

Performance Evaluation of Bentonite Muds Formulated using Cassava Starch Treated with Preservatives

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Abstract— Extensive works have been done on the subject matter of local sourcing of drilling fluid additives to reduce our importation burdens especially in this era of dwindling oil fortunes. This local sourcing will bolster industrialization and reduce unemployment in a vast economy like Nigeria. The results of the previous studies have shown promising potentials which are in tandem with our local content mandate of the government. Cassava starch has been identified as one of these additives and our ranking as the world largest producer of cassava remains instructive. Currently, all the starch used in the oil and gas industry is imported. The major constraint to the use of cassava starch is their extreme susceptibility to post-harvest degradation. This work, therefore, is an attempt to address this problem of stability by the application of appropriate preservatives without prejudice to the rheological properties of the mud. In carrying out this study at temperatures of 80, 120, 150 and 190°F, three cassava starch cultivars TMS 92/0057, TMS 98/0581 and TMS 96/1632 and four common preservatives in the food industry; the salts of benzoate, propionate, sorbate and metabisulphite were used in the bentonite mud formulations. The result showed that out of the sixty-one mud formulations, only five of them adequately met the API rheological properties threshold. These five muds exhibited properties that compare favourably to the imported starch sample. This stabilized product holds much promise as a substitute to the imported starch for use in water-based drilling mud formulations for the Nigerian oil industry.

Keywords— Cassava starch, Drilling fluids, Rheology, Preservatives.

I. INTRODUCTION

The use of preservatives predates history. The prehistoric men were known to have preserved their perishables with substances such as salt and vinegar [1]. The ante of the preservation industry has since then moved up to the present day whereby it is almost possible to preserve anything so desired. More often than not, this is done through a myriad of processes and operations that sometimes see a combination of such, to achieve some complex and even conflicting requirements [2].

A preservative is a substance that is added to a product to maintain an existing condition or prevent decomposition by microbial attacks or degradation through other undesirable changes. However concerning food preservation which starch belongs to, preserving what is, may not be just adequate as additional requirements of improving flavour, texture and visual appearance may also be imposed [3].

Preservatives are classified into two groups according to the form of attack as antimicrobial or antioxidants. The antimicrobial preservatives prevent the attacks from micro-organisms such as moulds, yeasts and bacteria and some common ones are the salts of benzoate, sorbate, propionate and metabisulphite [4]. The antioxidants prevent the oxidation of foods and especially those containing unsaturated fats and oils. It is this oxidation which produces the rancid taste in such foods and typical examples are the butylated hydroxyl toluene (BHT), butylated hydroxyl anisole (BHA) and the ascorbates [5].

Cassava (*Manihotesculenta*) is a major root crop largely grown in the tropics and subtropical regions of the world and over a wide range of soil and environmental conditions. It is because of its commonness that it is sometimes described as the “Bread of the Tropics” [6]. Documented reports of well over 40 cassava varieties have been identified and Nigeria is the world’s largest producer [7]. According to [8], the estimated world production in 2017 was 278 million tonnes, out of which Nigeria was accountable for 20%. Cassava demonstrates an amazingly stubborn resilience in that it can survive in the least of

farmland and environmental conditions [9]. Cassava is a reliable and convenient source of food for millions of Nigerians and it is estimated that more than 90% of our cassava production is processed into food [10]. However, the use of cassava and cassava products amongst which is starch has been finding wider applications other than the normal food industry over the years, such as biofuels, animal feeds, laundry, beverages and drilling fluids

Starch is employed in the oil and gas drilling fluid formulations as secondary viscosifiers and filtrate reducers to improve rheological properties and filtration characteristics, respectively [11], [12]. Starch is a polysaccharide consisting of the crystalline amylose and the amorphous amylopectin, with the latter accounting for the gelling properties [13]. As a polymeric material, it exhibits thixotropy and it is this property that has informed its application in the formulation of drilling fluids [Thomas, 1982 as cited by 14]. Additives that address specific requirements are also incorporated into the muds to function satisfactorily under varied down-hole conditions. According to [15], present-day muds are, therefore, formulated to address these key functions; controlling formation pressures, cooling and lubricating the drilling string/bit, removing of cuttings from the borehole, maintaining wellbore stability, transmitting hydraulic energy to the bit, suspension of cuttings in the borehole, protecting permeable zones by building a filter cake, supporting of the drill string, releasing of the cuttings at the surface, corrosion prevention, data logging and reducing filtration rate.

