Fluid Loss Control Additives

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ABSTRACT

For a drilling operation to be successful, the drilling fluid performance must be optimized. This research study the use of degradable agricultural waste namely cowpea skin powder (CSP), sugarcane rind powder (SRP) and yam bark powder (YP) as additives for fluid loss control. The elemental composition of these food wastes was determined using SEM-EDS. Proximate analysis was performed to investigate the content of moisture, ash, nitrogen, protein, volatile matter, fixed carbon, bulk density, specific gravity and pH. The local additives were used at 1% (5grams), 3% (10grams), 4% (15grams) and 5% (20grams) each. For CSP fluid loss increased at 5g and 10g (1% and 3%), by 14% and 9% respectively, at 15g and 10.6g, fluid loss decreased by 33% and 36% respectively. Using SRP of 5g increased fluid loss by 12% but there was decrease in fluid loss with 10g, 15g and 2g in these percentages; 14%, 33% and 37% respectively. YP resulted in fluid loss at 5g giving 1.5% loss, 12% loss with 10grams, 16% fluid loss with 15 grams and 33% filtrate loss with 20grams. Overall, SRP showed best fluid loss performance with 20grams (5%), resulting in 37% fluid loss decrease followed by Yam bark powder at 20grams with fluid loss performance of 33%. The least performance was by CSP at 5grams (3%) that increased the filtrate loss by 14%.

KEYWORDS: Fluid loss control, Fiber-rich agricultural waste, Nigerian white yam bark, sugar cane rind, black eye bean, cowpea skin.

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1 | INTRODUCTION

The rise in human population and industrial activities have increased energy demand. Petroleum is among the major sources of energy. Meeting the world demand for petroleum requires the efficient exploitation of petroleum using optimized oil well drilling practices. Drilling fluid properties are essential as it determines the success of a drilling operation. Drilling through hazardous terrain affects the drilling fluid properties. Hence, the need to beneficiate the drilling fluid using additives. Lack of maintenance of drilling fluid properties during drilling operation could lead to wellbore damage, loss of hole, and blow out. When any of these occur, it poses a threat to rig personnel and the environment. [1,2]

Essential drilling fluid properties are, the flow resistance offered by the fluid (viscosity), the weight of the fluid per unit volume, which is the density, and Gel strength which is the measure of the ability of drilling fluid to hold in suspension particles in even when the flow has stopped and Filtration. Others include pH (alkalinity or acidity), content and proportion of sand, and content of calcium present (hard water).

This work focuses on how to manage fluid loss in drilling fluid. loss of fluid is effectively controlled by controlling the flow characteristics of the fluid and balancing that with the permeability of the filter cake which possess a potential to settle on hole wall thereby influencing loss of liquid into the formation or invasion of formation fluid in an uncontrolled manner. Fluid loss is referred to the volume of filtrate that escapes by invasion into the permeable zones of the formation essentially by filtration during drilling. Fluid loss will mean a dehydrated clumps of filter cake settles on the hole wall and hence affect the rate of flow of hydrocarbon through the pores, this could then destabilize the overall performance of the zone or well. When the annular gap for flow is taken up by filter cake, flow area is restricted and increased pressure is required to repair this damage. [2,3] One of the measures used to prevent or reduce fluid loss control is by using additives. Proper application will help maintain a desirable ratio between water and solids in the cement slurry.

Synthetic fluid loss control additives form most of the contemporary stock in use, examples include micronized cellulose containing additives, low-viscosity carboxymethylcellulose (CMC), and CM-starch. [3] Rising global safety awareness has necessitated the need for safer alternatives for these synthetic additives. Organic options are being explored as substitutes for existing synthetic additives. In the bid to save cost, food waste presents an attractive front to be utilized where it is determined possible. [4,5] Agricultural waste though deemed useless to man, may contain valuable carbon compounds and polymers that would then form invaluable resources for controlling properties in drilling mud. Being Agricultural, they are biodegradable and if they were to be consumed by organisms during disposal, the agricultural substances would be digestible and not lethal as in the case of synthetic fibers. Agricultural wastes have been found to contain fibers and valuable cellulose. [6,7,8,9]

