

**EXPERIMENTAL INVESTIGATION ON THE EFFECT OF
TEMPRATURE USING YAM AS A DRILLING MUD ADDITIVE.**



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**A PROJECT SUBMITTED TO THE
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CERTIFICATION

This is to certify that this project was carried out by IBHAZE MOSES EMMANUEL of the Department of Petroleum Engineering with matriculation number ENG2002609 in partial fulfillment of the requirements for the Award of the Degree, Bachelor of Engineering (B.ENG)

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DEDICATION

This project is dedicated to Almighty God, whose infinite wisdom, guidance, and grace made this work possible.

I also dedicate it to my beloved parents Mr. and Mrs Ibhaze for their endless love, encouragement, and sacrifices throughout my academic journey.

To my lecturers, colleagues, and friends, whose support and inspiration motivated me to complete this research successfully this work is for you.

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First and foremost, I give all glory and thanks to Almighty God for His guidance, wisdom, and strength throughout the period of this research and for making its successful completion possible.

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Special thanks to my parents and family members for their love, patience, moral, and financial support throughout my academic pursuit. Your prayers and encouragement gave me the strength to persevere.

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ABSTRACT

Temperature increases with depth as we drill through or within deep formations; therefore, producing from such high temperature zones involves several challenges to petroleum engineers in terms of drilling, completion, and production. This makes it necessary to study the rheology of drilling fluids and how it is affected by these changes. Laboratory tests were carried out to determine the mud weight, pH, plastic viscosity, yield point, gel strength of mud samples at different conditions of temperature and concentration of yam powder used as an additive. The first stage was to investigate how the mud properties of water-based Bentonite muds are affected by different concentration (3g, 5g, 7g and 9g) of yam powder added as an additive to improve the muds properties. The second stage was to investigate the effects of temperature on the mud properties at different concentrations of yam additive with a temperature variation of 28°C, 40°C, 60°C and 80°C. From the results obtained, it could be seen that the mud weight, plastic viscosity, yield point and gel strength improved significantly but the pH reduced as the yam powder was added to the fresh mud at various concentrations. The mud weight, pH, plastic viscosity and yield point decreased as the temperature increased from 28°C to 80°C. The gel strength showed increase with increasing temperature of 28°C to 80°C. From this work, temperature has a remarkable effect on properties of drilling mud. Proper knowledge of the key factors governing the selection of drilling mud is critical for appropriate drilling mud selection because the behavior of the drilling mud under high temperature is extremely important for drilling geothermal wells and for drilling deep wells.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The oil industry as mentioned in many Petroleum Engineering books started from the famous Drake well which was believed to be the first oil well. It was drilled in 1859 at Titusville, Pennsylvania. Drake well was drilled with an iron rod and had a depth of 69½ feet. Shortly after that, many other wells were drilled in Pennsylvania to an extent where the oil prices dropped immensely. Ever since then, engineers continue to come up with new ideas to move the oil and gas from the ground to the market. The use of drilling fluid is one of the advancements achieved from these new ideas with the aim to remove the drilled cuttings from the wellbore, stabilize the hole and many others.

Failure of drilling fluid to undertake its required functions may lead to many other problems and eventually cause excessive loss of money. In fact, most drilling problems are affected either directly or indirectly to drilling fluid. Different types of drilling fluids used by drillers today depending on the formation to be drilled. To avoid any problem, the proper mud must be used with the correct properties (Amorin, 2014).

Drilling mud, also known as drilling fluid in Petroleum Engineering is a heavy, viscous liquid mixture that is used in oil and gas drilling operations to carry rock cuttings to the surface and also to lubricate and cool the drill bit (George and Darryl, 1983). The original use of the drilling mud was to remove cuttings continuously. Progress in drilling engineering demanded more sophistication from the drilling mud. Drilling mud selection is a function of the behaviour of the formation to be drilled (Johannes, 2011; Joel et al, 2012). As the drilling mud evolved, their design changed to have common characteristic features that aid in safe, economic and satisfactory

completion of a well. In addition, amongst other functions, drilling mud is also now required to Assist in cementing and completion of well, Seal the formation pores by forming low-permeability filter cake to prevent inflow of formation fluids into the well (Growcock and Harvey, 2005; Darley and Gray, 1988).

Drilling fluids are the fundamental demand in majority of drilling operations. Most wells are drilled with clear water for faster penetration rates, until a depth is reached where hole conditions dictate a need for a fluid with special properties (Dankwa *et al.*, 2018). Enhancers such as clay as filtrate reducers, viscosifying agents and dispersants for rheology control have to be added to the drilling fluids. The main requirement of any drilling fluid is to removing cuttings from the wellbore to the surface. For the effectiveness of the fluid to be able to remove cuttings, the fluid has to have some viscosity (Neff *et al.*, 2005). Therefore, it is important to monitor and continuously adjust the viscosity of the drilling fluid during drilling process to achieve the purpose the mud is designed for (Okumo and Isehunwa, 2007). Aside removing cuttings from the well, the mud should be capable of forming a thin seal preventing fluid from and to the formation otherwise, it will cause stuck pipe and loss of circulation, an influx or a kick that may graduate to a blowout, formation damage just to mention but few (Igbani *et al.*, 2015). Various materials, chemicals and polymers are used in mud formulation to convene different practical mud requirements such as density, rheology and fluid loss control, etc.

Hydroxyl-Propyl and Carboxyl-Methyl starches are used in drilling fluids, completion fluids and various brine systems as well as in drilling-mud systems. The use of starch typically causes temperature stability, a minimal increase in viscosity while effectively controlling fluid loss (Ademiluyi *et. al*, 2001).

1.2 Yam

Yam is any of several plant species of the genus *Dioscorea* (family Dioscoreaceae) grown for their edible tubers. Yams are native to warmer regions of both hemispheres, and several species are cultivated as staple food crops in the tropics. In certain tropical cultures, notably in West Africa and New Guinea, the yam is the primary agricultural commodity and the focal point of elaborate rituals. Yams are consumed as cooked starchy vegetables. They are often boiled and then mashed into a sticky paste or dough, but they may also be fried, roasted, or baked in the manner of potatoes.

Yam plants have thick tubers (generally a development of the base of the stem), from which protrude long, slender, annual, climbing stems. The leaves are either alternate or opposite and can be entire or lobed. The unisexual flowers are borne in long clusters. The flowers are generally small and individually inconspicuous though collectively showy. Each consists of a greenish bell-shaped or flat perianth of six pieces, enclosing six or fewer stamens in the male flowers and surmounting a three-celled three-winged ovary in the female flowers. The ovary ripens into a membranous capsule, bursting by three valves to liberate numerous flattish or globose seeds. Yam is in the class of roots and tubers that is a staple of the Nigerian and West African diet, which provides some 200 calories of energy per capita daily. In Nigeria, in many yam-producing areas, it is said that "yam is food and food is yam". However, the production of yam in Nigeria is substantially short and cannot meet the growing demand at its present level of use.

1.3 Rheology

Rheology is one of several important factors that need to be taken into consideration in the design of food processing plants in order to assure the quality of the end products. Rheology also, concerns the flow behavior of the products.

Rheologically, the consistency is described by two components, the viscosity (“thickness”, lack of slipperiness) and the elasticity (“stickiness”, structure).

In practice, therefore, rheology stands for viscosity measurements, characterization of flow behavior and determination of material structure. Basic knowledge of these subjects is essential in process design and product quality evaluation.

1.4 Statement of the Problem

The establishment of Nigerian Local Content Initiative in the Oil and Gas Sector by the Federal Government of Nigeria has necessitated the need for local substitutes to foreign drilling fluid materials. The use of drilling fluid in Nigeria over the years has been faced with the challenges of either importing materials for mud production or importing already prepared drilling mud which is extremely cost. The elevated temperatures downhole causes the rheological properties of drilling muds to vary from those measured at ambient temperatures. Additives that increase viscosity at the surface might perform differently downhole and rather decrease the fluid’s viscosity. Hence, it is important to study the effect of temperature on drilling muds with local additive and evaluate their various characteristics, then evaluate its suitability in drilling process.

1.5 Aim and Objectives of the Study

The aim of this work is to investigate the effect of temperature on the use of yam powder as a drilling mud additive.

The specific objectives are as follows:

- i. To collect and prepare drilling mud samples.
- ii. To experimentally determine mud properties of the formulated mud using local additive

iii. To determine the effect of temperature on the yam powder formulated drilling mud

1.6 Scope of the Study

This study will be based (centered) on study of effect of temperature on yam powder formulated drilling mud. The parameters such as viscosity, pH, mud weight, sand content, yield point and plastic viscosity will be based on analyzing effect of temperature on the drilling mud with local additive.

1.7 Significance of the Study

To meet the demand of formulating local drilling mud in the oil industry by Federal Government of Nigeria, eradicating the problems created through importation of foreign additives and identifying requirements to drill oil and gas wells at higher temperatures.

1.8 Limitation of the Study

This report/study limits to the use of only local yam as local additive in production of drilling mud without other local additives being used in manufacturing process.

CHAPTER TWO

2.0 LITERATURE REVIEW

According to McDermott (1973), drilling fluids have been in existence far before the emergence of the petroleum industry. Prior to 1844, when the first patents covering rotary drilling methods were issued to Robert Beurt in England, drilling fluids mainly water had been used in China, Persia, Egypt and Europe to drill wells. The use of only water was with the understanding that fine cuttings will mix with water to produce a mud that will perform the functions of drilling mud.

Hayem and Pollard (1914) investigated the use of mud laden fluid for the Oklahoma cable tool drilling. They explained a mud-laden fluid as a mixture of water with any clay which will remain suspended in water for a considerable length of time. They concluded that a “fire sticky clay” described as “gumbo” was a very good component of drilling mud. They equally warned against hard shale cuttings that were hither being used.

Neff (2010) brought forward the idea of improving the weight of the mud using additives. He recommended fine-ground iron-oxide as a good weighing material for water slurries, given a mud weight in the range of 15-18 ppg. The use of this material was short-lived due to its dark colour and skin staining effects. Further works in this respect led to his advancing Barium Sulphate (Barite) for mud weighing due to its high specific gravity, low abrasive properties and non-toxicity.