The major drawback to the use of cassava and cassava products is their ready susceptibility to post-harvest physiological degradation, infestations and inherent deterioration as a result of micro-organism activities [16]. This has not only brought severe losses to the farmers but has more importantly limited their potential for usage by our oil and gas industry and by extension, the export market. [Farquet and Fargette, 1990 as cited by 16], has reported losses of 20-90 % in 15 African countries, Nigeria inclusive.

Previous works on the use of local cassava starches for drilling fluid applications for exploration and exploitation activities in the petroleum industry have demonstrated good and promising potential as compared to the imported ones [13],[14],[17]. However, the equally important study on how these starches can be stabilized for storage with acceptable shelf life, have not been fully addressed. The over \$20 billion annual spends in the Upstream oil and gas industry have largely benefited the import market much to our detriment and gravely against the Nigerian government mandate through the Nigerian Content Development and Management Board (NCDMB), that 60% threshold of the chemicals/additives in the industry be sourced locally [18]. Therefore, advancing the course of knowledge to the ultimate market square economically is predicated on effective closure of this stability gap. The objective of this work, therefore, is to investigate and evaluate the performance of starches that were treated with preservatives for water-based drilling fluid formulations.

II. MATERIALS AND METHODS

Three 12-months old cassava cultivars TMS/92/0057, TMS98/0581 and TMS96/1632 were obtained and processed at the National Root Crop Research Institute (NRCRI), Umudike, Umuahia, Nigeria. Imported starch as a control sample (Amidon), bentonite and four common preservatives in the food industry were obtained from an industrial chemical supply company in Port Harcourt. These preservatives were the salts of benzoates, sorbates, propionates and sulphites.

Equipment used includes: mechanical grater, thermos-regulated oven tray drier, viscometer (OFITE model 800), API filter press (OFITE model), electronic balance, Hamilton Beach mixer, muslin cloth, measuring cylinder, beaker, spatula, 150-micron sieving mesh, stopwatch and mud balance.

2.1 Extraction of the starch

Each of the three cassava cultivars was subjected to starch extraction process as described by [14], [19]. Freshly harvested tubers were washed with potable water, peeled with a stainless knife and again washed thoroughly to remove all dirt and sand. The tubers were ground and sieved with the addition of a small quantity of portable water to facilitate the sieving operation. The filtrate was allowed to settle for 4 hours and then decanted. This left a white, tasteless and odourless starch at the bottom of the container. The wet starch was spread thinly over an aluminium tray for open-air drying at atmospheric conditions of 27^oC-30^oC for about 6 hours to minimize damage to native starch granules. The starch was further dried in an air oven for about 6 hours at 60^oC. The dried starch was finally milled in blenders to fine particles and sieved with 150-micron mesh.

2.2 Mud Preparation

Following [21] specification, and as shown in Table 2.1, bentonite mud was individually formulated with the three cassava starch cultivars TMS92/0057, TMS98/0581, TMS96/1632 and the imported starch sample (Amidon) with distilled water as

the continuous phase. The local starches were earlier treated with the four preservatives, at five different concentrations before the mud formulation exercise. Muds A1 to A15, B1 to B15, C1 to C15 and D1 to D15 were treated with the benzoate, propionate, sorbate and metabisulphite salts, respectively. The preservatives were the commonly encountered ones in the agricultural industry [21].