In drilling operation Fluid loss control involves managing the water/solid ratio in drilling fluid downhole, here the rate at which filtrate seeps and penetrate adjacent permeable zones of the rock is controlled, the control is achieved primarily by varying the viscosity of the fluid and altering the rate of deposition of filter cake. Essentially this control speaks to the borehole stabilization. A drilling engineer wants a stabilized hole. Examples of fluid loss additives in current applications are Sodium montmorillonite (bentonite), polyacrylamide, polyethyleneimines, carboxymethyl hydroxyethyl cellulose (CMHEC), hydroxyethyl cellulose (HEC), Carboxymethyl cellulose (CMC) and Polyanionic cellulose (PAC) which are essentially synthetic fibers.[6]

In the rising search for a more organic cheap alternative for carboxymethyl cellulose and other synthetic additives, Fiber appears to be an active and essential component of conventional additives hence the attention on fiber in this work. [10] This work examines the application of other food wastes, particularly skin of black-eye peas, Cowpea skin Powder (CSP), Sugar Cane rind (SRP) and Yam Bark (YP) were used as organic drilling fluid additive, these materials are high in fiber content and abundant in Nigeria. Beans, yams, and sugar cane are regular foods in most Nigerian homes. The elemental composition of these food wastes was determined using Energy Dispersive Spectroscopy (EDS), Proximate analysis was performed to investigate the content of moisture, ash, nitrogen, protein, volatile matter, fixed carbon, bulk density, specific gravity, and pH.

2 | MATERIAL AND METHOD

The materials and method used in this research is highlighted in three major methodological steps as follows: Sample Collection and Processing, Sample Characterization and Performance evaluation of agricultural waste powders as drilling fluid additives.

Sample collection

The organic food wastes selected are Cow pea skin, Sugar cane rind and Nigerian white yam bark, as shown in Figure 1, they were carefully sourced domestically.

Figure 1: Selected food waste

These wastes were washed and sun dried carefully for ten days before pulverizing each of the waste into powdered form of 200 microns, the powders were then taken to the laboratory for characterization of the samples to understand their elemental composition morphology and other quantitative components and further tested to obtain the performance characteristics of each formulation in drilling mud of water as flowing fluid.

Characterisation

In order to better understand the chemical characteristics of Cowpea Skin Powder (CSP), Sugarcane Rind Powder (SRP) and Yam bark Powder (YP), a Scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS) was carried out on all three to show both the morphology and elemental composition in weight concentration and percentage concentration. Proximate analysis was performed to investigate the content of moisture, ash, nitrogen, protein, volatile matter, fixed carbon, bulk density (fiber content), specific gravity and pH.

Performance Evaluation of Waste Powder as Drilling Fluid

Additives: One lab barrel of water-based mud was prepared by mixing 22.5 g of bentonite clay in 350 ml of water. [11]. The filtration properties of the mud were determined using the API filter press. The filter cake thickness was also recorded with the Vernier calliper. The rheological properties were determined using a rotational viscometer.

Twelve fresh lab barrels of drilling mud were prepared according to Table 1. Four batches of water-based mud containing 5, 10, 15 and 20 grams each of cowpea skin powder, four batches for sugar cane rind and another four for yam bark. The effect of the additives was tested on fluid loss of individual drilling mud. Table 1. illustrates the mixing volume of all the components used to constitute twelve batches of water-based drilling mud used for performance evaluation.

Table 1. *Drilling Mud samples constituent for performance evaluation*

Additive	Reference mud	Mud with Sugar Cane Rind Powder	Mud with Cow Pea Skin Powder	Mud with Yam Bark Powder
Water(ml)/(g)	350	350	350	350
Bentonite (g)	22.5	22.5	22.5	22.5
SCRP (g)	NIL	5,10,15& 20	NIL	NIL
CSP (g)	NIL	NIL	5,10,15& 20	Nil
YP (g)	NIL	NIL	NIL	5,10,15& 20

3 | RESULT AND DISCUSSION

The **Sem-Eds Analysis Result**

The chemical elemental compositions indicated from the SEM-EDS; Scanning Electron Microscope Energy Dispersive X-ray spectroscopy is presented in Table 2. The weight concentration and atomic concentration of each element detected is given in the same table.

