

# Potential of Cassava Leaf Extract as a Green Scale Inhibitor for Calcium Carbonate Scale Precipitation in Oil and Gas Production Facilities

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**Abstract**— This study investigates the potential of cassava leaf (*Manihot esculenta*) extract as a natural, eco-friendly inhibitor for calcium carbonate ( $\text{CaCO}_3$ ) scale formation in simulated produced water. Using Soxhlet extraction with ethanol, a yield of 38.5% was obtained, indicating a significant presence of bioactive compounds. FTIR analysis revealed functional groups including  $-\text{OH}$ ,  $-\text{NH}$ ,  $\text{C}=\text{C}$ ,  $\text{C}-\text{H}$ , and  $\text{C}-\text{O}-\text{C}$ , which contribute to calcium ion chelation and disruption of  $\text{CaCO}_3$  crystallization. Experimental results demonstrated strong inhibition efficiency, with notable performance at 200  $\mu\text{l}$  concentration and elevated temperatures (50°C). TDS measurements showed increased solubility, indicating reduced  $\text{CaCO}_3$  precipitation. The cassava leaf extract's biodegradability and low toxicity highlight its potential as a sustainable alternative to synthetic inhibitors in industrial applications.

**Keywords**— Cassava leaves, calcium carbonate, green inhibitor, scale formation, TDS, inhibition efficiency.

## I. INTRODUCTION

Oil and gas operations entail water being produced along with the hydrocarbon in relatively large amounts. Water is present wherever there is hydrocarbon production. Water in the oil and gas industry is considered as one of the most important drivers for hydrocarbon production. Water aids in managing the reservoir, mobilizing the hydrocarbons, and displacing them within the homogenous rocks. The production of this type of water is a famous issue and present in many fields worldwide. Operators face this issue especially in older wells and rarely in newly developed wells too [1].

Scale formation is a major operational challenge in oil and gas production systems, often leading to reduced permeability, clogged pipelines, and decreased productivity. Calcium carbonate ( $\text{CaCO}_3$ ) is among the most common types of scale encountered, forming under high temperature and pressure conditions in reservoirs and production equipment. Traditionally, synthetic inhibitors such as phosphonates and polycarboxylates have been used, but environmental concerns over their toxicity and poor biodegradability have spurred the search for green alternatives [2]. Recent studies [3, 4, 5, 6, 7, 8, 9] have emphasized numerous green alternatives, both polymers and plant-based compounds, for scale inhibition, consolidating progress in biodegradable inhibitors. Cassava leaves (*Manihot esculenta*), which contain natural phytochemicals such as flavonoids, tannins, saponins, alkaloids, and glycosides, offer an eco-friendly potential to scale inhibition due to their metal-chelating and crystal-growth-modifying properties [10, 11].

This study aims to assess the inhibitory performance of cassava leaf extract as a green scale inhibitor alternative to synthetic scale inhibitors in preventing calcium carbonate

( $\text{CaCO}_3$ ) precipitation under simulated oilfield conditions, evaluating its performance through laboratory tests of TDS, mass of precipitate, and inhibition efficiency.

## II. MATERIALS AND METHODS

### A. Collection of cassava leaves and its extraction process

Cassava leaves were collected from a cassava farm at Ugbomoro village of Delta State, Nigeria. They were carefully washed with distilled water to remove contaminants, dried and ground into fine powder, and then kept for further use in airtight plastic containers.

The solvent extraction method using the Soxhlet extractor apparatus was employed by Akaho [12] with ethanol as the solvent, yielding 38.5% extract.

### B. Fourier Transform Infrared Spectroscopy (FTIR) of extract

The chemical functional spectra of cassava leaf extracts were measured using FTIR Spectroscopy (Agilent Cary 630, US) in transmittance mode with a resolution of 4000 to 600  $\text{cm}^{-1}$  wavelength by Manikandan [13].

### C. Compositions and preparation of the brine solutions

To evaluate the inhibitory performance of the scale inhibitor, the synthetic brine solutions were prepared as below according to Ohimor *et al.*, [3]:

The calcium-containing brine solution (the cation):  $\text{NaCl} = 33.00\text{g/l}$ ,  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O} = 12.15\text{g/l}$ ,  $\text{MgCl}_2 \cdot 6\text{H}_2\text{O} = 3.68\text{g/l}$ .

