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Evaluation of the Efficiency of Cassava Peel as a Cement Retarder in Oil Well Cementing

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Abstract:

Cementing around the casing in oil and gas wells provides proper zonal isolation, holds the casing in place and prevents fluid migration. This procedure is an important part of completing the process and well plugging for abandonment. Retarders are one of the most important additives in oil well cementing if the desired pumping time of cementitious slurry is to be achieved. These retarders can be extracted from natural sources or chemically synthesized. However, synthesized retarders can have significant environmental effects. Thus, this study evaluated the efficiency of cassava peel powder as a biocompatible retarder in oil well cementing and its cement slurry properties. Cement slurry was prepared, and the thickening time and rheology were tested according to API RP 10B2 (2005) procedures. The performance of cassava peel powder as an oil well cementing retarder was tested at various concentrations and temperatures. Its retardation property was compared with those of a commonly used lignosulfonate-based and a synthetic retarder, respectively. The results obtained at various concentrations of the retarders showed that the thickening time for cassava powder at 70Bc was 02hr: 17mins for 0.03% by weight of cement (%bwoc), 02hr: 20mins for 0.06% and 02hrs:32mins for 0.1%bwoc. The results for lignosulfonate-based retarder are 02hr: 19mins for 0.03%, 02hr: 30mins for 0.06% and 03hr: 02mins for 0.1% bwoc. For the synthetic retarder, the results are 02hr: 29mins for 0.03%, 02hr: 31mins for 0.06%, and 02hr: 51 mins for 0.1% bwoc. These results suggest that the retarding ability of cassava peel powder in oil well cementing is much comparable with those of the existing retarders. It was also observed that cassava peel demonstrates a high-performance concentration response without hampering other cement properties.

Keywords: Thickening time, rheology, setting time, chemically synthesized retarder, American petroleum institute specification

1. Introduction

Cementing operation in the oil industry is the placing of oil well cement slurry in between the formation and casing to achieve adequate zonal isolation of the well. This procedure is essential to:

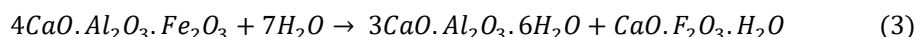
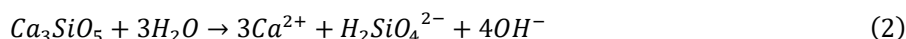
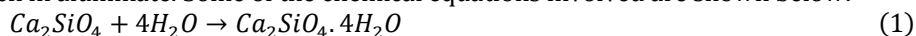
- Prevent the mixing of fluid-like gas and water as they pass from one zone to another in the well,
- Support the casing,
- Prevent casing from corrosion,
- Prevent casing from shock loads while drilling,
- Prevent blowouts and
- Achieve seal off lost circulation or thief zones and well abandonment

In the oil industry, well cementing is one of the major operations that must be carried out in the process of oil well construction of a wellbore (Looten, 2004). Therefore, a cement slurry of high grade is needed to achieve economic and safe crude oil production over the lifetime period of the well (Ridha et al., 2010). It also secures the extended durability of the wellbore by providing a high-quality casing (Pourafshary et al., 2009; Ershadi et al., 2011). When complete zonal isolation is not achieved, and a weak bond exists between the cement and the casing and the formation, the production capacity of the well is usually reduced, as this often leads to oil spills (Calvert, 2006). In well cementing, poor cement slurry design and poor cementing operation can adversely affect crude oil production. Some of the effects of such poor cementing are oil spills and the loss of world oil reserves (Lootens, 2004). The environmental effects of this are often death to aquatic life and land pollution, causing low production of agricultural produce. The environment is also uninhabitable, as this causes respiratory diseases.

1.1. Chemistry of Portland Cement Slurry Reaction

The predominantly used cement for cementing oil well is Portland cement. The four most essential clinker phases found in Portland cement are dicalcium silicate (Ca_2SiO_4), tricalcium silicate (Ca_3SiO_5), tetra calcium aluminoferrite ($\text{Ca}_4\text{Al}_2\text{Fe}_2\text{O}$), and tricalcium aluminate ($\text{Ca}_3\text{Al}_2\text{O}_6$). Each clinker is usually mixed with gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). The chemical reactions that result between water and cement are usually complex, and each part of Portland cement undergoes the hydration process in a unique chemical reaction route and at different reaction rates.