Table 2: *SEM-EDS Composition Analysis results on samples*

Element Number	Element Symbol	Element Name	SRP		CSP		YP	
			Atomic Conc.	Weight Conc.	Atomic Conc.	Weight Conc.	Atomic Conc.	Weight Conc.
6	C	Carbon	58.37	58.96	55.02	57.96	52.67	56.38
7	N	Nitrogen	2.77	1.36	0.8	0.35	1.25	0.56
8	O	Oxygen	12.02	6.75	4.61	2.32	4.65	2.38
11	Na	Sodium	0.79	0.64	5	4.43	6.93	5.09
12	Mg	Magnesium	2.12	1.81	2.61	1.99	1.65	1.28
14	Si	Silicon	1.59	1.57	2.69	2.37	2.7	2.42
15	P	Phosphorus	7.72	8.4	0.92	0.89	1.27	1.25
16	S	Sulphur	0.14	0.04	0.52	0.55	3.5	3.58
17	Cl	Chlorine	5.57	6.94	3.43	3.82	2.24	2.54
19	K	Potassium	4.76	4.26	3.29	4.04	2.91	3.64
20	Ca	Calcium	5.1	5.62	9.01	10.33	3.8	4.86
26	Fe	Iron	ND	ND	0.69	0.96	2.03	3.62
30	Zn	Zinc	ND	ND	9.85	9.22	15.79	12.97
41	Nb	Niobium	ND	ND	ND	ND	1.54	4.56

ND = Not Detected

The graphical representation of chemical atomic composition of all three additives are illustrated in Figure 2

