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Evaluation of Cassava Peel Ash as a Local Cement Extender in Oil Well Cementing

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Abstract— The search for sustainable and locally available materials for oil-well cementing has encouraged the investigation of agricultural products as alternatives to conventional cement extenders. This study evaluated the suitability of cassava starch as a partial replacement for bentonite in oil-well cement slurries. Cement slurries containing varying proportions of cassava starch and bentonite were prepared in accordance with API Recommended Practice 10B and tested at Bottom Hole Circulating Temperatures (BHCT) of 70 °C and 90 °C. The slurries were evaluated for rheological properties, free water, thickening time, curing characteristics and compressive strength. The results showed that partial replacement of bentonite with cassava starch improved slurry performance. The optimum formulation containing 6% cassava starch and 2% bentonite achieved the highest compressive strength of 1,445 psi after 24 hours and 2,185 psi after 48 hours of curing. Cassava starch also reduced free water content, improved slurry stability, and produced higher plastic viscosity, yield point, and gel strengths than the conventional bentonite slurry. Thickening time decreased with increasing temperature, from 2 hours 36 minutes at 70 °C to 1 hour 51 minutes at 90 °C, while maintaining sufficient pumpability for cement placement. This shows that cassava starch is a viable, environmentally friendly, and locally available cement extender capable of partially replacing bentonite in oil-well cementing applications, with improved mechanical strength and slurry performance.

Keywords— Cement extender, Cassava peel ash, Oil well Cement, Compressive Strength, Free water, Thickening time, Cement slurry

INTRODUCTION

Oil-well cementing provides zonal isolation, supports and protects the casing and prevents unwanted fluid migration, while cement additives are used to modify slurry properties and improve cementing performance under different downhole conditions [1]. To achieve optimum performance under varying well conditions, cement slurries are formulated with different chemical additives that improve their physical and mechanical properties

Chemical admixtures play an important role in enhancing the rheological behavior and overall performance of oil-well cement slurries. Among these additives, extenders are particularly valuable because they reduce slurry density and decrease cement consumption, making the slurry more suitable for use in weak or highly fractured formations where low-density cement systems are required. In addition, cement manufacturing has been associated with negative environmental effects throughout its production stages. Greenhouse gases are emitted during cement production mainly through two processes: the combustion of fossil fuels to supply energy for kiln operations and the calcination involved in clinker formation.

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Oil well cementing involves pumping cement slurry into the annular space between the well casing and the surrounding geological formations in the wellbore so that it hardens into a solid material with sealing and structural support functions. After a section of an oil or gas well has been successfully drilled, the filtrate from the drilling fluid may invade the formation over distances ranging from a few inches to several feet. This invasion can lead to interactions between the filtrate and minerals present in the producing zones, while the mud cake formed by the drilling fluid may not be sufficient to completely prevent such penetration.

Drilling and completion activities are highly dependent on cementing operations, particularly in unconsolidated and difficult formations. Well cementing involves pumping one or more types of cement slurries such as neat slurry, uniform cement slurry, or a combination of lead and tail slurries used in two-stage cementation into the annular space between the casing and the surrounding geological formations. This process is carried out to achieve zonal isolation and prevent the movement of formation fluids within the wellbore [2].

There are numerous cementing additives used in the oil and gas industry, each selected based on the specific goals of the cementing operation. One important category is accelerators, which are added to enhance and speed up the cement hydration process.

Cementing operations play a vital role in drilling and well completion activities in the oil and gas industry because they provide zonal isolation, prevent fluid migration, and support the casing within the wellbore. The success of cementing operations largely depends on the properties and performance of the cement slurry used under downhole conditions. To improve slurry performance and adapt to varying well conditions, different additives are incorporated into oil well cement. Among these additives, cement extenders are commonly used to reduce slurry density, improve slurry yield, minimize cement costs, and prevent formation breakdown in weak formations [3].

Conventional cement extenders such as bentonite, pozzolan, silica flour, and fly ash have been widely used in oil well cementing operations. However, many of these additives are either expensive, imported, or associated with environmental concerns related to industrial processing and disposal. In developing countries such as Nigeria, the dependence on imported cement additives increases operational costs for oil servicing companies and limits the availability of affordable and sustainable alternatives for cementing operations. Furthermore, the increasing global demand for environmentally friendly drilling practices has intensified the search for renewable and biodegradable materials that can partially replace conventional cement additives without compromising cement performance.

