Influence of Selected Natural Polymer Additives on the Fluid Loss Properties of Bentonite Mud

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Abstract:
Fluid loss refers to the volume of the filtrate lost to the permeable material due to the process of filtration. Fluid-loss prevention is a crucial performance attribute of drilling muds. Excessive fluid loss leads to several challenges from formation damage due to the invasion of the mud filtrate to formation and instability of the borehole due to an irreversible change in the drilling fluid properties. Thus, in order to prevent fluid loss into formation, an environmentally safe, non-toxic, high biodegradability and low cost of polymer additives in drilling mud were prepared as fluid loss control agent. Hence, the purpose of this study is to investigate the potential of utilizing four natural hydrocolloid-based products: corn starch, cassava starch, purple potato starch and yellow potato starch, and one cellulose-based product: saw dust by addition percentages (2%, 4%, 6%, 8% and 10%) as fluid loss control additive individually in water-based drilling fluid to establish their filtration capabilities. This study was carried out in order to evaluate the ability of the selected polymer in controlling and reducing fluid loss in drilling mud as well as to evaluate their effect on physiochemical properties (PH and Density). API standard were followed throughout the experimental study and the result from this investigation showed that, increasing the concentration of polymers enhances the fluid loss of the mud at ambient condition and all polymers selected reduced filtration loss. It was observed to have thermal stability up to 100°C.

Keywords: Additives, bentonite mud, filtration, fluid loss

1. Introduction
Fluid loss can be defined as the loss of mud filtrate into a porous permeable formation due to high hydrostatic pressure compared to the formation pressure. This phenomenon may cause some major problems to the work over operation such as information damage, stuck pipe, and poor job (Ghazali et al., 2015). The selection of the efficient drilling fluid is based, basically, on the features of the filter cake formed near wellbore region. Minimizing filtrate loss into the formation by forming a thin filter cake with low porosity and permeability is very critical in order to manage the formation damage problems (Bikoor and Fattah, 2013). In drilling operation, filtration control is the addition of material to drilling mud to reduce filtration rate and improve mud cake characteristics (Bourgoune et al., 2003). The two mechanisms responsible or the filter cake build-up process during the drilling process are static and dynamic filtration mechanisms (Bageri et al., 2013). The statics filtration occurs during drilling fluid non-circulation. According to the Agwu and Akpabio (2019), a thin filter cake has a low permeability which is an attractive property since it has a lot to do with the usability and functionality of the drilled wellbore, while a thick filter cake will cause lots of problem which include: differential pipe sticking, loss circulation, casing installation, etc.

To overcome the aforementioned technical challenges, the application of synthetic additive in particular, synthetic polymers, have attracted attention (Jain, 2017; Chu and Lin,2019). Academics and drilling practitioners have been alternatively focusing on synthetic polymer as a promising fluid-loss reducer of drilling muds (Sepheri,2018; Chu and Lin,2019; Anderson,1974). The filtration control additive for water-based drilling fluid can be used to prevent leak-off of water from the drilling fluid to the formation. Organic polymers constitute by far the huge number of filtration-control additives. The use of locally produced material as a substitute for imported drilling fluid additive have gained much attention over the years due to the high cost of the imported mud additives.

In recent times, there has been a shift in the use of commercial polymers to locally sourced materials as fluid loss control additives in water-based drilling fluids (Tugwell, 2018). Considering the economic, sustainable, and environmental...
effects, the evaluation of natural polymers has gained considerable attention. Some efforts, using wholly or partially substituted local materials have been reported in the design of muds for drilling (Dolzet et al., 2007; Gao, 2015, Igwillo and Zakka, 2014). In this direction, Agwu and Akpabio (2018) holistically looked at some of the works done in the use of local materials as fluid loss control additives in drilling fluid and they mentioned that most studies were on the water-based drilling fluids using sawdust, walnut shells, Arabic gum, starch, rice husk, among others. Also, they pointed out that most of the researchers graduated the concentration of the material they used; most probably to know the optimal content of the material that would reduce filtration loss in drilling fluid. A look at these locally sourced materials used so far as fluid loss control additives in drilling fluids as presented in Table 1 indicated that they are either cellulose (e.g., Sawdust, rice husk, groundnut husk, corn products) or hydrocolloid (starches). For the hydrocolloid-based products, they are very good in this work. Hence, the purpose of this study is to investigate the potential of utilizing four natural hydrocolloid-based products: corn starch, cassava starch, purple potato starch and yellow potato starch, and one cellulose-based product: sawdust in combating fluid loss.