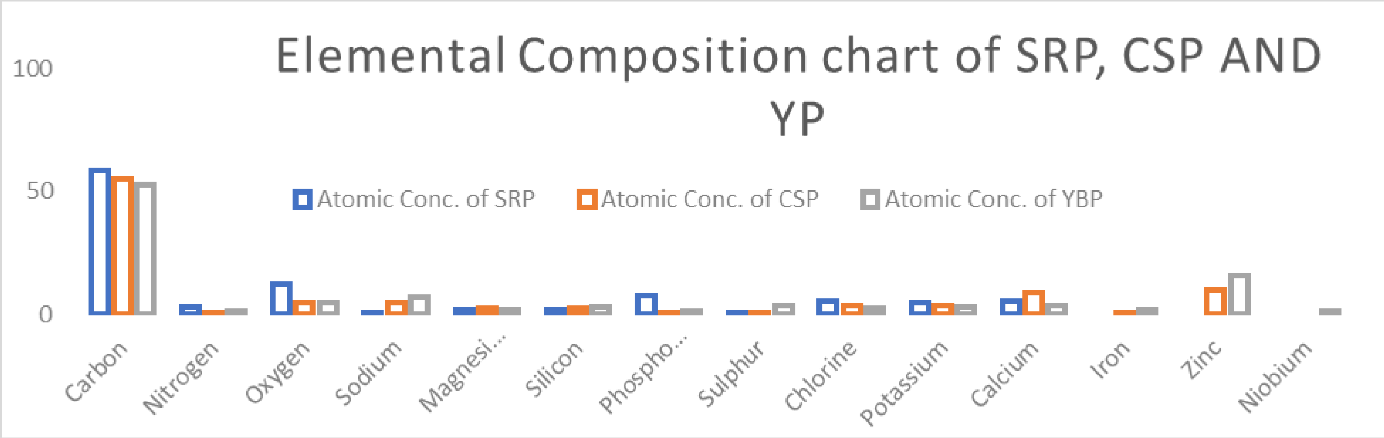

Figure 2 *atomic concentration of chemical elements in SRP, CSP AND YP*

Result Analysis of SEM

The result obtained from the SEM-EDS analysis shows a high carbon concentration in all three food waste powders, and a significant oxygen concentration as well, with the sugarcane rind powder having more of both carbon, oxygen, phosphorus, potassium and calcium, this result is of interest considering that polyanionic cellulose (PAC) and Sodium Carboxymethyl Cellulose (CMC) which are two mostly used fluid loss additives in use both contain sodium, carbon, hydrogen and oxygen. Hydrogen does not have characteristic X-Ray and cannot be detected using SED-EDX. Iron, zinc and niobium were not detected in sugarcane rind powder. Elemental compositions in cowpea skin powder and yam bark powder are similar and this outcome will be further observed in other outcomes. Figure 3 is the morphology image of all CSP, SRP and YP at field of view (FOV): 863 µm, 839 µm, and 832 µm respectively.

Figure 3: SEM Images of additives

Proximate Analysis Result

The results obtained from the proximate analysis carried out on sugarcane rind powder (SRP), cowpea skin powder (CSP) and yam bark powder (YP) are given in Table 3.

Table 3: "Proximate Analysis results on samples

S/N	PARAMETER	UNIT	SRP POWDER	CSP POWDER	YB POWDER
1	Moisture	%	6.89	8.87	9.54
2	Ash content	%	1.32	3.01	5.81
3	Nitrogen	%	0.18	2.62	0.43
4	Protein	%	1.1	16.37	2.66
5	Fixed Carbon	%	23.31	8.78	18.35
6	Volatile matter	%	68.48	79.34	66.3
7	Bulk density	g/l	1.063	1.137	1.129
8	Specific gravity	-	1.087	1.163	1.154
9	pH	-	7.2	7.4	7.3

Result Analysis for Proximate Analysis

The result obtained from the proximate analysis confirms high carbon content in sugarcane rind powder, and significant amount in CSP and YP, Also indicative is the high volatile matter, this are unstable materials that tend to rapidly transition into other forms, examples could be hydrogen which cannot be detected by SEM-EDS. Bulk density (fiber weight), specific gravity, moisture content, ash content and pH of SRP, CSP and YP were closely related.

Performance Evaluation Result and Analysis

The impact of Sugar-cane Rind powder, Cowpea Skin powder and Yam bark powder when used as additives in

managing the filtration properties of water-base mud was investigated at 26.5 °C under atmospheric conditions of low temperature and pressure (LTLP). Table 4 and Figure 4 illustrate the outcome of the performance test on cowpea skin powder.
The result of fluid loss control performance of the three additives are as follows:

Table 4: Fluid loss (ml) performance of cowpea skin powder additive

	Filtrate (Fluid) loss (ml) for Cow-Pea Skin Powder				
Time (mins)	**CSP 0g**	**CSP 5g**	**CSP 10g**	**CPS 15g**	**CPS 20g**
5	7.4	8	7.5	4.6	4.4
10	10	11.5	11	6.8	6.4
15	12	13.8	12.4	7.9	7.4
20	14.5	15.5	14.5	9.0	8.4
25	15.75	17.5	16.5	9.8	9.3
30	16.5	18.8	18	11	10.6

The performance is further illustrated in Figure 4, showing curves that represent the effect of CSP on fluid loss as the weight is increased from 5g to 20g.