TABLE 2.1
BASIC MUD RECIPE

Mud Type	1% Starch(TMS92/0057)	Bentonite	Distilled Water	% Benzoate salt preservative
A1	0.23g	22.5g	350ml	0
A2	0.23g	22.5g	350ml	0.05
A3	0.23g	22.5g	350ml	0.1
A4	0.23g	22.5g	350ml	0.5
A5	0.23g	22.5g	350ml	1.0

2.3 Rheological Properties Determination

The Bentonite-starch muds were variously formulated as detailed. Each of the mud suspension was poured into a viscometer cup and subjected to a multi-speed Fann Viscometer which was used to carry out the viscosity test at the shear speeds of 600, 300, 200, 100, 60, 30, 6 and 3 rpm, respectively. The viscosity tests were carried out at temperatures of 80°F, 120°F, 150°F, and 190°F respectively. The control sample (Amidon) mud was formulated by adding 1% of the starch to the bentonite and distilled water followed by thorough mixing. The only difference was that no preservative was added to the suspension. This was again subjected to a viscosity test at the same various temperatures both before and after ageing. The results were as shown in the graphs. The results from the viscometer were used to calculate the rheological properties by the following equations [22].

$$\text{Plastic viscosity (cP)} = 600\text{rpm reading} - 300\text{rpm reading} \quad (1)$$

$$\text{Yield Point} = 300\text{rpm reading} - \text{Plastic velocity (cP)} \quad (2)$$

$$\text{Apparent Viscosity (cP)} = 600\text{rpm reading} / 2 \quad (3)$$

$$\text{Yield stress} = (2 \times 3\text{rpm reading}) - 6\text{rpm reading} \quad (4)$$

$$\text{Shear rate (sec}^{-1}\text{)} = \text{rpm} \times 1.703 \quad (5)$$

$$\text{Shear stress (Pa)} = \text{Dial reading} \times 1.065 \quad (6)$$

III. RESULTS AND DISCUSSION

The rheological characterization of the muds are presented and discussed with the [23] as the basis.

3.1 Mud Viscosities

The viscosity performances for these muds before ageing were presented in Figures 1 - 3 for formulations with starches from TMS 92/0057, TMS 98/0581 and TMS 96/1632 cassava cultivars respectively. The performance of the control sample (Amidon) was also included for ease of better comparison.

All the muds from TMS92/0057 met the API minimum viscosity of 30 cP at the speed of 600 rpm and temperature of 80°F as the muds posted a viscosity range of 30-58 cP (Figure 1). Generally, muds containing the sulphite salt in its formulation showed the highest viscosity at a concentration of 1.0 per cent (D5). This was followed by muds with sorbate, propionate and benzoate, in that order.

Similarly, all the TMS 98/0581 muds met the threshold. Metabisulphite preserved starch muds again indicated the highest viscosity of 56 cP (D10), with increasing concentrations, followed by muds with propionate, sorbate and benzoate also in that order. All the muds met the API minimum viscosity threshold and ranged from 32 to 57cP. At the highest concentration of 1.0 per cent concentration, sulphite containing muds indicated the highest viscosity of 57cP, followed by benzoate, propionate and lastly the sorbate.

Figure 3 shows the profile of muds from TMS 96/1632. All the muds met the API minimum viscosity threshold and ranged from 32 to 57cP. At the highest concentration of 1.0 per cent concentration, the metabisulphite containing muds indicated the highest viscosity of 57cP, followed by benzoate, propionate and lastly the sorbate.

All mud formulations met the minimum threshold in terms of mud viscosity only and this is in tandem with the works of some researchers that our local cassava starches had promising viability for application in water-based drilling formulations as a viscosifying agent [13], [14], [17], [24].

