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Temperature and Time-Dependent Behaviour of a Water Base Mud Treated with Maize (*Zea mays*) and Cassava (*Manihot esculanta*) Starches

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Starch, one of the commonly used additives in drilling fluids, degenerates with time under cyclic temperature and pressure loads, causing changes in mud properties. This study was designed to establish the effect of temperature and aging on water base mud treated with starches prepared from maize (*Zea mays*) and cassava (*Manihot esculanta*) starches. The effect of potash and tannathin on the muds was also investigated. Plastic viscosity of treated samples at varying temperatures (24.4, 40.0, 60.0 and 80.0 O C) was determined using standard API practices over a period of 72 hours. At ambient conditions, the plastic viscosity of samples treated with maize and cassava varied between 5 and 7 cp and increased to between 6 and 12 cp when the samples were further treated with potash. Plastic viscosity for industrial starch varied from between 5 and 6 cp but increased to between 7 and 10 cp when further treated with potash. Predictive models for plastic viscosity and yield point gave coefficient of variance between 90 and 92% respectively. However, all the starches degenerated within 24 hours and would require further treatment to prevent biodegradation.

Keywords: Starches; plastic viscosity; yield point; potash; tanna thin.

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NOMENCLATURE

PV = Plastic viscosity; YP =Yield point; AV = Apparent viscosity; Gel = Gel strength; θ_{600} = rotational viscosity at 600 rpm; θ_{300} = rotational viscosity at 300 rpm; X_1,= Temperature (°C); X_2 = Starch (g); X_3 = Potash (g); β_o , α_o= Intercept coefficient; β_1 , β_2 and β_3 ; = empirical constants for plastic viscosity; α_1, α_2 and α_3 = empirical constants for yield point; COV = Coefficient of Variance.

1. INTRODUCTION

Drilling fluids are complex fluids consisting of several additives, added to enhance / control the rheological properties. They perform a lot of functions which ensure that a well is drilled successfully, safely, and economically. The control of the flow properties of drilling fluids is important as most of the drilling fluid functions are controlled by its rheological properties. Hence, there is a need to ensure that these properties are well monitored in the course of drilling to ensure a successful drilling operation Starch, is an abundant biomass found in nature [1], and was the first organic polymer used in substantial quantities in drilling mud. Its addition to bentonite dispersions as an additive is of great industrial interest because the properties of drilling fluids are strongly modified by such polymers [2,3]. There are two types of starch molecules; the linear or helical amylose and the branched amylopectin and always associated with them are minor constituents like proteins (0.25%), lipids (0.1-0.3%) and compounds of phosphorus [4]. The performance of a given starch is governed by its physicochemical properties which differ in their physical and chemical properties and these properties are dependent upon the arrangement of the bonds which link glucose units to one-another. Amylose affects the gelling behavior in starch molecules while the branched chain amylopectin reduces the mobility of the polymer and its orientation in an aqueous environment.

Starches are inexpensive, abundance in supply, renewable, environmentally friendly and fully biodegradable. Statistical and mathematical techniques have been used to study the influence of additives on the rheological properties of bentonite–water systems [5,6]. Isehunwa and Orji [7] had earlier employed factorial design to determine filtration properties of a drilling mud at high temperatures and pressures and stressed that the method could reduce risk, time and money. Amanuallh et al [8] developed corn-based starches using local resources to study their suitability for use as drilling fluid additive. Okumo and Isehunwa [9] used factorial design to obtain a statistical model for predicting the rheological properties of water base mud treated with starch and potash at high temperatures and pressures. Menezes et al [10] evaluated the influence of carboxymethyl cellulose on the rheological properties of bentonite dispersions in water-based drilling fluids. Adebayo and Imokhe [11], compared the use of barite and lignosulphate with some local additives. This present study was designed to evaluate the behavior of drilling muds treated with selected local starches.

2. MATERIAL AND METHODS

Cassava (*Manihot esculenta*) tubers and industrial starch were obtained from International Institute of Tropical Agriculture (IITA), Ibadan, while fresh maize (*Zea mays*) and potash were obtained from a local market in Ibadan. Fresh tubers of cassava (500 g) were washed, peeled, cut and soaked in water containing 100 ppm sodium metabisulphate. The tubers were wet milled at low speed using a blender with 1: 2 w/v of tap water. The solution was filtered through a muslin cloth, and suspension was kept overnight for settling of starch. The supernatant was decanted, and the settled residue was further purified with repeated suspension in tap water (1:2 v/v) followed by the settling for 3 hours. The purified starch was dried at 35°C, and sieved through a 200 μm sieve. Maize starch was extracted by steeping in hot water for 10 hrs and subsequent grinding. The resultant mash was centrifuged to allow the starch to settle down. The starch was then washed several times using clean distilled water. Starch obtained was then dried in an air forced oven at 40°C and then stored at room temperature. Potassium Carbonate was grinded and sieved using a 200 μm sieve to obtain a fine powder.