Dear *et al.* (2018) discovered use of bentonite in the search for better mud making material, subsequent tests showed that, it has the ability not only to suspend heavy cuttings but in addition has certain good mud properties which have been achieved only through chemical treatment. Some of these properties include moderate filtrate loss and good wall building properties, viscosity and gel strength.

Okorie, (2006) showed that the measured rheological properties of the Nigerian clays in their nature states were far below the API specification. Also, concluded that addition of 1g of hydroxide were appropriate to upgrade 20g-1000g of the nature clay samples in 350ml of distilled water.

Studies by Akanaga and Okoro (2016) on the suitability of some Imo state clays for preparing drilling muds showed that the clay did not show good drilling property in their natural states of occurrence, but on chemical treatment, they can be used as drilling muds but at low temperature and pressure conditions.

Oladuwa and Olanrewaju (2004) carried out a study the use of Tapioca as a substitute for standard viscosifier. A water base mud was prepared of two different sample, A and B. Sample A + CMC and Sample B + Tapioca. The result showed that tapioca acts as a viscosifier on drilling fluid although not as effective as the standard viscosifier in this case, CMC.

Studies by Ahmed et al, (2005) on the rheological characteristics of Arabic gum in combination with guar and xanthan using response surface methodology-effect of temperature and concentration showed meaningful results. Blends of guar, Xanthan and Arabic gum were prepared as per design. The combination of Arabic-guar exhibited shear-thinning behavior while Arabic-xanthan combination behaved as a dilatants fluid with yield stress.

Okorie (2009) studied the *“Modification of drilling fluid pH with local additives (ash of burnt palm head sponge (BPHSP) and a rich potash mineral known as Trona (AK-P) popularly called “akonku””*. The result showed that all two local Nigerian pH mud additives can increase the mud pH of water base mud.

Ademiluyi (2011) *et al* investigated a local polymer (Cassava starch) as a substitute for imported sample in viscosity and fluid loss control of water base drilling fluid mud. The results showed that

local starches could be used as substitute for the imported sample to control viscosity and fluid loss in water base drilling muds.

Olatude *et al* (2011) carried out a study on “*Improvement of Rheological Properties of Drilling Fluid using Locally Based Materials*”. The results showed guar gum can be used in the formulation of both water-based oil based drilling fluid and for all types of drilling processes where temperature and pressure would likely to be on the increase. It also demonstrated good fluid retaining properties.

Nmegbu *et al* (2014) carried out a study on corn cob cellulose and its suitability for drilling mud formulation. The researchers utilized a mixture of PAC + Xanthan gum, corn cob cellulose + Xanthan gum. The result shows that cellulose from corn cob can control fluid loss in a drilling mud significantly and even better when the concentration is increased in a water based mud.

From Kekpugile *et. al* (2014) formulated drilling fluid using cellulose from groundnut husk. Drilling fluid was successfully prepared from groundnut husk and it can adequately be used as a substitute for the standard one. The pH, mud density and specific gravity of the mud prepared from groundnut husk cellulose is higher than that of the standard mud. The rheological properties of the prepared mud were lower than that of the standard. Cellulose from processed groundnut can control fluid loss in a drilling mud effectively and also at higher concentration.

Omoniyi and Ádewale (2014) carried out a study on “*Potential Usage of Local Weighting Materials in Drilling Fluid a Substitute to Barite*”. Five different locally available ore minerals [minerals found within Nigeria] that has almost the same property with barite (BaSO_4) in terms of its specific gravity, hardness, solubility in water, cost effectiveness e.t.c or even better were used as weighting agents during the formation of the drilling fluids. namely: Barite[BaSO_4],

Hematite[Fe₂O₃], Galena[PbS], Calcite(CaCO₃), and Illmenite [FeTiO₃] with equal volume of water-base mud were prepared using each of this samples as a weighting Agent. The rheological properties of the muds as well as other properties were evaluated such as specific gravity, hardness, solubility in water, viscosity [plastic and apparent], yields point, PH, gel-strength and cost effectiveness are compared to the mud formulated using barite as a weighting agent. After careful observation and comparison of these mud properties to that of mud formulated using barite as weighting agent, possible substitute for barite, especially in the oil drilling industries include ilmenite.

Ifeoma (2015) carried out a work on “*Drilling Mud Formulation Using Potato Starch (Ipomoea Batatas)*”. A water base mud was prepared of two different sample, A and B. Sample A + PAC and Sample B + potato starch. Results from this study have shown the efficiency of Potato starch as a viscosifier and as a fluid loss reducing agent. It recorded a pH ranging from 7.0 to 9.0, Specific gravity between 0.83-1.09 and mud density ranging between 7.0 and 9.1ppg which are all in line with a standard mud specification.

Sunday Igbani, Suoton Philip Peletiri and Sonia Upulevie Egba (2015): *A Study on the Individual Impact of Cassava Starch and Hydroxyl Propyl-Modified Starch on Mud Density.* A water base mud was prepared of two different sample, A and B. Sample A + hydroxyl propyl-modified-starch+local clay and Sample B + cassava starch+ local clay. From the results of this research the following conclusions have been drawn;

- It was observed that the impact of hydroxyl propyl-modified-starch on the mud density of the formulated water-based drilling mud was more effective than that formulated with local starch.

- Hydroxyl propyl-modified-starch and cassava starch have the potential to be used as weighting materials during the formulation of water-based drilling mud.
- Primarily hydroxyl propyl-modified-starch and cassava starch very fine particles will not be abrasive to bottom-hole equipment.

U. Akpabio Julius, I. Akpanika Offiong and O. Etim Idorenyin (2015): *The Use of Galena as Weighting Material in Drilling Mud.* Two mud samples were prepared which comprised of fresh water, caustic soda, bentonite and the weighting material. The weighting materials are added to achieve the required density. **Sample A:** Water-based mud with commercial barite of density between 9.0 ppg and 15.0 ppg. **Sample B:** Water-based mud with galena of density between 9.0 ppg and 15.0ppg. The result show that galena mud sample gave a little higher yield point and gel strength than barite mud sample. Therefore, galena has the potential to be used as weighting material in drilling mud in place of Barite thereby enhancing the local content initiative of the government. When Galena is sourced locally and used it will reduce overall mud and drilling costs.

Akinade Akinwumi and Afolabi Funsho (2015): *Experimental Investigation of the Use of Local Clay (Abbi, Delta State, Nigeria) As A Substitute for Foreign Imported Bentonite Clay In: The Formulation Of water Base Drilling Fluid.* Two samples A and B were prepared. Sample A +locally sourced bentonite from Abbi (Delta state) and sample B + imported bentonite. At the end of this laboratory analysis, it was obvious that most of the properties of the local clay such as: mud weight, gel strength, sand content, consistency index and power law index meet the standard specification of imported foreign drilling mud, while other rheological properties and mud pH needed a little treatment with additives to improve it properties to meet that of a foreign imported mud.

Sonny Irawan, Chow Weng Sum and Kori B Mohammad (2010): *Formulation of Drilling Fluids for High Temperature Well Application Using Sabah Bentonite.* Two samples A and B were prepared. Sample A +locally sourced bentonite (sabah) and sample B + imported bentonite (India). The results of this work showed that the locally-sourced treated bentonite is technically and economically feasible for use as a drilling fluid.

Omotioma M, Ejikeme P. C. N and Ume J. I (2015): *Improving the Rheological Properties of Water Based Mud with the Addition of Cassava Starch.* From the analyses of the experimental results, water based mud with 4% locally sourced cassava starch appears to be the optimum concentration. The cassava starch additive improves the rheological properties of the drilling mud.

Th.S. Mihalakis, P. G. Makri, V. C. Kelessidis, G. E. Christidis and A. E. Foscolos (2004): *Improving Rheological and Filtration Properties of Drilling Muds With Addition Of Greek Lignite.* Water based mud was prepared using commercial bentonite (Zenith) and Greek lignite. It was observed that addition of lignite improves the stability of the drilling fluid. A major improvement is observed when 3% lignite is used as additive. The performance of Greek lignite was comparable to the performance of the commercially available lignite product. An attempt is made to quantify the positive effects in terms of the type of lignite added.

Samavati R., Abdullah N., Tahmasbi Nowtarki K., Hussain S. A., and Awang Biak D. R (2014): *Rheological and Fluid Loss Properties of Water Based Drilling Mud Containing HCl-Modified Fufu as a Fluid Loss Control Agent.* Mud samples were prepared in 3 different mud weights (75,100 and 150pcf representing light, average and heavy weight, respectively). HCl-modified *fufu* (cassava derivative) applied as an additive in WBMs formulation for use under the temperature of 300 °F has shown a significant improvement as compared to that without acid-

modification. A significant amount of fluid loss reduction was obtained within light and average mud weights formulation (75pcf and 100pcf). Although none of the samples (modified and unmodified) meet the NISOC fluid loss standard requirement (up to 2mL of fluid loss) for the applied temperature, a great improvement was observed in ascending order of 16%HCl > 8%HCl > unmodified *fufu* WBMs, accordingly.

Vikas Mahto and Rajat Jain (2013): *Effect of fly ash on the rheological and filtration properties of water based drilling fluids.* Initially, different drilling fluids combinations were prepared using carboxy methyl cellulose (low viscosity grade), polyanionic cellulose, xanthan gum, and potassium chloride. The rheological properties as well as filtration properties of these drilling fluids were measured by API recommended methods. These drilling fluids show very good rheological behavior but poor filtration loss characteristics. When fly ash was added in these drilling fluid combinations, a nanoparticles fluid system was established which has better control on filtration properties without affecting the rheological properties and has good potential for the drilling of sensitive formations.

