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Review of the Effect of Preservatives on the Stability of Cassava Starch-Bentonite Muds for Water-Base Drilling Fluid Formulations.

Nwosu, B. F. C., Ademiluyi F.T., Akpa J. G., and Abowei M. F. N.

Department of Chemical/Petrochemical Engineering, Rivers State University, Port Harcourt, Nigeria.
E-Mail: bernard.nwosu@ust.edu.ng , ademiluyi.taiwo@ust.edu.ng

ABSTRACT
Nigeria has acquired and is maintaining the status of one of the leading producers of oil and gases with estimated annual spends of over 20 Billion Dollars in the upstream sector activities. However, it is only a small portion of this that is domiciled locally. This is even though some of the inputs used in the industry can be sourced locally. It was this situation that gave rise to the NOGIC Act which mandated that some inputs like chemical/additives must have a 60% local sourcing threshold. Starch, a cassava product is one of such additives used in the industry. Copious works in literature have established a promising potential for Nigerian cassava starch as a substitute for the imported starch in the industry, for improvement of the rheological and filtration rate properties of water-based drilling fluids. Curiously, all the starches used in the industry to date are wholly imported even with the fact of Nigeria being the world's largest producer of cassava. Therefore, there is a challenge, a gap occasioned by the ready susceptibility of cassava starch to post-harvest physiological degradation. The treatment of these starches with preservatives will, therefore, address the gap.

KEYWORDS: Cassava Starch, Moisture Sorption, Preservatives, Rheology, Shelf life.

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1. INTRODUCTION

The building block of the oil and gas industry starts with the exploration or search for the location of these substances under the earth's crust otherwise referred to as seismic surveying (Van Der Meer *et al*., 2002). Modern oil and gas exploration history credits Colonel Charles Drake as being the man that drilled the first commercial well in the city of Titusville, Pennsylvania in the United States of America in the year 1859 (Ahmed & Makwashi, 2016). The rotary type of drilling has assumed the norm in oil drilling operations and the unique role of drilling fluids in ensuring a successful exercise may never be overemphasized.

Additives that address specific requirements are also incorporated into the muds for satisfactory performance. According to Mohammed (2007), present-day muds are, therefore, formulated to address these key functions; controlling formation pressures, cooling and lubricating the drilling string/bit, removing cuttings from the borehole, maintaining wellbore stability, transmitting hydraulic energy to the bit, suspension of cuttings in the borehole, protecting permeable zones by building a filter cake, supporting of the drill string, releasing of the cuttings at the surface, corrosion prevention, data logging and reducing filtration rate.

The continuous phase in which all the other components are carried is called the base fluid and the characterization of this fluid has an important effect on the properties and effectiveness of the eventual mud. The two broad classifications of these fluids according to Neff *et al*. (2000), are water-based and oil-based with a further division into ordinary refined oil and synthetic oil-based muds. Water-based muds are generally more economical but have limitation to exploration wells and the upper section of production wells. Oil-based muds on the other hand ensure wellbore stability even under reactive shale formations, thermal stability, better lubrication and quite effective in directional drilling operations (Dardir *et al*., 2014). However, the increasing environmental concerns have led to the development of the larger more biodegradable, higher penetration rate and low toxicity synthetic oil-based muds, although it has its challenges of costs (Burke & Veil, 1995).

Starch is a cassava product that is employed in the oil and gas drilling fluid formulations as secondary viscocifiers and filtrate reducers to improve rheological properties and filtration characteristics, respectively (Falode *et al*., 2008; Bentriou *et al*., 2014). The two components of a starch molecule; the crystalline, linear low molecular weight amylose and the amorphous branched high molecular weight amylopectin account for its rheological and filtration properties in water-base drilling fluids (Bergthaller & Hollmann, 2007).

