



## Investigation on the Utilization of Date Seed as a pH Enhancer in Drilling Mud Process

Oseke Godwin Gbenga, Precious Seibide Pereowei and Abiodun Olayomi Falowo

Department of Petroleum and Gas Engineering Baze University, Abuja, Nigeria

\*Corresponding authors' email: [gbenga.oseke@bazeuniversity.edu.ng](mailto:gbenga.oseke@bazeuniversity.edu.ng)

### ABSTRACT

This research explores the utilisation of Date seed ash (DSA) derived from dates as a sustainable, eco-friendly substitute for conventional chemical pH enhancers in water-based drilling mud. pH enhancers controls corrosion by increasing the drilling mud pH which prevents the corrosion of drill pipes and casing. The process involved date seed collection, dehydration of date seed, carbonisation and calcination of date seed to produce DSA. SEM and XRF analysis of DSA revealed porous morphology and a rich inorganic composition of different elements having Potassium in abundance (45.29%) making DSA alkaline in nature. Mud properties such as pH and rheology were measured and compared against a baseline mud and water-based drilling mud containing 0.4 g, 0.6 g, 0.8 g and 1 g of NaOH per 35 ml of mud. The results demonstrated that DSA effectively enhanced mud pH from 9.81 to 10.02 maintaining the pH within the optimal alkaline range (8.5-10.5). DSA also enhanced the rheological properties of the drilling mud by reducing the plastic viscosity (11.0 cP-6.0-6.8 cP) and apparent viscosity indicating an improved pumpability while increasing the yield point (4.4 Pa-5.5-7.2 Pa) enhancing hole cleaning capacity. DSA transformed a high progressive gel strength of 2.2 Pa to 45.6 Pa into a better gel strength (6.0 Pa to 12.2 Pa). This research provides a pathway for the petroleum industry to repurpose agricultural waste into a cost effective drilling fluid additive that not only improves mud pH but also improves the rheology enhancing wellbore stability.

**Received:** 25 May 2026

**Accepted:** 16 June 2026

**Published:** 02 July 2026

**Keywords:** Date seed ash, pH enhancer, Water-based drilling mud, Rheological properties

### INTRODUCTION

Drilling fluid which is commonly referred to as drilling mud is an important component in hydrocarbon exploration and production operations. Drilling mud is used for cooling and lubricating the drill bit, transporting drill cuttings to the surface, maintaining wellbore stability and providing hydrostatic pressure (Edition, 2009). The performance of drilling mud is dependent on the chemical and physical properties which is controlled to ensure safe and efficient drilling operations (Edition, 2009). One of the most important properties of drilling mud is the mud pH level. Maintaining an alkaline pH typically between 8.5 and 10.5 in water based drilling mud (WBM) is very important for different reasons. It minimizes corrosion of drilling equipment, optimizes the performance of bentonite and inhibits the growth of sulphate reducing bacteria. The alkaline environment ensures that the bentonite remains adequately dispersed preventing flocculation and enhancing viscosity and filtration control properties (Udoh & Okon, 2012). The use of conventional chemical additives such as caustic soda (sodium hydroxide), potassium hydroxide and lime (calcium hydroxide) is the most common and most used in the petroleum industry to achieve and maintain optimal pH levels as an adjusted mud pH protects expensive drilling equipment from corrosion thereby also preventing wellbore collapse. State some of the merits of pH adjustment in the oil exploration process. Although it is effective, these chemicals can cause problems such as safety hazards where chemicals like caustic soda and potassium hydroxide are highly corrosive hazardous material classified under Category 1B Acute Toxin where accidental exposure can cause chemical burns thereby needing a personal protective equipment while handling such chemicals. It also causes environmental concerns as they can significantly increase the pH of the environment upon

disposal harming either the soil or aquatic life if not disposed with caution.

Recent advancements in sustainable engineering have opened a new possibility for replacing such chemicals with eco-friendly alternatives derived from agricultural waste (Teniola *et al.*, 2025). The use of bio-waste aligns with global sustainability and circular economy principles reducing environmental footprints while creating economic value from waste streams (Biwott *et al.*, 2019).