Nasiri A. R, Valizadeh. M, Norouzi. H, and Hemmati. M (2012): *Investigating the Effect of Polythin and Polydrill on the Properties of Drilling Fluids.* Polythin and Polydrill were examined and the results indicate better rheological properties due to the presence of such polymers. In the case of calcium chloride, rheological parameters are almost constant, while FL has greatly increased. The addition of cement and gypsum results in smaller values of rheological parameters, while it causes a slight increase in FL. Also, pH lead to smaller AV and PV values. However, YP and FL are nearly constant.

Kaihe *et al* (2014) study on “*Properties Evaluation and Application of Organic Amine Inhibitor on the Properties of Drilling Fluids*” was done. An organic amine inhibitor was developed and evaluated. Experimental results showed that the organic amine inhibitor could decrease the surface tension to 50mN/m and had a little effect on the Zeta potential of clay. The inhibitor could effectively inhibit the dispersion of core and cuttings and had a lasting strong inhibition. The inhibitor had good compatibility with common drilling fluid, and it was useful to maintain drilling fluid stability under high temperature and could improve the filtration property of drilling fluid.

2.1 Composition of Drilling Fluid

Water-based drilling mud most commonly consists of bentonite clay (gel) with additives such as barium sulphate (barite), calcium carbonate (chalk) or hematite.

Oil-based drilling fluid is composed of oil as the continuous phase, usually diesel oil, mineral oil or low toxicity mineral oil. Because some water will always be present, OBM must contain water-emulsifying agents. Emulsifiers are important to oil-based mud due to the likelihood of contamination. The water phase of oil-based mud can be freshwater, or a solution of sodium or calcium chloride. The external phase is oil and does not allow the water to contact the formation. The shales don't become water wet. Various thickeners are used to influence the viscosity of the fluid, e.g. xanthan-gum, guar-gum, glycol, carboxyl-methylcellulose, polyanionic cellulose (PAC), or starch. In turn, deflocculants are used to reduce viscosity of clay-based muds; anionic polyelectrolytes (e.g. acrylates, polyphosphates, lignosulfonates (Lig) or tannic acid derivatives such as Quebracho) are frequently used. Red mud was the name for a Quebracho-based mixture, named after the colour of the red tannic acid salts; it was commonly used in the 1940s-1950s, then, was made obsolete when lignosulfonates became available. Other components are added to provide various specific functional characteristics as listed above. Some

other common additives include lubricants, shale inhibitors, and fluid-loss additives (to control loss of drilling fluids into permeable formations). A weighting agent such as barite is added to increase the overall density of the drilling fluid so that sufficient bottom-hole pressure can be maintained thereby preventing an unwanted (and often dangerous) influx of formation fluids (Darley, 1988).

2.2 Requirements of a Good Drilling Mud

A drilling fluid should be environmentally acceptable to the area in which it is used; in addition, it should be non-corrosive to the tubular being used in the drilling and completion operations. Most importantly, the drilling fluid should be non-damaging to the productive formation and it should not reduce the rate of penetration. Finally, the drilling fluid should not require excessive pump pressure at the desired circulation rate.

2.3 Type of Drilling Fluids

The term “drilling fluid” covers a wide range of fluids, including water-based, oil-based, synthetic-based, air, and even foam. The challenges met during drilling operations in the petroleum industry have led to the formulation of different types of drilling fluids. Drilling muds are classified based on the continuous phase of the mud and they include;

2.3.1 Water Based Muds

Also referred to as aqueous drilling fluid, which is 90–95 % of fresh water, salt or sea water and several dissolved substances meaning that water is the continuous phase here (Devereux, 1999). A water-based mud consists of four basic components: water, active colloidal solids, inert solids, and chemicals. A water-based drilling fluid or mud is one in which water is the continuous phase and the suspending medium for solids and other liquids, regardless of whether oil is present. The

primary function of the continuous phase is to provide the initial viscosity, which can be modified to obtain any desirable rheological properties. The second function of the continuous phase is to suspend the reactive colloidal solids, such as bentonite and inert solids, such as barite. Water also acts as a medium for transferring the surface available hydraulic horsepower to the bit on the bottom of the hole. Water is also the solvent for all conditioning chemicals added to the drilling fluid. In water-based drilling muds, clay is added to increase density, viscosity, gel strength, and yield point, and to decrease fluid loss. Clays used in water-based drilling fluids are mainly of three types: montmorillonites (bentonite), kaolinites, and illites. Chemicals used in water-based muds can be grouped according to their functions as follows: thinners, dispersants, and deflocculants. Water-based drilling muds are relatively inexpensive. Modern water-based drilling formulations are generally non-toxic to marine fauna. Discharged cuttings will disperse in the water column. It is predominantly used in the industry due to its environmentally acceptable nature, and also because it is relatively cheap to operate with. There are several types of Water Base Mud as seen below;

2.3.2 Dispersed Muds

These mud types is basically used at greater depths requiring higher densities or in problematic hole conditions where heightened treatments are required. The mud system would be dispersed with specific additives to give specific properties to the mud e.g thinners or dispersants.

2.3.3 Non – Dispersed Muds

These mud type is basically applied for shallow wells or top-hole sections. Clear or native water is used and examples are spud muds, natural muds and other lightly treated systems. The use of thinners or dispersants to disperse drilled solids and clay particles is not required, rather, the water

is allowed to react with formations containing shales/clays so that the mud will form solids content and density naturally.

2.3.4 Salt water Muds

This could either be a saturated salt system with chlorides concentration around 190,000 mg/l, which is suitable for salt formation drilling in order to prevent dissolving, or a saltwater system where chloride concentration lies between 10,000 and 190,000 mg/l. (Van, 1998).

2.3.5 Polymer Muds

Long chain polymers such as cellulose and acrylamide are used in mud systems to provide a number of functions; increase viscosity, prevent dispersion by acting as encapsulating agents to drilled solids, minimize fluid loss, and inhibit or prevent sloughing of shales by coating. Example of such is KCl/NaCl muds which are inhibited salts that stabilize shale formations.

2.3.6 Low solids Mud

This mud system is significantly used to control or improve the rates of penetration. These are systems where the amounts of solids are intentionally controlled with a range of 6 to 10 % total solids volume and clay volume not more than 3 %. They typically use polymer additives as viscosifier and are non-dispersed.

2.3.7 Calcium Muds

The presence of calcium or magnesium in fresh water drilling muds inhibits swelling and hydration of clays and shales, but with higher levels of dissolved calcium, the problems of shale sloughing and hole enlargement are greatly reduced. Calcium treated muds also resist contamination and are therefore suitable for use in drilling gypsum/anhydrite lithologies. However, they are susceptible to gelling and solidifying at elevated temperatures. (Downs *et al.*, 1993)

2.3.8 Oil Based Muds

These muds have oil as their continuous phase, usually diesel oil, mineral oil or low toxicity mineral oil, and although they may pick up formation water, no additional water or brine are added. This is due to the fact that they contain water emulsifying agents. This system which contains less than 5 % water has a number of advantages compared to Water Base Mud, but it also has some drawbacks (Van, 1998; Devereux, 1999).

2.3.9 Invert Emulsion Muds

These are water-in-oil emulsions typically with base oil or diesel as the continuous phase, and up to 50 % brine in the emulsifier phase. They are used in 10-20 % of all drilling jobs and find more application in stable, water sensitive formations and in inclined bore holes. They are very high thermal stabilities and provide excellent corrosion protection. However, their disadvantages are their high price, the great risk if gas reservoirs are bored through and their huge environmental problems. An example of an emulsifier used in these systems is calcium chloride brine.

2.3.10 Emulsion Muds

In these muds, water is the major continuous phase, with oil now making up the dispersed phase, normally between 5-10 %. Environmental issues and cost are both minimized with water constituting the main phase, but with the addition of oil, the advantages associated with oil base systems are provided, such as improved lubricity, increased rate of penetration, reduced torque and drag effects, reduced filter loss.

2.3.11 Synthetic-Base Muds

Out of an increased desire to reduce the environment impact of offshore drilling operations, synthetic-base muds were developed but without sacrificing the cost effectiveness of oil-based

systems. They (synthetic oils and mineral oils) provide much of the performance advantages of hydrocarbon oil systems but have none of the associated environmental concerns (Fink, 2011). Like OBMs, SBMs can be applied to minimize wellbore stability problems arising from reactive shales, maximize the rate of penetration and increase lubricity in directional and horizontal wells. Examples of synthetic mud systems are esters, ethers and poly or isomerized alpha olefins. These have high biodegradability and low toxicity and as such, are good base fluids for environmental performance.

2.5 Functions of Drilling Fluid

Some functions of the drilling fluid can vary with the type of well or formation, but the basic functions remain the same for most oil-well drilling operations.

The importance of a certain function of a drilling fluid will depend on the specific well being drilled.

2.5.1 Remove cuttings from the well

The drilled cuttings that are generated by the drill bit must be removed from the well. As the drilling fluid is circulated as described above, it carries the cuttings with it to the surface. This removal, also called hole cleaning, is a function of cuttings size, shape and density, rate of penetration (ROP), drill string rotation, and of the viscosity, density and annular velocity of the drilling fluid.

The viscosity has a significant role in hole cleaning, as cuttings will settle quicker if the fluid viscosity is low. A high viscosity usually means better hole cleaning.

The fact that the drilling fluid is thixotropic means that when there is no circulation, the cuttings can be suspended by the gelled fluid.

2.5.2 Controlling formation pressures

Controlling the pressure of the formation is one of the basic functions of the drilling fluid in order to prevent the influx of formation fluid into the well. This is achieved by controlling the density of the fluid with weighting agents such as barite. The hydrostatic pressure exerted by the drilling fluid must be equal or higher (preferably higher) than the formation pressure. This exerted pressure is a function of the True Vertical Depth (TVD). Geologists and Petrophysicists will provide a prognosis of the formation pressure. In the mud program, the drilling fluid density specification is given as a pressure gradient, usually specific gravity or pounds per gallon.

In case there is loss of well control (influx of formation fluid), a higher density fluid is pumped into the well to regain control of the well.

