The Application and Rheological Behavior of Igebu Garri (Cassava Derivative) as a Fluid Loss Inhibitor in WBM Formation

Rahele Samavati¹, Norhafizah Abdullah¹, Kourosh Tahmasbi Nowtarki², Siti Aslina Hussain¹, Dayang Radiah Awang Biak¹, Mojtaba Kalhor Mohammadi²

¹Chemical and Environmental Engineering Department, Universiti Putra Malaysia, 43400, UPM, Serdang, Malaysia; Tel.: (60)3 89466295; Fax: (60)3 86567120
²Pars Drilling Fluids Co., No. 43, 3rd Souri St., After Niayyesh Bridge, Ashrafi Esfahani Highway, Tehran, Iran; Tel.: (98)21 44849770; Fax: (98)21 44849789
*Corresponding Author: E-Mail: Samavati_Raheleh@yahoo.com

Received 19 May 2014; Accepted 22 July 2014

Abstract. The rheological understanding of the drilling mud is imperative to recognize mud performance to efficiency eradicating, suspend cuttings and stabilize wellbore. Rheology of the drilling mud is commonly conserved at requisite rheological standards during the application of additives or dilution, contingent on the operation requirements. This research presents a study on Igebu Garri (white garri) a local Nigerian cassava derivative and its potential as an alternative to commercial starches, potato and corn, for the purpose of fluid loss and viscosity control in WBM formation. The approximate analysis displayed Igebu Garri with maximum quantity of protein (5.2%) and fat (14%) among potato (0.8% and 0.68%) and corn (0.66% and 8%)- starch, accordingly. According to the rheological determination, Igebu Garri-WBM displayed the capability to form a WBM with superior viscosity and minimum fluid loss, compatible with potato and corn starch, when subjected to the temperature of 250 °F in light (1ml), average (2ml) and heavy (1.4ml) mud weights, whereas light weighted potato and corn-WBMs had failed the requirements with fluid loss volume of 3ml and 10ml, respectively. As results illustrate the starches utterly have degraded when subjected to temperature of 300 °F leading to high fluid loss, applied to all mud samples devoid of heavy weight potato-WBM (1.6ml). Igebu Garri (WG) proved the possibility to be used as polymeric additive for saline drilling fluid formations, in meticulously as fluid loss control additive. This efficiently diminishes the filtrate volume of the saturated salt mud up to 2ml, calculated according to the NISOC specifications.

Keywords: fluid loss control additive, Igebu Garri, potato, corn, starch, WBM, NISOC

1. INTRODUCTION

Drilling mud is a flowing fluid applied in rotary drilling for achieving single or multiple tasks during the procedure, and its typically consist of water/oil, clay, weighting compounds and few other chemical additives (American Institute of Petroleum, 1998). It’s most important physical characteristics are viscosity and water holding/retaining properties (Crowo, 1990). The successful and cost of the drilling process is known to depend extensively on the assets of drilling fluid used (Gray,et al., 1980). Drilling mud circulates in a loop, from the drilling platform, where is forced down into the formation system by entering the drill string, and then pushed up to the surface again via drill bit. The fluid characteristics such as density and temperature are variables that need to be regularly monitored for the perfect drilling performance according to the condition of the drilling well (Issham and Ahmad Kamal, 1997; Rabia, 1985).

Drilling fluids are commonly known for their gel or thixotropic characteristics, in which they can go through a reversible transformation from high to low viscosity status when being subjected to shear stress force (Dolz et al., 2007). These transformations ruin the microstructure of the fluid but will be gradually recovered when the fluid is in resting condition (Azar and Samuel, 2007).

Usually, the industrial capability of wells is impaired by multifaceted interfaces between rock and fluid, which decrease permeability to oil and gas. For that reason, drilling muds should be cautiously formulated to diminish these undesirable effects (Hamida, Kuru, & Pickard, 2010). Depth, pressure and mechanical/impact resistance of the well bore are the key parameters that determined which type of the mud is most relevant. In spite of their differences in categories, their main purposes and functions remain mutual (Barnes et al., 1998). They function to preserve hole reliability, convey the rock cuttings,
managing the pressure of mud system along with lubricating and cooling the drill bit (Baba Hamed and Belhadrí, 2009; Brazzel, 2009; Caenn and Chillingar, 1996; González et al., 2011). At the current time drilling muds are categorized by their external phase or basic material into five major groups, which are Oil-based drilling mud (OBM), Synthetic Based Drilling Mud (SBM), Water Based Drilling Mud (WBM), Gas Based Drilling Mud (GBM) and Nano Based Drilling Mud (Davies et al., 1984; Van Dyke and Baker, 1998). The significant factors for distinguishing the assets of a drilling fluid are gel strength, viscosity (apparent and plastic viscosity), explicit weight, pH, thermal stability and the filtration function (Caenn et al., 2011; Sondona, 1985).