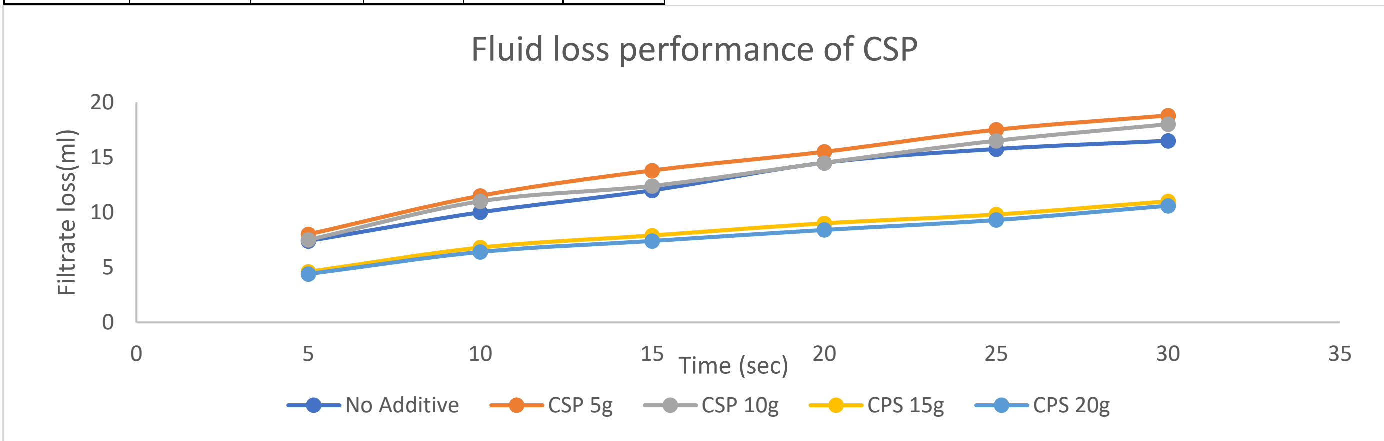

Figure 4: Fluid loss with time using CSP as additive.

The fluid loss control performance result of SRP as additives in drilling fluid is given in Table 5

Table 5: Fluid loss (ml) performance of Sugar-cane Rind Powder additive.

	Filtrate (Fluid) loss (ml) for Sugar-cane Rind Powder				
Time (mins)	**SRP 0g**	**SRP 5g**	**SRP 10g**	**SRP 15g**	**SRP 20g**
5	7.4	7.8	6	4.6	4
10	10	11.3	7.8	6.8	5.9
15	12	13.4	9.3	7.9	7.7
20	14.5	15.4	10.5	9	8.5
25	15.75	17	13	9.8	9.2
30	16.5	18.5	14.2	11	10.4

The SRP performance on fluid loss is shown graphically in Figure 5. The graph relates the curves of reference fluid without additives with SRP of 5g, 10g, 15g and 20g.

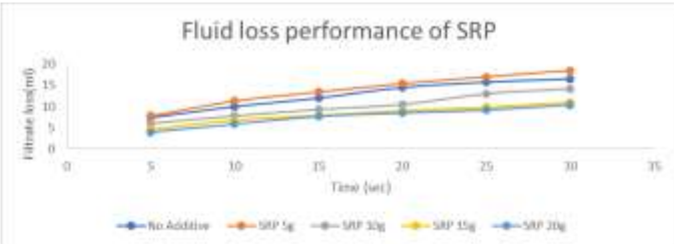

Figure 5: Fluid loss with time using SRP as additive.

The curves in Figure 5 show that SRP of 5g increased fluid loss by 12% but there was decrease in fluid loss with 10g, 15g and 2g in these percentages; 14%, 33% and 37% respectively. SRP gave an indication of a better fluid loss control than CSP by this outcome, showing fluid loss reduction at three different concentrations as opposed to two in CSP. SRP can therefore be used to control fluid loss under a Low temperature and low pressure (LTLP) drilling condition. The fluid loss control performance of YP as additives in drilling fluid is given in Table 6.

Table 6: Fluid loss (ml) performance of yam-bark powder additive

	Filtrate (Fluid) loss (ml) for Yam-bark Powder				
Time (mins)	**YP 0g**	**YP 5g**	**YP 10g**	**YP 15g**	**YP 20g**

5	7.4	6	5.9	5.8	4.3
10	10	10	8.3	7.6	6
15	12	12	10	9.3	7.5
20	14.5	13.5	11.8	9.9	8.5
25	15.75	14.7	13	12.2	9.8
30	16.5	16.25	14.5	13.9	11

The result is given by the curves in Figure 6. for a clearer perspective. YP resulted in a decrease in fluid loss volume with all four batches of 5g, 10g, 15g and 20g when compared with the reference fluid.

