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Phytochemical Characterization of certain Agro-waste as Natural Alkali Agents for Chemical Enhanced Oil Recovery.

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ABSTRACT
Research has shown that the use of alkaline during surfactant floodingresults in an ultralow interfacial tension between the oleic and aqueous phases,alteration of the rock's wettability, emulsification and coalescence and surfactant adsorption reduction. However, these alkalichemicals are toxic and non-eco-friendly.The development of natural based oil recovery agents is a novel solution. The potential of Brophyllumpinnatum (never die leaf), Elaeis guineensis ash (palm bunch ash), Musa paradisiaca ash (plantain peel ash) and potash as naturalalkaline sources for use as chemical enhanced oil recovery agent was assessed by evaluating their mineral and phytochemical composition. The mineral and phytochemical compositions of the materials were determined by using atomic absorption spectroscopy (AAS), Fourier-transform infrared spectroscopy (FTIR) and gas chromatography (GC-FID), respectively. The quantitative analysis of the elemental and biomolecule composition of these materials were used to evaluate their suitability for use as recovery agents. Results showed the presence of high organic matter and several phytochemicals such as flavonoids, alkaloids, and saponinin of varying proportions in Brophyllumpinnatum. pH which is a major criterion for alkaline flooding was determined and results indicate that these materials are good candidates for alkaline flooding, with potash having the highest pH value of 11.1 at 1% conc. Elemental analysis showed that divalent ions which are commonly found on rock surfaces or in the formation brine, (calcium and magnesium) were higher in potash at a value of 7.89 ppm and 4.50 ppm, respectively. Therefore, potash would be less susceptible to the problems associated with phase incompatibility and scale formation during oil production. Monovalent ions, potassium and sodium were higher in Elaeisguineensis ash and potash, respectively. All the materials considered except Brophyllumpinnatum contained potassium hydroxide and inorganic carbonates further confirming that they are good alkaline agents suitable for use in chemical flooding. These materials could serve as substitutes to the synthetic alkaline chemicals used for enhanced oil recovery due to their high recoverability, eco-friendly nature and scale inhibiting properties.
KEYWORDS*Enhanced oil recovery, alkaline flooding, phytochemical composition, agro waste, Atomic Absorption Spectrometer, FTIR.*

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I. INTRODUCTION

With the ever- increasing global energy demand, increase in oil production to meet this demand has become a necessity. Chemical enhanced oil recovery (cEOR) is a tertiary oil recovery method which is conducted to further produce residual oil trapped by capillary or viscous forces and left behind in the reservoir after primary and/or secondary oil recovery thereby increasing oil production. Certain chemicals such as polymers, alkalis and surfactants are injected into the oil reservoir. These chemicals can be used individually or as blends and are capable of increasing oil recovery by increasing the viscosity of the injected fluid, decreasing mobility ratio, lowering the interfacial tension or altering wettability. The success of this chemical flooding process has contributed greatly to additional oil recovery accounting for an incremental recovery of over 30%

depending on the crude oil and reservoir type. Shutang et al., (2010) reported that cEOR techniques recovered about 24% original oil in place (OOIP) (after water flooding during a pilot test in China. However, one of the demerits of the cEOR method is the high cost of the surfactants chemicals which makes the recovery process profitable only when there is an increase in oil price. More so, the use of toxic chemicals which constitute environmental and health hazards has given rise to recent laboratory studies on the use of environmentally friendly green chemicals obtained from agricultural waste. Research has shown that some of these materials contain chemical compounds that can act as chemical oil recovery agents (such as alkaline, surfactants, polymers) when modified or refined. There is, however, the need to identify or characterize these materials to ascertain their composition before the modification process; since these materials which are often regarded as agricultural waste are renewable, readily available and cost effective, determining their oil recovery abilities will make their application preferable.

