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MODIFICATION OF NIGERIAN BENTONITE FOR UTILIZATION IN OIL WELL DRILLING OPERATIONS

[1]Azeez G. O., [2]Dada E. O.*, [1]Muriana M., [1]Lawal I. A. and [2]Arinkoola A. O.

[1]Department of Science Laboratory Technology, The Oke Ogun Polytechnic, Saki (TOPS)

[2]Department of Chemical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

*Corresponding Author: eodada@lautech.edu.ng

ABSTRACT

More than 80 bentonite clay deposit sites had been identified in Nigeria. Yet, almost all clay and additives used for drilling oil well are imported. The reason is partly that in their natural states, they do not swell while polymers in their raw forms remain unstable at high temperatures. This study aimed at evaluating the potentials of chemically modified Nigerian bentonite for application in the oil and gas industry. The Gombe bentonite from Gombe State was beneficiated using $NAHCO_3$ and slurries were made by dispersion in distilled water. In the presence of other local additives, evaluation of the slurries was carried out on the basis of filtration loss and rheology at different temperatures (30, 60 and 85 ^oC) using a Central Composite Design (CCD). The clay sample was characterized for mineral and elemental compositions using X-ray diffractometer (XRD) and X-ray fractometer (XRF) while proximate analysis was carried out on the additives. At the optimum condition, the result shows a significant improvement in mud rheology and fluid loss at various temperatures which are in close agreement with the API recommended standard.

Keyword: Drilling mud, food gum, Ufor, cassava starch, corn starch, optimization, clay.

Introduction

Drilling fluids are circulating fluid used in rotary drilling to perform various functions required in the drilling operation. Some of these include carrying the solids to the surface, providing lubrication to the drill pipe, cooling the bits, suspending the cuttings when circulation is stopped and aiding the cutting process by imparting high energy to the bit. Drilling fluid has changed in the past 5-10 years, some of the challenges to their usage are those related to rheological, safety and economics. Polymers are used as additives in drilling fluids to enhance certain properties for the efficient drilling operation. Polymers are added in muds as a fluid loss control agent, viscosity booster or shale stabilizer.

Filtration control is primarily the main reason for polymers in muds as a supplement additive to bentonite. Because water-based (WBM) is the most common drilling fluid for both offshore and onshore with water the continuous phase and clay, polymer and other chemicals as additives, water-soluble polymers (WSPs) are utilized in drilling fluids. The WSPs are classified into two types; natural polymer and synthetic polymers. Examples of natural polymers include starch, carboxymethyl cellulose (CMC) and Hydroxyethylcellulose (HEC). Examples of synthetic polymers are hydrolyzed polyacrylate and vinyl acetate maleic anhydride copolymers. There are two main drawbacks in using synthetic polymers; (a) reaction with the calcium and (b) being insoluble, which results in severe viscosity and gelation of the mud (Bloys et al., 1994). Natural polymers can absorb water and increase the viscosity of water (i.e., thickening water) due to their molecular size and shape. They rely on chain extension and physical entanglement of solvated chains for viscosity enhancement. They are non-charged and therefore less sensitive to salinity in contrast with the synthetic ones (Annis and Smith, 1974). Long and complicated molecular chains of water-based polymers tie up the water and can build viscosity without solids (Mahto and Sharma, 2004). Water-based polymers are adsorbed on the clay particles and bond them together (Bohm et al., 1990) that accordingly lead to an increase in the yield point (YP) of clay slurries.

Within the food sector, some hemicelluloses have been utilized for a long time due to their nontoxicity, water solubility and ability to form gels. Typical examples are the mannans such as guar gum, locust bean gum, and konjac glucomannan, which are commercial emulsifiers and thickening agents (Teleman et al., 2003). Polysaccharides and gummy exudates are being used effectively in the oil and gas industry today. They are water-soluble and are found application in many oilfield operations including drilling, polymer-augmented water flooding, chemical flooding and profile modification (Sorbie, 1991). Gums include exudate (Arabic, karaya), microbial fermentation (pullulan, xanthan gum, dextran, and gellan gum) and seed gums (guar gum) (Lacroix and Le Tien, 2005). Different natural polymers

such as starch, soy protein isolate, guar gum, xanthan gum, and cellulose derivative have been applied to improve the rheological and filtration performances of WDFs (Dias et al., 2015, Li et al., 2015, Navarrete et al., 2000, Warren et al., 2003 Iscan and Kok, 2007).