The starches produced from maize and cassava were used as additives in drilling fluids with composition as shown in Table 1. A control test was carried out using industrial starch. Mud was allowed to hydrate for 24 hrs before treatment with additives. Potash and tannathin were also used as additives in concentrations as shown in

Table 2. A Hamilton beach mixer was used for mixing, a Fann VG model at six different speed values (600, 300, 200, 100, 6 and 3 rpm), to obtain rheological properties, at incremental temperatures of 24.4, 49, 60 and 80°C. Aging tests were conducted to determine how bottom-hole conditions affect mud properties, Experiments replication repeated for all mud samples after 24 and 48 hrs. Plastic viscosity, apparent viscosity, and yield point were determined from viscometer readings using, the equations (1), (2) and (3) respectively: Predictive models were obtained using response surface methodology and results were statistically analyzed.

$$\mu_p = \theta_{600} - \theta_{300} \qquad (1)$$

$$Av = \theta_{600} / 2.0 \qquad (2)$$

$$Y_b = \theta_{300} - \mu_p \qquad (3)$$

3. RESULTS AND DISCUSSION

The effects of maize and cassava starch on the rheological properties of a water base mud were investigated. Results on plastic viscosity (PV) and yield point (YP) were obtained for mud samples treated with starch before and after being subjected to increase in temperature over a period of 72 hrs.

3.1 Effect of Temperature

Fig. 1 shows the plastic viscosity of mud sample without additives at different temperatures. A decrease in the PV of the sample without starches was observed as temperature increased, this high temperature could have contributed to the thinning effect due to partial destruction of the hydration shell and furthermore, cohesive forces within bentonite molecules could have contributed to the viscous shear stress leading to viscosity reduction and this finding is in agreement with the report of Joel and Nwokoye [12].

Fig. 2 show results of PV of the mud sample treated with 5 g of starches at different temperatures. The PV of the mud samples increased to a peak for all samples treated with starches, because as the temperature increased, the starch molecules are agitated leading to a break in intermolecular bonds thus allowing increased interaction with water molecules. At high temperatures above 62°C, there was complete loss of starch crystallinity and gelatinization occurred leading to a decrease in the PV. As additional 5 g of starch was added to the mud samples (Fig. 3) the viscosity increased as a result of this additional solids. Increase in temperature, lower the viscosity; this is because higher temperature leads to a decrease the viscosity of the liquid phase in a drilling mud sample and also the breaking down of the bonds within the polymer chains resulting in thermal degradation of starch.

The behavior of cassava starch was closer to the control than that of maize starch and this could be attributed to the variation of constituents in the starch molecule as variation in the amount of amylose and amylopectin in starch changes its behavior of the starch, Amanuallh and Long [13].

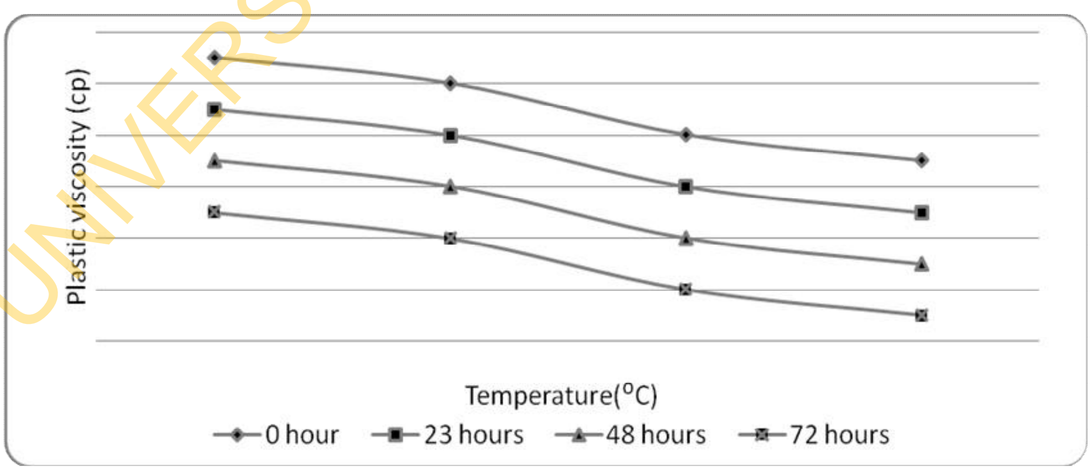

Fig. 1. Plastic viscosity (cp) against Temperature (°C) of the drilling fluid without additives