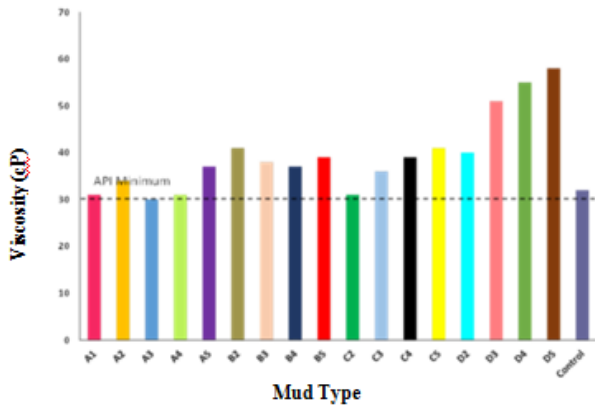


FIGURE 1: Mud Viscosity for TMS92/0057 starch muds treated with different preservative

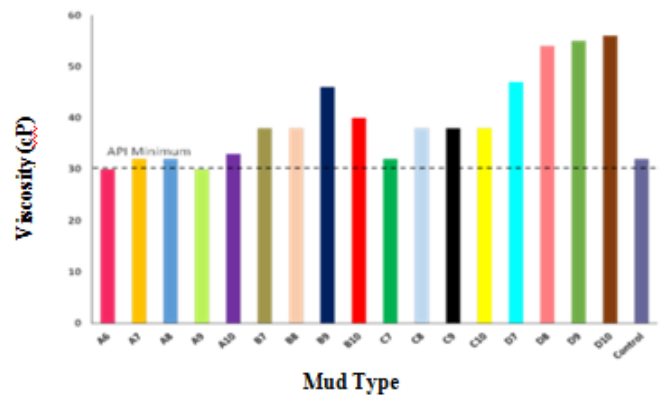


FIGURE 2: Mud Viscosity for TMS98/0581 starch muds treated with different preservatives

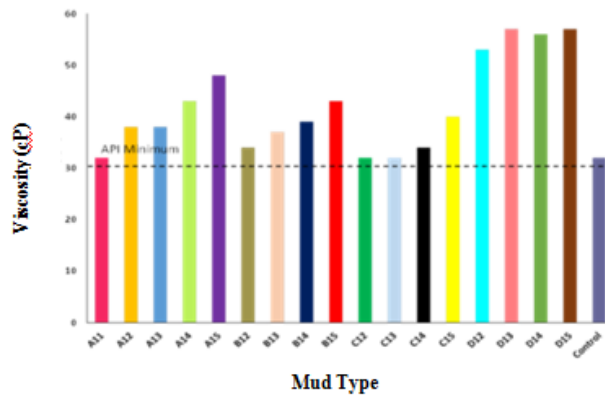


FIGURE 3: Mud Viscosity for TMS96/1632 starch muds treated with different preservatives

3.2 Yield Point of Mud Formulations

The presentation of yield point values of the three cassava starch cultivars as formulated are shown in Figure 4-6. All the muds from TMS 92/0057 cultivar were within the threshold of 15-45lb/100ft² [23] except for muds D3, D4 and D5. Comparable results were reported by [24]. The TMS 98/0581 muds all met the threshold whereas only mud D15 of the muds from TMS 96/1632 formulations failed the specification target with a value of 51lb/100ft². The mud yield point is a measure of its cuttings carrying capacity. Higher values have negative impacts on the mud pump, wellbore stability, borehole cleaning, amongst others due to pressure considerations [26].