Untreated colloids, basically starch and its modified types, were used in drilling fluid industry for a long time to defeat the hazardous effects of anhydrite and saline on drilling fluids (Civan, 2007; Windarto et al., 2011).

Managing the fermentation made by micro-organism in drilling muds, which are composed of gums, starches and tenants additives, is one of the most important problems in drilling mud formation. In an effective stated drilling mud, depending on the pH, Heat, ventilation group of enzymes get activated which assist microorganisms to ferment or hydrolyze the starch. Fermentation dilemma in starch based drilling muds is generally challenged by adding an antiseptic like paraformaldehyde, which is fairly economical (Myers, 1962; Soepenberg et al., 1983). In drilling mud composition different polymer and chemicals are used for various applications, this chemicals mostly influence the rheological and fluid loss properties of the mud (Austin, 1983). The most popular polymer applied is polyaniioniccellulose (PAC), considering it being costly, there is need of inexpensive polymers from local resources like corn, potato and wheat starch as an alternative (Anderson et al., 1991; Hudson and Coffey, 1983; Issham and Ahmad Kamal, 1997). One of the most important properties of a drilling mud is it fluid loss asset, which requires constant monitoring. Polymers and sodium bentonite are of the common filtration agents used (Hamida et al., 2010). Insufficient study had been made on the basics functional assists of different cassava starches in water based drilling muds mostly in viscosity field (Ademiluyi et al., 2001; Ikegwu et al., 2009). These investigations are only based on the rheological studies in laboratorial conditions devoid of actual manufacturing of drilling mud formulations for that reason there is a need for various cassava derivatives to be investigated in drilling mud standard industrial formulations in different drilling circumstances.

This research was focused on the preparation and rheological analysis of WBM system with the content of cassava derivative igebu garri (white garri) as an innovative starch, and its novel oilfield application as fluid loss control agent, in completion with commercial WBM fluid loss agents. The mud formulation and determination were based on National Iranian South Oil Company (NISOC) industrial standards of onshore drilling, and American Petroleum Institute (API) requirements.

1.1. Igebu garri (white garri)

Garri represents the most important food supply for numerous populaces in Africa and Latin America as well as the most developing countries. In a time that world is comprehensively experiencing cultural incorporation, cassava derivatives such as garri flour, may possibly be capable of playing an important role in the prosperous industrial world (Ukhun and Nkwocha, 1989). There are two types of garri known in Nigeria, yellow garri and white garri. The preparation Igebu garri (white garri) engages a numeral of procedures. First, cassava roots are skinned and then grated and treated for around 3-4 days, afterward the fermented crush is dewatered and gelatinized by heat up to some extent, desiccated up to 10% of moisture (on wet basis) and pounded. During this procedure, the HCN amount is decreased to standards of below 3.0 mg/100g of matter that is considered as acceptable in the manufactured goods (Ogunsua, 1980; Terry, 1984).

2. MATERIALS AND METHODS

Reagents applied in this study were all in analytical grade and purchased from Iran Kaolin and Barite Company (IKB Co.) in Tehran/Iran. Food graded igebu garri was acquired from Chow Kit local market in Kuala Lumpur/Malaysia. Bench mark fluid control starches (potato and corn) were bought from local shops in Tehran/Iran.

2.1. Production of drilling mud

The Investigation on igebu garri applicability as a fluid loss control agent was performed in Drilling Mud Laboratory at Pars Drilling Company (Tehran/Iran). As Table I presents, mud samples were prepared in 3 different mud weights (75, 100 and 150pcf) which respectively represent light, average and heavy weight. The rheological and fluid loss evaluation of mud samples containing igebu garri were investigated using the same method and environmental conditions which were applied for fufu (cassava derivative) in authors preceding research.
The mud samples were subjected to drilling temperatures of 250°F and 300°F via rolling oven (Fann, model 705ES, USA) for 8hr under constant heating and circulation. Then, the mud samples were ejected and evaluated for their rheological and fluid loss properties.

2.2. Rheological and fluid loss control evaluation of the WBM

The research analysis was based on NISOC industrial formulations and standards of onshore drilling and API requirements, in contrast with commercial fluid loss control agents (corn and potato starch). The rheological characterization of the WBM samples were carried out by evaluating plastic viscosity (PV), yield point (YP), apparent viscosity (AV) and gel strength at 10sec and 10min (GS) via viscometer (OFITE, model 800, USA). The level of fluid loss was calculated with a High Pressure-High Temperature filter press (HPHT) manufactured by Fann (model 3878, USA).