Cassava (*Manihot esculenta*) is a major root crop largely grown in the tropics and subtropical regions of the world and over a wide range of soil and environmental conditions. Documented reports of well over 40 cassava varieties have been identified and Nigeria is the world's largest producer (FAOSTAT, 2014). According to Chuasuwan (2018), the estimated world production in 2017 was 278 million tonnes, out of which Nigeria was accountable for 20%. Cassava is a reliable and convenient source of food for millions of Nigerians and it is estimated that more than 90% of Nigeria's cassava production is processed into food (Nweke *et al*., 2001). However, the use of cassava and cassava products amongst which is starch has been finding wider applications other than the normal food industry over the years, as in drilling fluids formulation.

Unfortunately, the major drawback to the use of cassava and cassava products such as starch is their ready susceptibility to post-harvest physiological degradation, infestations and inherent deterioration as a result of micro-organism activities (Zidenga, 2012). This has not only brought severe losses to the farmers but has more importantly limited their potential for usage by our oil and gas industry and by extension the export market. Farquet and Fargette (1990) as cited by Rabson *et al*. (2019) had reported losses of 20-90 % in 15 African countries, Nigeria inclusive. This has set the agenda for this work in terms of the application of preservatives for stability.

The use of preservatives predates history. The prehistoric men were known to have preserved their perishables with substances such as salt and vinegar (Evans *et al*., 2010). The ante of the preservation industry has since then moved up to the present day whereby it is almost possible to preserve anything so desired. More often than not, this is done through a myriad of processes and operations that sometimes see a combination of such, to achieve some complex and even conflicting requirements (Gayán *et al*., 2012).

Previous works on the use of local cassava starches for drilling fluid applications for exploration and exploitation activities in the petroleum industry have demonstrated good and promising potential as compared to the imported ones (Ademiluyi *et al*., 2011; Wami *et al*., 2015; Harry *et al*., 2016). However, the equally important study on how these starches can be stabilized for storage with acceptable shelf life, have not been fully addressed. The over $20 billion annual spends in the Upstream oil and gas industry have largely benefited the import market (NNPC-NAPIMS Bulletin, 2014). This is much to our detriment and gravely against the Nigerian government mandate through the Nigerian Content Development and Management Board (NCDMB), that 60% threshold of the

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chemicals/additives in the industry be sourced locally (NOGIC Act 2010). The objective of this work, therefore, is to carry out a review work on the effect of preservatives on the stability of cassava starch-bentonite mud for water-base drilling fluid formulations.

2. REVIEWS AND LIMITATIONS OF PAST WORKS

2.1. Mineralogy and Crystallinity of Cassava Starch

Starch characterization is one key factor in assessing its desirability and performance in the increasing applications of starch for non-food uses. The x-ray fluorescence (XRF) technique is increasingly becoming one of the common analytical methods of determining the mineralogy of liquids and solids. It is an elemental chemical analysis technique that has some wide applications both in science and industry. It is based on the principle that when individual atoms are bombarded or excited by a high energy source, particularly of short wavelength, they emit x-ray photons of characteristic energy and wavelength (Revenko, 2002). Based on the number of such photons emitted from a sample, and using appropriate instrumentation, the elements present in the sample can not only be identified but also quantified.

The mineralogy studies of some cassava starch cultivars using crystallographic analysis by Harry *et al*. (2016) reported the prevalence of the following chemical compounds; magnesium hydroxide, calcium oxide, titanium oxide, calcium sulphate, sodium aluminium silicate and potassium aluminium silicate.

Starch crystallinity vis-à-vis the amorphous content is also one of the functional properties that define its versatile applications and have been extensively studied (Zeeman *et al*., 2002; Burell, 2003; Charles *et al*., 2005). A common feature of these studies is the apparent limitations in the use of native cassava starch but by modifying it with such processes as enzymatic, esterification and etherification reactions, novel starches have been produced (Han *et al*., 2004; Zhang *et al*., 2004).

Starch like other semi-crystalline material has a definite crystalline structure that characterizes it. X-ray diffraction (XRD) is a quick analytic technique that is used primarily for phase identification of crystalline materials (Hillier, 2003). It is based on the principle of constructive interference of monochromatic x-rays and the crystalline sample under conditions that satisfy Bragg's Law as stated below (Eby, 2004)

$$n\lambda = 2d\sin\theta \quad (1)$$

where n (an integer) is the order of reflection, λ is the wavelength, d is the interplanar distance of the spacing and θ is the angle of incidence.