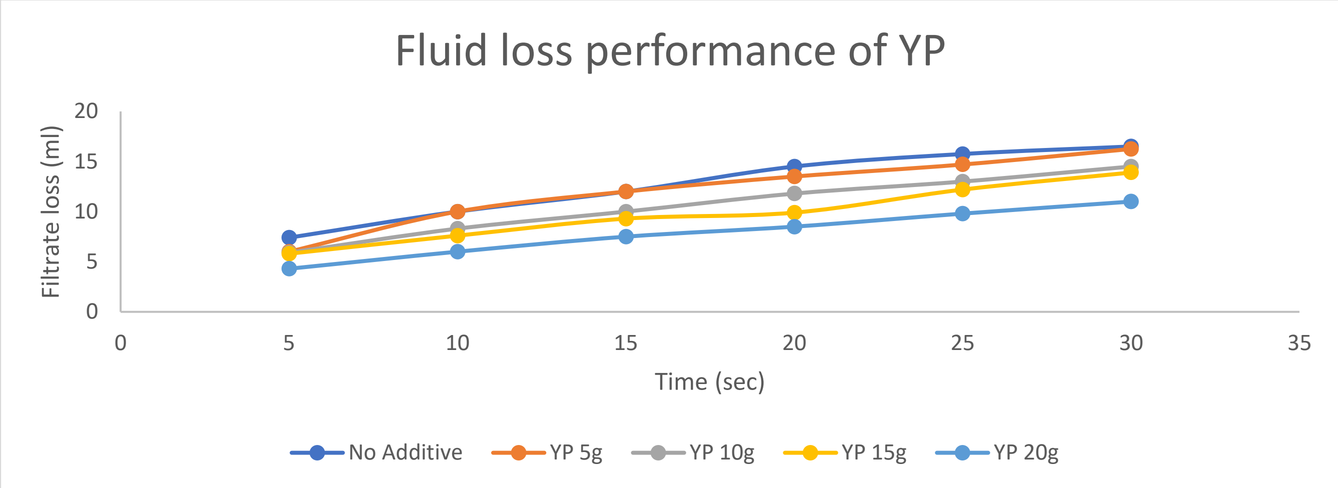

Figure 6: Fluid loss with time using YP as additive

YP at 5g showed decrease in fluid loss, the decrease was 1.5%, 12% with 10grams, 16% fluid loss with 15 grams and 33% decrease with 20grams. From proximate analysis YP has the highest moisture content of the three additives and this might have been responsible for the different outcome. In Figure 7, YP showed a different response on mud cake thickness from CSP and SRP, mud cake thickness decreased as YP weight increased, it would be expected that fluid loss increase but the opposite was observed, This overall result favours YP as a promising fluid loss additive leading to a stabilized hole that keeps the drilling mud in its best property for longer. This result shows that yam bark powder gave the best fluid loss control, by keeping the filtrate in the drilling mud. The concern of evacuating filter cake is reduced as the cake build up is slow.

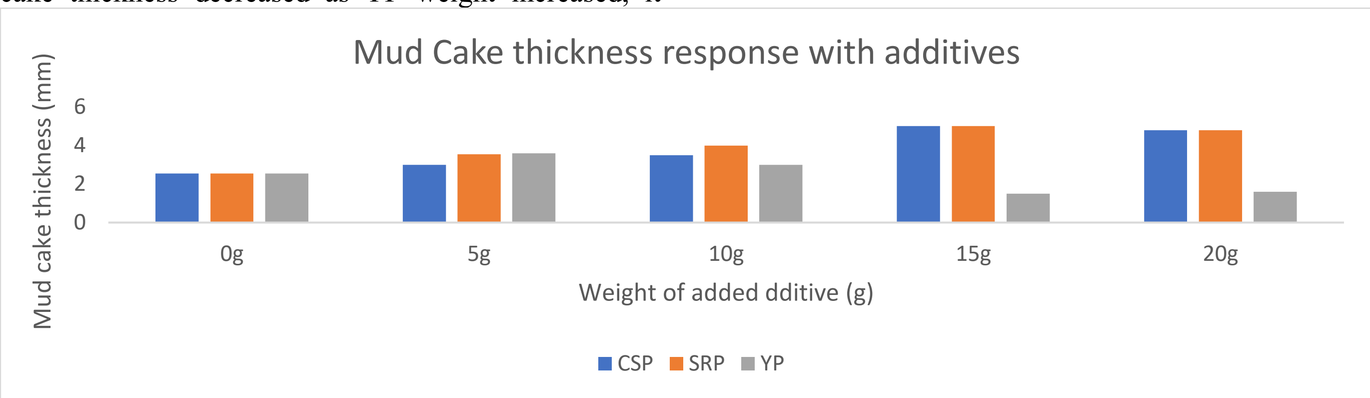

Figure 7: Mud cake thickness response with additive.