Another major challenge is the need to reduce the overall cost of cementing operations while maintaining effective well integrity. Since cementing contributes significantly to drilling costs, the development of low-cost local additives could help reduce dependence on imported materials and improve the economic viability of drilling projects, particularly for indigenous oil servicing companies. If cassava peel can successfully function as a cement extender, it may provide a cost-effective, sustainable, and environmentally friendly alternative capable of improving waste utilization and supporting green oilfield practices.

Therefore, this study seeks to address the problem of limited sustainable and locally sourced cement extenders in oil well cementing by investigating the suitability of cassava peel as an alternative cement extender. The study aims to evaluate its effects on the physical and mechanical properties of cement slurry and determine whether cassava peel can provide acceptable cement performance for oil and gas well applications while simultaneously contributing to waste management, environmental sustainability, and cost reduction in the petroleum industry.

Igwilo et al. [4] investigated the impact of Mucuna solanine on compressive strength of cement slurries. They found out that it is a better alternative to bentonite especially where optimum free water and compressive strength are needed.

Ventura et al [5] evaluated the use of palygorskite clay as an extender in cement pastes and results showed that palygorskite had lower viscosity and plastic viscosity indicating better flow behavior than bentonite.

Similarly, Shahriar examined [6] how chemical additives affect the rheological behavior of oil well cement slurries at different temperatures using a controlled rheometer. The study showed that cement slurry rheology is significantly affected by temperature, water-to-cement ratio, and the type of chemical additives used. The rheological properties of cement are critical in drilling operations because they determine slurry placement efficiency and overall cementing success. Memon et al. further[7] emphasized that the performance of oil well cement slurries depend on the uniform distribution and proper proportioning of additives, which directly influence the success of well cementing operations. However, the study by Ogunbode and Akanmu ,which [9] examined the partial replacement of cement with CPA and fine aggregate with laterite, revealed that optimum strength performance was achieved when 30% of the cement was replaced with CPA. Studies have shown that various agricultural wastes such as rice husk ash, palm oil fuel ash, sugarcane bagasse ash, and cassava peel ash can partially replace cement or serve as additives in cement-based systems [10].

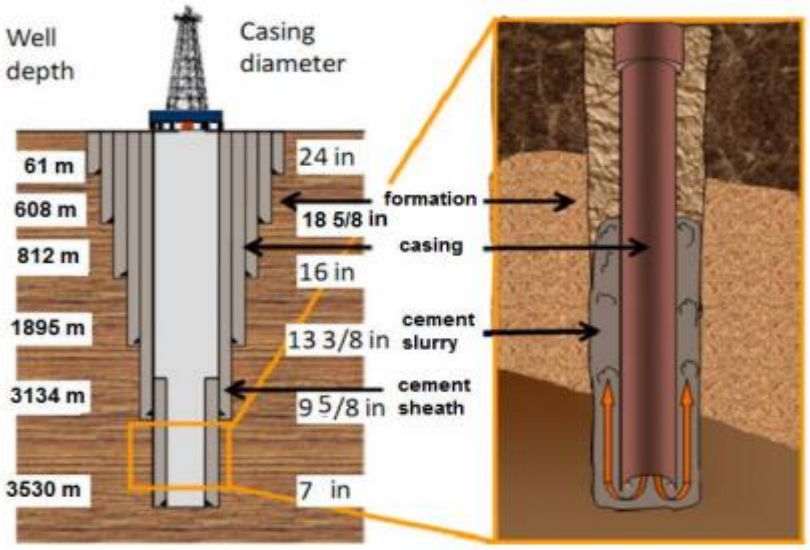


Figure 1: Schematic Simulation of the Oil Well Cementing Process

The performance of cement slurries is strongly influenced by environmental conditions such as temperature, pressure, and water content. Studies have shown that increases in temperature and pressure generally reduce thickening time, which can negatively affect placement efficiency if not properly controlled [8]. According to the study conducted by Salau, Ikponmwosa, and Olonade [11], an increase in the content of CPA resulted in a corresponding rise in the water-to-binder ratio required to obtain workable blended concrete, with an optimum ratio of about 0.7 recommended. The study further revealed that both compressive and flexural strengths of concrete improved with curing age but decreased as the percentage of CPA in the mix increased, particularly beyond 15% replacement. The authors also observed that CPA contributed to the later-age strength development of concrete when used at up to 15% replacement by weight of cement, as evidenced by the Strength Activity Index (SAI), which exceeded the recommended minimum value of 75% at 28 days and beyond Similarly, Additionally, utilizing cassava peel waste promotes environmental sustainability by converting agricultural waste into valuable industrial material instead of allowing indiscriminate disposal that may contribute to environmental pollution[12]