Xanthan gum is a rigid polysaccharide that is not readily shear degraded and is not sensitive to an increase in salinity or divalent ion concentration (Nasr-El-Din and Noy, 1992). However, xanthan is characterized by higher cost, high susceptibility to biodegradation and exhibition of decreasing viscosity as the temperature is increased. Another common biopolymer for drilling fluid design is Scleroglucan also known as schizophyllan with high viscofying properties at low concentrations. In comparison to other biopolymers, Scleroglucan is more stable thermally, more tolerance to divalent and trivalent cations such as Ca^{2+}, Mg^{2+} and Fe^{3+} and characterized by excellent carrying capacity (Biovis, 2003). But the presence of additives which chemically react in the aqueous medium and geological formations can influence the rheological behaviour, especially at high temperature.

Welan gum (WLG) has been reported to have exhibited good viscosity at elevated temperatures and in the presence of sodium chloride (Chen, 2007). Welan Gum is produced by fermentation of sugar by bacteria of the genus Alcaligenes. The molecule consists of repeating tetrasaccharide units with single branches of Lmannose or L-rhamnose (Rakitsky and Richey., 1992). WLG is a widely used thickener in the food industry. WLG was also patented as a cement additive (Allen et al., 1991), as well as a water shutoff chemical (Hoskin et al., 1991). However, WLG gum is not effective in reducing fluid filtrate loss (Gao, 2015).

Many indigenous polymers have become very popular for their use in drilling fluid due to their ability to modify rheological properties of clay suspension and their environmental friendliness (Dolz et al., 2007). The common challenges experienced are an excessive fluid loss, low gel strength and the need to formulate a fluid with desirable rheological properties to withstand increasing temperature and pressure conditions (Olatunde et al., 2012). A number of synthetic polymers have been developed for high-temperature water-based drilling fluids. Although some of them exhibit thermal stability at high temperatures, limitations still persist. The drawback of these polymers is that they are cost-ineffective and generally salt- and pH-sensitive, which limits their utility. It is worthy to note that importation of these chemicals has not allowed the indigenous companies involved in oil and gas especially in the developing nations to compete favorably with their foreign counterparts.

Considering economy, sustainability, and environmental effect, utilization of natural polymers as modifiers for rheology and fluid loss in WDFs is highly preferred. To this end, efforts have been made using locally derived materials in the design of muds for drilling (Olatunde et al., 2012, Igwilo and Zakka, 2014 and Salawudeen et al., 2016). The limitations that highlighted some of their findings could be summarized thus: (1) excessive fluid loss, (2) low gel strength and (3) thermal instability and (4) sensitivity to sodium, potassium and calcium salts. The objective of this present research was to experimentally examine three lesser-known natural polymers (Cissus populnea, Detarium micocarpum and B. Eurycoma) based on rheology, filtration control, and thermal stability.

Methodology

Material, chemical and Equipment

The materials and chemicals used in this study include: Ufor, Achi, Clay, Fiber (coconut fiber and corn starch fiber), food gum, distilled water, $NAHCO_3$, H_20 and NAOH. The various equipment used include weighing balance, glass rod, electric sieve shaker, Soxhlet extractor, foil paper, mortar, pestle, mud balance, stop watch, spatula, petri dish, glass wares, electric grinder, tissue paper, tray, and bowl.

Sample collection, purification and processing

Clay samples were collected from a mining site (6.97514^o N and longitude 3.74545^o E) between Filia and Cham, Dongaje, Gombe state, Nigeria. Sample collection was achieved with the aid of a hand auger which was used in scooping the clay materials from dug pits. The raw clay samples (1 kg) were purified to remove all impurities and ground to a particle size of less than 60 µm using an electric grinder. The powder was wet sieved in distilled water to separate the clay from the sand. The colloidal slurry was allowed to sediment under gravity and decanted. Wet sieved clay was then air-dried to reduce the moisture content and thereafter oven-dried at 70 ºC in an electric oven until a constant weight was achieved.
The polymers, *C. populnea gum* and *D. micocarpum* seed, were ground using Hamilton grinder to powder. They were sundried for 24 hours and re-ground to pass through 120 US mesh sieve.