2.5.3 Suspend and release cuttings

As mentioned in the first point, when there is no circulation in the well, the drilling fluid must be able to suspend the cuttings, avoiding the accumulation of cuttings at the bottom of the well, also called pack off. Cuttings suspension is better achieved when a fluid has high viscosity. On the other hand, when the fluid passes the solids control equipment, a low viscosity would be ideal, so that the cuttings are released by the fluid. The solution for this is the shear thinning nature of the drilling fluid, which allows for the cuttings to be removed.

The fluid must also be able to suspend the weighting material used, otherwise it will sag and the density will not be homogeneous throughout the drilling fluid.

2.5.4 Seal permeable formations

Because the hydrostatic pressure created by the drilling fluid column is higher than formation pressure, some of the fluid will enter the formation around the well bore. The fluid is designed to minimize this invasion, by the addition of fluid loss agents. A high fluid loss is undesirable because

it can contaminate the formation and have a negative effect on wellbore stability and future production from the well. The protective layer, also called filter cake, produced should be easily removable if the well is to be used for production or injection.

2.5.5 Maintain wellbore stability

Wellbore stability depends on both chemical and mechanical factors. If the drilling fluid is not compatible with the formation, this may swell and cause the drill string to become stuck. The density also plays a role in wellbore stability by balancing the mechanical forces that act on the wellbore, thus avoiding collapse of the formation.

2.5.5 Cool, lubricate and support the bit and drilling assembly

While drilling, the rotation of the drill string and the circulation of the drilling fluid create friction forces that generate heat. As one drills deeper, the formation temperature also increases significantly. All this heat combined can be excessive for the bit, mud motor or other down hole equipment, and the drilling fluid helps to reduce the bottom hole temperature. Some rigs may have a mud cooler installed at surface, when bottom hole temperatures are elevated.

Lubrication is also provided by the fluid and this will depend on the drill solids content, pH, salinity and hardness of the fluid.

Support of the drilling assembly is achieved by buoyancy. This helps reduce the hook load when running the drilling assembly and casing strings.

2.5.6 Transmit hydraulic energy to tools and bit

Down hole tools like Measurement While Drilling (MWD) and Logging While Drilling (LWD) are usually powered by the energy of the flowing drilling fluid. The same happens when drilling with mud motors. To achieve good hole cleaning, the sizes of the bit nozzles are usually chosen

so that the hydraulic efficiency at the bit is high. This has a great positive impact removal of cuttings from the well.

2.5.7 Ensure adequate formation evaluation

During a drilling operation, the cuttings retrieved at the solids control equipment and the mud returning from the well, are analysed and monitored for traces of oil and gas. The drilling fluid must allow a clear distinction between the hydrocarbons and the fluid, as well as the identification of the minerals present in the rock.

The chemical composition of the drilling fluid also affects the readings from the logging tools, taken either while drilling or at a later stage. These readings are of extreme importance for the operator company to obtain more knowledge of the subsurface and the formation around the specific well. (MacDermott, 1973)

2.6 Properties of Drilling Fluids

Properties of drilling fluids During a normal drilling operation, the drilling fluid is tested at least twice per 12 hour shift to determine the values of a set of properties. The monitored properties depend mostly on the type of fluid being used, and can include the following:

2.6.1 Density

It is necessary for controlling the pressure and all pressure control calculations are done based on the weight of the mud column in the hole. As density is increased, the buoyancy effect increases carrying capacity for cuttings but decreases settling rate in the mud pit. A mud balance is used to carry out weight measurements on mud samples during drilling operations. During this measurement, precaution must be taken not to include air or entrained gas in the mud sample as this would give a false density measurement, particularly with muds having high yield points or gel strengths. (Max R. Annis and Martin V. Smith., 1974).

2.6.2 Rheological Properties

These properties, otherwise known as flow properties, describe the flow characteristics of a mud under different flow conditions. In order to predict or know the effects of this flow, it is important that the flow behaviour of the mud at various points of interest in the mud circulating system are known. The categories of drilling fluid are determined by the fluid behaviour when it is subjected to an applied force (shear stress). Based on rheological properties, fluids can be categorized into two types depending on the viscosity of the fluid.

- Newtonian fluids
- Non-Newtonian fluids.

Very simple fluids such as oil or water that have the ratio of the shear stress to shear rate giving a constant are called Newtonian fluids. For such, measurement of shear stress at one shear rate is good enough to predict flow behaviour at all shear rates. The ratio of shear stress to shear rate is termed the viscosity.

Viscosity, which is a measure of a fluids resistance to flow, is used to characterize flow behaviour of Newtonian fluids. It has units of centipoises. Between layers of a liquid, it can be said to be a measure of the internal friction developed as one layer slides over another and shows how thick a fluid is.

Drilling fluids where the flow relationship between shear stress and shear rate is non-linear are referred to as “Non-Newtonian fluids”. They require a certain amount of shear stress to initiate flow, and thereafter, additional stress must be added as there is an increase in shear rate. For these kinds of fluids e.g. drilling fluids and cement slurries, they contain solids that connect together to form a structure causing flow to stop when the pressure or shear stress is reduced to a point which is less than the shear strength of the structure. This point at which the shear stress is required to

initiate flow is called the fluid's yield stress or point. Allowing these non-Newtonian fluids to stand static for some time would continue to build a semi rigid structure causing the shear stress required to initiate flow to increase. The shear stress at this point is called the gel strength and the structure gains more rigidity with time resulting to increased gel strength. (Max R. Annis and Martin V. Smith., 1974). To the driller, 4 important areas where shear rate values are of paramount interest include;

- The annulus, where shear rates are low.
- The bits, having super high shear rates.
- The pits, with almost no shear rate values.
- The drill string and collars, through which hydraulic power is supplied to the bit from a pump.

2.6.3 Plastic viscosity.

It is an important mud property that gives a measure of the internal resistance to flow due to amount, type and size of solids in the mud. Due to collision of solids with one another and with the liquid phase of the mud, mechanical friction is produced deterring movement. The plastic viscosity is essentially a function of the viscosity of the liquid phase and the volume of solids contained in a mud. It describes the expected behaviour of mud at the bit. In order to minimize high shear rate viscosity, the plastic viscosity has to be minimized. By decreasing the plastic viscosity, a driller correspondingly reduces the viscosity at the bit.

Generally, a high plastic viscosity is never desirable as one might think that having a high plastic viscosity would improve the hole cleaning ability of a mud, but this would only cause more harm than good. Actually, an increase in plastic viscosity, which causes a pressure drop increase down the drill string would retard the rate of flow and tend to offset any increase in lifting ability. It is

therefore safe practice to keep the plastic viscosity as practically low as possible. The viscosity of the liquid phase is increased by addition of any soluble material.

2.6.4 Yield point

This is a measure of the attractive forces between the particles in a mud as a result of opposite charges existing on the particle surfaces causing initial resistance to flow. This mud property is dependent on the type of solids present and their respective surface charges, the concentrations of these solids, and the type and concentration of other ions or salts that may be present.

Ways by which yield point is increased include;

- Increased solids concentration e.g. addition of bentonite, -as a result of increased surface charges if the solids are in an active mode. This reduces the space between the particles if they are inactive.
- Bit action by grinding of the particles thereby exposing more active surface charges.
- Less chemical treatment as dispersants making some active charges available for interaction.
- Introduction of contaminants such as salt, cement, e.t.c. that cause the mud particles to flocculate.

A fluid with large molecules or colloidal solids tend to have them bumping into one another producing large resistance to flow. With particles that are quite long compared to their thickness, then at low shear rates, the inter-particle interference will be quite large when they are randomly oriented in the flow stream causing them to link together. However, at increased shear rates, the effect of particle interaction is reduced as the particles will be arranged in line in the flow stream. This would lead to the linked bonds being broken and fluidity is increased. The combination of these two effects determines the yield point of a mud. Chemical treatment is used to control the

electrical interaction of the solids while the mechanical interaction is controlled by regulating the quantity and type of solids in a mud.

In summary, a high yield point is caused by flocculation of clay solids or high concentrations of colloidal solids. Flocculation may be caused by high temperature, lack of sufficient deflocculent, or contaminants introduction. Flocculating agents or clay extenders are sometimes added to promote linking and cause higher yield points to be achieved. Examples include soda ash, polyacrylates and several calcium compounds. Two important mud functions which are associated with yield point include;

- Hole cleaning capability and
- Pressure control capability of the mud.

In terms of hole cleaning, the carrying capacity of a mud and the circulating annular pressure drop is increased by a higher yield point. Due to the fact that an increased yield point is detrimental to the problems of lost circulation and swabbing but good for hole cleaning, then a compromise has to be reached. Since hole cleaning capabilities are improved by increasing mud weights, then, higher yield points are usually not necessary in high weight muds to insure good cuttings carrying capacity. Furthermore, in terms of pressure control, this is often critical where high weight muds are required. As a consequence, the need to get yield point to a minimum usually outweighs any advantages of maintaining a high yield point in high density muds (Max R. Annis and Martin V. Smith., 1974).

2.6.5 Gel strength

This is a very vital mud property that measures the shear stress necessary to initiate flow of a fluid that has been quiescent for a length of time i.e. a measure of its thixotropic character. In

very plain language, it is the ability of the mud to suspend cuttings when circulation stops. It is as a result of the association between electrically charged particles within the structure causing it to be rigid which means that anything that prevents or promotes the bonding of particles in the mud will decrease or increase respectively, the tendency to gelate. The rigidity of the structure so formed is dependent on factors as the quantity and type of solids in suspension, the chemical environment, time and temperature.

2.6.6 Filtration

The fluid loss reveals the ability of the drilling fluid to form a barrier, called filter cake, which will prevent the loss of fluid into the area of the formation around the wellbore. This fluid is composed by the liquid fraction of the drilling fluid and is known as filtrate.

The filter cake should be thin and smooth, and the fluid loss should be low. The specification value for the fluid loss varies from well to well. Fluid loss is measured by placing the fluid in a cell, over a piece of filter paper and exerting back pressure, to simulate the situation found during drilling.

2.6.7 pH

The pH of a drilling fluid is important for controlling corrosion and the development of bacteria that can consume polymer additives and produce H₂S gas. It also affects the efficiency of additives such as viscosifiers and may influence the lubricity of the fluid. The pH is usually specified as a range of values and is measure using a pH-meter or by titration, in oil-based fluids.