Harry *et al*. (2016) have reported degrees of crystallinity of 22 and 35 for two native cassava cultivars. Similar values have also been documented by other researchers (Nuwumanya *et al*., 2010; Sandoval *et al*., 2013). The crystalline arrangement of the starch structure is a function of its botanical origin (Cereda & Vilpoux, 2003)

According to Zeng *et al*. (2011), four starch crystal structure types have been identified as A, B, C and V types. The A structure pattern such as maize show diffraction peaks around 15, 17, 18 and 23^o while the B pattern as exemplified by potato gives the strongest diffraction peaks at 2θ of 17^o and the C structure pattern is a hybrid comprising of A and B patterns (Shujun, 2005). Cassava crystal structure had been variously classified as A – form (Nuwamanya *et al*., 2011; Popov *et al*., 2009; Khanh & Thanh, 2019; Valencia *et al*., 2012).

Previous works on the mineralogy and crystallinity of native cassava starch are in existence for starches of different botanical sources. The works of some researchers even focused on the use of such starches for drilling fluid formulations (Harry *et al*., 2016). However, reports of studies on mineralogy and crystallinity of stabilized cassava starches for water-based drilling fluid formulations are not commonplace.

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2.2. Preservatives

The preservatives market predates history. The prehistoric men were known to have preserved their perishables with substances such as salt and vinegar (Evans *et al*., 2010). A preservative is a substance that is added to a product to maintain an existing condition or prevent decomposition by microbial attacks or degradation through other undesirable changes.

Preservatives are classified into two groups according to the form of attack as antimicrobial or antioxidants. The anti-microbial preservatives prevent the attacks from micro-organisms such as moulds, yeasts and bacteria and some common ones are sodium benzoate, potassium sorbate, calcium propionate, sodium metabisulphite (Dalton, 2002). The antioxidants prevent the oxidation of foods and especially those containing unsaturated fats and oils. It is this oxidation that produces the rancid taste in such foods and typical examples are the butylated hydroxyl toluene (BHT), butylated hydroxyl anisole (BHA) and the ascorbates (Msagati, 2012).

Admittedly, the use of preservatives in the industry has witnessed enormous progress and diversity in the 21st century. However, most of the works have largely addressed the concerns of the food industry. It is only recently that the twin impacts of technology and economic nationalism are refocusing attention to the non-food uses of starch such as a viable component for drilling fluid formulations in the oil and gas industry. Accordingly, such studies are understandably very limited.

2.3 Rheological Properties

Rheology is the study of the flow and deformation behaviour of a matter and it has undoubtedly become one of the most important parameters in characterizing drilling fluids (Amjid *et al*., 2013). It describes the response of fluid materials to stress introduction and this response is a function of the complexity or otherwise of the fluid. Fluids can be classified broadly into simple fluids such as water, pure substances and structured ones such as mixtures, dispersions and solutions (Barnes *et al*, 1989). Simple fluids have a uniform phase as in solutions and pure substances. However, fluids of heterogeneous phase such as emulsion and solid particles dispersed in a liquid are considered structured fluids and drilling fluid belong to this group.

In broad terms, the rheological properties are the key indicators used to characterize muds (Neff, 2005). The rheology addresses the transport ability, suspension capability and gelatin properties of the mud. Specifically, mud plastic viscosity, density, pH, gel strength, and yield point parameters are constantly monitored and controlled as the drilling lasts (Okumo & Isehunwa, 2007)

2.3.1 Viscosity of Fluids

Viscosity is an important index in the flow characterization of drilling fluids. It is a measure of the resistance to flow and factors such as nature, size, shape, concentration and chemical properties of the solid affect its value (Coghill, 2003; Slatter *et al*., 2002). It is a measure of the fluid's thickness and is commonly expressed in stokes, poise or centipoise. This resistance to flow is caused by the friction between these suspended particles as well as by the viscosity of the continuous liquid phase (water or oil) in which it is dispersed. The removal of cuttings from the wellbore to the surface is a key function of the drilling fluid and the degree to which this is done effectively depends on the mud viscosity (Neff, 2005).