| Researchers                  | Mud Type | Source(s)         | Temperature and Pressure | API Filter Loss(mL/30mins) |
|------------------------------|----------|-------------------|-------------------------|---------------------------|
| Bazanova et al. (2001)       | WBM      | Carboxymethylated | 12-16                   |                           |
| Iscan and Kok (2007)         | WBM      | Walnut Shells     | 11-14.5                 |                           |
| Hamida et al. (2010)         | Saline Mud | Waxy Hull Less Barley | 3-8.8                   |                           |
| Olatunde et al. (2012)       | WBM      | Gum Arabic        | 150°F, 100psi          |                           |
| Dagde and Nmegbu (2014)      | WBM      | Groundnut Husk    | 7.6 and 6.5             |                           |
| Okon et al. (2014)           | WBM      | Rice Husk         | 60°C-100°C              | 16-42.5                   |
| Nmegbu and Bari-Agara (2014) | WBM      | Corn cob Cellulose| 60°C-100°C              | 5.8 and 5.8               |
| Hossain and Wajheeddin (2016)| WBM      | Grass             | 11-14.6                 |                           |
| Samavati and Abdulah (2016)  | WBM      | UbiKayu Starch    | 250-300°F               | 0.4-250                   |
| Chinwuba et al. (2016)       | WBM      | Pleurotus tuber regium | Room temp.-180°F | 8-10.8                   |
| Saengde and Terakulsaitit (2017)| WBM  | Sugarcane bgasse ash | 25-80°C                 | 18-22.5                   |

Table 1: Some Studies Results on Filtration Loss of Some Locally Sourced Materials

2. Materials and Methods

2.1 Sample Preparation and Sampling Techniques

In this research work, the additives employed with their functions in the formulation of the water-based drilling fluids were Barite as weighting material, bentonite as viscosifier and filtration control material, starch and saw dust as fluid loss agent, Distilled water as continuous base, Soda Ash (Na$_2$CO$_3$) as hardness control material and caustic soda as pH control material (NaOH). The concept used for the design, standard mud preparation composition as well the preparation of cassava potato and corn flour starches along with sawdust particles have been thoroughly described in a recent paper (Rufai and Oduola, 2021).

2.1.1 Drilling Mud Formulation

The bentonite used in this experiment was obtained from MI Swaco at F.O.T, Onne oil and Gas Free Zone Eleme Local Government Area, Rivers State. Spatula was used to transfer 22.5g of the bentonite on an electronic balance while 500ml measuring cylinder was used to measure 350ml of distill water according to API requirement for preparing drilling fluid. The measured water (350ml) was transferred into the steel cup of the multi – mixer and weighed bentonite was added. The mixture of the bentonite and water was vigorously agitated with the aid of multi mixer powered to rotate for about 20minutes, until homogenous mixture is obtained. The mixture was then allowed to stand for 24 hours for the proper hydration and swelling of bentonite. This represents mud without treatment. The drilling mud samples were subsequently treated with chemical additives in different proportion and thereafter formulated in the absence and presence of difference concentration (2%, 4%, 6%, 8%, and 10%) of saw dust, cassava starch, potato starch and corn starch. As the additives have been properly measured into the mixer steel cup containing the mud sample, it was left for 60minutes under stirring condition to react well with the mud for complete uniformity. The mud balance was used to measure the density of the mud. The LPLT filter press was used to measure the fluid loss from the drilling mud and pH meter was used to measure the pH of the formulated drilling mud.

2.2 Methods

The strategy of the work employed during the whole experiment is shown in the Figure 1.
2.2.2. Mud Weight Determination

A mud balance is an equipment used in the determination of mud density. It provides a simple method for the accurate determination of mud density. An outstanding advantage of this balance is the fact that temperature does not materially affect the accuracy of readings. The durable construction of the mud balance makes it ideal for both laboratory and field use (Ogiriki and Ndienye, 2017).

This mud balance consists of a constant-volume sample cup, with lid, connected to a balance arm. The balance arm is inscribed with four graduated scales. On the front of the arm are scales for measuring density in pounds per gallon and specific gravity. On the back of the arm are scales for measuring pounds per cubic feet and pounds per square inch per 1000 feet of depth. A rider is moved along the balance arm to indicate the scale readings. There is a knife edge attached to the arm near the balance cup, and a bubble level built into this knife edge for leveling the arm. The knife edge fits into the fulcrum that is mounted in the base stand.