When cement is mixed with water, five principal chemical reactions occur. Dissolution of some parts of the clinker sulphates in gypsum occurs, generating a basic or an alkaline solution rich in sulphates. As soon as mixing is over, the Tricalcium aluminate that reacts most among the components undergoes a chemical reaction with the water and develops a gel-like solution rich in aluminate. Some of the chemical equations involved are shown below:



The gel undergoes reactions with sulphate produced in the mixture to form a minute rod-like structure of ettringite (hydrous calcium aluminium sulfate mineral). The tricalcium aluminate hydration process is usually a heat evolution process that lasts for a short while, after which it is immediately taken over by a few hours of comparably low energy production. This period is known as the induction period. The early stage of the induction period lasts for hours and that is enough for cementing operation. As the induction time continues, the slurry turns very hard to pumpable, after which the tri and dicalcium silicates in the Portland cement begin to undergo hydration. This gives rise to the build-up of calcium hydroxide and hydrated calcium silicate. The strength of the cement simultaneously develops, and the particles react within the surface to cause a reduction in the size of the anhydrous cement grains. At the same time, the hydration of tricalcium aluminate progresses as new crystals are easily available in the water. In a mixture having cement particles as major cementitious particles, the main strength development attained usually occurs within 30 days. Ferrite hydration begins immediately after water is introduced to the system and gradually decreases thereafter. This is usually attributed to the formation of a film gel of iron hydroxide on the surface of the iron, thus, acting as a hindrance to future chemical reactions. This rate of reaction between water and cement particles can be altered by the addition of chemical additives (Liska M et al., 2019).

1.1.1. Cement Additives

The rate at which hydration occurs when water is mixed with cement can be altered using chemical additives (Joel OF, 2009). Additives are chemicals or materials blended into base cement slurries to change the performance of the cement. Due to the inherent nature of base cement and the demands placed on the cement sheath throughout the life of an oil well, the performance properties of the cementing slurry are modified to address the specific and unique conditions of each well (Anon, 2016a). Many of the additives currently used are organic polymeric materials specifically formulated for well cementing operations (Joel et al., 2009). Typical chemical additives for oil and well cementing operations include accelerators, retarders, extenders, fluid loss and loss circulation additives, dispersants, etc. (Roshan et al., 2010).

1.1.2. Retarders

Retarders are chemical additives for decreasing the speed of cement dehydration and are used at high temperatures to allow time for mixing and placement of the cement slurry (Soltanian, 2011). The types of cement commonly used in well applications do not have a sufficiently long fluid life span (thickening time) for use at Bottom Hole Circulating Temperatures (BHCTs) above 100°F (Bett et al., 2010). Retarders decrease or inhibit dehydration and delay setting, allowing enough time for slurry placement in deep and hot wells (Taheri et al., 2009). Therefore, retarders are required to extend the thickening time of cement slurry (Joel, 2009). Besides this, most retarders affect the viscosity of the cement matrix to some degree. Though the ultimate compressive strength of cement is not decreased, the rate of strength development is slowed down (Joel et al., 2009). Retarding effects depend upon several factors, including dosage of the additives, and curing conditions, among others (Khan et al., 2004). Therefore, BHCTs should be carefully predicted so that the correct retarder concentration is used to avoid flash setting or very long set-up time due to over-retarded cement slurry (Joel, 2009).

According to Taheri et al. 2009, the retardation process is not completely understood. However, it is known that retarders bind to calcium ions (Taheri et al., 2009), inhibiting ettringite crystals' growth (Calvert, 2006). The most common retarders are natural lignosulfonates and sugar derivatives (Calvert, 2006). Calvert reported that the chemical nature of a cellulose-derived retarder is dependent on the cement phase (silicate or aluminate). Lignosulfonates and hydroxyl carboxylic acids, generally derived from naturally occurring sugars, are retarders that are believed to have good performance in oil well types of cement with low tricalcium aluminate contents. Lignosulfonates are normally used at circulating temperatures up to 200°F, while sugar compounds perform best at circulating temperatures between 200 and 300°F. Interestingly, it has been found (Sanni, 2013) that sugar acts as a retarder of cement slurries when added in small concentrations and as an accelerator when added in a high concentration of 0.2 to 1% by weight of cement. Some admixtures also act as retarders when used in small amounts but behave as accelerators when used in large amounts (Sanni et al., 2013). The newest retarders are made from varieties of synthetic compounds. In 2014, Anon reported using carbohydrates such as sucrose as a retarder. According to Sanni 2013, adding carbohydrates such as sucrose can

significantly extend thickening time or even prevent setting completely. However, these carbohydrates are not commonly used in oil and gas well cementing because of the sensitivity of the degree of retardation to small variations in concentration (Taheri et al., 2009).

