Effectiveness of different Starches as Drilling Fluid Additives in Non-Damaging Drilling Fluid

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Abstract
Keeping the cost and environmental effects in mind, an alternate locally available and suitable drilling mud additive was searched for. This study focuses on the effectiveness of banana starch and cornflour starch as rheology modifier and fluid loss control agent in non damaging drilling fluids (NDDFs). Comparative study of properties obtained from the different types of starch added mud and the base mud were carried out. Starch is an environment friendly drilling mud additive used in water based drilling fluids to control filtration loss. They are also said to have thermal stability upto 250 °F. In this study, the authors have experimented to find out environment friendly alternatives for drilling fluid additives which are cheap, organic, bio-degradable, non-toxic and easily available.

Keywords: Corn Starch; Banana Starch; NDDF; Environment Friendly; Fluid Loss; Rheology.

INTRODUCTION
The exploitation of complex, fractured and/or depleted production zones, and the application of new drilling techniques such as open-hole, slim-hole drilling etc., requires the development of new drilling fluids which do not damage the reservoirs in order not to reduce the productive capacity of the wells. For this purpose, the polymeric additives, mud particles, drilled particles, etc. must be prevented from penetrating into the formation and thus irreversibly blocking the rock pores and threatening the productivity. NDDFs prevent damage to the reservoir by the formation of a thin filter cake on its surface which is impermeable and can easily be removed by the initial production or by the action of enzymes and acids. [1]

Growing orientation towards new techniques has led to development of Non-Damaging drilling fluids. Most important component of these fluids is bridging material. Bridging is required to initiate filter cake formation, and filter cake itself will then control further losses of filtrate and fine to the formation. [2]

Since drilling fluid is an integral part of the drilling process and most of the problems encountered during the drilling of a well can be directly or indirectly attributed to the drilling fluids. Therefore, these fluids must be carefully selected and formulated to fulfil their roles in the drilling process. The effectiveness of the drilling fluid to perform its primary functions is based on certain properties, which are maintained continuously to meet formation conditions during drilling operations. Failure of the mud system to meet its intended functions can prove extremely costly in terms of loss of materials and time. [3]

During the drilling process, mud viscosity and fluid loss control are very important factors to investigate. If proper care is not given to these factors, the drilling problems such as improper hole cleaning and formation damage may occur, which in turn, may lead to reduction in well productivity and increase in cost. [4] Various materials, chemicals and polymers are used in mud formulation to meet different practical mud requirements such as density, rheology, fluid loss control, etc. One of such material, starch (polymers) used for fluid loss control and as a viscosifier, forms the basis of this study. Starches are carbohydrates of a general formula of (C\textsubscript{6}H\textsubscript{10}O\textsubscript{5})\textsubscript{n} and are derived from corn, wheat, oats, rice, potatoes, yucca and similar plants and vegetables. They consist of about 27% linear polymer (amylose) and about 73% branched polymer (amylopectin). [4]

Different researchers have carried out several works with different materials for improving the properties of drilling fluid in a cost effective and environmentally sound manner. Ghazali et al. (2015) mentioned that Polymer based material has been used widely to overcome the problem of fluid loss. Amongst the standard fluid loss control agents used, the hydroxyl ethyl cellulose (HEC) and polyacrylamide cellulose (PAC) have to be introduced at a higher price. Natural polymers such as starch, guar gum, etc. are ready for use after slight processing. Starch can be categorized as the second most abundant biomass that can be found in nature [5].

Ghazali et al. also marked that starch will form colloid particles when it is added to the drilling mud and having the ability to compress and bend they will plug the pores in the filter cake to lower the potential of fluid loss. [5]

According to Ismail & Abdul Kadir (1998), compared to PAC and HEC, corn starch is one of the natural resource that is less expensive. [6] Corn starch is considered to have a high potential as mud additive for drilling wells having a low bottom hole temperature because of its high biodegradability. [7]

Nyeche W. E. et al. (2015) observed that the combination of potato starch and PAC in a near equal proportion is suitable for the improvement of rheology and fluid loss control properties of drilling mud. The use of starch typically causes temperature stability, a minimal increase in viscosity while effectively controlling fluid loss. [7]

Amanullah and Yu (2004) also showed the superior
characteristics of the Corn-based Starches for Oil Field Application. [8]

Talukdar and Gogoi (2015) used the Pre-Gelatinized Starch (PGS) as the fluid loss control agent in the Non Damaging Drilling Fluid (NDDF). [9] They also demonstrate the effectiveness of the formaldehyde (Bactericide) as the biodegradation control agent in the Non Damaging Drilling Fluid (NDDF). [10]

Thus, it is imperative to search for locally available alternatives as drilling fluid additives and evaluate their characteristics, then formulate fluids that can be used in the drilling process. This study focuses on the formulation of drilling fluid additives using locally available materials and determine their effectiveness and thereby, reducing the overdependence on some very expensive additives. The experimental works are carried out on a clay and barite free drilling fluid systems. The effect of increase in concentration of mud additives (corn starch and banana starch) on the rheology and fluid loss of drilling mud is determined and compared the findings.