Clay modification

Clay modification was carried out using $NaHCO_3$ at concentrations ranging from 1.1 to 5.5 M

(Salawudeen et al., 2014; Akinwande et al., 2014). A 100 g of processed clay was dispersed in 100 ml of distilled water to form a slurry. The mixture was pre-heated to 60 ºC for 5 minutes. $NaHCO_3$ (100 ml) of a known concentration was added to the pre-heated slurry and the mixture heated to 90 ºC. The heating period ranged between 60 and 80 mins under continuous stirring. $NaHCO_3$ concentration and heating period were randomized in a full factorial experiment. The slurry formed from each experiment was sundried to reduce the moisture content and later oven-dried in an electric oven (Surgifield Laboratory oven, SM9053A) at 80 ºC until a constant weight was achieved.

Characterization of samples

X-ray diffraction (XRD) was used to determine the mineralogical composition of the raw and modified clay samples. The XRD patterns were recorded in the range of 5–70° 2θ at a scanning speed of 1.2 °2θ.min−1. The elemental composition of the clay samples was determined using the X-ray fluorescence spectroscopy (XRF). The polymers, *C. populnea gum* and *D. micocarpum* seed, were characterized qualitatively by proximate analysis.

Preparation of base fluid

The clay sample (17.5 gram) was dispersed in 350 ml distilled water to produce laboratory barrels of fluid. The mixture was mixed vigorously for 10 minutes using a high speed mixer to produce a homogeneous system. The mixture was hydrated for 24 hours at ambient condition before tested for pH, rheological properties, water loss and sand content according to Okorie, (2006). The base fluid was formulated by adding 2 g of *B. eurycoma*, 1.25 g of corn starch and 0.25 g cocoanut fiber (Salawudeen *et al*., 2016).

Mud beneficiation

The API Fluid loss (12 ml/30 Mins/100 psi), plastic viscosity (5 cp), yield point (2 lbf/100ft^2), 10 Sec/10 mins gel strength (1/1 gel), pH (7.35), mud weight (8.6 lbm/gal) and cake thickness (0.2 inch) recorded were below API standard values. In order to improve on these properties, *D. micocarpum* and *C. populnea* were added in the range of (2 – 5 g) and (1.5 – 4 g) respectively. These polymers were combined according to Central Composite Design (CCD) and evaluated for rheology and filtration properties at 85, 150 and 185 ^{o}F.

Rheology measurements

All rheological data were collected in triplicates using OFITE 8-speed viscometer. The viscometer measures the torque under 8 different rotational speeds, ranging from 600 to 3 rpm. The readings were translated into mud plastic viscosity, mud yield point, and mud apparent viscosity using equations 1 – 3. Mud filtrate was measured with OFITE Model 14030 filter press. Mud passes through a filter paper under 100 psi of pressure, and the filtrate volume after 7.5 min of filtration is recorded. The pressure is provided by a cartridge containing pressurized carbon dioxide. Mud was prepared with a high-speed mixer. The mud viscometer, filter press, and mud mixer are all industry-standard devices.

The Plastic viscosity (PV) was calculated by the following formula:

$$PV = \theta_{600} - \theta_{300}\ (in\ cp) \quad (1)$$

The Apparent Viscosity (AV) was calculated by

$$AV = \frac{\theta_{600}}{2}\ (In\ cp) \quad (2)$$

The yield point (Yp) was estimated by

$$Yp = \theta_{300} - PV\ \left(in\frac{lb}{100ft^2}\right) \quad (3)$$

θ_{600} is the dial reading at 600 rpm and θ_{300} is the reading at 300 rpm.

Drilling mud experiments

Experimental design

Design expert software was used for the experimental design and the evaluation of mud rheology of the filtrate was performed using central composite design. The choice of which is due to study objectives which among others consists of optimization study. Table 1 shows the parameter settings and PV AV, YP, Gel strength, and Filtrate loss are the respective responses.

	Actual		Coded	
	Low	High	Low	High

D. micocarpum (gram)	1.5	4	-1	+1
C. populnea (gram)	2	5	-1	+1

Table 1 Design parameters and levels

3.0

Results and discussion

The microscopic structure of the raw clay was analyzed using X-ray diffraction (XRD). The diffraction of X rays represented in Figure 1 showed that the clay is predominantly composed of kaolinite, illite, and quartz. Kaolinite, $Al_2Si_2O_5(OH)_4$, is a layered aluminosilicate with a dioctahedral 1:1 layer structure consisting of tetrahedral silicate sheets and octahedral aluminum hydroxide sheets (Bailey, 1980).