2. Materials and Methodology

Weighing Balance, Blender Jar, Viscometer, Pycnometer, Atmospheric and High-Pressure High Temperature (HPHT) Consistometers, and Waring Blender are all products of Fann instrument company, USA. Thickening Time cup and Deformer (Fann Instrument Company, USA)

2.1. Reagents

Cassava peel, Cortex samples, Dyckerhoff class G cement, and Freshwater were obtained locally. Synthetic Retarder (HES USA) Lignosulfonate Retarder (HES USA) D-air 3000L (HES USA)

2.2. Sample Collection and Preparation

The Cassava Peel samples were divided into two portions:

- Crude peel, made up of periderm, cortex, and tissue
- Cortex only

The cassava peels were washed with faucet water over and again to dispose of surface pollutants. The strips were dried at a constant weight, then ground to fine powder utilizing a homegrown blender and sieved to acquire an advantageous molecule size of $< 150\mu\text{m}$. The end results were saved in a hermetically sealed plastic compartment for additional examination.

2.2.1. Thickening Time Test

Consistency of substantial slurry is measured in Bearden units of consistency (Bc). The Thickening Time (TT) test was performed using a High-Pressure/High-Temperature Consistometer assessed at a strain of up to 206.8 MPa (30 000 psi) and temperatures of up to 204°C (400°F). The substantial slurry was mixed by API techniques and subsequently poured into a slurry cup which was put into the consistometer for testing. The testing strain and temperature were controlled to re-enact the conditions. The slurry gave an insight into the well. The test wrapped up when the slurry showed up at a consistency pondered un-pumpable in the well. The time it takes the substantial slurries to show up at 50Bc, 70Bc, and 100Bc consistency was recorded (Anon, 2013).

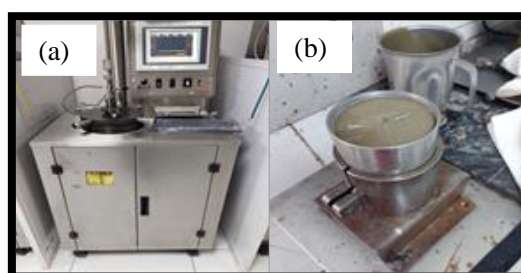


Figure 1: (a) High Pressure/High-Temperature Consistometer
(b) Thickening Time Cup

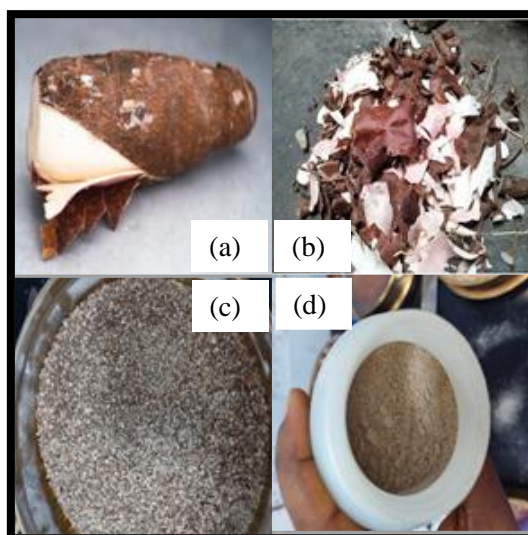


Figure 2: (a) Fresh Cassava (b) Dried Cassava Peel
(c) Sieving of Ground Cassava Peels (d) Sieved Cassava Peels

3. Results and Discussion

3.1. Proximate Analysis of Cassava Peel

Proximate Composition (%)						
Sample	Moisture Content	Ash	Fat	Protein	Crude Fibre	Carbohydrate
CP	6.69	3.70	0.65	6.57	20.30	62.09
IR	8.73			4.21	8.46	
Fibre Fractions (%)						
Sample	NDF	ADF	ADL	Cellulose	Hemicellulose	Lignin
CP	21.89	9.18	3.75	5.43	12.71	2.98
IR						2.5-4.8

Table 1: Results of Proximate Analysis on the Cassava Peel Sample

Note: CP--Cassava Peel, NDF--Neutral Detergent Fibre, ADF--Acid Detergent Fibre, ADL--Acid Detergent Lignin and IR—Imported Retarder

3.2. Cassava Peel vs. Lignosulfonate and Synthetic Retarder

The efficiency of cassava peel and cortex as retarders in oil well cementing was evaluated using 15.8-lbm/gal cement slurry at temperatures of 49, 60, and 82°C. The Cement slurry was prepared using dyckerhoff Class G cement with 43.21L/100kg fresh water and 0.02gal/sk defoamer. A thickening time test was performed in an HP/HT consistometer at 3000psi. Three stable and pumpable slurry designs were conceived using different retarders, cassava peel, and cortex powders. The retarder concentration was adjusted to achieve a thickening time between 2 and 3 hours. The results obtained are shown in table 2 and the charts below.