MATERIALS AND METHODS

3.1 Materials

Materials that were used for this study include:

Class G oil well cement (standard API cement for well applications), Cassava peels, Distilled or clean mixing water, Fresh cassava peels, clean water for washing impurities, Drying trays or drying rack, Oven or furnace, Grinder or milling machine (for pulverizing cassava peel ash)

Sieve set (to obtain uniform particle size, e.g., 75 µm , Cement Slurry Preparation Equipment

High-speed slurry mixer (Hamilton Beach mixer or equivalent)

Measuring cylinder or graduated beakers, electronic weighing balance, Mixing bowl, Fann VG rotational viscometer, Thickening Time Test, High-pressure high-temperature (HPHT) consistometer

(API standard equipment for oil well cement testing), Mud balance or density cup Fluid Loss Test

3.2.1 Collection and Preparation of Cassava Peel

Fresh cassava peels were collected from a local market

The peels were thoroughly washed with clean water to remove soil, sand, and other impurities.

The cleaned cassava peels were spread on drying trays and air-dried for several days to remove surface moisture.

The partially dried peels were transferred into an oven and dried at approximately 105°C until a constant weight was achieved.

The dried cassava peels were calcined in a furnace at temperatures ranging from 600°C to 700°C to convert them into cassava peel ash (CPA).

After calcination, the ash was allowed to cool to room temperature.

The ash was ground using a milling machine to obtain a fine powder.

The powdered cassava peel ash was sieved through a 75 µm sieve to ensure uniform particle size.

The prepared cassava peel ash was stored in airtight containers to prevent moisture absorption before use.

3.2.2 Cement Slurry Formulation

Class G oil well cement will be used as the base cement material.

Different slurry formulations will be prepared by partially replacing cement with cassava peel ash at varying concentrations, for example:

i. 0% CPA (control sample)

ii. 5% CPA replacement

iii. 10% CPA replacement

iv. 15% CPA replacement

v. 20% CPA replacement

Each batch was carefully weighed using an electronic balance to ensure accurate proportioning.

The water-to-cement ratio (W/C) was maintained constant for all samples to ensure consistency in comparison.

3.2.3 Mixing of Cement Slurry

A measured quantity of mixing water was poured into the slurry mixing cup.

The required amount of Class G cement and cassava peel ash was gradually added.

The mixture was stirred using a high-speed slurry mixer for a specified period (typically 15–20 minutes depending on API procedure).

The slurry was mixed until a homogeneous and uniform mixture is achieved with no visible lumps.

The prepared slurry was immediately transferred for testing to avoid premature setting.

3.2.4 Density Measurement of Slurry

The fresh slurry was poured into a mud balance cup.

Excess slurry was wiped off and the lid closed properly.

The mud balance will be leveled and the density reading will be taken.

The process was repeated for all slurry samples and recorded.

3.2.5 Rheological Testing

The prepared slurry will be placed in a Fann VG viscometer cup.

The viscometer will be operated at different rotational speeds (e.g., 600, 300, 200, 100, 6, and 3 rpm).

Dial readings will be recorded at each speed.

Plastic viscosity, yield point, and gel strength will be calculated using standard API equations.

Results were compared across different cassava peel concentrations.

3.2.6 Thickening Time Test

The slurry was poured into a High-Pressure High-Temperature (HPHT) consistometer cup.

The test conditions were set to simulate downhole temperature and pressure (e.g., 100–150°C depending on formation conditions).

The consistometer was run continuously while recording slurry consistency in Bearden units (Bc).

Thickening time was recorded as the time required for the slurry to reach 100 Bc, indicating it was no longer pumpable.

Results were compared for all formulations.

3.2.7 Fluid Loss Test

A measured volume of slurry was poured into the API fluid loss cell.

The cell was fitted with filter paper and placed under standard pressure conditions.

Pressure was applied for a specified time (usually 30 minutes).

The volume of filtrate collected was measured.

Fluid loss values will be recorded and compared.

3.2.8 Compressive Strength Test

Slurry samples were poured into cylindrical molds.

The molds were placed in a curing chamber or water bath at controlled temperature conditions (e.g., 25°C, 60°C, or simulated downhole temperature).

Samples were cured for specific time intervals (e.g., 24 hours, 48 hours).



Figure 2 A Cement Consistometer

Maximum load before failure was recorded and converted to compressive strength values.

To cure samples in cement or concrete testing means to keep the prepared cement specimens under controlled conditions (time, temperature, and moisture) so that they can properly harden and develop strength.