Table 1. Composition for starch samples

Mud	Bentonite (g)	Water (ml)	Starch (g)	Potash(g)	Tannathin (g)
Sample A	22.5	350.0	5.00	0.00	0.00
Sample B	22.5	350.0	10.0	0.00	0.00
Sample C	22.5	350.0	5.00	5.00	5.00
Sample D	22.5	350.0	5.00	10.0	10.0
Sample E	22.5	350.0	10.0	5.00	5.00

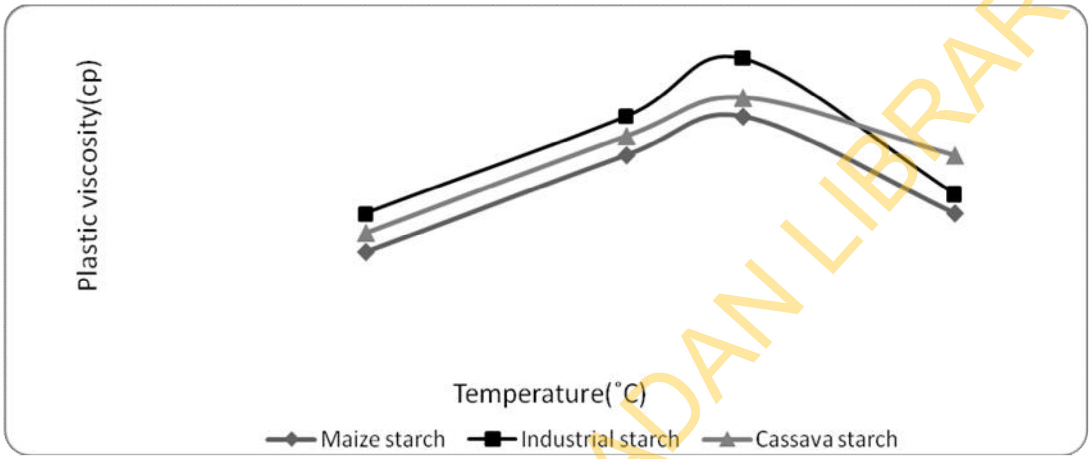

Fig. 2. Plastic viscosity (cp) against temp (°C) of drilling fluid treated with 5 g of starch

Table 2. Order of Addition for mud samples

Order of addition (g)	Mixing time (mins.)
Hydrated sample	10
Starch	5
Potash	5
Tannathin	5

3.2 Effect of Aging

Fig. 1 also shows the plastic viscosity of untreated drilling fluids over a period of 72 hrs showing decrease in PV of untreated mud showing agreement with Santoyo et al [14]. Fig. 4 shows the apparent viscosity, yield point and gel strength for treated muds, this properties initially increased but eventually decreased within 48 hour this is in agreement with the finding of Ali and Al-Marhoun [15] who observed that effective viscosity, plastic viscosity, yield point and gel strengths (10 sec. and 10 min.) of aged mud increase with aging time. Above 62°C a decrease in PV occurred as aging time increased and its effect on yield point diminished. This result agrees with that obtained by Shokoya et al [16] in their study of the rheology and corrosivity of water-base drilling fluid under simulated down hole conditions.

The plastic viscosity of the mud samples treated with the different starches decreased as the time increased this can be as a result of the flocculation of the bentonite clay resulting from the loss of the continuous phase in the mud The plastic viscosity of starches treated with maize starch decreased more than that of cassava starch others, showed that aging enhance the hydration process for samples that have higher amylose content and higher water absorption capacity. An aged mud sample (before stirring) determines gelling tendencies of fluid in the borehole. Lyons and Plisga [17] observed setting of mud solid in an aged mud as an indication of formation of a layer (hard/soft) of sediment in the borehole.

3.3 Effect of Potash and Tanna thin

The use of thinner in the drilling fluid system reduced the viscosity of the mud and therefore reduced the amount of energy needed to rotate the drill stem and the drill bit. The effects of potash on different mud treated with starches are shown in Fig. 5. As the amount of potash added increased, the viscosity of the samples decreases, this might be as a result of potash preventing attractive forces between the clay and the starch molecules which in turn will reduce the amount of energy needed to rotate the drill stem and the drill bit.

In order to ascertain the performance of potash, tanna thin was added into the same mud composition. The results of mud treated with tanna thin are shown in Fig. 6. Tanna thin did not show an instant increase in the plastic viscosity at low temperature but as temperature increased there were changes as an increase in plastic viscosity above 62°C after 23 hrs was observed.