2.6.8 Sand Content

It is important to maintain a low level of sand content in the drilling fluid due to its abrasiveness on equipment such as pumps and pipes. The sand should be removed by the solids control equipment.

2.6.9 Solid and Liquid Content

The total solids content of a drilling fluid is measured with the same test mentioned for the oil-water ratio, with the solids fraction being the volume of the initial fluid not distilled in the retort. The data is usually introduced in computer software for calculating the low gravity solids (LGS) and high gravity solids (HGS).

The low gravity solids content should be kept at low levels and is usually one of the specified parameters in a fluid program. The amount and nature of these solids will affect the density and viscosity of the fluid, filter cake build up, hole cleaning, increase pressure losses due to friction and may also limit the solubility of viscosifiers. (Gray,*et al.*,1980)

2.7 Factors Affecting Drilling Fluid Performance

The factors affecting drilling fluid performance are:

- The change of drilling fluid viscosity
- The change of drilling fluid density
- The change of mud pH
- Corrosion or fatigue of the drill string
- Thermal stability of the drilling fluid
- Differential sticking

2.8 Materials for the Production of Drilling Fluid

1. **Bentonite Clay:** Bentonite is a material composed of clay minerals, predominantly montmorillonite with major amounts of other smectite group minerals, commonly used in drilling muds.

2. **Weighting Agents:** They are used to increase the fluid density to get the fluid to control formation pressures. E.g. Barite, Iron Oxides, Calcium Carbonates, etc.
3. **Thickeners:** These are added to influence the viscosity of the drilling mud. Examples include xanthan gum, guar gum, glycol, starch, etc.
4. **Deflocculants:** Deflocculants are used to reduce the viscosity of clay based muds; anionic polyelectrolytes. Tannic acids derivatives such as Quebracho are frequently used.
5. **Fluid Loss Additives:** These are used to control loss of drilling fluids into permeable formations.
6. **Lubricants:** Lubricants are used to alter the coefficient of friction of the drill bit. Poor lubrication causes high torque and drag.
7. **Stabilizers:** They help to increase the rheological and shale stability by helping drilling fluids to perform the intended tasks under unconventional (HPHT) conditions or by preventing water contacting a shale zone.
8. **Alkalinity Agents:** They are used to control the alkalinity of the fluids as any pH level above 9.5 will increase the viscosity, however, any pH below 7 is considered acidic.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Materials

The materials used in this work are shown in table 3.1 below:

Table 3.1 Materials Used For Experiment and Function

S/N	MATERIALS	FUNCTION
1.	Bentonite	It was widely used to thicken fresh water drilling mud.
2.	Water	Served as base for drilling mud
3.	Barite	This was used as weighting agent to improve the mud properties.
4.	Yam powder	This was a local additive that was used to improve the rheological properties of the mud samples.

3.2 Equipment used for Experiment

- 1) Oven (type 48 BE Apex Tray Drier)
- 2) Weighing balance
- 3) Measuring cylinder
- 4) Hamilton beach mixer
- 5) Mud cup
- 6) pH indicator strip
- 7) Thermometer
- 8) Stop watch
- 9) Mud balance

10) 150-micron sieve

11) Spatula.

3.3 Raw Materials

The raw materials used for this study are listed below

- Bentonite from the Drilling laboratory at the Petroleum Engineering Department, University of Benin.
- Yam tubers purchased at New Market and processed into powdery form at Petroleum Engineering Department, University of Benin.

3.4 Sample Collection and Processing of Yam

The yam preparation followed a series of processes. Preparation included washing of the tubers, Pre-treatment operation which included peeling off the tuber skin, slicing, drying, grinding and sieving. Potato tubers were purchased in large amounts from New-Benin market, Benin City and the experiment was conducted at the University of Benin drilling mud laboratory. The yam samples were washed peeled using a steel knife and washed again thoroughly with clean water to remove dirt and adhering sand particles. The peeled tubers were sliced. The sliced yam was spread over an aluminium tray and sun dried for 1 week and was then measured at a weight of 1904g. It was further oven dried in the laboratory for about 6 hours at 60⁰C and the weight reduced to about 1561g and further reduced to a constant mass of 1553g after 6 hours. It was then grinded into dry powder in the laboratory using a mortar and pestle. It was sieved to obtain fine powdered particles and eventually weighed 1522g due to losses of solid particles during sieving process.



Plate 3.1: Showing yam powder

3.5 Methods of Data Collection

In course of carrying out this research, most of the data were obtained from experiment carried out on the following samples:

- a. Yam powder and Bentonite Solution

Dial readings were obtained by varying the rpm values. Mud balance was used to weigh mass of samples. Dried sample was measured over a period of time to ensure the moisture content was appreciably reduced before usage.

3.6 Instrumentation

The range of oil field equipment is so vast that we will limit ourselves to the equipment which were used in the course of the experiments. This equipment includes;

- 1) **Oven (type 48 BE Apex Tray Drier):** This was used to heat and dry materials that were used in carrying out this experiment.



Plate 3.4: Type 48 BE Oven

2) **Weigh balance and measuring cylinder:** This device finds its place when there is a need to determine the weight or volume of samples used for an experiment. Whereas the weighing balance measures dry substances, the measuring cylinder measures wet samples, i.e. liquids.



Plate 3.5: Digital weighing balance

- 3) **Mixer:** The mixer is used to provide proper mixture. They come in handy when homogeneity in the drilling fluid system is needed. The instrument has low, medium and high speed. Any of this speed can be selected depending on the desired speed.



Plate 3.6: Mud mixer

- 4) **Mud balance:** Mud balance was used to measure the density and effectively the weight of the drilling fluid. It measures in pounds per gallon (lb/gal). This is necessary because the weight of the drilling fluid is an important parameter which determines whether there will be need for weighting up or further analysis. The mud weight is taken at certain temperatures which are room temperature, at 20°F and at higher temperature if necessary.



Plate 3.7: Mud balance

- 5) **Viscometer:** Used to measure the rheological properties of the drilling fluid. It is calibrated in revolutions per minute (RPM) and the results are in centipoises (cp). It is with this equipment we calculate values for the average viscosity AV, plastic viscosity PV, and yield point and gel strengths. The rheological properties are of primary concern in the design and formulation of any type of drilling fluid, thus viscometers are very sensitive equipments and their usage has to be precise and as accurate as possible.



Plate 3.8: Fann Viscometer

- 6) **pH kit:** Used to measure the pH of any drilling fluid system. The principles are as simple and basic as always. The pH of the drilling fluid is important because different formation types have different pH requirements, thus the pH of the drilling fluid has to be carefully monitored to ensure that when the drilling fluid is used on the formation there is a balance in properties to prevent the seeping in of formation fluids to the system.



Plate 3.9: pH content kit

- 7) **Baroid sand content tube:** This was used to measure the quantity of sand present in the mud. The quantity of sand in the mud is represented in percentage by volume.



Plate 3.10: sand content tube

- 8) **Thermometer:** used basically to measure the temperature of the drilling fluid at specific intervals to ensure the temperature does not drop or increase beyond the required range. Also used alongside certain equipment like the high pressure high temperature (HPHT) filter press.



Plate 3.11: Laboratory Thermometer

3.7 Laboratory Procedure for Mud Formulation

- The yam bought from the market was dried under moderate temperature and spread out in a plastic tray in a drying oven.
- The sliced yam was then subjected to pulverization by pounding it in a mortar.
- The pulverized potato sample was sieved to obtain fine powdered particles.
- The sieved yam sample was collected in a beaker and labelled appropriately.
- Afterwards, 350ml of distilled water was measured using a 500ml measuring cylinder into the already weighed bentonite samples.
- Mud samples were prepared by mixing 22.5g of clay sample (i.e. Bentonite) with 350ml of distilled water which was measured using a 500ml measuring cylinder
- 5g of Barite was added to the solution and stirred using the mud mixer at 20 degrees for 10 minutes.
- Static ageing was used in these experiments where by the prepared samples were stored in a covered container and allowed to age at room temperature (20°C) for the days required.

- Rheological properties of the samples were determined by rotational viscometers at different ageing time and at temperatures of 20°C to 60°C with 10°C or 20°C interval between each measurement.
- Measurements were done once, likewise, gel strength was taken after 10 seconds only.

The mud was tested for the following properties; Mud weight, Plastic Viscosity, Yield point, pH and Gel strength.

3.7.1 Determination of the Mud Weight

The mud density test was conducted in order to determine the weight per unit volume of the mud. Mud density must be great enough to provide sufficient hydrostatic head to prevent influx of formation fluids, but not so great to cause loss of circulation, damage to the drilled formation, or reduce the rate of penetration (ROP). This test was done to determine whether the prepared local mud samples possess API minimum required weight for oil well drilling. The Multi-Hamilton beach mixer and Bariod mud balance were the equipment used in this study while freshly prepared sample, rag, water, masking tape, recording book and biro were reagents/materials used.

The procedures used to determine the weight of the prepared mud are;

- Before beginning, calibrations were checked (calibration mark provided on the scale for fresh water, 8.33 lb/gal or 1.0 S.G.), and the cup was cleaned and dried.
- The lid was removed from the mud cup and the filled with the mud sample. The cup was taped by the side to ensure all entrapped air bubbles were removed.
- The temperature of the heated mud was tested using a thermometer, and immediately replaced the lid on the cup and rotated it until it was firmly seated; made certain that some mud squeezed out the vent hole.

- Excess mud was washed and wiped from the exterior of the mud balance covering the vent hole. The balance was dried with the vent hole covered.
- The balance was placed in its base with the knife edges on the fulcrum rest.
- The rider was then moved until the beam was balanced. The spirit level bubble was set on the center line.
- The mud weight and hydrostatic pressure or mud gradient at the edge of the rider nearest the fulcrum (toward the knife edge) was taken.