II. BACKGROUND INFORMATION

An alkali (organic or inorganic) is a strong water-soluble base that forms hydroxide ions when dissolved in alcohol or water. It is formed from the chemical dissolution of alkali metals. When dissolved in water, an alkaline solution has a high pH usually greater than 7.

$$NaOH \rightarrow Na^{+} + OH^{-} \quad (1)$$

Alkaline flooding also known as caustic flooding involves the addition of an alkali such as sodium hydroxide to the injected brine, this increases the pH due to the dissociation of alkali (releasing the OH^{-} ions) which alters the wettability of the formation leading to oil displacement. The main benefits of alkaline flooding include lowering interfacial tension and reducing adsorption of anionic surfactants thus decreasing costs and improving surfactant efficiency. A basic requirement for alkaline flooding is that the crude oil in use must contain high acidic components, which will react favourably with the alkali. The minimum value of acid number required during chemical flooding is 0.3 mgKOH/g. Alkaline flooding is best performed on light-medium crude with API values ranging from 13˚ to 35˚ and in clastic reservoirs as opposed to carbonate reservoirs mainly due to the adsorption of the carbonate minerals on alkalis. It is most effective in low salinity brines and has no temperature constraint. Different types of alkalis have been used in alkaline flooding with the aim of reducing residual oil saturation. They include strong alkalis such as sodium hydroxide, potassium hydroxide and sodium orthosilicate. However, due to their high pH value (12 to14) and increasing reaction with reservoir rock type resulting in scaling problem, precipitation, chemical consumption etc., less reactive alkali such as sodium carbonate (pH=10.9 to 11.3), sodium silicate (pH =10.5 to 11.5) and sodium bicarbonate (pH = 9) have become a preferred option. The formation of either carbonate or silicates scales due to the interaction of alkali with the rock minerals has remained a problem as noted by Arensdorf et al., (2011). Furthermore, Stoll et al., (2011) in their experimental and field analysis listed scaling as one of the operational issues associated with chemical flooding. Scaling gives rise to reduced permeability resulting from plugging of the formation and/or injection wells. Abubakar et al., (2013) affirmed the fact that the pH of a system is a major determining factor in the formation of scales noting that as alkali chemicals react with formation water and with the minerals on the rock surface thus there are in contact with divalent ions, it increases the concentration of the divalent ions giving rise to scaling. Olsen et al., (1990) proposed the use of sodium tri-polyphosphate (pH=11.2 to 12.3) as a buffer in minimizing scaling issue. He further stated that for its effective use in generating surfactant and reducing IFT, it should be used alongside other weaker alkali.

Flatten et al. (2008) investigated the use of novel alkali sodium metaborate as a sequestering agent in the presence of divalent ions. Recent studies used the combination of sodium hydroxide and ethylene diaminetetra acetic acid (EDTA) which acts as a chelating agent to reduce the effect of divalent ions in the formation brine. Kumar et al. (2010) proposed the use of green scale inhibitors to inhibit scale formation during oil production. In addition, Sheng (2011) suggested the use of moderate pH chemicals such as sodium carbonate during ASP formulations, noting that pH values within the range of 9 to 11 is preferable in reducing emulsion and scaling problems. He summarized conventional alkali chemicals and their corresponding pH commonly used during alkaline flooding. Recent studies have also shown the effectiveness of this in alkaline flooding. Obot et al., (2014) comparing the use of potash and Elaeis guineensis ash in alkaline flooding, reported that Potash gave a higher recovery. A recent study by Obuebite et al., (2019) using alkali from locally sourced agro-waste showed that these materials were effective in enhancing oil recovery and inhibiting scale formation.

Alkali can be obtained from agricultural waste materials such as Theobroma cocoa pod, ash of Elaeis guineensisbunch, Maple wood ash, Sugar beet waste, ash of Musa paradisiacapeels, Potash, Zeamayscob and Khaya ivorensis ash (Uzoho et al., 2015). Table I shows the pH values of conventional alkali and local alkali chemicals at 1 %wt. concentration.