For simple fluids, their viscosity remains constant at the same temperature and pressure for all shear rates. However, structured fluids are referred to as non-Newtonian fluids because they are not subject to a linear relationship between shear stress and shear rate but their viscosity is a function of the rate of shear and sometimes on the shear history (Skalle, 2011). These fluids have a linear relationship between the shear rate and the shear stress at a constant temperature. The constant of this proportionality is called viscosity. Newton's law of viscosity is given by this expression;

$$\tau = \mu \frac{dv}{dy} \quad (2)$$

Where: τ = shear stress, μ = viscosity of fluid and $\frac{dv}{dy}$ = shear rate or velocity gradient

The viscosity is independent of the shear applied as well as the duration of the shear (time-dependency). Alcohol, mineral oil and water are ready examples of Newtonian fluids. However, fluids whose viscosities are not constant but depend both on the rate of shear and the duration of shear are referred to as non-Newtonian fluids. Consequently, based on time-dependency, shear thickening and shear thinning characteristics, Non-Newtonian fluids are classified as, dilatant, rheopectic, Bingham, pseudoplastic and thixotropic fluids (Chhabra & Richardson, 1999).

The unique behaviour of starch in the presence of water and heat deserves a mention for clarity of its functional performance as a drilling fluid additive. The ability of starch to exhibit gelling capability is part of its physicochemical characteristics that enables it to function as such. This property is explained by the twin processes of gelatinization and retrogradation. Starch gelatinization is a process of breaking down the intermolecular bonds of starch molecules in the presence of heated water and these twin processes largely define the functional properties of starch especially for wider applications (Wang *et al.*, 2015).

In their work on the Application of selected Cassava starches as Drilling mud additives, Harry *et al.* (2016) posited that cultivars TMS 98/0581, TMS 92/0057 and TMS 96/1632 showed comparable performance to the imported starch sample in terms of viscosity enhancement at 1.0% concentration. Akintola and Isehumwa (2015) characterized local cassava starches and came with a result that showed close similarities in terms of rheological properties, between the imported starch and the local ones. The rheological performance of cassava cultivar TMS98/0505 in a water-based drilling fluid formulation was equally comparable with that of polyanionic cellulose (Abah & Egun, 2013).

Ademiluyi *et al.* (2011) investigated the performance of five different cassava starches as substitute secondary viscocifiers for the imported starch (Barazan D). The report of their findings indicated a promising potential for some of these cultivars. Also, cassava starch research conducted by Igbani *et al.* (2015), found that the density of the drilling mud so formulated was improved by the cassava starch addition. Furthermore, the works of Dankwa *et al.* (2018) on cassava starch performance evaluation posted a positive rheology improvement result. However, in their research on the comparative performance of cassava starch with PAC, Okumo and Isehunwa, (2007) noted that the thermal stability of such muds was suspect due to their increased hydrolysis and degradation at temperatures of 225^0F and above.

2.3.2 Gel Strength

This is a measure of the thixotropic properties of the fluid and is a function of the inter-particle attractive forces when at rest. Measured normally in lb/100ft^2, it indicates the degree of gelation that takes place when fluid circulation is brought to an end and the mud is left in static condition. The level of flocculation in a mud system has a direct effect on its gel strength. Gels are described as progressive or flat/fragile/weak depending on how their values change with time and or temperature. Flat or weak gels are generally preferred in drilling muds for better pump pressure management and borehole formation stability (Hilfiger *et al.*, 2016)).

Dankwa *et al.* (2018), reported comparable suspension capability of cassava starch and imported starch muds in water-base drilling fluid formulation. It is a time-dependent property and is a function of the temperature, suspended solids and solids content of the fluid phase. Therefore, effective solids control is one sure method of gel strength management in the field. The gel strength determines the suspension of drilling cuttings when the pumping is stopped for reasons such as pump failure or tripping operation when the mud is under static condition. In the industry, the common metrics for gel strength measurement are the 10 seconds and 10 minutes gel values.