To ensure that measurements are accurate, the inside of the balance arm cup should be clean and dry before it is filled with the drilling fluid sample.

2.2.3. Drilling Fluid Weight Testing Procedure

The instrument base was set up so that it was approximately leveled. The freshly prepared mud was poured into a clean, dried mud balance cup. The lid was placed on the cup and set it firmly but slowly with twisting motion. It was ensured some mud spilled on the outside of the cup through the vent. Then the reading of the mud balance scale is taken on the outside of the cup through the vent. The degree of acidity or alkalinity of mud is indicated by the hydrogen ion concentration, which is commonly expressed in terms of pH. A neutral mud has a pH of 7.0. An alkalinity mud has pH readings ranging from just above 7 for slight alkalinity, to 14 for the strongest alkalinity, Acid mud range from just below 7 for slight acidity, to less than 1 for the strongest acidity (Akinade, 2015).

The pH meter was standardized using deionized water and the mud sample to be measured was poured into a glass beaker. The pH meter probe was immersed in the mud sample and at steady pH value indicated on the meter. This was recorded as the pH value of the mud sample. Alternatively, phyrion dispenser paper was removed and placed gently on the surface of the mud. Sufficient time was allowed to elapsed (about few seconds) for the paper to soak up filtrate and change colour. The soaked paper strip was matched with chart on the dispenser from which the strip was taken. The pH range of the mud was read and the value recorded in the table of result respectively. The procedure was repeated for other concentration of the mud.

2.2.4. API Fluid Loss Determination

The loss of liquid from a mud due to filtration is controlled by the filter cake formed of the solid constituents in the drilling fluid. The test in the laboratory consists of measuring the volume of liquid forced through the mud cake into the formation drilled in a 30-minute period under given pressure and temperature using a standard size cell. The two commonly determined filtration rates are the low-pressure, low-temperature and the high-pressure, high-temperature test by API filter press which consists of a filter cell, a pressure source, a filtering medium, and a graduated cylinder for receiving and measuring the filtrate. The filtering medium is a filter paper that has been specially hardened for filtrate testing. (LMDE, 2003).

2.2.5. Filter Press Testing Procedure

This procedure to operate the filter press with a compressed gas:

- Assembled the dry parts of the filter cell in the following order: base cap, rubber gasket, screen, a sheet of filter paper, rubber gasket, and filter cell and then secured the cell to the base cap by rotating it clockwise.
- With the air pressure valve closed, filled the cell with a fresh mud sample to within approximately ¼’ (6mm) of the top. (filling the cell to this level lessens the volume required from the pressure source).
Clamped the mud cup assemble to the frame by tighten the screw clamp while holding the filtrate outlet end finger tight.

* Checked the top cap to make sure the rubber gasket is in place. Place the top cap, already connected to the pressure source, onto the filter cell and secure the cell in place with the T-screw.

* Opened air pressure valve to 100psi and start timing at the same time.

* At every 5 minutes, the filtrate level of the cylinder with respect to time was measured.

* Placed a dry graduated cylinder under the filtrate tube to collect filtrate.

* At the end of 30 minutes, the pressure source valve was closed or back off the regulator, and open the safety-bleeder valve.

* The volume of filtrate collected in the graduated cylinder was measured and recorded. The volume was recorded in milliliters as the API 30-minutes filtrate loss of the drilling fluid.

### 3. Results and Discussion

The result of the experiment obtained have been compared with the American petroleum Institute (API) standard specification for drilling mud and these specifications are for all the montmorillonite clay family as contained in API practices 13A (Akinade, 2015).