Table 1: pH values of selected conventional and natural alkali chemicals

S/N	CONVENTIONAL ALKALI AGENTS	pH value @ 1% conc.	LOCAL ALKALI AGENTS	pH value @ 1% conc.
1	Sodium carbonate (Na_2CO_3)	11.3	Potash	11.1
2	Sodium metaborate ($NaBO_2$)	11.1	Palm Bunch Ash	10.0
3	Sodium hydroxide (NaOH)	13.1	Plantain Peel ash	10.9
4	Sodium orthosilicate (Na_4SiO_4)	13.0	Saw dust	9.5
5	Sodium metasilicate (Na_2SiO_3)	12.8	Wood ash	9.5
6	Sodium silicate pentahydrate ($Na_2SiO_3.5H_2O$)	12.6	Banana leaves	10.3
7	Sodium phosphate (Na_3PO_4)	12.0	Cocoa pod ash	10.5
8	Sodium tripolyphosphate ($Na_5P_3O_{10}$)	9.4	Maize cob	10.8
9	Sodium bicarbonate ($NaHCO_3$)	8.7	Sugar beet waste	10.7
10	Ammonium hydroxide (NH_4OH)	11.6	Never die leaves	9.8
11	Ammonium carbonate (NH_4CO_3)	7.8		
12	Sodium silicate (Na_2SiO_3)	11.6		

Source: {Sheng, 2011; Uzoho, 2019}

Recovery Mechanism of Alkali in Chemical Flooding

Alkaline flooding as a means of enhancing oil recovery has been practiced as far back as the early twentieth century but it became more commonly practiced and widely accepted from the mid-seventies. The mechanism of Alkaline flooding in oil recovery was reported by Sheng (2015) as follows: (i) Emulsification and entrainment (ii) Wettability reversal (iii) Emulsification and entrapment (iv) Emulsification and coalescence. Other recovery mechanism includes mobility control by divalent precipitates and fines.

Alkali plays a unique role in chemical flooding as the injected alkali can generate in-situ surfactants by its reaction with the organic acids in the oil as investigated by Sedaghat et al., (2013) creating a more negatively charged rock surface due to higher hydroxyl ion concentrations which gets adsorbed onto the rock surface thereby reducing adsorption of synthetic surfactants. Understanding the use and the recovery mechanism of these local materials (green fluids) as alkali agents has gained attention of researchers in this field (Obot et al., 2012; Ojukwu et al., 2013; Uzoho et al., 2017; Obuebite et al., 2021). In this study, some local alkali agents were characterized to aid in-depth understanding and possible modification of the inherent chemical components for improved oil recovery and scale-inhibiting process.

III. MATERIALS AND METHODS

Materials

Natural agro-waste such as Elaeis guineensis (oil palm bunch), Musa paradisiaca (unripe plantain peel), Bryophyllum pinnatum leaf extract (never-die leaf) and potash were evaluated.

Apparatus

Porcelain crucible, furnace, desiccator, sample cup, beaker, Gas-chromatograph flame ionization detector (GC-FID), Fourier-transform infrared spectroscopy (FTIR), Atomic Absorption Spectroscopy (AAS), pH meter.

Sample Collection and preparation

The raw materials used as alkali agents during the experimental study were purchased from an open market located in Bayelsa State, Nigeria. They include:

a. Potash which is a salt of Potassium carbonate originates from wood ash. It is a white, water-soluble salt that is commonly used in the production of natural soap. Potash is largely found and mined in the northern part of Nigeria.

b. Elaeis guineensis ash is an agro waste consisting mainly of Calcium, Potassium, Iron and Aluminum. Whenashed, it iscommonly used in the production of soap.

c. Bryophyllum pinnatum leaf extract is a fleshy shrub with health benefit. It is a good base with pHvalue above 9.

d. Musa paradisiaca ash, the peel was obtained from the waste dump at the market, then dried and ashed.