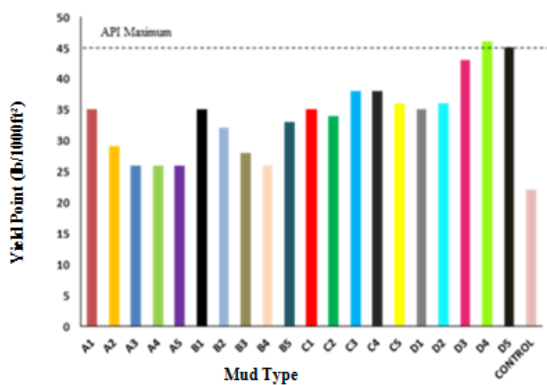


FIGURE 4: Yield Point for TMS92/0057 starch-bentonite formulated muds

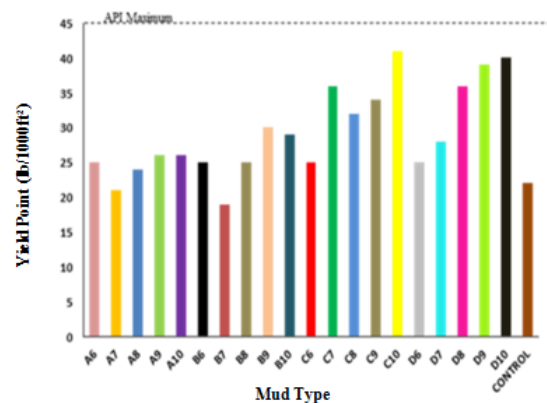


FIGURE 5: Yield Point for TMS98/0581 starch-bentonite formulated muds

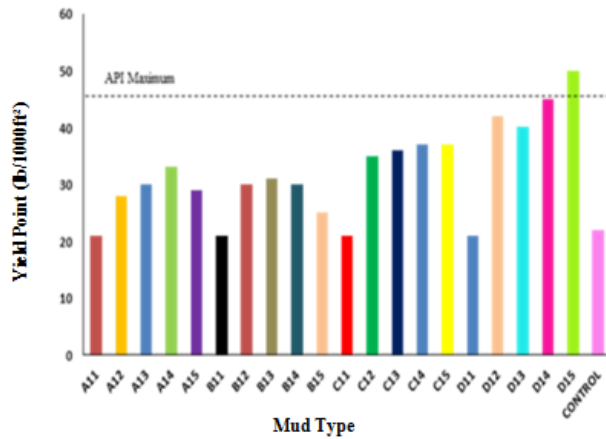


FIGURE 6: Yield Point for TMS96/1632 starch-bentonite formulated muds

3.3 10-Seconds Gel Strength of Mud Formulation.

The 10-second gel strength values of muds formulated with the three starch cultivars TMS 92/0057, TMS 98/0581 and TMS 96/1632 were presented as in Figures 7, 8 and 9 respectively. Four of the muds from TMS 92/0057 formulations (A2, A3, A4, C2) and TMS 96/1632 formulations (A12, B12, C12, C13) have gel strength values within the API Specification of 3-20lb/100ft² [23], while for the TMS 98/0581 formulations, eight muds (A6, A7, A8, A9, B6, C6, C7, D6) met the threshold. Reference [24] had reported comparable results for cassava starch bentonite muds. Mud gel strength is an indication of the cuttings suspension capacity of the mud under static conditions. Managing operational drilling challenges such as cessation of fluid flow, caused by pump failures could lead to catastrophic damages but for a good controlled gel strength value. The interaction between the mud components and the preservatives at their various concentrations may be responsible for these observations.