METHODOLOGY

This section outlines the methodologies used to determine the effects of different starch on the rheological properties of the prepared drilling mud.

Material and Methods

The components used for formulation of the base mud are fresh water, calcium carbonate as bridging agent, XC-Polymer, biocide and very small amount of Polyanionic Cellulose (PAC). Different mud samples have been prepared by adding 25 gms of CaCO\textsubscript{3} to 500 ml of fresh water and 2.5 gms of XC polymer to obtain a CaCO\textsubscript{3} to water ratio of 5% and XC-Polymer to water ratio of 0.5%. Almost 1 ml of a biocide and 0.5 gms of PAC (RG) were also added to the same mixture in the ratio of 0.2% and 0.1% respectively. These ratios were maintained constant for all the mud samples used throughout the research work. The rheological properties of these muds have been measured and recorded. Thereafter, several other mud samples with varying additive concentrations were prepared and their rheological properties were measured and recorded. Graphs were plotted for proper analysis of the recorded data. All the rheological properties were measured at ambient conditions (77°F temperature).

Preparation of additive

- **Banana starch:** Around 7 mature green bananas were taken and peeled with a sharp knife. Soak in water and rinse. Cut them into thin slices and sun dried them for a day or two. Then, oven dried these slices at a very minimum temperature until they are crispy enough. Pulverize them in a grinder and store in an airtight container.

- **Corn flour starch:** Remove corn kernels from the cob. Wash them and soak them in a large bowl for up to 3 days changing the water every 12 hours. Thoroughly rinse them with cold water and then crush them until extremely smooth. Using a sieve run the blended corn through with lots of water to discard the chaff. Leave the sieved corn to rest for 2 hours, the solid part settles at the bottom and the excess water can be poured out. Strain further using normal fabric. Let it dry and store.

Equipment used

1. Mud Balance
2. M3600 Grace Rotational viscometer
3. Electronic Balance
4. M3600 DAQ software
5. Dead weight hydraulic filter press

Experimental Works

As discussed, several mud samples with varying additive (Banana starch and Corn starch) concentrations were prepared and their rheological properties as well as the density and fluid loss properties were measured and recorded as shown in the Table 01 & 02.

Table 1: Properties of the mud with Banana Starch

<table>
<thead>
<tr>
<th>Composition of Banana Starch, gm/100ml</th>
<th>Θ600</th>
<th>Θ300</th>
<th>Apparent Viscosity, CP</th>
<th>Plastic Viscosity, CP</th>
<th>Gel Strength, lb/100ft\textsuperscript{2}</th>
<th>Yield Point, lb/100ft\textsuperscript{2}</th>
<th>Density of Mud, ppg</th>
<th>Fluid Loss, ml</th>
<th>Temperature, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>36.845</td>
<td>27.786</td>
<td>18.4225</td>
<td>9.059</td>
<td>9.198</td>
<td>19.549</td>
<td>8.1</td>
<td>6.3</td>
<td>73</td>
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<td>1</td>
<td>35.898</td>
<td>27.006</td>
<td>17.949</td>
<td>8.892</td>
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<td>5.2</td>
<td>73</td>
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<td>17.417</td>
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**Table 2: Properties of the mud with Corn Starch**

<table>
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<tr>
<th>Composition of Corn Starch, gm/100ml</th>
<th>ø600</th>
<th>ø300</th>
<th>Apparent Viscosity, CP</th>
<th>Plastic Viscosity, CP</th>
<th>Gel Strength, lb/100ft²</th>
<th>Yield Point, lb/100ft²</th>
<th>Density of Mud, ppg</th>
<th>Fluid Loss, ml</th>
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</table>

**RESULTS AND DISCUSSIONS**

**Effect of Corn Starch and Banana Starch on Fluid Loss**

In this section, the effect of the increasing composition of the corn starch and banana starch on fluid loss in the base NDDF samples with composition of a 0.1% of PAC-R, 0.5% of XCP and 5% of CaCO₃ have been studied. In the Fig.01, it can be observed that the API fluid loss for both the mud samples are decreasing (showing downward trend) with increasing concentration of corn starch and banana starch for the respective sample due to the presence of the long chain high molecular weight molecules in both the starches. The fluid loss decreasing rate is decreasing with the increasing composition of both the agents and the produced mud cake for both the samples were very thin. But, it is noticed that the fluid loss decreasing rate is more in the sample with banana starch with its increasing composition from the initial point i.e. from 0.5% of composition. From this observation, it can be concluded that both the corn starch and banana starch are effective for decreasing the API fluid loss of mud, but in comparison with corn starch the banana starch is more effective for decreasing the fluid loss in NDDF.