The preparation of these materials was dependent on form. The ashes of Musa paradisiaca and Elaeis guineensis were obtained by sun-drying the samples and then subjecting the dried samples to a temperature of about 550 ˚C in a closed furnace for about 90 min. Potash, due to its hygroscopic nature was properly air dried, then pulverized and packed into a sealed container. Bryophyllum pinnatum leaf extract was washed, sun dried to remove its moisture content, pulverized, packed and sealed in an airtight container to prevent air inflow and/or contamination before use.

Methods

3.3.1. Determination ofpH

A solution of 1g of the selected local agent in 100ml distilled water was prepared and properly stirred for 10min, using a magnetic stirrer. The pH value of the solution was determined using a pH meter and recorded thereafter.

3.3.2. Gas Chromatography- Flame Ionization Detector (GC-FID) Analysis

A beaker containing 1g of each pulverized sample, 15 ml of potassium hydroxide and 100 ml of ethanol solution was allowed to sit for 24 h. It was thereafter filtered into a test tube and heated in a water bath at 60 ˚C temperature for 1h.

The content in the test tube was transferred into the separatory funnel. The GC with the flame ionization detector used had an injector temperature of 280 ˚C and an injector volume of 2 µL. Helium gas was used as the carrier gas with a flow rate of 40 ml/min.

Initially, the oven was kept at 200 ˚C and later increased to 330 ˚C for 5 min while the detector was kept at a temperature of 320 ˚C.

Phytochemicals were determined by the ratio between the area and the mass of the internal standard and the area of the identified phytochemicals. The concentration of the various phytochemicals was expressed in µg/g.

3.3.3. Atomic Absorption spectrophotometry (AAS) Analysis

A mixture containing 650 ml conc. HNO_3, 20ml conc. H_2SO_4 and 80ml perchloric acid was prepared.5g of the sample was digested into 20 ml of the acid-mixture and kept in a digestion flask. The digestion flask was heated until a clear digest was obtained, afterwards, 50 ml of distilled water was then added to dilute the digest.

Using the AAS, the sample was aspirated into the flame and atomized only when the light beam in the AAS is directed through the flame to the detector which then measures the amount of light absorbed by the atomized element in the flame. This was performed according to the method of American Public Health Association (APHA,1998)

The amount of energy absorbed in the flame is proportional to the concentration of the element in the sample.

3.3.4. Fourier- transform infrared spectroscopy (FTIR) Analysis

For each of the sample, 10 mg of the powdered sample was mixed with a drop of methylene chloride solvent and then placed on a potassium bromide thin plate. The plate was then placed into the FTIR spectrometer, and a background spectrum was selected.

The sample was placed in the path of the infrared radiation frequency to allow the infrared radiation beam to penetrate through the sample thereby leading to some infrared radiations being absorbed while some pass through the sample. The amount of radiation and the frequency at which the sample absorbed the infrared light was measured. The peak points were identified from the spectrum.

IV. RESULTS AND DISCUSSIONS

Determination of pH

The pH value of the selected materials showed that all had pH values above 7 indicating that they are alkaline in nature (Table 2). The pH of a solution is a more important parameter in alkalineflooding than viscosity, due to its role in altering the wettability of the rock and reducing surfactant adsorption (Obuebite *et al.*, 2019).Using 2-6% maple wood ash as a local alkali source, Rahman *et al.*, (2000) reported that maple wood ash increased the alkalinity (pH) of the solution and its pH value (13.5) at 6% concentration was like that of 0.5% concentration of Sodium hydroxide. Comparing the use of Potash and *Elaeis guineensis* ash in alkaline flooding, Obuebite *et al.*,(2021) reported that potash gave a higher recovery even at reservoir conditions due to its higher pH value.Moreover, the studyobserved that these alkali agents had pH values ranging from 9 to 11 at constant alkalineconcentration (1 %wt.) which corroborates the preferred pH value range for alkaline flooding as reported by Sheng (2011).