The addition of potash to the different starches contained in the drilling fluid had varying effects which were more pronounced in the industrial starch, followed by cassava starch than maize starch.

3.4 Predictive Models for Rheological Properties

Response surface methodology was used to develop predictive models for rheological properties of the muds. The response variables were plastic viscosity (PV) and yield point (YP), while the independent variables were temperature (X_1), starch (X_2) and potash(X_3). Equations (4) and (5) were obtained for PV and YP respectively. Table 3 shows the empirical constants derived for plastic viscosity (PV) and yield point (YP), while Table 4 gives the coefficient of variance for plastic viscosity. Equation (4) and Table (3) show that PV increases with increasing Temperature and Starch concentration but decrease with potash concentration. A similar trend was observed in the prediction of YP (equation 5 and Table 3). Furthermore, statistical analysis shows that there was a good correlation between the predicted PV using the model with experimental values (Table 4).

$$PV = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \quad (4)$$

$$YP = \alpha_o + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 \quad (5)$$

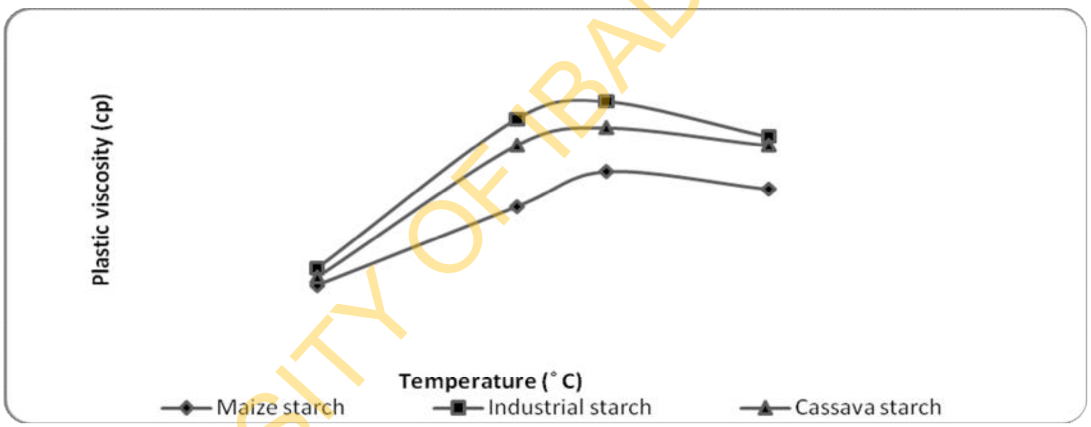

Fig. 3. Pv (cp) against Temp (°C) a drilling fluid treated with 10 g Starch

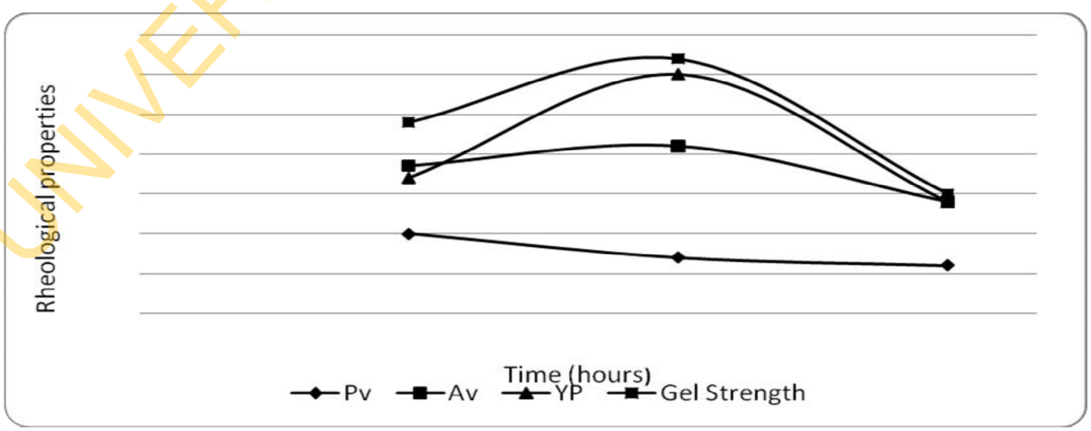

Fig. 4. Rheological properties against time for drilling fluid treated with starch

Table 3. Empirical constants for plastic viscosity and yield point predictive models