2.3.4 Yield Point

The yield point is a measure of the fluid flow resistance caused by electro-chemical or attractive forces in the fluid. The degrees of these attractive forces are dependent on the electric environment of the solids, mud solids surface properties and solids volume concentration (Forseberg *et al*., 2004). The cuttings carrying capacity of the mud is predicated on an appropriate or corresponding yield point value. It is also measured in $lb/100ft^2$ or kg/m^2 and is very critical in the hole cleaning function of the fluid. Dankwa *et al*. (2018) has reported yield point values of 78.4- 156.8 kg/m^2 for cassava starch water-base muds in performance investigation studies and these values were favourable for good cuttings transport.

2.3.5 Rheogram and Rheological Models

A flow curve generated by plotting shear rates and shear stress is called a rheogram (Guibao *et al*., 2005). There are several rheological mathematical models in the industry that have been used successfully in the characterization of the flow behaviours of various fluids. Some of the common ones are Bingham, Power-law, Casson and Herschel Bulkley models (Shah *et al*., 2010; Vipulanandan & Mohammed, 2014)

These models are used essentially to predict the viscous flow behaviour of non-Newtonian fluids under the varying condition of shear stress and shear rates and sometimes also concerning the time of the shear application. However, in practical terms, some of these models have proved deficient in their predictive capability to define the fluid rheological characterization and hydraulic behaviour over the full spectrum of shear rates (Barnes *et al*., 1989, as cited by Folayan *et al*., 2017).

In their works, Folayan *et al*. (2017) posited that the Power-law models predict a better rheological characterization of synthetic-based drilling muds at the onset of the low shear rate regimes quite unlike the Bingham plastic model. The Power law was used to do a relational rheological characterization and hydraulics of corn starch under varying amylose content specifications (Xie *et al*., 2009). Also, in relating the viscosity to the viscometer rotational speed, Mepba and Ademiluyi (2007) showed that the Power-law model reasonably characterizes the rheological behaviour of coconut milk yoghurts, with the consistency coefficient having a strong temperature dependence.

On the other hand, the Herschel - Buckley model showed a good predictive rheological capability for polymer muds, especially at very low shear rate viscosities (Kevin & Bala, 2014). The low shear rate viscosities regime is predominantly prevailing in the annulus and as such is very critical to the hole cleaning capacities of the drilling mud (Thixolle, 2004). Further credence was laid to this position by Harry *et al*. (2017) in their work on the rheological modelling of cassava starch-bentonite muds for the drilling operation. They reported that the modelling and rheological characterization of the muds found that the consistency index and the flow index behaviour were closely modelled by the Herschel Bulkley model equation while both the Bingham plastic and Power-law equations showed wider deviations.

Folayan *et al*. (2017) in their works on synthetic base mud, established that the Casson rheological model fully characterizes the mud behaviour over the wide spectrum of shear rate regimes, reasonably attributable to the correction factors in the model equation. The obvious drawback of the Bingham plastic model is that its rheological equation cannot satisfactorily describe the flow behaviour of fluids with viscosity and shear rate or shear stress dependencies.

However, despite the copious works on starch rheology, the novel study on the rheology of

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cassava starch treated with preservatives for water-base drilling fluids are not readily available in the literature.

2.4 Filtration Properties

The filtration property of a drilling fluid denotes its ability to limit fluid loss to the formation due to the tendency of the fluid-solid particles to form a filter cake on the formation walls. In defining this property, it is not only the thickness of the cake that is important but much more is the nature of the cake formed in terms of its permeability. Low permeability cake makes thicker cakes with lower filtrate loss into the formation while the thick cake is undesirable as they constrict the walls of the borehole and permit a large amount of the filtrate into the formation (Saboori *et al*., 2018). This situation could easily lead to severe formation challenges like instability, stuck ups, caving and tight pulls (Igbani *et al*., 2015).