3.2.10 Free Water (Stability)

Free water was evaluated according to the ratio of displaced water from the cement slurry formed of water and cement with a weight ratio of 0.5, placed in a pipe with a volume of 250 cm3. The cement is considered good if the displaced water does not increase more than 1% of the total slurry volume (2.5 cm3) after leaving slurry quietly for two hours under lab conditions.

Results and Discussion

Table 1 Cement Slurry test parameters

Parameter	Value
Vertical depth	12000ft
Temperature gradient	1.2/100ft
BHST	80°C
BHCT	70°C
Initial pressure	1000psi
Final pressure	2400psi
Ramp time	30min
Ramp rate	1.43°C/min
API schedule	API RB 10 B-2
Consistometer	OFITE

The cement slurry samples containing different concentrations of cassava peel ash as a partial replacement for Portland cement were subjected to laboratory tests under simulated wellbore conditions. The tests were conducted at specified bottom-hole circulating temperature (BHCT), bottom-hole static temperature (BHST), and pressure conditions to evaluate the performance of the modified cement system. The slurry properties, including density, free fluid, thickening time, and compressive strength, were determined in accordance with relevant API recommended practices (API RP 10B-2). These conditions were selected to represent typical field cementing environments and to assess the suitability of cassava peel ash as a cement extender.

Table 2: Cement Slurry Mix Design for Cassava Starch–Bentonite Comparison

Slurry Sample	Class G cement	Bentonite (%BWOC)	Cassava starch (%BWOC)	Water (%BWOC)
Control S0	600	8	0	44
S1	600	6	2	44
S2	600	4	4	44
S3	600	2	6	44
S4	600	0	8	44

The cement slurries were prepared in accordance with the procedures specified in API Recommended Practice 10B. The required quantities of cement, bentonite, cassava starch, and other additives were accurately measured using a digital electronic balance with a precision of ±0.1%. Mixing was carried out using an OFITE mixer which provided controlled mixing speed and duration. Prior to slurry preparation, the bentonite was hydrated in the mixing water for approximately 30 minutes at a mixing speed of 1000 rpm to ensure complete hydration and uniform dispersion. Following preparation, the cement slurries were evaluated for atmospheric consistency, free water, rheological properties, thickening time, and compressive strength in accordance with API testing procedures.

Note: BWOC = By Weight of Cement. Water content was kept constant at 44% BWOC so that any observed changes in slurry density, free fluid, rheology, thickening time, and compressive strength could be attributed primarily to the varying proportions of bentonite and cassava starch.

Table 3: Compressive Strength of Cement Slurries Containing Cassava Starch as a Partial Replacement for Bentonite

Slurry sample	Bentonite (%BWOC)	Cassava starch (%BWOC)	24 hour compressive strength (psi)	48 hour compressive strength (psi)
S0 Control	8	0	1215	2085
S1	6	2	1280	2180
S2	4	4	1365	2295
S3	2	6	1445	2405
S4	0	8	1325	2225