3.7.2 Determination of Rheological Properties

This test is done to obtain the Rheological properties of the mud such as viscosity at 600 rpm and 300 rpm, 10 minutes and 10 seconds Gel strength, plastic viscosity and yield stress. The equipment used was an OFITE 900 MODEL viscometer while the reagents/materials were freshly prepared mud sample, masking tape, recording book and biro.

- The cord of the viscometer was connected to the power source and the instrument power button switched on.
- The prepared mud was poured into the sample cup of the viscometer, the ENTER button pressed and the rotor was allowed to rotate for few seconds for stabilization.
- The rotor sleeve was then immersed until the mud touched the scribed line of the rotor sleeve.
- The mud button was pressed and the viscometer automatically carried out the measurement of the 0600rpm and 0300rpm.
- The equipment calculated the 10seconds and 10minutes gel strength.

3.7.3 pH Determination

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 alkaline 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. pH measurements aid in determining the need for chemical control of the mud, and indicates the presence of contaminates such as cement and gypsum. The appropriate pH of drilling mud varies with the mud type. This study used the Multi-Hamilton beach mixer equipment with freshly prepared sample, ph-hydriion dispenser paper, masking tape, recording book and biro as reagents/materials.

As a procedure to determine the pH of the mud, the following were carried out:

- The prepared mud was re-stirred to obtain homogeneous mixture.
- The temperature of the mud was measured.
- About one inch strip of the ph-hydriion dispenser paper was removed and placed gently on the surface of the mud and sufficient time was allowed to elapsd (about few seconds) for the paper to soak up filtrate and change color.
- 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.

3.7.4 Viscometer Readings

Plastic Viscosity (cp) = Reading at 600 – Reading at 300

Yield Point (lb/100sqft) = Reading at 300 – Plastic Viscosity

The whole process was repeated for a maximum temperature of 80°C and repeated for a temperature drop of 40, 60, 80, and 28°C (room temperature).

Table 3.2: API Standard Numerical Value Requirement for Drilling Fluids

(API practices 13A section 5)

Drilling Fluid Property	Numerical Value Requirement
Mud density (lb/gal)	8.65-9.60
Viscometer dial reading @600rpm	30cp
Plastic viscosity (cp)	8 – 10
Yield point (lb/100ft ²)	3 x plastic viscosity
Fluid loss (Water)	15.0ml maximum
pH level	9.5min – 12.5max
Sand content	(1 - 2)% maximum
Screen analysis	4 (maximum)
Moisture content	10% (maximum)
Ca 2+ (ppm)	2.50 (maximum)
Marsh funnel viscosity	52 – 56 sec/q+
Mud yield (bbi/ton)	91 (maximum)
API filtrate (ml)	30 (minimum)
Montmorillonite	70 – 130
Vermiculite	100 – 200
Illite	10 – 40
Kadinite	3 – 15
Chlorite	10 – 40
Marsh funnel viscosity for water	26 sec/q+ ± 0
N-Factor (power law index)	1 (maximum)
Yp/Pv ratio	3.0 (maximum)

3.8 Precautions on using Viscometer

- Made sure that the viscometer base cover has vents to help prevent heat buildup.
- Ensured that the bob, bob shaft was cleaned after each experiment to avoid contamination with other experimental samples.
- Made sure that clothes and other objects were kept away from the rotating parts of the machine to prevent seizure of clothes by the moving parts.
- Made sure the power cord and other wiring associated with these cups and the Model 35 assembly is in good condition and properly grounded before it was used.
- Ensured the viscometer's power switch is on the OFF position and unplugged from the source before it was cleaned after each experiment.
- Made sure the viscometer base didn't get wet with the experimental samples.

3.9 Precautions on using Mud Mixer

- Ensured that the bob, bob shaft was cleaned after each experiment to avoid contamination with other experimental samples.
- Made sure the power cord and other wiring associated with these cups and the Model 35 assembly is in good condition and properly grounded before it was used.
- It was ensured that the mud cup was properly placed as the rotary shaft was in motion.
- For proper mixing, the various materials to be added to the mud for mixing were poured into the mud cup when the mud mixer was in motion and care was taken as the materials were gently poured to avoid cake formation at bottom of mud cup.

3.10 Precautions on using Mud Balance

- When filling the mud balance, it was ensured that the mud balance was filled with the mud to the tip of the balance to avoid aeration.
- Ensured the mud balance was washed and cleaned properly before placing mud samples at regular intervals
- The mud balance was very brittle; hence care was taken in handling it.
- Ensured error due to parallax was avoided when taking readings from the balance.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Results

*Table 4.1: Result of Water Based Mud + 0g Yam Additive at various
Temperatures*

Mud Property	28 °C	40 °C	60 °C	80 °C
Mud weight (lb/gal)	8.75±0.5	8.70±0.5	8.65±0.5	8.60±0.5
Mud pH	9.1±0.2	8.80±0.2	8.60±0.5	8.50±0.5
Viscometer reading @600rpm (cp)	23±0.1	23±0.1	22±0.1	21±0.1
Viscometer reading @300rpm (cp)	20±0.1	20±0.1	20±0.1	19±0.1
Mud PV (cp)	3±0.1	3±0.1	2±0.1	2±0.1
Mud gel strength @ 10seconds (lb/100 ft ²)	3.0±0.2	5.2±0.2	7.0±0.2	8.5±0.2
Mud gel strength @ 10 minute (lb/100 ft ²)	20.0±0.2	22.3±0.2	23.3±0.2	23.9±0.2
Mud yield point (lb/100 ft ²)	25.0±0.2	23.2±0.2	20.5±0.2	18.3±0.2
Mud sand % volume	0.1±0.005	0.1±0.005	0.15±0.005	0.2±0.005

*Table 4.2: Result of Water Based Mud + 3g Yam Additive at various
Temperatures*

Mud Property	28 °C	40 °C	60 °C	80 °C
Mud weight (lb/gal)	8.80±0.5	8.75±0.5	8.70±0.5	8.60±0.5
Mud pH	9.0±0.2	8.9±0.2	8.5±0.2	8.4±0.2
Viscometer reading @600rpm (cp)	25±0.5	28±0.5	27±0.5	28±0.5
Viscometer reading @300rpm (cp)	20±0.5	24±0.5	24±0.5	25±0.5
Mud PV (cp)	5±0.5	4±0.5	3±0.5	3±0.5
Mud gel strength @ 10seconds (lb/100 ft ²)	3.7±0.2	5.9±0.2	7.7±0.2	9.2±0.2
Mud gel strength @ 10 minute (lb/100 ft ²)	22.2±0.2	23.7±0.2	25.4±0.2	25.8±0.2
Mud yield point (lb/100 ft ²)	30.2±0.3	28.4±0.3	25.6±0.3	21.6±0.3
Mud sand % volume	0.15±0.05	0.2±0.05	0.20±0.05	0.25±0.05

*Table 4.3: Result of Water Based Mud + 5g Yam Additive at various
Temperatures*

Mud Property	28 °C	40 °C	60 °C	80 °C
Mud weight (lb/gal)	8.95±0.5	8.70±0.5	8.65±0.5	8.40±0.5
Mud pH	8.9±0.2	8.7±0.2	8.5±0.2	8.3±0.2
Viscometer reading @600rpm (cp)	34±0.4	37±0.4	39±0.4	43±0.5
Viscometer reading @300rpm (cp)	25±0.4	29±0.4	32±0.4	37±0.4
Mud PV (cp)	9±0.4	8±0.4	7±0.4	6±0.4
Mud gel strength @ 10seconds (lb/100 ft ²)	4.7±0.2	6.8±0.2	8.6±0.2	10.2±0.2
Mud gel strength @ 10 minute (lb/100 ft ²)	26.2±0.2	28.4±0.2	29.4±0.2	30.2±0.2
Mud yield point (lb/100 ft ²)	35.8±0.3	30.4±0.3	25.7±0.3	22.3±0.3
Mud sand % volume	0.2±0.05	0.25±0.05	0.30±0.05	0.35±0.05

*Table 4.4: Result of Water Based Mud + 7g Yam Additive at various
Temperatures*

Mud Property	28 °C	40 °C	60 °C	80 °C
Mud weight (lb/gal)	9.10±0.5	8.80±0.5	8.60±0.5	8.40±0.5
Mud pH	8.8±0.2	8.6±0.2	8.4±0.2	8.2±0.2
Viscometer reading @600rpm (cp)	38±0.4	42±0.4	46±0.4	50±0.4
Viscometer reading @300rpm (cp)	24±0.4	29±0.4	33±0.4	39±0.4
Mud PV (cp)	14±0.4	13±0.4	13±0.4	11±0.4
Mud gel strength @ 10seconds (lb/100 ft ²)	5.7±0.2	7.8±0.2	9.6±0.2	12.2±0.2
Mud gel strength @ 10 minute (lb/100 ft ²)	27.2±0.2	28.4±0.2	30.4±0.2	36.6±0.2
Mud yield point (lb/100 ft ²)	36.8±0.3	33.5±0.3	31.2±0.3	25.3±0.3
Mud sand % volume	0.2±0.05	0.25±0.05	0.30±0.05	0.30±0.05

*Table 4.5: Result of Water Based Mud + 9g Yam Additive at various
Temperatures*

Mud Property	28 °C	40 °C	60 °C	80 °C
Mud weight (lb/gal)	9.3±0.5	9.0±0.5	8.4±0.5	8.3±0.5
Mud pH	8.7±0.2	8.5±0.2	8.3±0.2	8.1±0.2
Viscometer reading @600rpm (cp)	38±0.4	42±0.4	45±0.4	47±0.4
Viscometer reading @300rpm (cp)	22±0.4	28±0.4	33±0.4	38±0.4
Mud PV (cp)	16±0.4	14±0.4	12±0.4	9±0.4
Mud gel strength @ 10seconds (lb/100 ft ²)	7.7±0.2	9.8±0.2	11.4±0.2	14.2±0.2
Mud gel strength @ 10 minute (lb/100 ft ²)	29.2 ±0.2	29.8±0.2	30.1±0.2	39.9±0.2
Mud yield point (lb/100 ft ²)	37.8±0.3	32.4±0.3	28.7±0.3	26.3±0.3
Mud sand % volume	0.2±0.05	0.30±0.05	0.30±0.05	0.35±0.05