Many works have reported the high potential of Nigeria's cassava starches as an effective filtration loss control agent (Ismail & Idris, 1997). Ademiluyi *et al*. (2011) had reported in an investigative work on the use of cassava starch as a fluid loss control agent that muds produced from starches of high amylose content and water absorption capacity presented values that were within the API threshold. Samavati *et al.* (2014) observed that fufu; a cassava derivative indicated good prospects as a filtration agent in water-base drilling fluids at temperatures of 250^0F and below.

Harry *et al*. (2016) had also reported that some of Nigeria's cassava starch cultivars showed comparable fluid loss properties to the imported ones. A cassava starch performance evaluation as a drilling fluid by Dankwa *et al*. (2018), stated that a fluid loss improvement of about 8% and mud thickness of 2mm to 3mm were achieved with the application of some starch cultivars. Further works on the subject matter also corroborated this position that local cassava starch could serve not only as a good substitute for viscosity enhancement but even better filtration properties when compared with the imported ones (Orji & Joel, 2012; Akintola & Isehunwa, 2015).

The level of past works on the filtration characterization of native starches has been quite extensive as can be easily concluded here. However, such works that are solely directed at the non-food uses of modified or stabilized starch such as an additive in water-based drilling fluid formulations are seemingly not commonplace.

2.5. Moisture Sorption and Water Activity

Generally, water is known to play a critical role in considering the stability of food products in terms of both quality and safety. Paradoxically, this same water is desirably always present not only in foods but is practically central to life itself and so efforts to know the amount of this water are of steady importance in the industry.

Monitoring and controlling this water in a product by such ancient methods as drying and salting have long been used by man for preservation purposes. The more common measure of water is the moisture content of the product, which is largely a quantitative analysis. However, moisture content alone is not a reliable and sufficient measure of the microbial, chemical and physical responses in foods. Therefore, when the quality or nature of the water in a product is desired, a thermodynamic property called water activity (a_w) is denoted and measured (Xin, 2007). Water activity is the ratio of the vapour pressure of water in a material (product) to the vapour pressure of pure water at the same temperature (Sahin & Gulum, 2006).

The thermodynamic relationship between moisture content and water activity at constant temperature is known as moisture sorption isotherm (Abramovic & Klofutar, 2006). A moisture sorption isotherm is constructed by generating and collecting water activity and moisture content data over the desired water activity.

In a comparative study of the sorption isotherm characteristics of two cassava products (garified and ungarified) using the conventional gravimetric method according to COST 90 Project, at temperatures of 20, 30 and 40^{0}C, Ikhu-Omoregbe (2006) reported a sigmoid shaped curve with Guggenheim, Anderson, de Boer (GAB) model presenting the best fit for the isotherm. The report further noted that the monolayer value was more dependent on the sorption model applied rather than on the temperature. Blaise *et al.* (2014) investigated the thermodynamic analysis of sorption isotherm of cassava with a presentation that the isotherm is sigmoid curved, the equilibrium moisture content is inversely proportional to increases in temperature at constant water activity and the experimental data fitting the GAB model best. The study of the thermodynamic properties of moisture sorption in cassava flour at temperatures of 25, 30 and 35^{0}C indicated that the equilibrium moisture content increases with increasing water activity at constant temperature (Ayala-Aponte, 2016). The report concluded that the experimental data fitted acceptably to the GAB, Halsey and Peleg model.

There are many works on moisture sorption studies on various fruits and food substances including cassava in literature. However, not much is readily available concerning its application to stabilized cassava starch-bentonite mud for use in water-base drilling fluids formulation.