The chemical composition of the samples after beneficiation using X-ray fluorescence spectroscopy (XRF) shows that the major oxides are oxides of silica and alumina. Comparing the result with the result reported by Bailey, (1980), the silica content (68.9%) is comparable to that of Wyoming bentonite (68.0%). However, the Fe_2O_3 and TiO_2 (8.5 and 7.67%) content were higher than the reported Wyoming bentonite (3.94 and 0.16%, respectively).

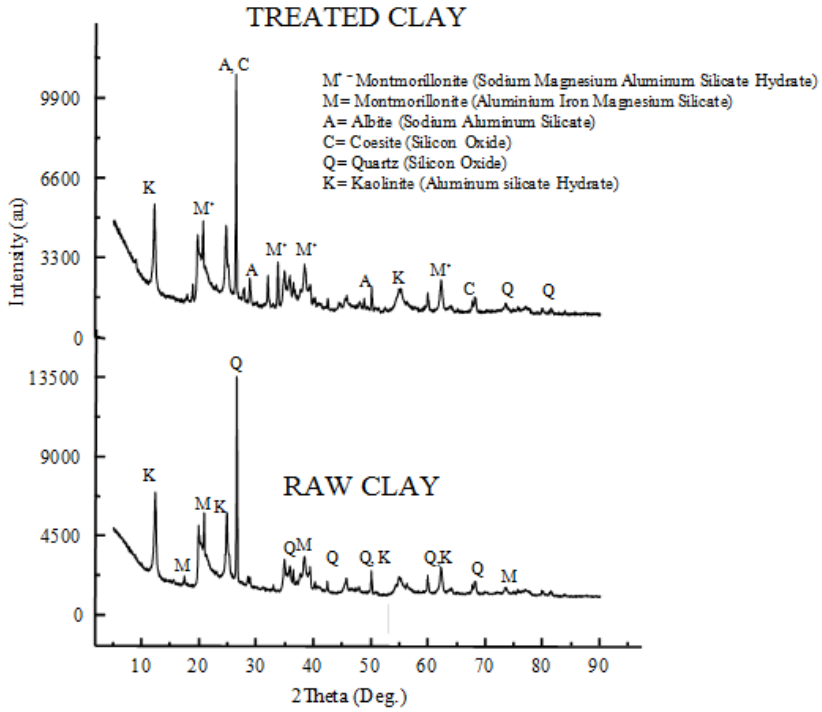


Figure 1: Diffraction of X-rays: microscopic structure of the raw clay

Table 2: XRF Result for the analysis of chemical composition of the raw samples of Nigeria Bentonite

		Gombe Clay	
Oxides	Element	Raw	Treated
SiO_2	Si	68.9	67.5
Al_2O_3	Al	11	10
Fe_2O_3	Fe	8.5	8.48
MnO	Mn	ND	ND
MgO	Mg	ND	ND

CaO	Ca	ND	ND
Na_2O	Na	0.08	3.12
K_2O	K	1.4	ND
TiO_2	Ti	7.67	7.87
P_2O_5	P	ND	ND
LOI	LOI	2.15	3

*Note: ND signify not detected

The phytochemical constituents of the extracted liquor of *C. populnea* made it applicable in ethnomedicine for the treatment of male infertility. The result of the proximate analysis of *C. populnea* is shown in Table 3. The *C. populnea* fibers contain more than 60 % cellulose and about 15% Hemicelluloses by weight. Table 4 shows the proximate composition of *D. micocarpum* fruit. The seed polysaccharide was described as a stabilizer and gelling agent in some processed fruit products (Onweluzo et al., 1994).