4.1.1 RELATIONSHIP OF EFFECT OF TEMPERATURE ON MUD PROPERTIES

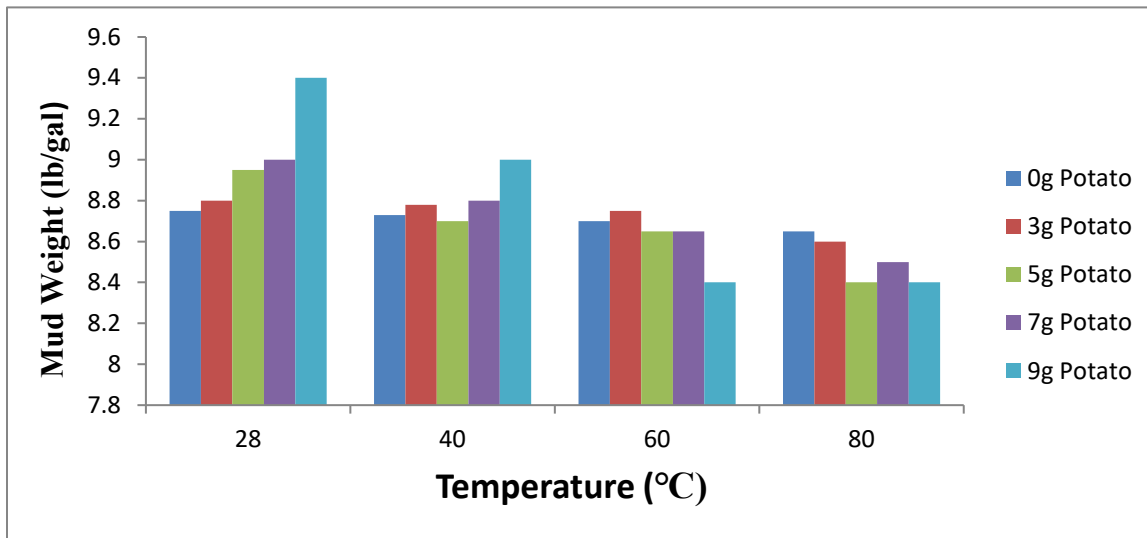


Fig. 4-1: Mud Weight of Yam Mud Formulations at Different Temperature

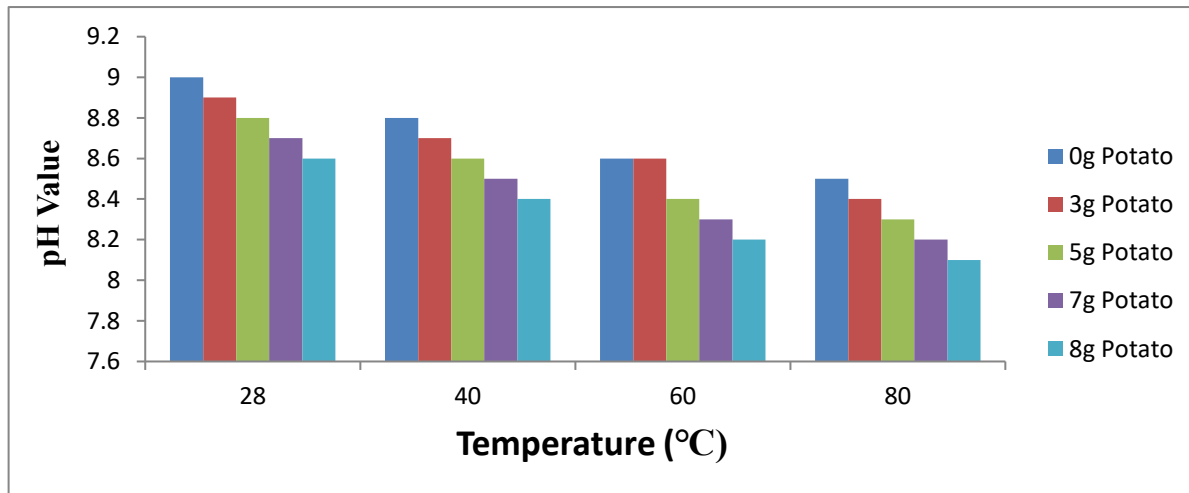


Fig. 4-2: pH Value of Yam Mud Formulations at Different Temperature

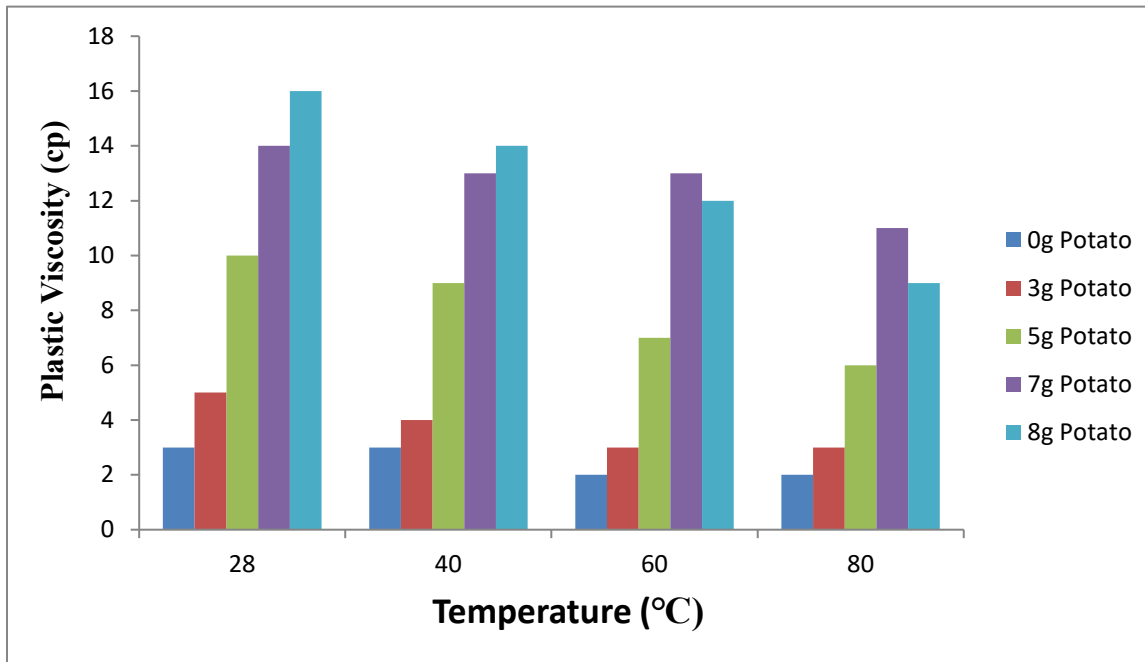


Fig.4- 3: Plastic Viscosity of Yam Mud Formulations at Different Temperature

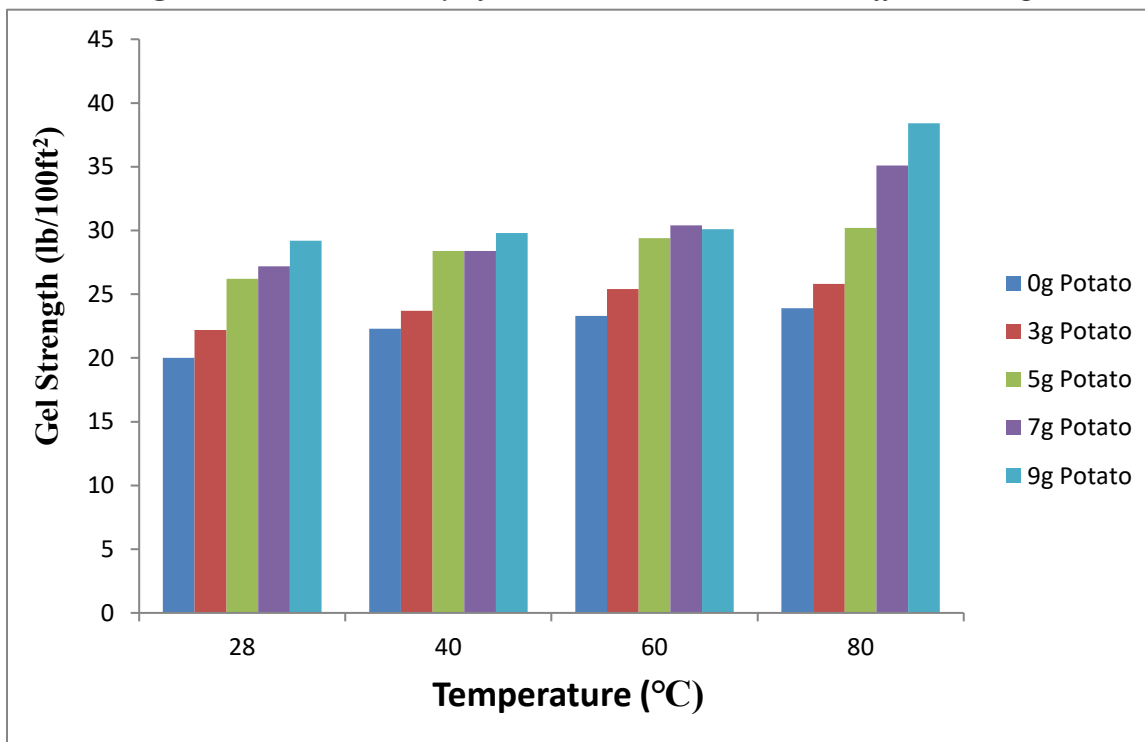


Fig. 4-4: Gel Strength (lb/100 ft²) of Yam Mud Formulations at Different Temperature