Date Palm (*Phoenix dactylifera*) are one of the oldest and most cultivated plants known to man. While date seeds which are gotten from date palm are not considered waste, they are underutilized resource with a growing number of sustainable applications (Ramasamy *et al.*, 2016). Date fruit production has surpassed 9.8 million metric tons with over 6.5 million metric tons consumed domestically. The remaining 3.3 million metric tons were exported across North America, Europe, Asia-Pacific and Africa (*Dates Fruits Market Size, Demand, Growth By 2035*, n.d.). In Nigeria, date production has reached a yearly production of 21,000-250,000 metric tons (Garba *et al.*, 2012)(*History of Date Palm Production in Nigeria - AgroNigeria*, n.d.). Their unique properties allow them to be used for animal feed, fuel, biochar, and even as a caffeine-free coffee substitute (Al-zahrani *et al.*, 2022). Date seeds are approximately 10% of the total fruit weight and are typically discarded as waste. These seeds are rich in minerals and organic compounds making them a promising substitute for conventional chemical additives in drilling fluids in the oil and gas industry (Nzerem *et al.*, 2024).

This research investigates the utilization of date seed ash as a natural, sustainable pH enhancer in water based drilling mud. The structural, sustainable pH enhancer in water based drilling mud. The study aims to evaluate the pH increasing ability of DSA, determine its effect on key rheological

properties (plastic viscosity, yield point, gel strength, apparent viscosity and mud density) and characterize its elemental composition and physical morphology using Scanning Electron Microscopy (SEM) and X-ray Fluorescence (XRF) analysis. The performance of DSA modified mud is compared with conventional NaOH to assess its viability as a substitute additive.

## MATERIALS AND METHODS

### Research Design

This study adopts a quantitative, experimental research design to evaluate the performance of date seed ash (DSA) as a pH enhancer in water-based drilling mud. The approach is structured to prepare DSA through a controlled thermal processes, characterize the material, formulating drilling mud with varying DSA concentrations and measure key properties including pH, rheological parameters and mud density. Results are compared with baseline (without additive) and literature data for conventional NaOH (Mahmoud & Saleh, 2013).

### Sample Preparation and Collection

Fresh dates (*Phoenix dactylifera*) of total weight of 2736 g were collected from Durumi 3 market in Abuja, Nigeria. The date fruits were dissected using a knife to extract the seeds. Extracted seeds were thoroughly washed with clean water to remove any adherent fruit pulp and rinsed to ensure cleanliness.

### Dehydration Process

Cleaned date seeds were weighed and placed in hot air oven (ILO-2, India) trays. The dehydration process was conducted at 105 °C in two batches (Al-zahrani *et al.*, 2022). Weight measurements were recorded at 2-hour intervals for a total of 6 hours.

### Carbonization and Calcination

Date seeds (dried) were placed in ceramic crucibles and introduced to a muffle furnace. The process involved carbonization in which the seeds were heated at 400 °C for 2 hours to thermally decompose biomass, remove volatile components, and convert seeds to carbon-rich char.

Calcination in which the carbonized material was calcined at 600 °C for an initial 2 hours. Upon inspection, incomplete conversion was observed. The calcination was extended for an additional 4 hours at the same temperature, resulting in a total calcination time of 6 hours at 600 °C. After calcination, the furnace was allowed to cool naturally to room temperature. The resulting Date Seed Ash was sieved to obtain uniform particle size for characterization and drilling fluid preparation. From 600 g of dried date seeds, 6 g of DSA was obtained, representing a conversion rate of 1%.

### Drilling Mud Formulation

Water-based drilling mud was formulated following standard laboratory procedures (Taleb *et al.*, 2020). The base formulation consisted of 350 ml distilled water (base fluid), 22.5 g bentonite clay (viscosifier and filtration control agent) and varying concentrations of Date Seed Ash: 0 g (baseline), 0.4 g, 0.6 g, 0.8 g, and 1.0 g

### Material Characterization

#### Scanning Electron Microscopy (SEM)

SEM analysis was conducted to examine the surface morphology and particle structure of Date Seed Ash. The analysis was performed at magnifications of 295×, 400×, and 500× to observe particle size distribution, porosity, and

surface texture. SEM imaging was also conducted on the specific area used for XRF analysis to correlate morphology with elemental composition.