Table 2: pH value of the Local Materials

Samples	pH value
Bryophyllum pinnatum leaf	9.8
Elaeis guineensis ash	10.0
Musa paradisiaca ash	10.9
Potash	11.1

Physicochemical property analysis

Results from elemental analysis using AAS showed that potash, ashes of *Elaeis guineensis*, ashes of *Musa paradisiaca* and *Bryophyllum pinnatum* leaf extract all contained magnesium and calcium which are the chemical elements of interest (due to their occurrence in formation brine and on rock surfaces). Their presence in the selected materials indicates their ability to chelate these divalent ions. These materials form complexes with divalent ions present in the formation brine, thus there are less cations for the chemicals to interact. As shown in Table 3, potash has a higher content of magnesium, sodium and calcium while ashes of *Elaeis guineensis* has a slightly higher potassium content than potash and the others. The high potassium content of all the selected materials except the *Bryophyllum pinnatum* leaf extractcan be attributed to the process of ashing these materials result in high level of potassium hydroxide. The results also show that potash has a higher content of the divalent ions (magnesium and calcium ions). This implies that potash is more tolerant when in contact with hard water or rock surfaces that contains these divalent ions. These alkalis can best substitute synthetic materials since they contain high metallic oxide and exhibits high pH needed for enhanced oil recovery.

Table 3: Mineral content of the selected Local materials

Minerals (ppm)	Potash	*Elaeis guineensis ash*	*Musa paradisiaca ash*	*Bryophyllum pinnatum* leaf
Magnesium	4.503	4.110	4.125	4.040
Sodium	7.624	7.484	7.482	7.376
Potassium	7.840	7.988	7.807	4.898
Calcium	7.899	5.899	6.989	5.999

GC Analysis

Analysis using GC-FID was done to characterize the alkaline materials to determine the set of phytochemicals. From the results (Table 4),these selected materials contain various phytochemical types such as flavonoids, phenols, alkaloids, saponins etc. It was also observed that certain phytochemicals and organic molecules were absent in some of the selected materials. They presented high levels of alkaloids which favors their alkalinity. *Bryophyllum pinnatum* leaf extract showed the highest alkaloid, flavonoids and saponin content while *Elaeis guineensis* ash contained more water-solublephenolic phytochemicals than the others. The presence of saponin especially in the *Bryophyllum pinnatum* leaf extract suggest the presence of inherent surface-active properties.It was also observed that the low levels and/or absence of phytochemicals in Potash, *Elaeis guineensis* ash and *musaparadisiaca ash* could have been because of the destruction of most of the organic matter and molecules when these materials were ashed. Furthermore, the FID spectrum of the *Brophyllum pinnatum* leaf extract provides further evidence of the presence that the flavonoid phytochemical grade is dominant in this extract as shown in Figure 1. Bachari*et al.*,(2019) also highlighted the effectiveness of these materials in the enhanced oil recovery process.

Table 4: Phytochemical Composition of the selected materials

Components	Palm Bunch Ash (ug/g)	Never-die leaf (ug/g)	Plantain peel ug/g	Potash (ug/g)	Type of Phytochemical
Proanthocyanin	2.1233	------	4,5110	1.8091	Anthocyanin
Naringin	9.7126	20.5858	-----	------	Flavonoids
Oxalate	------	2.6544	------	2.2699	Oxalate
Anthocyanin	8.7831	4.8616	2.5712	7.000	Anthocyanin
Ribalinidine	8.4585	13.3318	------	--------	Flavonoids