The bicarbonate-containing brine solution (the anion):  $\text{NaCl} = 33.00\text{g/l}$ ,  $\text{NaHCO}_3 = 7.36\text{g/l}$ ,  $\text{Na}_2\text{SO}_4 = 0.03\text{g/l}$ .

Below (Table 1) are the characteristics of the synthesized brine solution used as the formation water.

TABLE 1: Characteristics of the simulated formation water

Property	Value
Density (g/cm <sup>3</sup> )	0.9875
pH	7.14
EC (μS/cm)	4562
TDS (ppm)	5320
Turbidity (NTU)	82.4
Salinity (ppt)	7.25
Cations	Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup>
Anions	Cl <sup>-</sup> , CO <sub>3</sub> <sup>2-</sup> , SO <sub>4</sub> <sup>2-</sup>

#### D. Evaluation of the Inhibitory Efficiency of the Extract

To determine the efficiency of the extract, six 100ml beakers were added with 50 ml each of the brine solution water. Various concentrations (40 ppm, 80 ppm, 120 ppm, 160 ppm, and 200 ppm) of the extract were added to five of the beakers, and one other beaker was left with no extract added. The six beakers were placed in a water bath set to a constant temperature of 30 °C for two hours. The temperature was checked using a thermometer, and then Total Dissolved Solids (TDS) was measured and recorded for the six beakers. The mixture was poured into a filter paper set in the funnel to separate the precipitate formed. The precipitate was dried in an oven at 105 °C for 2 hours and 30 minutes and was placed in a desiccator to cool down. The precipitate was then weighed on an electronic weighing balance. This analysis was repeated for the temperatures of 40 °C and 50 °C and recorded.

TDS values and CaCO<sub>3</sub> precipitate mass were measured to determine inhibition efficiency using

$$E = \frac{m_0 - m}{m_0} \times 100$$

E = Inhibition efficiency, m<sub>0</sub> = the precipitate mass without the inhibitor, and m = the mass with the inhibitor.

### III. RESULTS AND DISCUSSION

#### A. Characterization of the cassava leaf extract

Fourier-Transform Infrared (FTIR) spectroscopy was employed to analyze the cassava leaf extract and identify functional groups associated with various bioactive compounds. The observed peaks provide insight into the specific chemical bonds and functional groups present in the extract. These functional groups are linked to compounds with known scale inhibition properties, such as flavonoids, tannins, and alkaloids.

The FTIR spectra shown in Figure 1 were used to confirm the structure of the tested inhibitor extract. The peak value around 3417.12 cm<sup>-1</sup> is ascribed to the broad N – H medium stretching for primary amine compounds. The peak at 2927.47 cm<sup>-1</sup> is assigned to the C – H alkane medium stretching. The Alkene vinylidene C=C medium stretching is confirmed by peaks at 1651.08 cm<sup>-1</sup>. The wavelength around 1416.35 cm<sup>-1</sup> confirms the O-H alcohol bending. The peak at 1047.97 cm<sup>-1</sup> is assigned to the CO – O – CO anhydride strong broad stretching. The OH of hydroxyl and NH of amino observed in the FTIR of the developed scale inhibitors are hydrophilic with a lone pair of electrons and can improve the molecule’s solubility in water [14]. The presence of C-O-C and O-H functional groups confirms the existence of flavonoids and tannins. These

compounds are well-regarded for their ability to chelate calcium ions, thus preventing CaCO<sub>3</sub> crystallization [11, 15, 16, 17]. The N-H stretching vibration suggests alkaloids, which can affect pH and ion interaction, influencing crystal nucleation and growth [18]. The C-H stretching of aliphatic chains indicates saponins, which contribute by dispersing scale particles and reducing their adhesion [10, 11, 18]. The functional groups identified in this FTIR analysis support the presence of these bioactive compounds, all of which play a role in inhibiting scale formation by interacting with metal ions, altering crystal growth, and dispersing particles in solution.