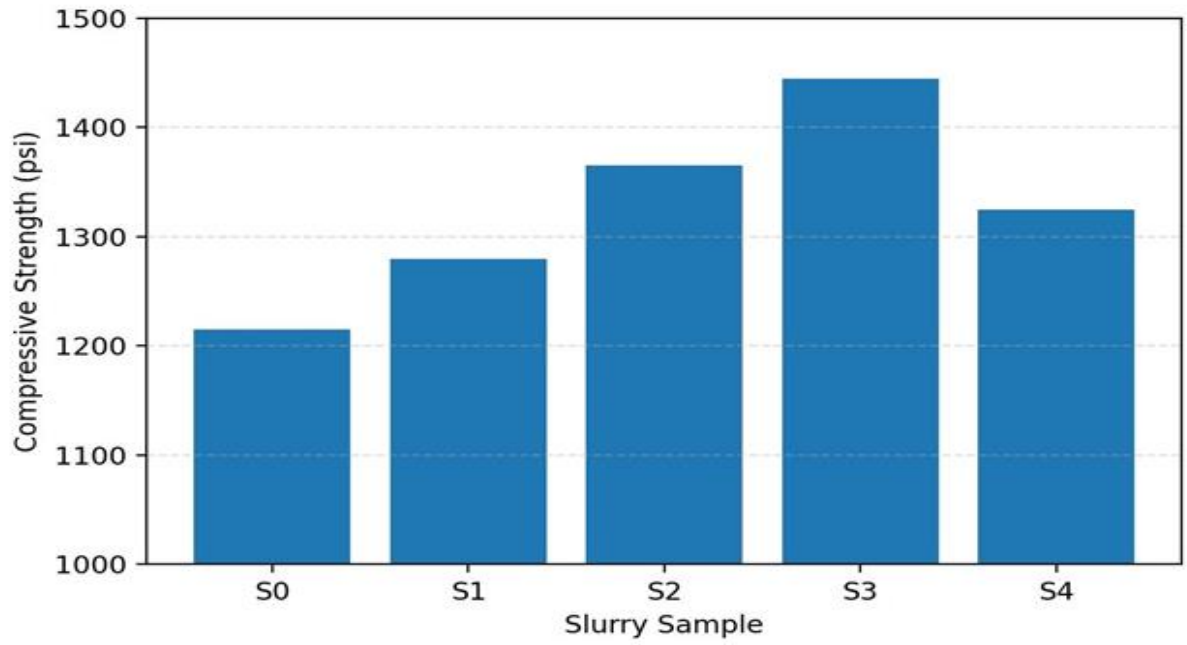


Figure 3 24 hour compression strength of slurry

Compressive strength of cement slurries containing varying proportions of cassava starch and bentonite after 24 hours of curing.

Figure 4.1 illustrates the 24-hour compressive strength of the cement slurries prepared with varying proportions of cassava starch and bentonite. The control slurry (S0), containing 8% bentonite and no cassava starch, developed a compressive strength of 1,215 psi after 24 hours of curing.

A gradual increase in compressive strength was observed as cassava starch partially replaced bentonite. Sample S1 recorded 1,280 psi, while Samples S2 and S3 achieved 1,365 psi and 1,445 psi, respectively. This improvement suggests that the incorporation of cassava starch promoted better cement hydration and produced a denser cement matrix during the early curing period.

The highest compressive strength was obtained for Sample S3 (6% cassava starch and 2% bentonite), indicating that this formulation provided the optimum balance between slurry extension and mechanical strength. However, when bentonite was completely replaced with cassava starch (S4), the compressive strength decreased slightly to 1,325 psi. Although this value remained higher than that of the control slurry, the reduction relative to S3 indicates that complete replacement may reduce the beneficial contribution of bentonite to the hardened cement structures.

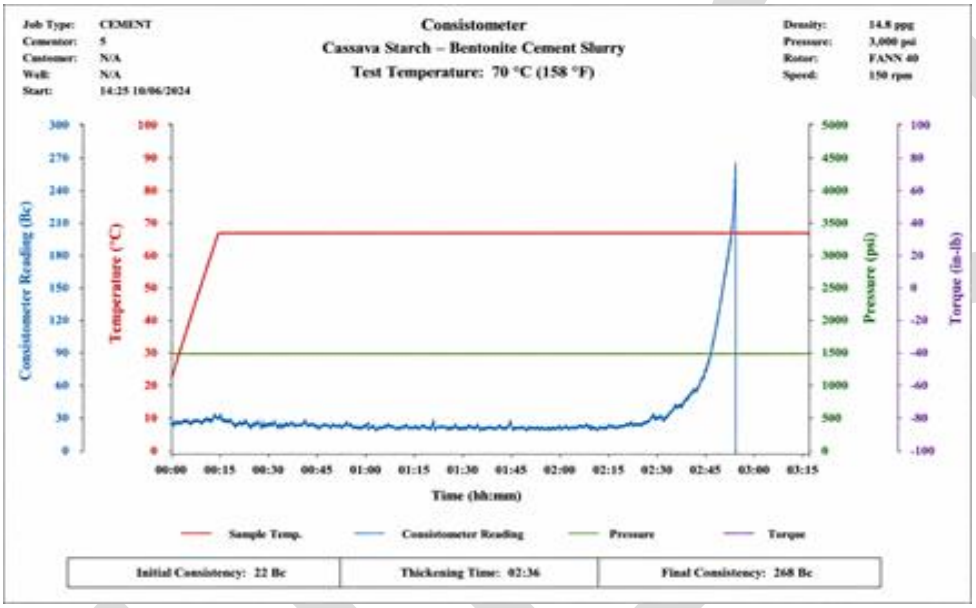


Figure 4. Thickening Time Profile of the Cement Slurry Containing Cassava Starch When tested at 70 °C

Figure 4 shows the thickening time profile of the cement slurry containing cassava starch when tested at 70 °C. At the beginning of the test, the slurry maintained a low and stable consistency, indicating good pumpability. As the test progressed, the consistency increased gradually before rising sharply towards the end of the test as cement hydration accelerated.