#### X-Ray Fluorescence (XRF) Analysis

XRF analysis was performed to determine the elemental composition of Date Seed Ash. The analysis identified and quantified major and minor elements present in the ash sample. Operating conditions: FOV: 912 μm, Mode: 15 kV – Image, Detector: BSD Full.

### Drilling Mud Property Testing

#### pH Measurement

pH measurements were conducted using a digital pH meter (HI2020, Italy) calibrated with standard buffer solutions.

#### Rheological Properties

Rheological measurements were conducted using a digital viscometer (OFTITE Model 900 Viscometer, USA) following standard API procedures which calculated gel strength, plastic viscosity, yield point and apparent viscosity which the mud density was calculated using a mud balance.

#### Plastic Viscosity, Yield Point and Apparent Viscosity

The drilling mud formulated was transferred into a sample cup until it reached a mark indicated inside the cup in which it was raised until it reached the bob of the viscometer. The digital viscometer was used at speed 600rpm and 300rpm to record the plastic viscosity of the drilling mud by their differences in value after reaching stability. The yield point was calculated based on the difference between 300rpm and the plastic viscosity. The value of the apparent viscosity was directly outputted in centipoise (cP) by the digital viscometer.

#### Gel Strength

The drilling mud was allowed to be agitated at the highest speed (600rpm) for 3 – 5 minutes where the drilling mud was allowed to rest for 10 seconds. The digital viscometer was switched on at 3rpm and the highest value gotten was recorded as the gel strength.

#### Mud Weight/Density

The drilling mud was transferred into the density cup which was filled and closed to remove air bubbles. The knife edge was placed at the fulcrum and the rider was adjusted until equilibrium in which the value of the mud density was recorded. The Equipment used to carry out this test is known as the mud balance (HMD200R, China).

## RESULT AND DISCUSSION

### Dehydration and Calcination

First Batch: 717 g of wet date seeds were dehydrated at 105 °C. Weights recorded: 633 g (2 hrs), 623 g (4 hrs), and 621 g (6 hrs). Moisture content removed was calculated as 11.72%, 13.11%, and 13.39% respectively. Second Batch: 820 g of the wet date seeds were dehydrated at 105 °C for 4 hours. Weights recorded: 738 g (2 hrs) and 722 g (4 hrs), corresponding to moisture removal of 10% and 11.95% respectively. The minimal weight loss between 4 and 6 hours (0.28%) indicated that 4 hours of dehydration was sufficient for subsequent processing (Al-zahrani *et al.*, 2022). The calcination process resulted in drastic weight reduction of 1% of the total dried date seeds highlighting high organic (combustible) content of the seeds

### XRF/SEM Analysis

The XRF analysis Showcases the dominance of Potassium (45.29%) is critical, as potassium compounds (KOH, K<sub>2</sub>CO<sub>3</sub>)

are well-established alkaline agents. The presence of Magnesium (3.80%) and Calcium (3.28%) further contributes to the ash's basicity. This is seen as follows in Table 1 below.

This inorganic mineral composition directly explains the pH-enhancing capability observed in the drilling mud tests.

**Table 1: Elemental Composition from XRF Analysis**

Element Number	Element Name	Weight Conc.
19	Potassium	45.29
8	Oxygen	11.07
15	Phosphorus	7.92
40	Zirconium	7.64
7	Nitrogen	6.96
50	Tin	5.86
12	Magnesium	3.80
6	Carbon	3.55
16	Sulfur	3.39
20	Calcium	3.28
14	Silicon	0.61
13	Aluminium	0.33
17	Chlorine	0.31
53	Iodine	0.00
30	Zinc	0.00
47	Silver	0.00
29	Copper	0.00
26	Iron	0.00
22	Titanium	0.00
11	Sodium	0.00
56	Barium	0.00
25	Manganese	0.00

SEM images in Plate 1 revealed the porous and irregular morphology of DSA particles. This porous structure significantly increases surface area, enhancing chemical reactivity when mixed with drilling fluid. Furthermore, such

morphology could contribute to fluid loss control by physically plugging micro-pores in the filter cake, a property previously reported for date seed-based additives. This is seen in figure 1 below.