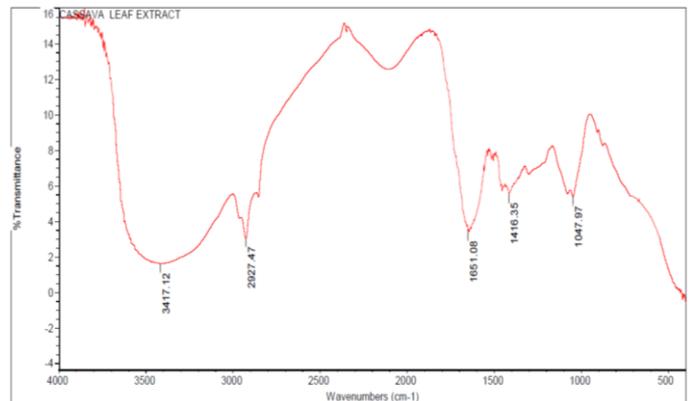


Figure 1: FT-IR Result for the Cassava Leaf Extract

#### B. Scale inhibition efficiency of cassava leaf extract

The cassava leaf extract exhibited significant inhibitory activity. The mass of CaCO<sub>3</sub> precipitate decreased with increasing inhibitor concentration, with complete inhibition observed with 200 ppm at 50 °C. The inhibition efficiency reached 77% under these conditions, demonstrating cassava extract’s potential as a green inhibitor (Figure 2).

TDS values increased with higher inhibitor concentrations and temperature, suggesting enhanced solubility and inhibition. At 200 ppm concentration and 50 °C, TDS reached 5881 ppm, indicating strong inhibition (Figure 3).

The figure shows that TDS levels increase consistently with higher concentrations of cassava extract and elevated temperatures, indicating the extract’s ability to maintain calcium and carbonate ions in solution. At 0 μl (blank sample), TDS remained relatively stable, ranging only slightly from 5363 ppm at 30 °C to 5420 ppm at 50 °C, implying a limited effect on CaCO<sub>3</sub> dissolution. However, when cassava extract was introduced at 40 μl, TDS showed an increase—153 ppm at 30 °C and 89 ppm at 50 °C—suggesting the beginning of an inhibitory effect on CaCO<sub>3</sub> precipitation. As the concentration was raised to 120–200 μl, TDS increased more notably, with a maximum of 5881 ppm observed at 200 μl and 50 °C, demonstrating that higher cassava extract concentrations enhance inhibition and prevent precipitate formation, particularly at higher temperatures. The high temperatures contribute to the formation of calcium carbonate, necessitating an increased dosage of the inhibitor for enhanced efficiency. This suggests that further inhibitor adsorption takes place on the calcium carbonate deposit at elevated temperatures [19].