2.6. Shelf Life and Packaging

Shelf life refers to the maximum allowable changes in a product in terms of microbial, sensory, chemical and physical stability concerning time and environment (Bell & Labuza, 2000). Factors such as water activity, the temperature of storage, moisture content and packaging, to a very large extent determine the shelf life of cassava products (Ikhu-Omoregbe, 2006). Discussing the shelf life of a product in exclusion of its packaging plans is a veritable omission. Therefore, according to Coles (2003), the strategic plan of preparing food from processing, transporting, distributing, storing and retailing to satisfy the eventual consumer at a competitive cost is defined as food packaging. Advances in food or products packaging, in general, have been quite phenomenal and is in tandem with consumer demands, expectations and even dreams.

Addressing wastage is one of the key underlying objectives of packaging. It has been estimated that more than 25% of food is wasted due to poor packaging (World Packaging Organisation (WPO), 2009). Nonetheless, even with the euphoria of these advances in packaging technology, a balance must be struck between food quality protection and such other factors as costs, social and environmental considerations (Marsh & Bugusu, 2007). In literature, not much is readily available on the packaging and shelf-life determination of stabilized cassava starch to be used in water-base drilling operations.

2.7 Economics of Cassava Starch

The demand for cassava starch in Nigeria is high and it is increasing. According to Knipscher *et al*. (2007), there are two major categories of cassava and cassava products market in Nigeria namely; the industrial and the food-oriented markets, with the latter accounting for about 90% and the former only about 10% by industries such as Nestle, Cadbury and the Nigerian Flour Mills. The reason for this demand is attributable to the wider applications to which starch is finding itself in the pharmaceuticals, household products, chemicals, textiles, culinary, beverages, adhesives, oil drilling fluids and paper industries amongst others. Additionally, the Nigerian government's mandate to user industries under the Presidential Initiatives on Cassava (PIC) to implement a partial substitution of corn starch with cassava starch to support our foreign earnings rather than depleting the reserves is part of the demand driver (Sanogo & Adetunji, 2008).

According to the DOING Machinery Report, (2015), our annual cassava starch demand is more than 350,000 metric tonnes. Ironically, about 95% of this is imported to the country despite the record of being the world largest producer of cassava of which starch is a by-product (Okojie, 2017). The prize of imported cassava starch is $328/tonne @ 2017 (FOB) Bangkok basis with Thailand being the largest producer and exporter of super high-grade quality starch (STATISTA, 2020).

There are two known cassava starch processing industries in Nigeria to date namely; Nigerian Starch Mills, Ihialla in Anambra State and Matna Starch Industry, Akure in Ondo State with installed capacities of 14,000MT and 4500 MT, respectively (PIND, 2011). The report further indicated that the two companies have been operating well below these capacities due to challenges of public power supply as well as other logistics issues and that their starch product is dedicated to the beverages and food industries. In all these, however, studies in the literature on cassava starch treated with preservatives for water-based drilling fluid formulations in Nigeria are not commonplace.

3. SUMMARY OF LIMITATIONS OF PAST WORKS AND KNOWLEDGE GAP.

In principle, it has been established hitherto that our local cassava starch could be used to substitute either wholly or partially the imported starches that are currently being used in the Nigerian oil and gas industry for drilling operations. The starch usefulness as a drilling fluid additive in water-based mud application is demonstrated in improved rheological and filtration rate characterization even at temperatures of up to 225°F. Paradoxically, to date, all the starches that are used in the industry are imported even against the backdrop of the fact of Nigeria consistently maintaining the leading position as the largest producer of cassava of which starch is a cassava product. Painfully enough, this is in flagrant violation of the NOGIC Act mandate of local sourcing of oil and gas chemicals/additive to a minimal threshold of 60%. However, in practice, some of these additives have not been fully commercialized and applied because of some existing gaps inherent in their applicability. The major constraint as in the case of cassava starch is their ready susceptibility to post-harvest physiological degradation due to infestations and microorganism activities. Therefore, the treatment of the cassava starch with the appropriate preservative to stabilize it will help in bringing closure to this gap.

4. CONCLUSION

Accordingly, this work is set to address this stability gap in cassava starch industrial utilization which could result in more industrialization, reduction in youth unemployment and restiveness, and increased foreign reserves. Prevailing Nigeria’s dwindling oil fortunes underscore the appropriateness and timeliness of this study.

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