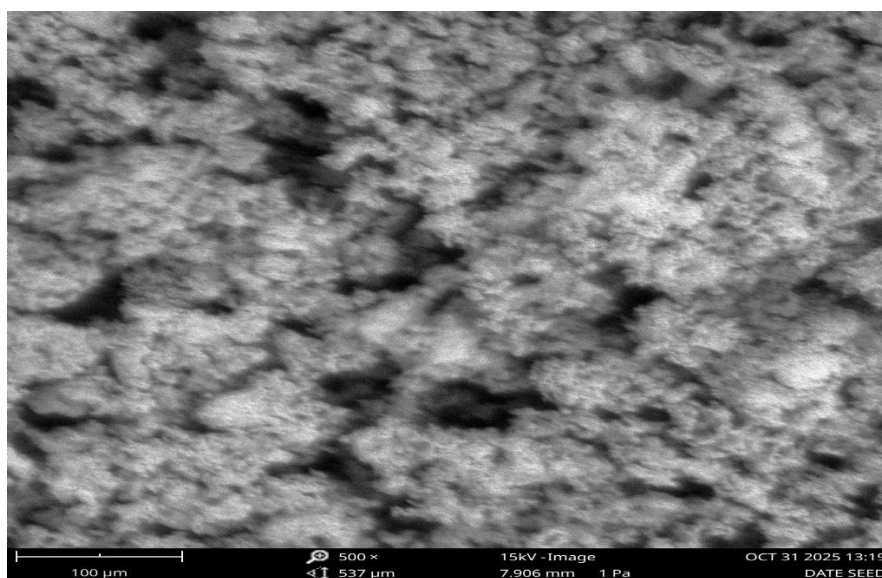


Plate 1: SEM Analysis of DSA at 500 Magnification

### Drilling Mud Performance Analysis

#### *pH Enhancement*

Baseline mud (bentonite only) had a pH of 9.81. With 0.4 g DSA, pH increased to 9.95; with 0.6 g, to 10.00; with 0.8 g, to 10.02 (maximum); and with 1.0 g, pH was 9.98. All values remained within the optimal alkaline range of 8.5–10.5 recommended for water-based drilling fluids. The slight decrease at 1.0 g may indicate an optimal concentration

threshold around 0.8 g per 350 ml. The pH enhancement correlates directly with the high potassium content identified in XRF analysis. When DSA is added to water, potassium compounds (likely present as  $K_2O$ ,  $K_2CO_3$ , or  $KOH$  formed during calcination) hydrolyze to produce hydroxide ions ( $OH^-$ ), increasing the pH of the system. The experimental results confirmed DSA's effectiveness as a pH enhancer as seen in the figure below.

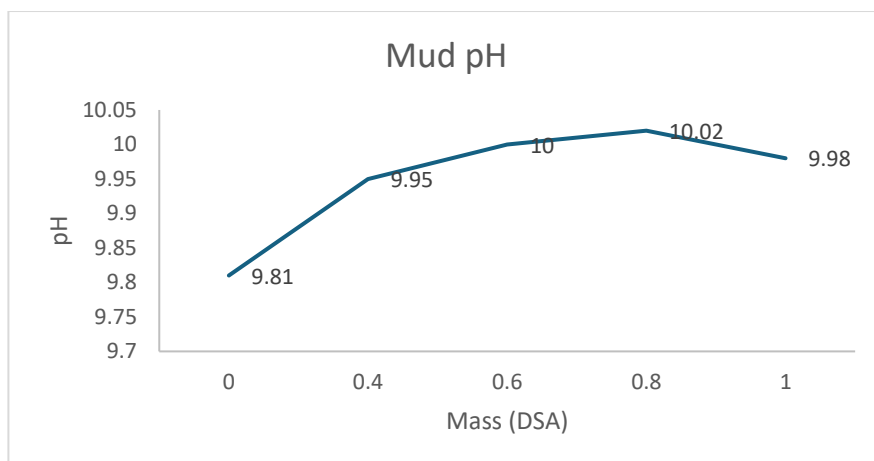


Figure 2: pH Increasing Abilities of DSA at Various Compositions

## CONCLUSION

This research has successfully demonstrated the viability of transforming an abundant agricultural waste product such as date seeds (*Phoenix dactylifera*) into a multifunctional additive for water-based drilling mud. Through laboratory experimentation, material characterization and comparative analysis, the study provides compelling evidence that DSA is not only an effective natural pH enhancer but also a superior rheology modifier that outperforms conventional chemical additives like caustic soda (NAOH) in several key aspects.