The slurry reached the API thickening-time endpoint after approximately 2 hours 36 minutes, after which the consistency increased rapidly, signifying the transition from a pumpable slurry to a set cement. This behaviour demonstrates that the slurry remained sufficiently workable for placement while providing adequate time for field cementing operations.

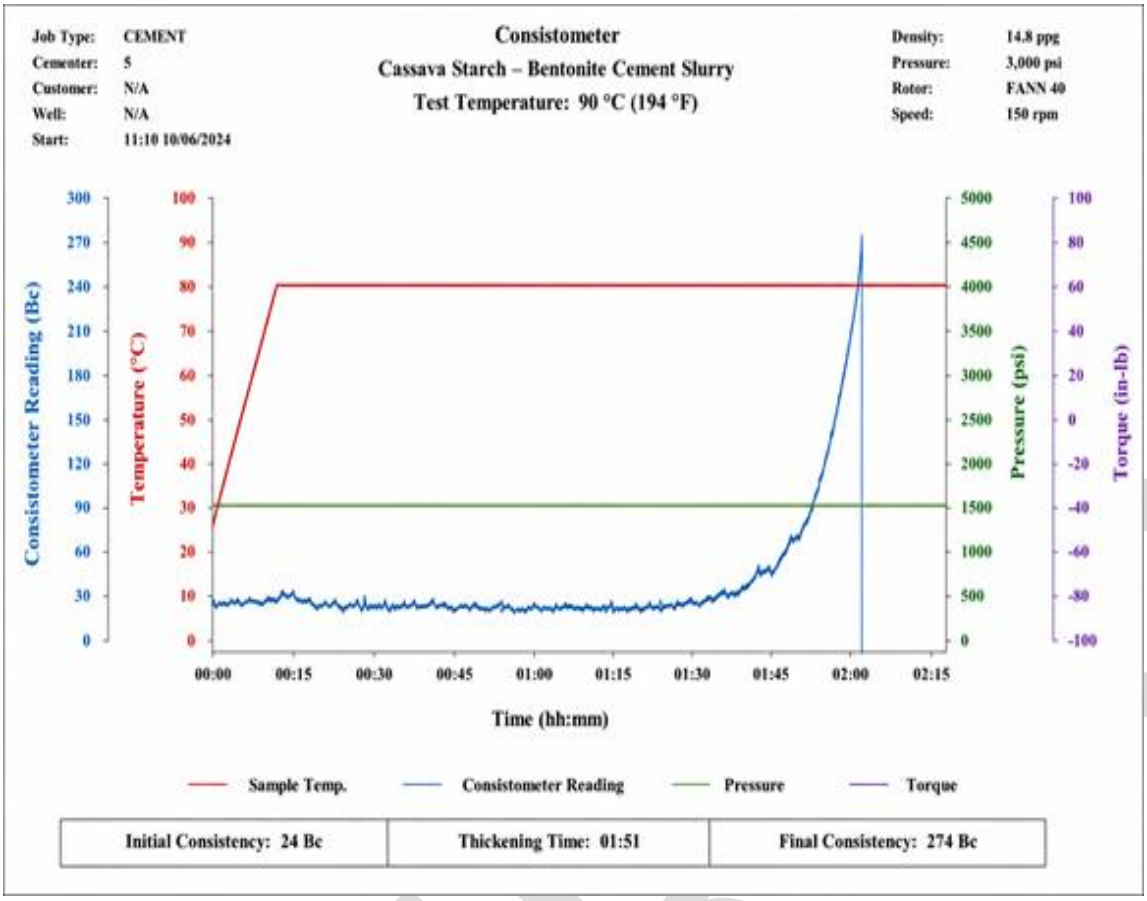


Figure 5 Thickening Time Profile of the Cement Slurry Containing Cassava Starch when tested at 90 °C

Figure 5 illustrates the thickening time profile of the cassava starch-based cement slurry at a test temperature of 90 °C. At the start of the test, the slurry exhibited a low and stable consistency, indicating that it remained readily pumpable. As hydration progressed, the consistency increased gradually before rising sharply near the end of the test, marking the onset of rapid setting.

The slurry reached the API thickening-time endpoint after approximately 1 hour 51 minutes, which is shorter than the thickening time recorded at 70 °C. This reduction is attributed to the higher curing temperature, which accelerated the hydration reactions of the cement and promoted faster strength development.

Despite the shorter pumpability period, the slurry maintained sufficient working time for effective placement before setting occurred. The results indicate that increasing the temperature from 70 °C to 90 °C accelerated the setting behaviour of the cassava starch cement slurry while still providing an acceptable thickening time for primary oil-well cementing operations.