Tables 2 to 4 show the laboratory measurement of the mud properties from mud formulated with corn starch, cassava starch, purple potato and yellow potato starch and saw dust respectively. The mud densities are determined using mud balance, pH values using a pH meter and fluid loss are measured suing LPLT filter press.

| Property | Control Mud | Control Mud + Polymer | Control Mud + Polymer | Control Mud + Polymer | Control Mud + Polymer | Control Mud + Polymer |
|----------|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Polymer weight | 0.00        | 2% corn starch         | 4% corn starch         | 6% corn starch         | 8% corn starch         | 10% corn starch        |
| Density(ppb) | 8.75        | 8.00                  | 8.85                  | 8.9                   | 9.00                  | 9.10                  |
| pH        | 8.85        | 9.00                  | 9.00                  | 10.00                 | 10.00                 | 10.00                 |
| Polymer weight | 0.00        | 2% Cassava starch      | 4% Cassava starch      | 6% Cassava starch      | 8% Cassava starch      | 10% Cassava starch     |
| Density(ppb) | 8.75        | 8.90                  | 8.95                  | 9.00                  | 9.95                  | 10.00                 |
| pH        | 8.85        | 8.90                  | 9.00                  | 9.50                  | 9.50                  | 9.50                  |
| Polymer weight | 0.00        | 2% Purple potato starch| 4% Purple potato starch| 6% Purple potato starch| 8% Purple potato starch| 10% Purple potato starch|
| Density(ppb) | 8.75        | 8.80                  | 8.90                  | 9.00                  | 9.10                  | 9.20                  |
| pH        | 8.85        | 9.00                  | 9.50                  | 9.50                  | 10.00                 | 10.00                 |
| Polymer weight | 0.00        | 2% yellow potato starch| 4% yellow potato starch| 6% yellow potato starch| 8% yellow potato starch| 10% yellow potato starch|
| Density(ppb) | 8.75        | 8.90                  | 9.00                  | 9.10                  | 9.20                  | 9.30                  |
| pH        | 8.85        | 9.00                  | 9.00                  | 9.50                  | 9.50                  | 10.00                 |
| Polymer weight | 0.00        | 2% saw dust            | 4% saw dust            | 6% saw dust            | 8% saw dust            | 10% saw dust           |
| Density(ppb) | 8.75        | 9.20                  | 9.30                  | 9.40                  | 9.50                  | 9.60                  |
| pH        | 8.85        | 9.00                  | 9.50                  | 10.00                 | 10.50                 | 10.50                 |

*Table 2: Physio-Chemical Properties of 22.5g of Bentonite Mud with and Without Polymer at Room Temperature*

The effect of increasing the composition of the bentonite-based mud with various concentrations of polymers has been studied. It was noted that mud weight increased with increase linearly in the concentration of polymers (Figure 2). Various polymers were found to have different effects on the mud weight as shown in Table 2 and Figure 3.

The effect of increasing the polymer concentration on the pH of the water-based mud has been studied. It was observed that, the pH of the mud increased fairly with the concentration of various polymers as shown in Table 2 and as illustrated in Figure 4.
| Time (min) | Control Mud | Control Mud with Polymer Weight |
|-----------|-------------|---------------------------------|
|           |             | 2% corn starch                  | 4% corn starch | 6% corn starch | 8% corn starch | 10% corn starch |
| 5         | 5.40        | 5.00                            | 4.500          | 3.500          | 2.500          | 1.500          |
| 10        | 8.00        | 7.00                            | 6.00           | 5.00           | 4.00           | 3.00           |
| 15        | 10.4        | 9.50                            | 8.00           | 6.50           | 5.00           | 4.00           |
| 20        | 120.5       | 10.80                           | 9.200          | 7.40           | 6.20           | 5.40           |
| 25        | 14.00       | 12.00                           | 10.50          | 8.60           | 7.40           | 6.20           |
| 30        | 17.5        | 13.200                          | 11.00          | 9.50           | 8.50           | 7.50           |

|           |             | 2% Cassava starch               | 4% cassava starch | 6% cassava starch | 8% cassava starch | 10% cassava starch |
|-----------|-------------|--------------------------------|-------------------|-------------------|-------------------|-------------------|
| 5         | 5.40        | 4.00                            | 3.50              | 3.00              | 2.50              | 2.00              |
| 10        | 8.00        | 7.50                            | 7.00              | 6.50              | 6.00              | 5.50              |
| 15        | 10.4        | 9.00                            | 9.50              | 8.00              | 7.50              | 6.00              |
| 20        | 12.50       | 11.50                           | 10.00             | 9.50              | 9.00              | 7.50              |
| 25        | 14.00       | 12.60                           | 11.50             | 10.00             | 9.50              | 8.00              |
| 30        | 17.5        | 13.00                           | 12.50             | 11.50             | 10.00             | 9.50              |