Table 3 Proximate composition of *C. populnea* fibers

Composition	Percentage (w/w %)
Moisture	3.94 ± 0.23
Dry matter	96.06 ± 0.2
Ash	1.59 ± 0.14
Wax	2.94 ± 0.31
Water soluble	2.33 ± 0.27
Pectins	1.14 ± 0.03
Lignins	11.52 ± 0.27
Hemicelluloses	14.74 ± 0.42
Celluloses	61.80 ± 0.45

Table 4 Proximate composition of *D.micocarpum*

Composition	Mesocarp (%)	Seed (%)
Moisture	15.0 ± 0.01	5.0 ± 0.01
Crude fat	10.5 ± 0.01	15.5 ± 0.02
Crude Ash	3.3 ± 0.01	3.5 ± 0.02
Crude fiber	10.2 ± 0.02	11.2 ± 0.01
Crude protein	6.0 ± 0.03	13.5 ± 0.02
Total Carbonhydrate	54.0 ± 0.01	50.5 ± 0.03

** Results are mean ± SD of duplicate determinations*

Rheological properties

Table 6 through 8 shows the result of the estimated rheological properties (plastic Viscosity (PV), Apparent Viscosity (AP) and Yield Point (YP) for temperatures of 30, 60 and 85 ^{o}C. It is clearly shown from Table 6 that the rheological properties increases as temperature increased from 30 to 60 ^{o}C. Beyond 60 ^{o}C, the PV, AV and the yield point decrease gradually showing that the biomaterials used in the preparation of the mud are highly sensitive to temperature.

Table 6: Plastic viscosity, apparent viscosity and yield point at 30 °C

RUN	A:Fgum	B:Ufor	600 RPM	300 RPM	PV CP	AV CP	Yp lbf/100ft3
1	4	5	35	21	14	17.5	7
2	2.75	5	51	37	14	25.5	23
3	2.75	3.5	30	16	14	15	2
4	2.75	2	21	11	10	10.5	1
5	1.5	3.5	32	28	4	16	24
6	1.5	2	15	9	6	7.5	3
7	4	3.5	29	18	11	14.5	7
8	1.5	5	64	45	19	32	26
9	4	2	20	15	5	10	10

Table 7: Plastic viscosity, apparent viscosity and yield point at 60 °C

RUN	A:Fgum	B:Ufor	600 RPM	300 RPM	PV CP	AV CP	Yp lbf/100ft3
1	4	5	81	55	26	40.5	29
2	2.75	5	75	50	25	37.5	25
3	2.75	3.5	26	15	11	13	4
4	2.75	2	13	7	6	6.5	1
5	1.5	3.5	35	20	15	17.5	5
6	1.5	2	14	9	5	7	4
7	4	3.5	49	32	17	24.5	15
8	1.5	5	77	53	24	38.5	29
9	4	2	27	18	9	13.5	9

Table 8: Plastic viscosity, apparent viscosity and yield point at 85 °C

RUN	A:Fgum	B:Ufor	600 RPM	300 RPM	PV CP	AV CP	Yp lbf/100ft3
1	4	5	67	46	21	33.5	25
2	2.75	5	65	41	24	32.5	17
3	2.75	3.5	16	9	7	8	2
4	2.75	2	11	7	4	5.5	3
5	1.5	3.5	26	16	10	13	6
6	1.5	2	12	6	6	6	0

7	4	3.5	45	21	24	22.5	-3
8	1.5	5	54	35	19	27	16
9	4	2	19	11	8	9.5	3

Data analysis

To study the factor effects, main or interaction (D. micocarpum and C. populnea) in the proposed mud formulation, a response surface methodology involving analysis of variance (ANOVA) was performed and model equations that best described the experiment were developed for optimization study. For practical consideration, the analysis at 85 ^{o}C is presented in Table 9.

3.3.1 Diagnostic checking of the fitted models

All main effects, linear, quadratic and interaction were calculated for each model at 95 percent confidence interval (α = 0.05). The correlation coefficient obtained for PV, Yp, AFL and Gel model is 0.941, 0.966, 0.988 and 0.982, respectively. These values are quite high for response surfaces and indicated that the fitted quadratic models accounted for more than 90% of the variance in the experimental data, which were found to be highly significant. Based on F-statistics, the only regression coefficients not significant at 95% is C. populnea for PV and Yp however highly significant for API filtrate and Gel.