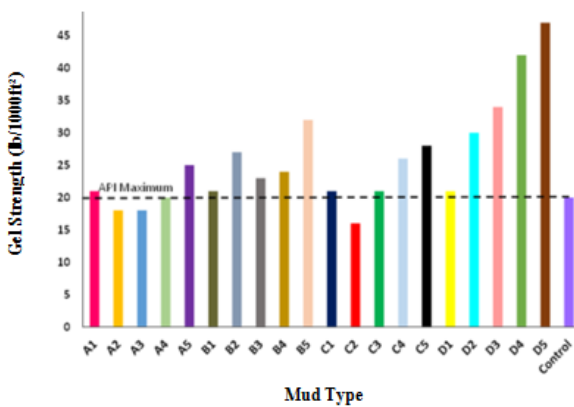


FIGURE 7: 10 Secs Gel Strength for TMS92/0057 Starch-Bentonite formulated muds

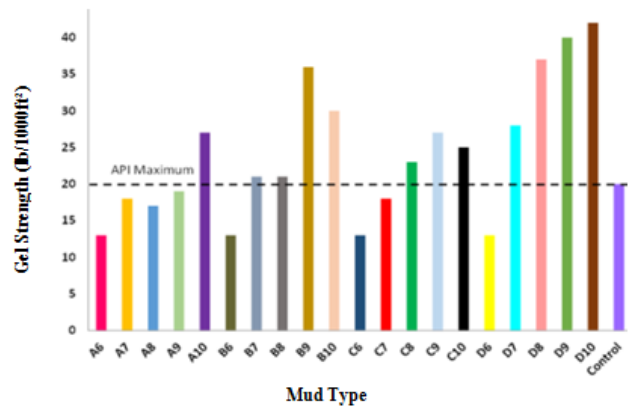


FIGURE 8: 10 Secs Gel Strength for TMS 98/0581 Starch-Bentonite formulated muds

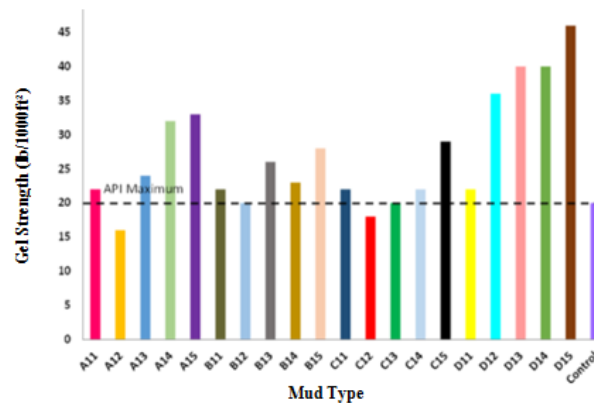


FIGURE 9: 10 Secs Gel Strength for TMS 96/1632 Starch-Bentonite formulated muds

3.4 10-Minutes Gel Strength of Mud Formulation.

The 10- minutes gel strength values of muds formulated with the three starch cultivars were presented as in Figures 10to 12. These six muds; B2, B5, D2,D3, D4, D5, failed to meet the API specification threshold of 8-30lb/100ft² for the TMS 92/0057, seven muds (A10, B9, B10, D7, D8, D9, D10, for TMS 98/0581 formulations and eight muds (A14, A15, B15, C15, D12, D13, D14, D15) of TMS 96/1632 formulations were also above the threshold. Mud gel strength is an indication of the cuttings suspension capacity of the mud under static conditions. According to [27], flat rheology phenomenon is critical for effective drilling operations and this implies a small differential between the 10-seconds and the 10-minute gel strength values as indicated by most of these formulations.

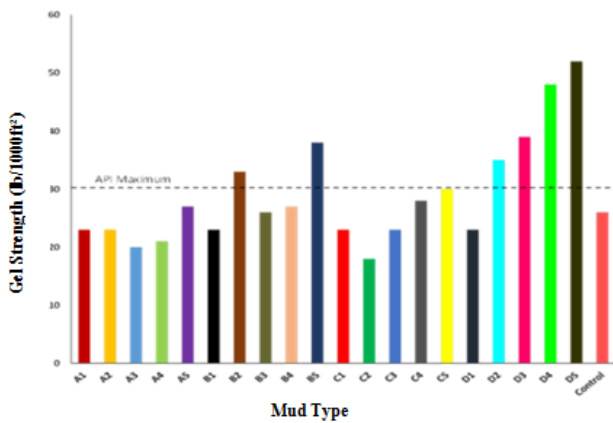


FIGURE 10: 10 Min. Gel Strength Profiles for TMS 92/0057 Starch-Bentonite formulated muds