Table 1: The composition of mud formation based on NISOC standards for WBM

| Mud Composition                  | light weight | Average weight | Heavy weight |
|----------------------------------|--------------|----------------|--------------|
| Saturated Salt Water (Mud base)  | 350cc        | 350cc          | 350cc        |
| Fluid Loss Control Agent         | 14g          | 14g            | 14g          |
| Barite (Viscofier)               | -            | 226g           | 900g         |
| Hematite (Viscofier)             | -            | -              | 70g          |
| Mud Weight                       | 75pcf        | 100pcf         | 150pcf       |

Table 2: The characterization analysis of *igebu garri* compared to potato and corn-starch

| Technique Applied                | Samples Properties | *Igebu garri* | Potato | Corn |
|----------------------------------|--------------------|---------------|--------|------|
| Oven-Direct Heat pH meter        | Humidity (%)       | 12            | 11.22  | 10.22|
| Digestion & Distillation System  | pH                 | 4.8           | 4.8    | 5.8  |
|                                  | Protein (%)        | 5.2           | 0.8    | 0.66 |
| Soxhlet Method                   | Fat (%)            | 14            | 0.68   | 8    |
| Muffle Furnace                   | Ash (%)            | 1.0           | 2.1    | 0.16 |

3. RESULTS AND DISCUSSIONS

The experiments were carried out in 3 different mud weights (75, 100 and 150 pcf), to represent NISOC standards applied for WBM in industrial formulations of exact on-shore drilling circumstances. The rheological analysis of the mud samples were studied and compared with commercial fluid loss starches (corn and potato) before and after being subjected to intense temperatures of 250°F and 300°F emulating drilling well conditions and.

3.1. Starch characterization analysis

Table (II) presents the approximate characterization analysis outcome for applied fluid loss control agents. *Igebu garri* displayed a major difference in quantity of protein (5.2%) and fat (14%) in contrast to corn and potato starch (0.66 and 0.8%, respectively).

3.2. The effect of hot-roll temperature on plastic viscosity

Temperatures of 250°F and 300°F were assessed for each mud samples (75, 100 and 150pcf). Figure 1(a-e) presents, the plastic viscosity of *igebu garri* mud samples when subjected to various temperatures. As presents in fig.1(a), PV had notably increased after hot-roll at 250°F in mud weight of 75pcf. Compared to potato and corn which almost retained their value. An opposite reaction has occurred with the same mud weight at 300°F, from which the PV value of potato and corn starch were reduced significantly while *igebu garri* remained constant, as shown in Fig.1(b).

As presents in fig.1(c), mud samples of average weight (100pcf) in 250°F, delivered a similar PV pattern as previously observed in fig.1(a) only with higher volume. In 300°F as showed in fig.2(d) *igebu garri* had a very slight drop after hot-roll. While,
while potato and corn starch had been reduced significantly. For samples of heavy weight (150pcf) a similar PV pattern observed in light and average mud weight was delivered in 250°F, except potato starch retained the same value fig.1(e). In 300°F as presented in fig.1(f), *igebu garri* had a slight increase of PV while potato and corn starch displayed a significant reduction.

Fig. 1: (a) The PV before and after hot-roll at 250 °F in mud weights of 75pcf (b) PV before and after hot-roll in 300 °F in mud weights of 75pcf (c) PV before and after hot-roll in 250 °F in mud weights of 100pcf (d) PV before and after hot-roll in 300 °F in mud weights of 100pcf (e) PV before and after hot-roll in 250 °F in mud weights of 150pcf (f) PV before and after hot-roll in 300 °F in mud weights of 150pcf

3.3. The effect of hot-roll temperature on yield point

As fig.2(a) presents, the YP of *igebu garri* mud samples (75pcf) after hot-roll at 250 °F had a considerable drop. Meanwhile, the YP of potato sample retained it value but corn mud sample showed a slight increment. As revealed in fig.2(b), an opposite observation was occurred with the same mud weight at 300°F, where the YP of *igebu garri* mud samples had raised significantly and displayed the maximum yield point among fluid loss agents. The YP of potato starch mud samples diminished considerably while corn sample retained it value.

As Fig.2(c) displays, *igebu garri* mud samples (100pcf) at temperature 250 °F presented a slight diminish in YP after the hot-roll and documented the minimum value among applied fluid loss control agents. Potato starch had a minor increment of YP, while corn starch retained its value. In the temperature of 300°F, *igebu garri* exposed a zero YP, while corn and potato starch presented a significant reduction in after hot-roll (fig.2(d)).