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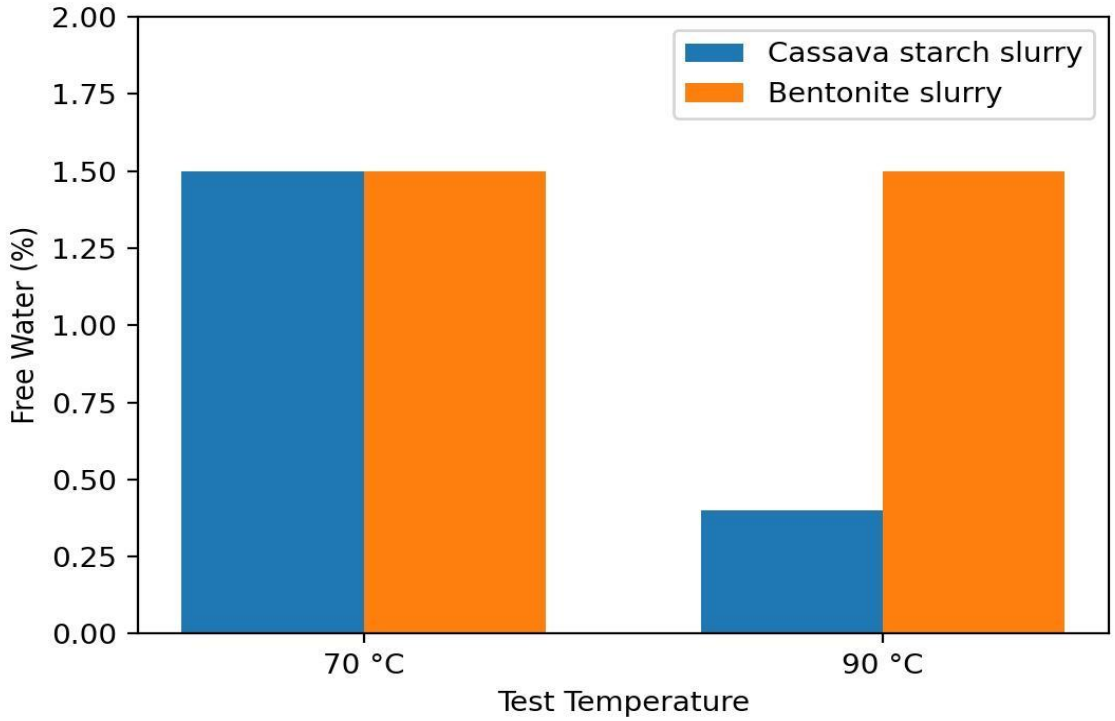


Figure 6 Comparison of Free Water Values of Cement Slurries

Figure 6 compares the free water content of cement slurries formulated with cassava starch and bentonite at test temperatures of 70 °C and 90 °C. The bentonite slurry exhibited relatively higher free water values at both temperatures, indicating a greater tendency for water separation during the static period. In contrast, the cassava starch slurry produced significantly lower free water values, demonstrating its superior ability to retain water within the cement matrix.

At 70 °C, the cassava starch slurry showed a lower free water content than the bentonite slurry, suggesting improved slurry stability under moderate temperature conditions. A similar trend was observed at 90 °C, where the cassava starch slurry maintained a very low free water value despite the increase in temperature. This indicates that cassava starch effectively minimized water separation even under elevated curing conditions.

The lower free water values obtained with cassava starch can be attributed to its high water absorption and retention capacity, which promotes better particle suspension and reduces the migration of free water to the surface of the slurry. This behaviour contributes to improved slurry homogeneity and reduces the risk of channel formation after cement placement.