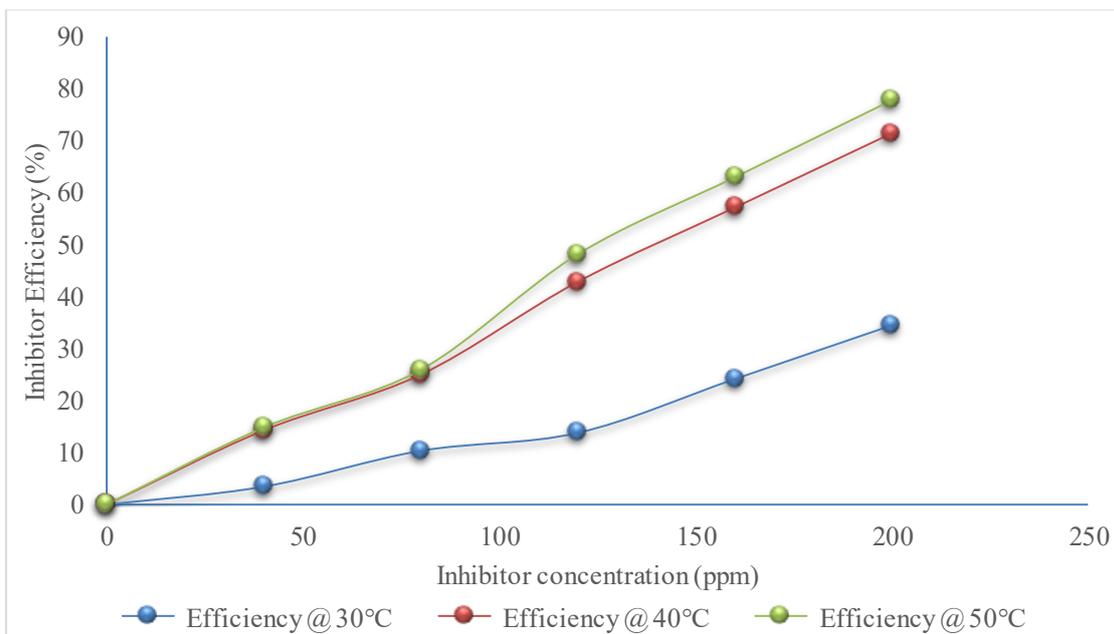


Figure 2: Graph of inhibition efficiency against inhibitor concentration

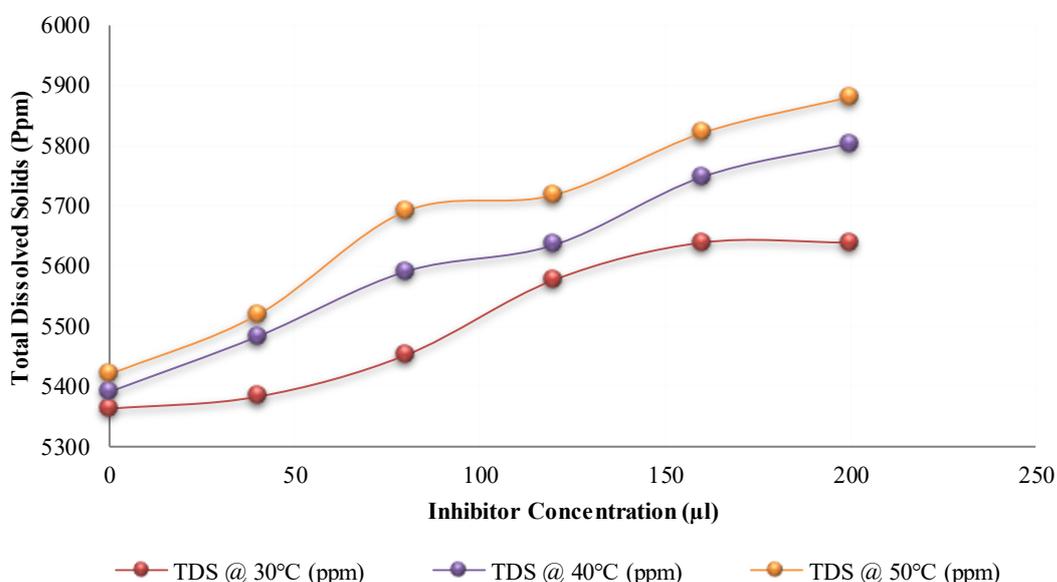


Figure 3: Graph of TDS against Inhibitor Concentration

The experimental data confirm that cassava leaf extract effectively inhibits calcium carbonate scale formation. The increased TDS values with higher extract concentration indicate that the extract prevents  $\text{CaCO}_3$  from precipitating by stabilizing  $\text{Ca}^{2+}$  and  $\text{CO}_3^{2-}$  ions in solution. FTIR analysis revealed the presence of hydroxyl, amine, and carbonyl groups that likely interact with metal ions, forming soluble complexes that hinder nucleation and crystal growth. These findings align with other studies on plant-based inhibitors, such as orange and neem leaf extracts [2, 20].

#### IV. CONCLUSION

This study demonstrates that cassava leaf extract is an effective green inhibitor for  $\text{CaCO}_3$  scale formation. Its

efficiency increases with both concentration and temperature, reaching up to 77% inhibition at 200  $\mu\text{l}$  and 50°C. The functional groups identified via FTIR are responsible for its ion-binding and inhibition properties. Given its biodegradability, low toxicity, and abundance, cassava leaf extract offers a sustainable alternative to synthetic inhibitors for industrial use.

#### V. RECOMMENDATIONS

Further research is recommended to test cassava leaf extract under real oilfield conditions, optimize extraction processes for higher yield and stability, isolate and analyze specific bioactive compounds responsible for inhibition, and compare cassava extract performance with conventional inhibitors in field applications.

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