For mud weight of 150pcf in temperature of 250°F, YP of *igebu garri* sample augmented extensively, while potato and corn starch displayed a reduction as shown in fig.2(e). In temperature of 300 °F as presented in fig.2(f), *igebu garri* mud sample (150pcf) had a decrease of YP as well as potato and corn starch mud samples.
Fig. 2: (a) The YP before and after hot-roll at 250 °F in mud weights of 75pcf (b) YP before and after hot-roll in 300 °F in mud weights of 75pcf (c) YP before and after hot-roll in 250 °F in mud weights of 100pcf (d) YP before and after hot-roll in 300 °F in mud weights of 100pcf (e) YP before and after hot-roll in 250 °F in mud weights of 150pcf (f) YP before and after hot-roll in 300 °F in mud weights of 150pcf

Fig. 3: (a) The AV before and after hot-roll at 250 °F in mud weights of 75pcf (b) AV before and after hot-roll in 300 °F in mud weights of 75pcf (c) AV before and after hot-roll in 250°F in mud weights of 100pcf (d) AV before and after hot-roll in 300 °F in mud weights of 100pcf (e) AV before and after hot-roll in 250 °F in mud weights of 150pcf (f) AV before and after hot-roll in 300 °F in mud weights of 150pcf
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3.4. The effect of hot-roll temperature on apparent viscosity

As illustrated in fig.3(a), AV of igebu garri mud sample (75pcf) after hot-roll at 250°F had significantly raised while potato and corn mud samples remained about the same value. As fig.3(b) presents the previous mud weights at 300°F, igebu garri revealed a slight volume increase of AV while potato and corn starch mud samples had a notable reduction.

Apparent viscosity of igebu garri mud samples (100pcf) at 250°F had a slight decrease while potato mud sample had increased and corn sample retained it as presented in Fig.3(c). At temperature of 300°F igebu garri mud sample almost retained it AV value while potato and corn samples were reduced, as in Fig.3(d).

As fig.3(e) presents, AV of igebu garri mud sample (150pcf) at 250°F had a slight increment while potato mud sample almost retained it value. At temperature of 300°F as presented in Fig.3(f), the AV of igebu garri mud sample (150pcf) almost remained constant while mud samples involving potato and corn starch were reduced following the same reduction pattern observed in Fig.3(d).

3.5. The effect of hot-roll temperature on gel strength

The gel strength valuation in time lag of 10s and 10min was investigated in 250°F and 300°F for all mud samples.

As presented in fig.4(a), in mud weight of 75pcf at temperature of 250°F (after hot-roll) the GS of igebu garri mud sample showed an increment from 10s to 10min, which is identical to potato mud sample as observed, while corn retained it same value. In the temperature of 300°F gel strength (10s and 10min), all samples remained constant as presented in fig.4(b).

As illustrated in fig.4(c), at 250°F the GS of all mud samples (100pcf) had followed the same pattern as observed in previous mud weight (75pcf) in the same temperature (Fig.4.(a)). As presented in fig.4(d), at temperature of 300°F, igebu garri and corn mud samples retained their GS value while potato’s had a significant increase.

As exhibited in fig.4(e and f), the GS value of all mud samples (150pcf) at 250°F and 300°F had a slight augment in 10 minute time lag, which was very high compared to the other mud weight formations.
3.6. The effect of hot-roll temperature on pH

As revealed in Fig. 5(a, c and e), the pH value of all mud weights containing fluid loss control agents remained around neutral (pH around 7) when subjected to 250 °F. Meanwhile, at 300 °F, mud samples were in neutral-mild acidic state (pH less than 6-7) as presented in Fig. 5(b, d and f).

3.7. The effect of hot-roll temperature on fluid loss

The acceptable fluid loss volume as required by NISOC standards is up to 2ml. Fluid loss control agents which exceed this value are considered as rejected. As illustrated in fig. 6(a, c and e), at of 250 °F, all igebu garri mud samples were in an acceptable fluid loss range (≤ 2ml). Meanwhile, potato and corn mud samples in mud weight of 75pcf were both rejected due to their high fluid loss value.

As presented in fig 6(b, d and f), all the fluid loss control agents exceeded the acceptable fluid loss volume and rejected by NISOC standards (more than 2ml) when subjected to extreme temperature of 300°F. The only acceptable fluid loss control agent was potato starch (in mud weight of 150pcf) with fluid loss of 1.6ml as shown in fig 6(f). The results illustrated that WBM samples involving potato starch as a fluid loss additive exhibited the minimum fluid loss volume in compares to the applied agents.