|           |             | 2% purple potato starch         | 4% purple potato starch | 6% purple potato starch | 8% purple potato starch | 10% purple potato starch |
|-----------|-------------|--------------------------------|------------------------|------------------------|------------------------|------------------------|
| 5         | 5.40        | 4.80                            | 3.40                   | 2.80                   | 2.50                   | 2.00                   |
| 10        | 8.00        | 7.40                            | 6.00                   | 4.50                   | 3.00                   | 2.00                   |
| 15        | 10.4        | 9.20                            | 8.10                   | 5.60                   | 4.50                   | 3.50                   |
| 20        | 12.50       | 10.50                           | 9.00                   | 7.40                   | 6.00                   | 5.00                   |
| 25        | 14.00       | 12.00                           | 10.00                  | 8.50                   | 7.20                   | 6.20                   |
| 30        | 17.5        | 12.70                           | 11.50                  | 9.50                   | 8.50                   | 7.40                   |

|           |             | 2% yellow potato starch         | 4% yellow potato starch | 6% yellow potato starch | 8% yellow potato starch | 10% yellow potato starch |
|-----------|-------------|--------------------------------|------------------------|------------------------|------------------------|------------------------|
| 5         | 5.40        | 4.00                            | 3.00                   | 2.20                   | 2.00                   | 2.00                   |
| 10        | 8.00        | 6.50                            | 5.00                   | 3.80                   | 2.50                   | 1.50                   |
| 15        | 10.4        | 8.50                            | 7.00                   | 5.20                   | 3.40                   | 2.00                   |
| 20        | 12.50       | 10.00                           | 8.00                   | 6.40                   | 5.00                   | 3.40                   |
| 25        | 14.00       | 11.20                           | 9.60                   | 7.20                   | 6.00                   | 4.50                   |
| 30        | 15.5        | 12.50                           | 10.80                  | 8.00                   | 7.30                   | 6.60                   |

|           |             | 2% saw dust                     | 4% saw dust            | 6% saw dust            | 8% saw dust            | 10% saw dust           |
|-----------|-------------|--------------------------------|------------------------|------------------------|------------------------|------------------------|
| 5         | 5.40        | 4.60                            | 3.80                   | 3.00                   | 2.50                   | 2.00                   |
| 10        | 8.00        | 7.50                            | 7.20                   | 6.80                   | 5.40                   | 4.50                   |
| 15        | 10.4        | 10.00                           | 9.20                   | 8.20                   | 7.30                   | 6.60                   |
| 20        | 12.50       | 11.80                           | 11.00                  | 10.50                  | 8.60                   | 8.00                   |
| 25        | 14.00       | 13.00                           | 12.50                  | 11.50                  | 11.00                  | 10.20                  |
| 30        | 17.5        | 14.00                           | 13.50                  | 12.60                  | 12.00                  | 11.50                  |

Table 3: Fluid Loss (Ml) Test Laboratory Result at 25°C

![Figure 2: Typical Time Dependence of Fluid Loss (Ml) for Various Additive Concentrations at 100°C](image-url)
The impact of saw dust, yellow potato starch, purple potato starch, cassava starch and corn starch applied as fluid loss control agent in combating the filtration properties of bentonite mud in different concentrations was investigated at room temperature and 100°C. The result of filtrate volume was measured and recorded to determine the most efficient fluid loss control agent among the various local selected polymers. Fann low temperature low pressure (LTLP) filter press was used for this laboratory test. Each part of the cell was assembled as indicated in the equipment operation manual. The mud samples were placed in the sample cell and operating pressure was set at 100psi. The filtrate volume was collected at 5 minutes intervals until 30 minutes elapsed under this pressure with a graduated measuring cylinder and recorded in Table 3.

**Figure 3: Effect of Polymer Concentration on the Density of the Bentonite Mud**

**Figure 4: Effect of Polymer Concentration on the Ph of the Mud**

**Figure 5: Variation of Fluid Loss of Bentonite Mud Formulated with Polymer at Various Concentrations**
4. Conclusions

Four various natural polymers, namely corn, potato, cassava starches and saw dust particles have been investigated with regard to their application as fluid loss additives upon drilling operations. Their effects on the physiochemical properties of the drilling fluid have also been examined. It has been established that it is possible to control the API water loss of the bentonite mud below 17.5ml/30min at 100°C and 100psi using additives and the effectiveness of additives decreases with elevated temperature.

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