Overall Performance

The overall fluid loss performance of all the additive powders as illustrated in Figure 8. shows that cowpea skin powder (CSP) and sugarcane rind powder (SRP) gave an increase in fluid loss at 5g (1%) and both powders decreased filtrate volume at 15g (4%) and 20g (5%). Yam bark reduced filtrate loss all through 5g, 10g, 15g and 20g. SRP has the best fluid loss performance with 20grams (5%) resulting in 37% fluid loss decrease followed by Yam bark powder at 20grams also resulting in in a decrease in fluid loss up to 33%. The least performance was produced by CSP at 10grams (3%) that increased the filtrate loss by 14%.

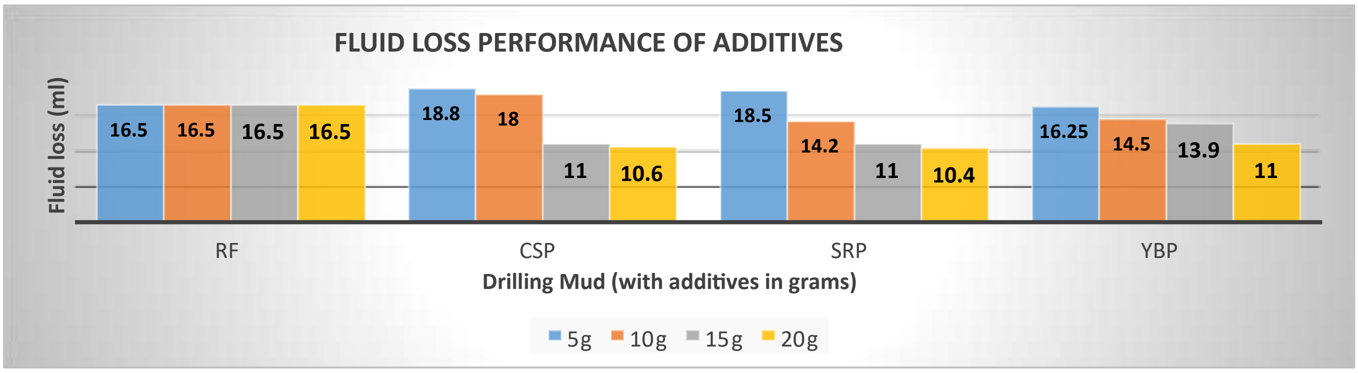

Figure 8: Effect of Additives on fluid loss.

4| CONCLUSION AND RECOMMENDATION

Conclusion

Fluid loss characteristics and filter cake build-up characteristics during drilling are essentially the means of control for filtrate seepage into the permeable zone of the formation. Three biodegradable fiber rich materials were evaluated as fluid loss control additives, they were cowpea (beans) skin powder, sugarcane rind powder and yam bark powder.

Fiber rich materials were collected and prepared for experimentation, the samples were tested using SEM-EDX to obtain their elemental composition, the proximate analysis were carried out and moisture, ash, protein, and Nitrogen content as well as carbon content, pH and bulk density were obtained. The Performance evaluation was also carried out, and the results clearly reported in this research. All objectives were met.
Cowpea skin powder when used as additive in water-based drilling mud resulted in fluid loss increase at 5g and 10g (1% and 3%), by 14% and 9% respectively, while a decrease in fluid loss was realized at 15g and 10.6g, by 33% and 36% respectively. Filter cake thickness increased with CSP grams giving 18%, 38%, 97% and 89%. Cowpea skin has good potential as filtrate loss additives.