Naringenin	6.6537	27.1224	7.7193	9.4729	Flavonoids
Phenol	13.7460	6.8259	3.9885	4.9133	Phenol
Flavanones	4.2351	6.2798	4.4873	4.3615	Flavonoids
Steroids	25.5025	12.8631	9.9563	16.3217	Steroids
Epicatechin	17.5467	27.2886	--------	17.7546	Flavonoids
Kaempferol	5.1493	5.8214	3.9835	6.8896	Alkaloid
Flavone	6.4748	8.3941	3.9934	3.3008	Flavonoids
Tannins	15.3281	9.5249	-------	0.0148	Water soluble Polyphenols
Catechin	9.8105	21.3962	---------	-------	Flavonoids
Resveratrol	7.4149	12.8968	------	10.8470	Alkaloids
Terpenes	11.8442	6.3247	--------	4.1647	Terpenoids
Lunamarin	------	7.4483	-------	--------	Flavonoids
Cyanogenic glycoside	1.0625	2.786	-------	0.5669	Glycosides
Rutin	1.8552	2.7114	---------	---------	Flavonoids
Saponin	3.256	4.899	1.1326	3.997	Saponin
Cardiac glycoside	6.3209	8.3247	----------	3.4505	Glycosides
Spartein	15.9745	18.0481	5.7536	4.5832	Alkaloid
Phytate	6.2777	1.3838	---------	2.9797	Impairs adsorption of Ca, Zn, Fe

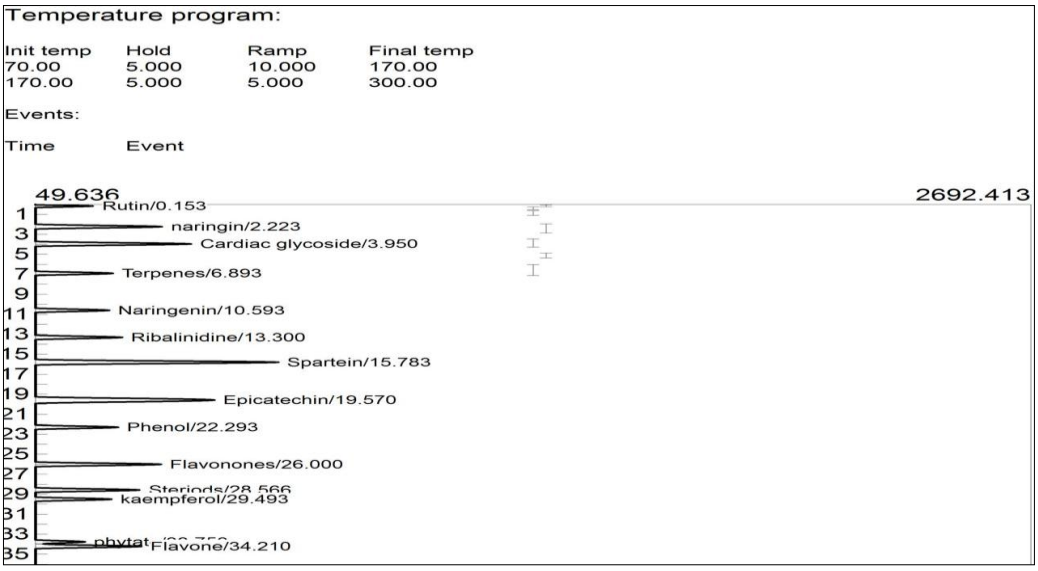

Fig. 1.FID Spectrum of *Brophyllum pinnatum* leaf

FTIR Analysis

The FTIR spectrum of *Bryophyllum pinnatum* leaf extract (Figure 2) showed a strong broad peak 3275 cm^{-1} which is likely due to O-H stretching vibrations of alcohols and phenols with some possibility of intermolecular hydrogen bonding. The peaks at 2918cm^{-1} and 2851cm^{-1} correspond to C - H stretch of methylene groups. The bands at 1622 cm^{-1},1562cm^{-1} and 1544cm^{-1} are due to C = C stretch of aromatics showing strong presence of aromatic groups likely due to flavonoid content of the extract. C - O vibration of alcohols groups give rise to the bands at 1238 cm^{-1} and 1033 cm^{-1}. Low transmittance of O-H stretch and C-O of alcohol indicate an abundance of hydroxyl groups in the leaf extract.