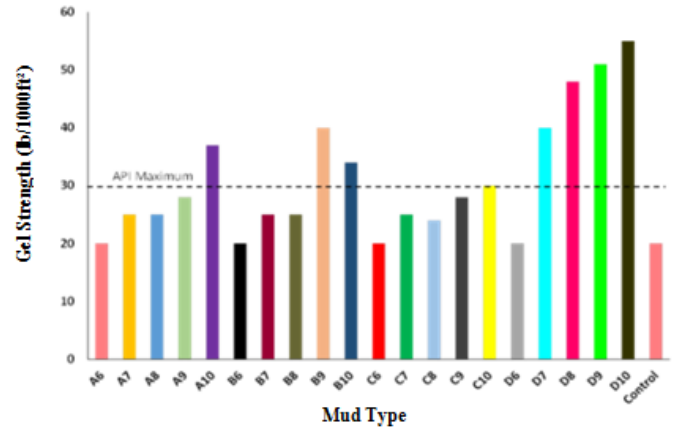


FIGURE 11: 10 Min. Gel Strength Profiles for TMS 98/0581 Starch-Bentonite formulated muds

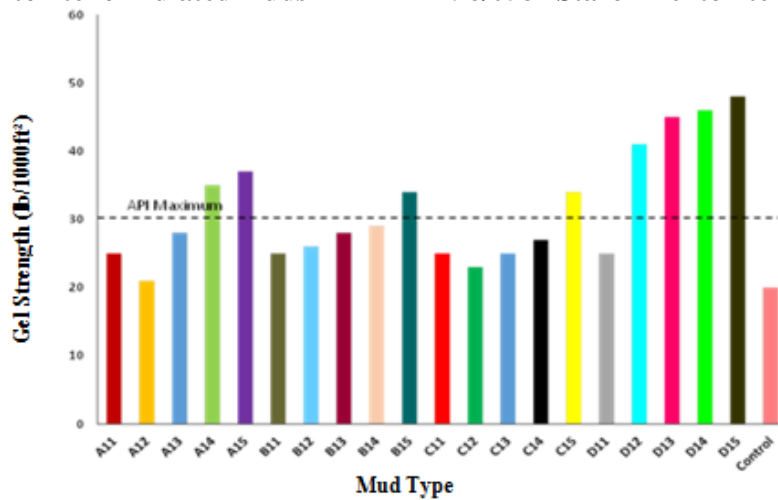


FIGURE 12: 10 Min. Gel Strength Profiles for TMS 96/1632 Starch-Bentonite formulated muds

3.5 Muds that met API Specifications

A determination and analyses of the rheological characterization of all the mud samples from the three cassava starch cultivars of TMS 92/0057, TMS 98/0581 and TMS 96/1632 treated with the four preservatives at varying concentrations were made. The analyses were made concerning the API standard specifications (API 2004). It was only the following five muds that met the threshold of the specifications; A2, A7, A8, B7 and C7.

Muds A7, C7, A8 and B7 were all formulated with TMS 98/0581 starch cultivar, containing 0.05% benzoate, 0.05% sorbate, 1% benzoate and 0.05% propionate, respectively. Mud A2 was a formulation of TMS 92/0057 with 0.05%benzoate. In advancing this work, therefore, it is evident that the benzoate could be considered as an appropriate preservative at low concentrations in formulation with TMS 98/0581 and TMS 92/0057 starch cultivars. It is instructive to note that the findings of previous researchers on this subject matter posited similar observations as to the promising potentials of these cassava starch cultivars as effective colloids for water-based drilling fluids formulations[13, [17]. Most importantly, the

characterization of the control starch mud sample E1 (Amidon) compares very favourably with these recommended samples but particularly mud samples A2 and A7.

IV. CONCLUSIONS

In this work, a total of sixty-one mud samples were prepared and analyzed. The deliberate and elaborate sampling and analyses were to ensure that the results will make a good contribution towards the closure of the work that has been done towards the industrial application of local cassava starches in drilling fluid formulations. Accordingly, we conclude as follows:

The application of benzoate preservatives at low concentration of 0.05% to each of the two cassava starch cultivars holds much promise as a substitute to the imported starch, for use in water-based drilling mud formulations for the Nigerian oil and gas industry

Both mud formulations showed similar rheological characterization with the imported starch sample (control sample) and all the parameters conformed to the API standard.

The last step in these positive closure efforts is ongoing and that will be the deployment of moisture sorption studies to validate the acceptable shelf life for these stabilized cassava starch products.

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