Table 9 ANOVA of various responses

Parameter	PV (cp)		Yp (lb/100ft^2)		API Filtrate (ml)		10 min Gel	
	F-value	P>F	F-value	P>F	F- value	P>F	F- value	P>F
Model	36.14	0.0002	64.7	< 0.0001	1819.73	< 0.0001	123.60	< 0.0001
C.pop	2.36	0.1754[a]	0.006	0.9408[a]	2890.00	< 0.0001	19.20	0.0047
D.mic	105.28	< 0.0001	207.09	< 0.0001	240.00	< 0.0001	235.20	< 0.0001
C.pop^2	42.54	0.0006	18.37	0.0052	1163.64	< 0.0001	240.00	< 0.0001
D.mic^2	11.81	0.0139	78.40	0.0001	2645.00	< 0.0001	58.80	0.0003
C.pop*D.mic	18.73	0.0049	19.69	0.0044	2160.00	< 0.0001	64.80	0.0002
Multiple. R^2	**0.941**		**0.966**		**0.998**		**0.982**	

**a = not significant at α = 0.005 (95 confidence level)*
**P>F values less than 0.05 indicate significant model and model terms*

The Plastic viscosity (PV), Yield point (Yp), API filtrate loss (AFL) and 10 mins Gel (Gel) at the test condition are best approximated by equation 4 – 7.

$$PV = 56.03075 - 29.56347 * CP - 15.84901 * DM + 4.47123 * C.Pop^2 + 2.21613 * D.mic^2 + 2.84201 * C.pop * D.mic \quad (4)$$

$$Yp = 77.9065 - 19.74612 * CP - 31.75769 * DM + 1.81918 * C.Pop^2 + 4.15221 * D.mic^2 + 2.54977 * C.pop * D.mic \quad (5)$$

$$FL = 2.35156 + 12.29867 * CP - 5.12889 * DM - 1.664 * C.Pop^2 + 1.02222 * D.mic^2 - 0.64 * C.pop * D.mic \quad (6)$$

$$Gel = 6.155 - 3.1733 * CP - 0.8444 * DM + 0.88 * C.Pop^2 + 0.3889 * D.mic^2 - 0.4 * C.pop * D.mic \quad (7)$$

These equations are applicable within the following range of parameters: D. micocarpum (2 – 5 g) and C. populnea (1.5 – 4 g).

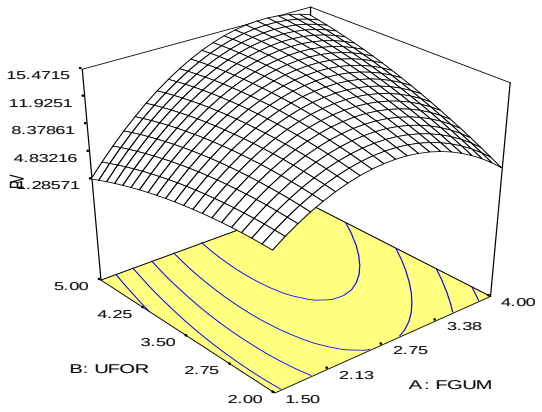
Result and discussion

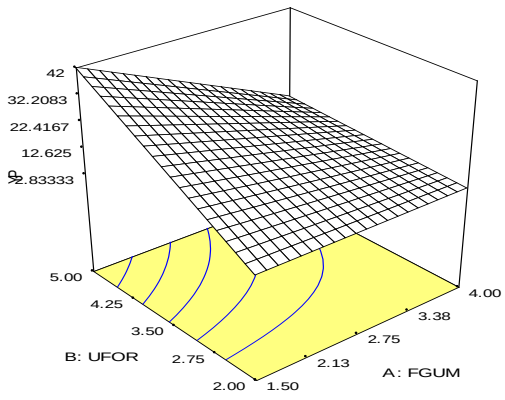
Effect of interaction factor at temperature of 30 ˚C

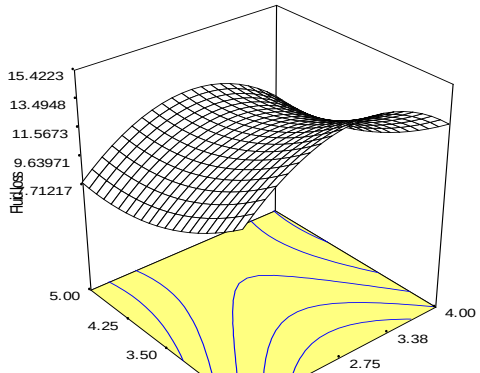
Figure 2 shows the 3D-plot for the interaction of Ufor and Food gum on PV, AV, YP, gel strength, fluid loss, and cake thickness. It is evident that for PV, both factors interacted at a different amount. For the low value of ufor (2g) as the amount of food gum is increased, the PV increased correspondingly. for the low value of food gum (1.5) increase in ufor decrease the plastic viscosity gradually. However, at high amount of Ufor (5g), increase in the amount of food gum increased the amount of PV greatly, until a gradual decrease and at high amount of food gum (4g) increase in Ufor also increase the PV rapidly this indicate that Ufor and food gum at high value has a positive effect on the PV.