Temp. (°C)	Conc. (% bwoc)	Lignosulfonate	Synthetic	Cassava Peel	Cortex
49	0.03	02:19	02:29	02:17	02:05
	0.06	02:30	02:31	02:20	02:10
	0.10	03:02	02:51	02:32	02:22
60	0.03	01:59	02:01	01:43	01:30
	0.06	02:16	02:56	01:56	01:42
	0.10	02:39	02:40	01:54	01:44
82	0.03	01:51	01:46	01:37	01:30
	0.06	02:13	02:24	01:42	01:36
	0.10	02:40	02:43	01:42	01:38

Table 2: Retarding Abilities (Hrs.: Mins) of Lignosulfonate, Synthetic Retarder, Cassava Peel, and Cortex at Different Concentrations (% Bwoc)

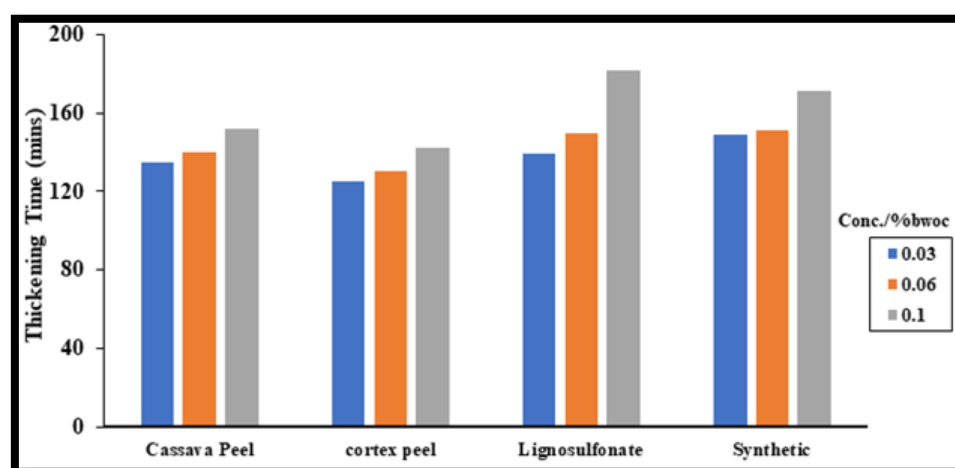


Figure 3: Thickening Time (Mins.) Versus Concentration (%Bwoc) of the Retarders at 49°C

Figure 3 shows that an increase in the concentration of all retarders leads to an increase in thickening time of both synthesized cement retarders and imported cement retarders. This may be because of the building of a coating film on the cement particles making it less permeable. It could also result from the development of calcium hydrogen nuclei bonding, which would increase the induction period. Thus, indicating that the slurry would remain in the pumpable state throughout the induction period. Comparing the performance efficiency of cassava peel with lignosulfonate and synthetic retarders at 49°C (Table 2 and Figure 3), it is observed that for 0.1%bwoc, cassava peel pumped at 02hrs:32mins,

lignosulfonate at 03hrs:02mins while cortex pumped at 2hrs:22mins. The synthetic retarder is pumped at 02hrs:51mins, which means that cassava peel has a more retarding ability than these other retarders.

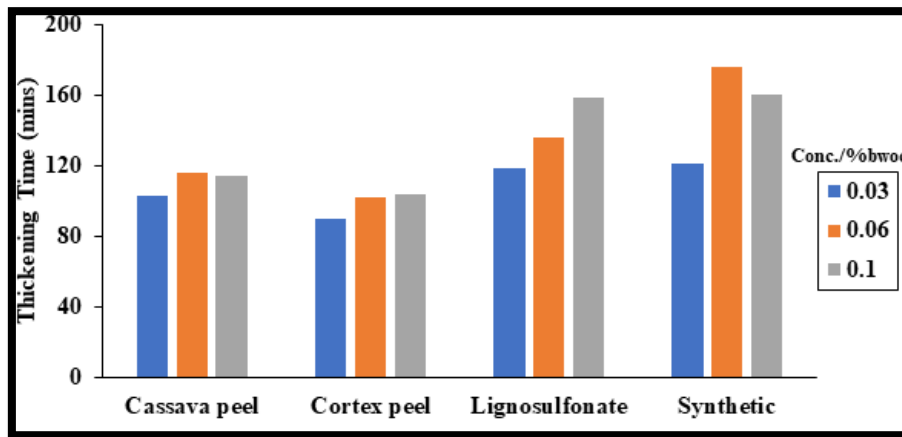


Figure 4: Thickening Time (Mins.) Versus Concentrations (%Bwoc) of the Retarders at 60°C