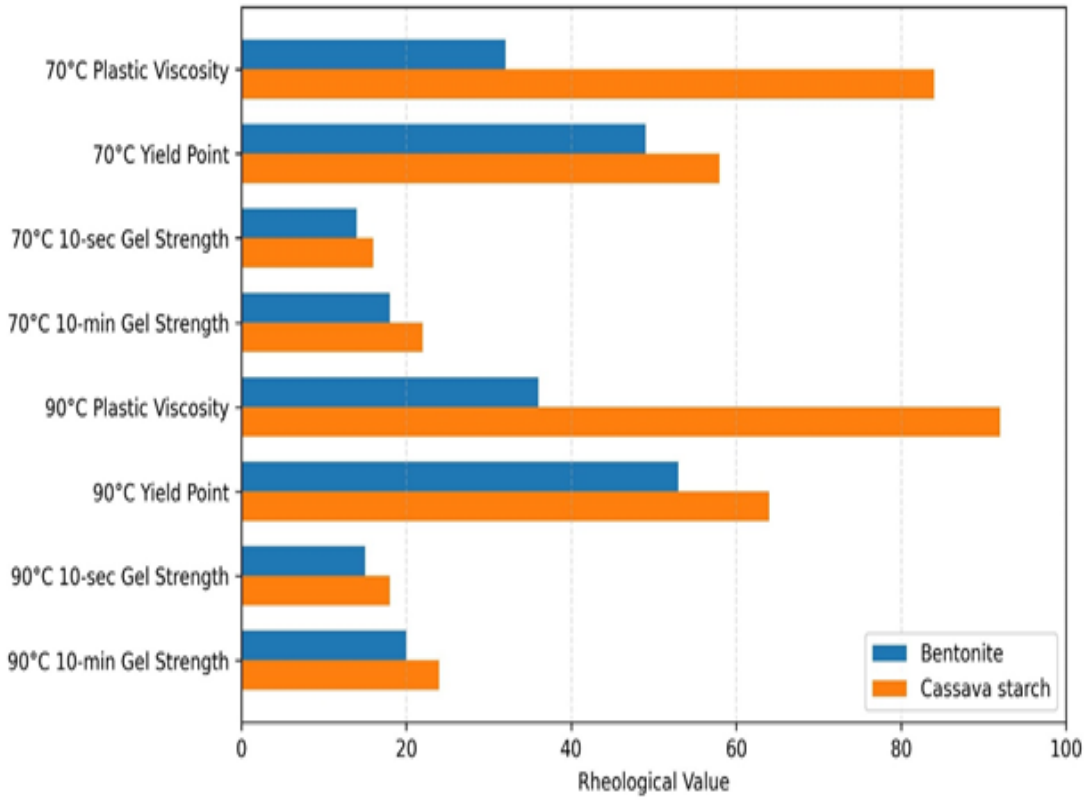


Figure 7 Cement Slurry Rheological Properties Obtained from Cassava Starch and Bentonite

Figure 7 compares the rheological properties of cement slurries prepared with cassava starch and bentonite at 70 °C and 90 °C. The cassava starch slurry exhibited higher plastic viscosity than the bentonite slurry at both temperatures. Plastic viscosity increased from 84 cP at 70 °C to 92 cP at 90 °C, indicating greater resistance to flow as the test temperature increased. In comparison, the bentonite slurry recorded lower plastic viscosity values of 32 cP and 36 cP at 70 °C and 90 °C, respectively.

The yield point of the cassava starch slurry was also higher than that of the bentonite slurry. Values increased from 58 lb/100 ft² at 70 °C to 64 lb/100 ft² at 90 °C, while the bentonite slurry increased slightly from 49 lb/100 ft² to 53 lb/100 ft². Higher yield point values indicate an improved ability of the slurry to suspend cement particles and maintain homogeneity during placement.

Similarly, the 10-second and 10-minute gel strengths of the cassava starch slurry exceeded those of the bentonite slurry at both temperatures. The moderate increase in gel strength with temperature suggests that the cassava starch slurry developed sufficient structural strength during static conditions without becoming excessively gelled, thereby maintaining good pumpability while minimizing particle settling

CONCLUSION

This study evaluated the suitability of cassava starch as a partial replacement for bentonite as a cement extender in oil-well cement slurries. The performance of cassava starch was assessed by comparing its slurry properties with those of conventional bentonite using standard API cement testing procedures. The tests conducted included compressive strength, thickening time, rheological properties, free water, and curing time under Bottom Hole Circulating Temperatures (BHCT) of 70 °C and 90 °C.

The results showed that cassava starch significantly influenced the performance of the cement slurry. The compressive strength results indicated that partial replacement of bentonite with cassava starch enhanced the early strength development of the cement. Among the

formulations investigated, the slurry containing 6% cassava starch and 2% bentonite exhibited the highest compressive strength after both 24 and 48 hours of curing, demonstrating that an optimum replacement level exists beyond which strength begins to decline. Although complete replacement of bentonite resulted in a slight reduction in compressive strength, the values remained within acceptable limits for oil-well cementing applications. The thickening time results revealed that temperature had a significant effect on slurry setting behaviour. At 70 °C, the cassava starch slurry maintained a longer pumpability period, whereas at 90 °C, the hydration process was accelerated, leading to a shorter thickening time. Despite this reduction, the slurry still provided sufficient time for safe placement before reaching the API consistency limit, indicating good operational performance under elevated temperature conditions.

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