Also, for AV, at a low amount of Ufor (2g) increase in food gum increase the AV, but slowly, at a low value of food gum (1.5g) increase in Ufor increase the AV sharply. However, at high value of Ufor (5g) increase in food gum decrease the AV gradually and at high value of food gum (4g) increase in Ufor increase the food gum but slowly. This indicates that an optimum amount (minimum) of food gum is required to have positive effects on the AV.

For yield point, at a low amount of Ufor (2g) increase in the amount of food gum has no impact on the YP, at a low value of food gum (1.5g) increase in the amount of ufor increase the YP very greatly. However, at a high value of ufor (5g) increase in food gum decrease the YP rapidly. At a high value of food gum (4g) increase in food gum increase the YP but slowly, this indicates that food gum at low amount has a positive impact on the YP.







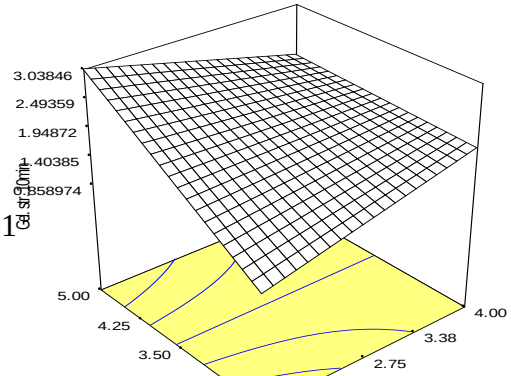


Figure 2: 3D plots of interaction of rheological and filtration properties at temperature of 30 °C

Effects of interaction of factor at a temperature of 85 ºC

Figure 3 shows the 3D-plot for the interaction of Ufor and Food gum on PV, AV, YP, gel strength, fluid loss and cake thickness it is evident that for PV, both factors interacted at a different amount. At the low amount of Ufor(2g) as the amount of food gum is increased, PV increases but slowly, at a low value of food gum(1.5g) as the amount of ufor is increased, the PV increased correspondingly. However, at high value of Ufor (5g) the PV increases slowly, at high value of food gum(4g) as the amount of Ufor is increased PV also increases correspondingly. This indicates that ufor at high temperature has a more positive effect on the PV.

Figure 3 also shows the 3D-plot for the interaction of Ufor and Food gum YP. It is evident that for YP, both factors interacted at a different amount. For the low value of ufor (2g) as the amount of food gum is increased, the YP increased rapidly, for a low value of food gum (1.5) as the amount of ufor increase the YP decreased to a point (3.50g) before increasing sharply. However, at high amount of Ufor (5g), an increase in the amount of food gum increased the amount of YP greatly and at a high amount of food gum (4g) increase in Ufor also increase the YP at first before rapid increase at 2.75g.