4. CONCLUSION

This study presented the prospective of igebu garri starch as a fluid loss control agent in WBM formation based on NISOC standards and requirements. According to the rheological determination and obtained results, Igbe garri-WBM displayed the capability to form a WBM with superior viscosity and minimum fluid loss when subjected to the temperature of 250 F. The fluid loss improvement of investigated agents competed with cassava derivative known as fufu, previously investigated by author (Samavati et al., 2014), was observed in ascending order of light mud weight: Igbe garri (1ml)< fufu (2ml)< Potato(3ml)< Corn (10ml), average mud weight: Potato ( 0.6ml)< Corn (1ml)< fufu (1.5ml)< Igbe garri (2ml), heavy mud weight:Corn (0.8ml)< Potato and fufu ( 1ml)< Igbe garri (1.4ml). As results illustrated the starches utterly have degraded when subjected to temperature of 300 °F leading to high fluid loss applied to all mud samples devoid of heavy weight potato-WBM (1.6ml). Compared with potato, wheat and corn starches, Igbe garri (WG) presented...
corresponding filtration control aptitude and improved viscosification by lower cost.

Considering the obtained results, application of *Igebu garri* (WG) as a drilling mud additive will open up a new marketing for cassava appliance; which with no doubt will present economical profit to petroleum industry.

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\begin{array}{cccc}
\text{Fluid loss} & \text{Fluid loss} & \text{Fluid loss} & \text{Fluid loss} \\
(\text{ml}) & \text{agent} & \text{agent} & \text{agent} \\
150 & 75 & 20 & 60 \\
120 & 3 & 3.4 & 0.6 \\
90 & 10 & 90 & 1 \\
60 & 1.4 & 2.2 & 0.8 \\
30 & 1 & 1.6 & 0.8 \\
30 & 0.8 & 1 & 0.8 \\
\end{array}
\]

**Fig. 6:** (a) The fluid loss after hot-roll in 250 °F in mud weights of 75pcf (b) Fluid loss after hot-roll in 300 °F in mud weights of 75pcf (c) Fluid loss after hot-roll in 250 °F in mud weights of 100pcf (d) Fluid loss after hot-roll in 300 °F in mud weights of 100pcf (e) Fluid loss after hot-roll in 250 °F in mud weights of 150pcf (f) Fluid loss after hot-roll in 300 °F in mud weights of 150pcf

**ACKNOWLEDMENT**

The authors expressing their gratitude to PARS Drilling Fluid Company, Tehran Iran for provision of Drilling mud laboratory and facilities in this work, and Ms. Maryam Nemati for her technical assistance for Ms. Raheleh Samavati.

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Raheleh Samavati is a PhD student at the Department of Chemical and Environmental Engineering (Material and Science Engineering), Universiti Putra Malaysia. Her research activities are in the area of starch based drilling fluids. She can be contacted at e-mail: samavati_raheleh@yahoo.com

Associate Prof. Dr Norhafizah Abdullah is a lecturer at the Department of Chemical and Environmental Engineering, Universiti Putra Malaysia and the head of Material Characterization Laboratory at Faculty of Engineering, Universiti Putra Malaysia. Her research activities are in the area of purification engineering and macromolecules design for drug delivery and formulation. She can be contacted at e-mail: nhafizah@upm.edu.my.

Kourosh Tahmasbi Nowtarki is director manager of Pars Drill Fluid Co., Tehran. He earned a PhD in chemical engineering (1997) from Imperial College, University of London, and is a member of the dual-degree program committee, at Petroleum University of Technology, Tehran (2003-Present). Email: ktahmasbi@hotmail.com

Associate Prof. Dr Siti Aslina bt. Hussain. Dip. (UTM), B.Eng. (Hons) (Wales, Swansea), Ph.D. (ImperialCollege, London). Research Areas: Multiphase Flow, Chemical Process, Modelling, Simulation, Biomedical Engineering and Microwave Pyrolysis. Email: aslina@upm.edu.my / aslina@eng.upm.edu.my

Dr Dayang Radiah bt. Awang Biak. B.Eng. (CWRU), PhD (Birmingham) Research Areas: Heat Transfer; Modelling; Food Processing; Crystallisation; Pharmaceutical Products, Nanoscale Technology Email: dradiah@upm.edu.my / dayang@eng.upm.edu.my

Mojtaba Kalhor Mohammadi, Ms (Curtin University of Technology, Western Australia); Technical Services Manager Pars Drilling Fluids Co