Sugarcane rind powder at 5g weight increased fluid loss by 12%, however decrease in fluid loss resulted when 10g, 15g and 2g of SRP was used. These percentage decreases were recorded; 14%, 33% and 37% respectively. Filter cake thickness with all four batches were, 39%, 57%, 97% and 89% respectively with 5grams, 10 grams, 15 grams, and 20 grams.
Yam bark powder resulted in filter cake thickness of reduction as the grams of YP was progressing when compared with reference fluid. The corresponding fluid loss performance was a decrease of 1.5% with 5grams, 12% with 10grams, 16% fluid loss drop with 15 grams and 33% with 20grams.

This research concludes that yam bark powder worked well for fluid loss control. The results from this research showed that SRP has the best fluid loss performance with 20grams (5%). 20grams of SRP as additive resulted in 37% fluid loss decrease followed by Yam bark powder at 20grams which fluid loss performance up to 33%. The least performance was produced by CSP at 5grams (3%) that increased the filtrate loss by 14%.

Recommendation

It is recommended that Economic analysis be conducted to compare the cost effectiveness and feasibility of the twelve formulations in application in the industry. This research was conducted under low temperature and low pressure, laboratory tests should be designed to demonstrate the real temperature and pressure conditions during drilling operation. Other performance analysis of the formulations should be checked. Yam bark powder showed an interesting relationship between fluid loss and filter cake thickness, while the other powders resulted in increased filter cake thickness, the opposite was seen in YP, this outcome should be further researched to enhance the body of knowledge.

References

[1] [1] Gunnar DeBruijn, and Sarah Misser Whitton. (2021) Applied Well Cementing Engineering. 163-251 *Petroleum Science, 13(2), 23-34*

[2] Clark, Peter E. "Drilling Mud Rheology and the API Recommended Measurements." Paper presented at the SPE Production Operations Symposium, Oklahoma City, Oklahoma, April 1995. *doi: https://doi.org/10.2118/29543-MS*

[3] William, J. K. M., Gupta, P., & Sangwai, J. S. (2021, March 9). Interaction of lubricants on the rheological and filtration loss properties of water-based drilling fluids. Petroleum Science and Technology, 39(7–8), 235–248. [https://doi.org/10.1080/10916466.2021.1892757]

[4] Agwu, O.E. and Akpabio, J.U. (2018). Using agro-waste materials as possible filter loss control agents in drilling muds: *a review Journal of Petroleum Science and Engineering*, 163, 185-198.

[5] Al-Hameedi, A. T. T., Alkinani, H. H., Dunn-Norman, S., Alkhamis, M. M., & Feliz, J. D.

(2020, February). Full-set measurements dataset for a water-based drilling fluid utilizing biodegradable environmentally friendly drilling fluid additives generated from waste. Data in Brief, 28, 104945. [https://doi.org/10.1016/j.dib.2019.104945]

[6] Okon, A. N., Udoh, F. D. and Bassey, P. G (2014) "Evaluation of Rice Husk as Fluid Loss Control Additive in Water-Based Drilling Mud" Society of Petroleum Engineers doi:10.2118/172379-MS.

[7] Agwu, O.E. and Akpabio, J.U. (2018). Using agro-waste materials as possible filterate loss control agents in drilling muds: *a review Journal of Petroleum Science and Engineering*, 163, 185-198.

[8] Hossain, M.E. and Wajheeuddin, M. (2016) The use of grass as an environmentally friendly additive in water-based drilling fluids: *Petroleum Science, 13*(2), 292-303.

[9] Iheagwara, O "Comparative Analysis of the Use of Banana Peels and NaOH in Ph Control in Nigerian Clays" *Journal of the Nigerian Association of Mathematical Physics, 2015* Vol. 30, pp.12-58.

[10] Reddy, N., Yang, Y. (2015). Fibers from Sugarcane Bagasse. In: Innovative Biofibers from Renewable Resources. Springer, Berlin, Heidelberg. *https://doi.org/10.1007/978-3-66245136-6_8*

[11] Young B. D. (1993). Drilling fluid. In D. Morton-Thompson and A.M. Woods (Eds.), *Development Geology Reference Manual* (pp.76-82). Tulsa, Oklahoma: The American Association of Petroleum Geologists