**Figure 1: API Fluid Loss vs Concentration of Starch**

**Effect of Corn Starch and Banana Starch on Plastic Viscosity**

In this section, the effect of the increasing composition of the corn starch and banana starch on plastic viscosity in the base NDDF samples with composition of a 0.1% of PAC-R, 0.5% of XCP and 5% of CaCO₃ have been studied.
In Fig. 02, for banana starch, it can be noticed that the plastic viscosity undergone a gradual decrease from the initial level i.e. from 0.5% concentration of banana starch due to the effect of lubricity (reduced friction among the mud particles). Again, for corn starch, it is noticed that the plastic viscosity experienced a minimal increasing trend from 0% to 2% concentration due to the increase in fine solid particles in the mud. From this experimental data, it is clear that both of these starches do not have a great role in controlling the viscosity of the NDDF.

**Effect of Corn Starch and Banana Starch on Gel Strength**

In this section, the effect of the increasing composition of the corn starch and banana starch on gel strength in the base NDDF samples with composition of a 0.1% of PAC-R, 0.5% of XCP and 5% of CaCO$_3$ have been studied.

In Fig. 03, it is observed that the gel strength undergone a gradual increase for both the NDDF samples having corn starch and banana starch from 0% upto 2% concentration due to the presence of the long chain high molecular weight molecules in both the starches. For both the starches slight increases in the gel strength values have been noticed.
Effect of Corn Starch and Banana Starch on Yield Point

In this section, the effect of the increasing composition of the corn starch and banana starch on yield point in the base NDDF samples with composition of 0.1% of PAC-R, 0.5% of XCP and 5% of CaCO$_3$ have been studied.

In Fig. 04, it is observed that the yield point undergone a gradual increase for both the NDDF samples having corn starch and banana starch from 0% upto 2% of concentration of respective starch due to the increase of gel strength of both the NDDFs. For both the starches, slight increases in the yield point values have been noticed.

Effect of Banana Starch and Corn Starch on Mud Density

In this section, the effect of the increasing composition of the corn starch and banana starch on mud density in the base NDDF samples with composition of 0.1% of PAC-R, 0.5% of XCP and 5% of CaCO$_3$ have been studied.

In Fig. 05, it is observed that the mud density undergone a gradual decrease for both the NDDF samples having corn starch and banana starch from 0% upto 2% of concentration of respective starch due to the decrease of gel strength of both the NDDFs. For both the starches, slight decreases in the mud density values have been noticed.
In Fig. 05, it is noticed that for banana starch, the density of the mud experienced a decreasing trend from 0% to 2% concentration of banana starch. Again, for corn starch, it is observed that the density of the mud undergone gradual increase with the increasing concentration of the starch.

Low mud density results in underbalanced condition of the well and thus, the well may collapse and may create lots of well complications. High mud density results in lost circulation, differential pipe sticking, decrease in ROP and formation damage. Since, the mud density decreased with the increase in concentration of banana starch and slightly increased with the increase in concentration of corn starch, the composition of the CaCO₃ must have to increase slightly for the NDDF with banana starch and must have to decrease slightly for the NDDF with corn starch to compensate the change in density due to their addition.

CONCLUSION

Banana Starch and Corn Starch work excellently as the fluid loss control agent in NDDF which also has a moderate role in controlling the rheology of the mud. Besides control of fluid loss by banana starch, it also affects the rheological properties of NDDF e.g. it slightly decreases the PV and increases the gel strength and yield point with its increasing concentration. While corn starch decreases fluid loss and increases the rheological properties of NDDF such as PV, gel strength and yield point with increasing concentration. It is known that starch reduces the fluid loss, and, as expected, this characteristic was confirmed in the assays by the use of both banana and corn starch. Additionally, these starches also contributed to nominal increase in rheological properties.

Banana starch found more effective in controlling the fluid loss in the NDDF. But, corn starch found more effective in controlling the rheological properties in the NDDF. But, their drawback is that they are highly degradable. After few days of formulation it starts degrading and adversely affects almost all the mud properties. Therefore, the drilling time using NDDF should be as low as possible or the drilling rate in the pay zone should be as high as possible. The biocide must be used to decrease the degradation rate.

Besides the effect on the fluid loss and rheology, the banana starch will also increase the lubricity of the mud.

Based on the laboratory results, the optimum composition range of banana starch and corn starch respectively can be chosen for successful drilling.

Continuous investigation of the properties and functions of the mud, whether they are fulfilling the requirements or not, is necessary, and if required, the composition of the mud may have to be changed during drilling.

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REFERENCES