The ash demonstrated a consistent and effective ability to elevate and maintain the pH of water-based drilling mud within the optimal alkaline range of 8.5-10.5, which is critical for corrosion control. The pH increased from a baseline of 9.81 to a maximum of 10.02. This enhancement is directly attributed to the ash's rich inorganic composition specifically its high potassium content revealed by the XRF confirming its role as a reliable alkaline agent.

Beyond pH enhancement, DSA substantially improved the rheological properties of the drilling mud. Plastic viscosity was reduced from 11.0 cP to 6.0-6.8 cP, indicating improved pumpability, while yield point increased from 4.4 Pa to 5.5-7.2 Pa, enhancing hole cleaning capacity. This research provides a pathway for the petroleum industry to repurpose agricultural waste into a drilling fluid additive that not only improves mud pH but also enhances rheology, thereby improving wellbore stability.

## REFERENCES

Al-zahrani, K. S., Faqeeh, A. A., Abdulghani, Z. R., & Thomas, S. P. (2022). A review on the physicochemical properties and utilization of date seeds in value-added engineering products. In *Polymer Bulletin* (Vol. 79, Issue 12). Springer Berlin Heidelberg. <https://doi.org/10.1007/s00289-021-04048-3>

Biwott, T. C., Kiprop, A. K., & Akaranta, O. (2019). *Terminalia mantaly* leaves as a novel additive in water-based drilling MUD. 7(6), 2173–2181.

Dates Fruits Market Size, Demand, Growth By 2035. (n.d.).

Edition, F. (2009). *Recommended Practice for Field Testing*

*Water-based Drilling Fluids*. 2008(March).

Garba, I. D., Eseigbe, E., & Omofonmwan, E. I. (2012). *Nutritional components of Date palm and its production status in Nigeria*. 4(2), 83–89.

*History of Date Palm Production in Nigeria - AgroNigeria*. (n.d.).

Mahmoud, A., & Saleh, K. (2013). THE EFFECT OF USING DIFFERENT WEIGHTS OF CAUSTIC SODA ON THE WATER-BASE MUD DRILLING FLUID By The effect of using different weights of caustic soda on the water-base mud drilling fluid. September.

Nzerem, P., Jakada, K., Salihu, A., & Ibrahim, K. S. (2024). *Influence of Local Additives on Water Based Drilling Mud : A Review*. May. <https://doi.org/10.5455/NJEAS.161742>

Ramasamy, J., Al-arfaj, M. K., & Aramco, S. (2016). Journal of Petroleum Science and Engineering Application of an indigenous eco-friendly raw material as fl uid loss additive. *Journal of Petroleum Science and Engineering*, 139, 191–197. <https://doi.org/10.1016/j.petrol.2015.12.023>

Taleb, A., Hameedi, T. Al, Alkinani, H. H., Dunn, S., Mustafa, N., Alwani, A. Al, Al, W. H., Abdullah, B., Hussien, F. A., & Rusul, W. A. (2020). Experimental investigation of bio-enhancer drilling fluid additive : Can palm tree leaves be utilized as a supportive eco-friendly additive in water-based drilling fluid system? *Journal of Petroleum Exploration and Production Technology*, 10(2), 595–603. <https://doi.org/10.1007/s13202-019-00766-7>

Teniola, O. S., Bello, S. O., Odekanle, E. L., & Iyala, F. A. (2025). *Comparative studies of the effects of date plant seed and palm kernel shell powder with metal oxide particles on the rheological properties of water-based mud*.

Udoh, F. D., & Okon, A. N. (2012). FORMULATION OF WATER-BASED DRILLING FLUID USING LOCAL MATERIALS. 14(2), 167–174.



©2026 This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International license viewed via <https://creativecommons.org/licenses/by/4.0/> which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is cited appropriately.