Table 2 and figure 4 show that at 60°C and 0.1%Bwoc, Cassava peel was pumped at 01hr: 54mins, the lignosulfonate was pumped at 02hrs:39mins, and synthetic retarder was pumped at 02hrs:40mins. Comparing the retarding abilities of these samples at different temperatures, cassava peel performs slightly lower than the imported retarders at a higher temperature.

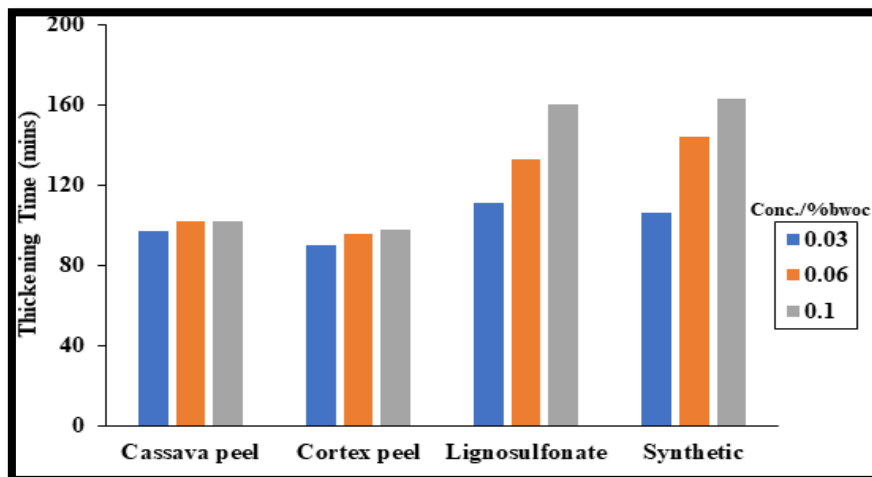


Figure 5: Thickening Time (Mins.) Versus Concentrations (%Bwoc) of the Retarders at 82°C

From figures 3-5, it can be inferred that imported retarders perform better at higher temperatures, while cassava peel does better at lower temperatures. It is generally known that temperature is one of the major factors that affect the hydration of cement. The hydration rate of cement, the nature, stability, and morphology of the hydration products are strongly dependent upon this parameter and the concentration of the retarder. As temperature increases, cement slurry dehydrates faster, and thickening time decreases. However, this depends on the concentration of the retarder.

The overall results reveal that an increase in the concentration of cassava peel and cortex powders increased the thickening time of cement slurry but with reduced performance as the temperature increased. The charts also show the same trend for lignosulfonate and synthetic retarders. However, as concentration increased, the synthetic retarder showed the highest retarding efficiency at higher temperatures, probably to withstand the temperature variation. Lignosulfonate performed better at lower temperatures. The optimum performance temperature for cassava peel and cortex powders was 49°C. However, cassava peel had a greater ability for cement slurry retardation than the cortex.

4. Conclusion

The effectiveness of cassava peel in retarding cement slurry has been evaluated and compared with some existing retarders for oil well cementing. It was observed that cassava peel has the capacity to cause retardation in setting the time of cement slurries, as demonstrated with class G cement. The optimum temperature for this effect was found to be 49°C. In general, the results of this research show that an increase in temperature leads to the faster setting of the cement slurry or a decrease in the thickening time. An increase in retarder concentration either delays the setting time of the cement slurry or increases the thickening time of the cement slurry. The yield point of the cement slurry decreases as the concentration of the locally synthesized cement retarder increases. It was also observed that the concentration of the cement retarder depends on the type of cement, the volume of cement slurry required for the given operation, and the temperature of the

well. That the locally synthesized cement retarder has the capacity to retard dyckerhoff- G cement prepared at 15.8 lbm/gal with 43.21L/100kg of fresh water. Thus, this study has discovered that cassava peel, a waste material from the agricultural industry, can be converted into a useful resource for wealth creation and an alternative source to imported oilfield cement chemicals.

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