	Plastic viscosity				Yield point			
Mud Sample	β_0	β_1	β_2	β_3	α_0	α_1	α_2	α_3
Maize starch	5.95	1.06	0.81	-0.19	12.67	6.99	0.30	-5.13
Industrial starch	8.19	2.06	1.06	-0.56	13.77	7.63	0.38	-5.27
Cassava starch	7.76	1.94	0.94	-0.31	13.67	7.36	0.34	-5.23

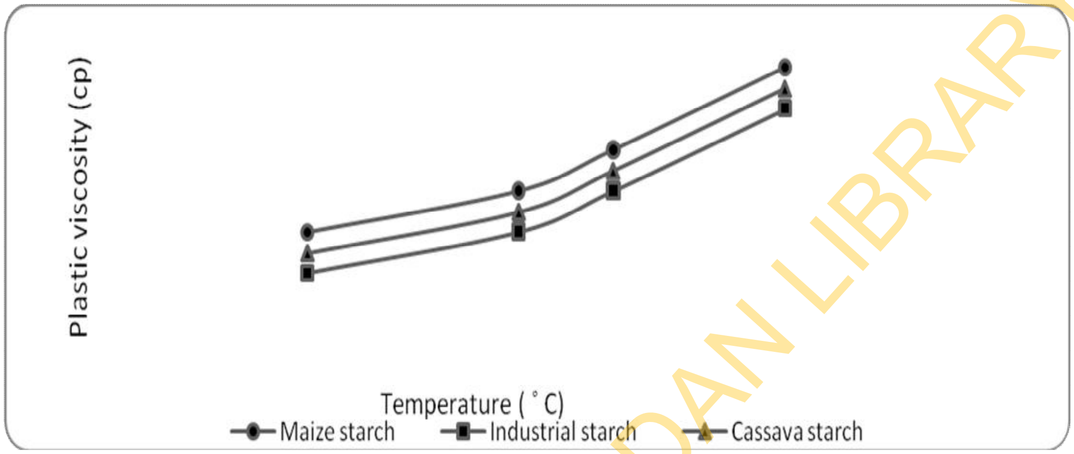

Fig. 5. Plastic viscosity (cp) against Temp (°C) for drilling fluid treated with 10 g starch and 5g potash

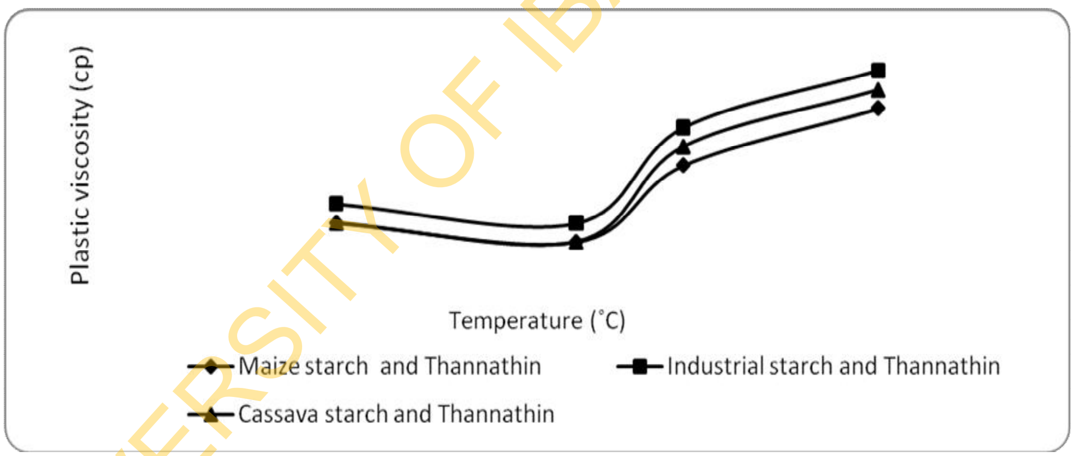

Fig. 6. Plastic viscosity (cp) against Temp (°C) of drilling fluid treated with 10g of starch and 5g tanna thin

Table 4. Coefficient of Variance for Plastic Viscosity of Starches

Starch	Variance	CoV %
Maize	0.219	92.87
Industrial	0.219	93.75
Cassava	0.219	93.25

4. CONCLUSION

Based on this study, it can be concluded that the rheological properties of water based drilling fluids treated with maize and cassava starches decrease with increase in temperature. This shows that these locally produced starches are useful in controlling the rheological properties of water base muds. Cassava starch provided closer rheological profiles to that of industrial starch. Empirical models have been developed to predict the rheological properties of treated water based drilling fluids. This method can help to achieve improved performance and significant cost reduction. Furthermore, it was observed that both maize and cassava starches degraded with time hence further research on their modification is required to reduce their biodegradation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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