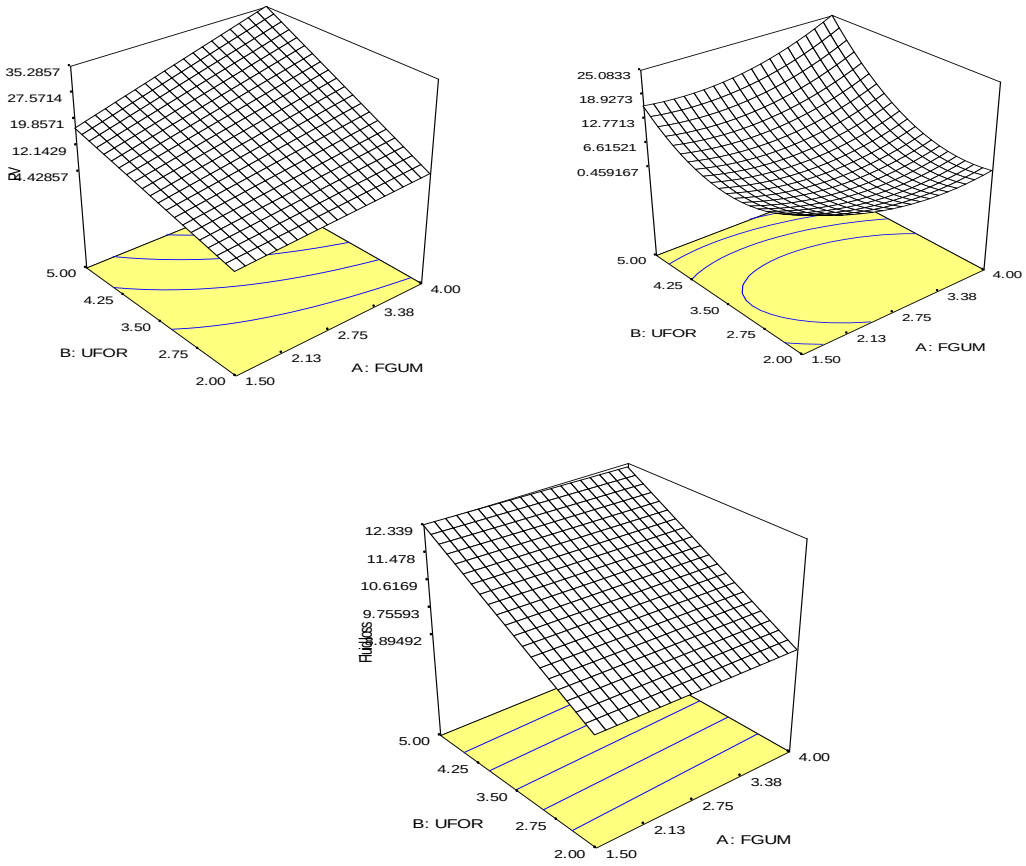


Figure 3: 3D plots of interaction of rheological and filtration properties at temperature of 85°

Optimization

The numerical optimization was done with Design-Expert Software (6.0.8). The two selected factors (Ufor and Food gum) were all set to their range while the PV, AV, YP, gel strength and cake thickness were all set to a maximum while the fluid loss was set to a minimum. The optimum value generated for the factors (food gum, Ufo, PV, AV, YP, gel str. at 10 minutes, fluid loss and cake thickness) at 30ºC is 2.16,

5, 9.2463, 28.3977, 32.7942, 2.77418, 10.5596 and 0.631282.

Also, at a temperature of 60 ºC, the optimum value generated for the factors (food gum, Ufo, PV, AV, YP, gel str. at 10 minutes, fluid loss and cake thickness) are 1.5, 5, 24.833, 38.9027, 28.1388, 4.19444, 10.4667 and 0.8333 respectively.

At 85 ºC, the optimum value generated for the factors (food gum, Ufo, PV, AV, YP, gel str. at 10 minutes, fluid loss and cake thickness are 1.5, 4.80, 16.4965, 25.4016, 13.8415, 3.64808, 12.1126, 1.03339.

Figures 8 through 10 show the optimization result obtained at 30, 60, and 85 ^{o}C respectively.

Validation of optimum condition

To ascertain the accuracy of the optima conditions obtained from the numerical simulation, the optimum conditions (Ufor and food gum) were tested in the laboratory and PV, AV, Yp, Fl, Gel at 10 mins and Cake thickness were evaluated at 85 oC. The result obtained is presented in Table 12.

Table 12: Optimum values of the selected factors

	Optimum factors	**Temp.**	**PV**	**AV**	**YP**	**FL**	**Gel. Str.**	**cake thickness**
Base Mud	Ufor, food gum	85 ^{o}C	16	23.5	13	4.1	11.3	1.2

Conclusion

The performance of beneficiated Gombe clay with $NAHCO_3$ exhibit a better and an improved rheological property as a result of its viscosity enhancement capacity at different temperature but the best result is obtained at a temperature of 60 ^oC. The local additives such as the processed Ufor and food gum improved the filtration loss of the drilling mud significantly. The optimum value of the rheological property and filtration property is obtained by using a low amount of food gum(1.5g) and the high value of Ufor (5g) optimized values are obtained using the tool of numerical optimization in DOE.

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