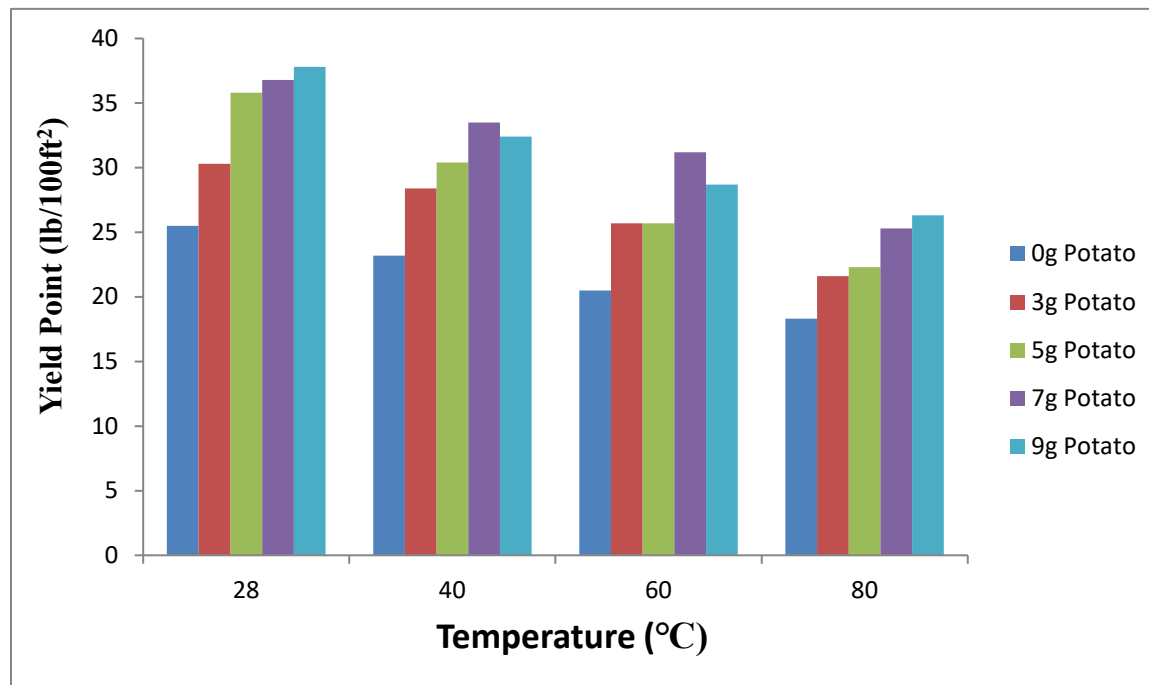


Fig. 4-5: Yield Point (lb/100 ft²) of Yam Mud Formulations at Different Temperature

4.2 Discussion of Results

4.2.1 Effects of Yam Powder on Mud Weight

The mud weight (density) is the weight per unit volume of the mud. Mud density must be great enough to provide sufficient hydrostatic heat to prevent influx of formation fluids, but not so great to cause loss of circulation, damage to the drilled formation, or reduce the rate of penetration (ROP). From Figure 1, it is seen that at 28 °C the mud weight at different concentrations of the mud was not the same. This is because yam powder acted as a weighting agent as well as being a viscosifier. Relatively, as the temperature increased from 28 °C to 80 °C, the mud weight for all the concentrations of the yam powder decreased. This is due to the differences in temperature and heat energy required to dissipate bonds, which vary with fluid properties (i.e. the continuous

phases)..The mud density being a rheological property decreases with increase in temperature, this is as a result of the mud contents being heated at higher temperature and they become degraded; hence contributing to the decrease in mud density. This justifies the earlier work cited by Civan and Engler (2007).

4.2.2 Effects of Yam Powder on pH

pH measurements aid in determining the need for chemical control of the mud, and indicates the presence of contaminates. From figure 2 above, at 28 °C, the pH of the mud at different mud powder concentrations was not the same. As the temperature was increased from 28 °C to 80 °C, it could be observed that the pH reduced relatively for all the different concentrations of yam powder. Temperature affects pH of drilling mud by causing dissociation of water into H⁺ and OH⁻. Increase in temperature will cause a shift of the reaction's equilibrium to the right thereby increasing the number of H⁺. This is in agreement with work done by Okorie (2006).

4.2.3 Effects of Yam Powder on Plastic Viscosity

From Fig. 3, it can be seen that at 28 °C temperature, increase in yam powder concentration resulted in increase in plastic viscosity of the mud samples, thereby acting as a secondary viscosifier. On the other hand, a decrease in plastic viscosity was observed as the temperature increased from 28 °C to 80 °C. The yam powder with concentration of 9 g had its PV steadily decreasing with increasing temperature. This drift helps to reduce suspension of particles in mud during drilling process. In the sample with 3g yam powder concentration, it can be seen that, Plastic Viscosity decreased with increasing temperature (28 °C to 40 °C), however, there was no further decrease in PV when the temperature was increased to 80 °C. The same behavior was observed for mud sample with 5g yam powder as was done in 3g sample. Mud sample with 7g yam showed a decrease in PV as temperature increased from 28 °C to 80 °C. The reason for the decrease in the

PVs results from the fact that, increase in temperature increase tends to decrease the liquid phase of the mud and thermally degrades particles due to the breaking of polymer bonds in the powder. This trend is in agreement with earlier work done by Ademiluyi *et al.* (2011), Amani (2012) and Windarto *et al.* (2005). A low PV shows that the mud is capable of drilling rapidly because of low viscosity of mud flowing out the bit. Generally, the plastic viscosity was affected by the changes in temperature and yam concentration as both are function of the PV.

4.2.4 Effects of Yam on Gel Strength

From Fig. 4, it is observed that, the gel strength of all the mud samples with yam powder formulations (3g, 5g, 7g, and 9g) increased with increasing temperature. However, at 80 °C of 7g and 9g powder mud recorded values of 36.6 lb/100 ft² and 39.9 lb/100 ft² respectively which is not favourable for ensuring optimum drilling. This can be attributed to the deterioration of the polymer bonds in the mud samples as temperature increased from 28 °C to 80°C. Therefore, from the results obtained at the end of the laboratory experiment, temperature was found to have undoubted huge effect on the mud samples. The gel strength is one of the important factors in drilling fluid properties because it gives the drilling fluid the ability to suspend drill solid and weighting material when circulation is halted. When drilling mud has high gel strength, it will require high pump pressure in order to break the static bonds after the mud has been static for a long time (Saboori *et al.*, 2018).

4.2.5 Effects of Yam on Yield Point

Yield point (YP) is a measure of the electrochemical or attractive force in the mud under flow (dynamic) conditions. From Figure 5, as temperature increased from 28 °C to 80 °C, the yield point decreased with increasing yam concentrations. This is a result of loss of water by evaporation due to increased temperature making the mud thicker. It is worthy of notice in Fig. 5 that, temperature

and concentration of yam powder have significant effect on yield point. Basically, YP also indicates the ability of the drilling mud to carry cuttings to surface. If a drilling mud sample has a very low yield point it will flow at a faster rate leaving the cuttings behind in the wellbore. The behaviour observed with the effect of temperature and concentration on the yield point clearly suggest a threshold limit at which any addition of yam powder would have a negative impact on the yield point property. This is because higher YP will result in high pressure loss when the drilling mud is being circulated. In contrast, if the mud's yield point is too high, it informs the mud engineer that if such a mud is used to drill, it would require a high pumping pressure to cause the mud to flow, which is also undesirable in the industry.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

1. The mud weight and pH value of the mud was affected by temperature as both decreased as the temperature increased.
2. The mud weight and pH value of the mud was affected by concentrations of potato additives as the mud weight increased while the pH decreased as the potato concentrations increased.
3. The plastic viscosity and yield point of yam powder formulated drilling fluids decreases as temperature increases.
4. The plastic viscosity, yield point and gel strength of bentonite mud increases as concentration of yam powder added as an additive to the mud increases.
5. Higher values of plastic viscosity and yield point were obtained after treating the mud with yam additives, both of which decreases with temperature.
6. Yam powder at different concentrations increased the swelling ability of the powder thereby increasing the viscosity of the mud.

From the results obtained, it can be generally concluded that temperature has a huge effect on drilling mud property as drilling through high temperature zone in a formation with water based mud constitutes a problem of significant proportion in the oil and gas industry.

5.2 Recommendations

This project recommends the following;

1. The use of locally produced materials as a substitute for imported drilling fluid additives due to high cost of the imported mud additives should be encouraged by the authorities in the oil and gas sector.
2. Digital laboratory equipment should be used when conducting experiments on drilling mud to yield better and higher accuracy of results.
3. Approval for the exploration and new oil field development must be at the conditionality of oil companies in Nigeria utilizing local additives formulated drilling muds.
4. Subsequently, researchers who intend to investigate the suitability of yam powder as an additive to drilling muds must consider the various formation properties so as to estimate tolerable pressure and temperature levels.

5.3 Contribution to Knowledge

This experimental investigation provides a significant and original contribution to the body of knowledge in Drilling Engineering, specifically within the realm of locally sourced, thermally stable drilling fluid additives.

1. This research provides a significant contribution by definitively demonstrating the technical feasibility of using locally sourced yam powder as an effective, low-cost substitute for imported commercial drilling additives, confirming its ability to simultaneously act as both a weighting agent (increasing mud weight) and a viscosifier (enhancing rheological properties).

2. The study generates novel, primary experimental data on the thermal performance of yam starch polymers in water-based drilling muds, specifically filling a knowledge gap by detailing how these formulations behave across the critical operational temperature range of 28 °C to of 80 °C.
3. A key original observation is the identification of a critical thermal constraint: the undesirable and substantial increase in the mud's Gel Strength with increasing temperature, which serves as a necessary warning for future mud engineers regarding the potential risk of thermal flocculation and excessive pump start-up pressures.
4. This work successfully extends the application of existing biopolymer models to a new, locally abundant agricultural resource, *Dioscorea rotundata* (yam), in the context of drilling fluid rheology, thereby broadening the library of validated local materials suitable for use in the petroleum industry.
5. By scientifically validating the technical suitability and performance of a readily available local resource under critical drilling conditions, this research directly contributes to supporting the Nigerian Local Content Initiative, helping to reduce reliance on costly imported materials and promoting national self-sufficiency.

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