Figures 3 – 5 present the FTIR spectrum of palm (*Elaeis guineensis*) bunch ash, plantain (*Musa paradisica*) peel ash and potash, respectively. The spectra of the biomass ashes show some similarities. The notable absence of peaks at 2900 -2800 cm^{-1} range (which is common in most organic compounds), in the

spectra of palm bunch ash and potash suggest low/insignificant amount of organic matter in the plant ashes. The band at 3033cm^{-1} in the spectrum of plantain peel ash may indicate presence of some organic matter in the biomass ash. The bands between 3629 cm^{-1} – 3887 cm^{-1} are due to the O-H stretching vibrations of hydroxides. The small peak around 1640 cm^{-1} – 1629 cm^{-1} indicate the presence of associated/adsorbed water. The vibrations at 1452 – 1422 cm^{-1} are likely due to C-O of carbonates. Likewise, the intense peak at 1380cm^{-1} can be attributed to the asymmetric stretching of CO_3^{2-}. Bending vibrations of carbonate groups (CO_3^{2-}) occur at 866 – 851 cm^{-1} in the spectrum of potash and plantain peel ash. The peaks in the lower frequency region of the biomass ash spectrum 1115 cm^{-1} – 796cm^{-1} are likely due to aluminum-silicon structures. Si-O asymmetric stretching vibrations are likely the origin of the peaks at1115 cm^{-1} and 1041 cm^{-1} in the spectrum plantain peel ash, 1060 cm^{-1} in potash and 1004 cm^{-1} in whereas the peaks around 784 cm^{-1} – 705 cm^{-1} are due to Si-O-Si symmetric bridge stretching vibration. Overall, the FTIR spectra of the biomass ashes indicate high content of hydroxides and carbonates. These hydroxides are essential components of alkaline flooding and hence the viability of these materials for this process.

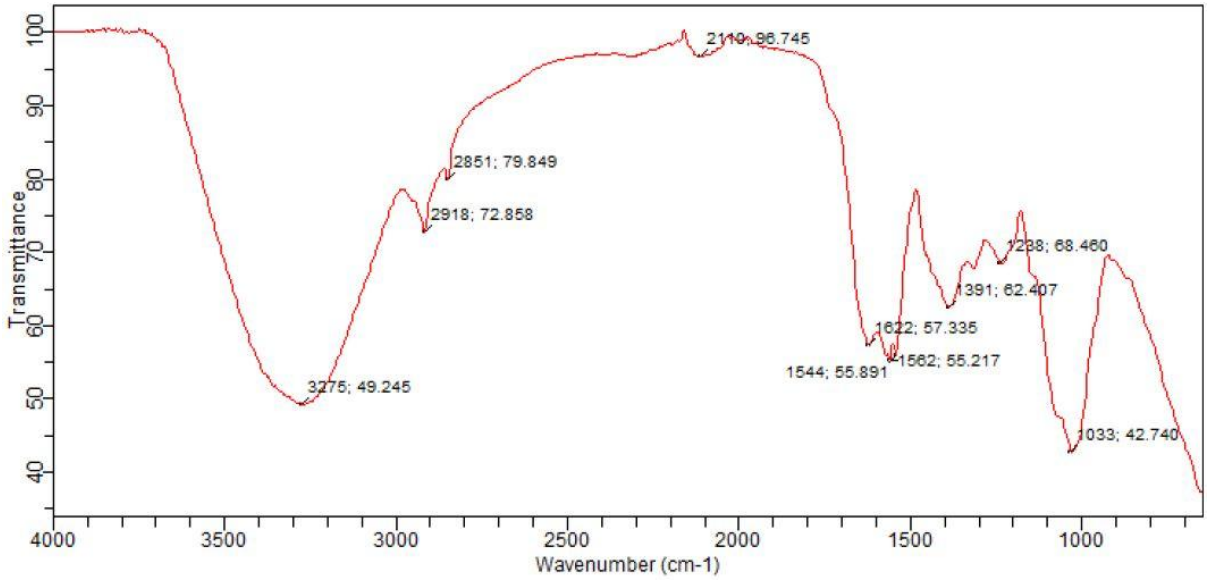

Fig.2. FTIR spectrum of *Bryophyllum pinnatum leaf*

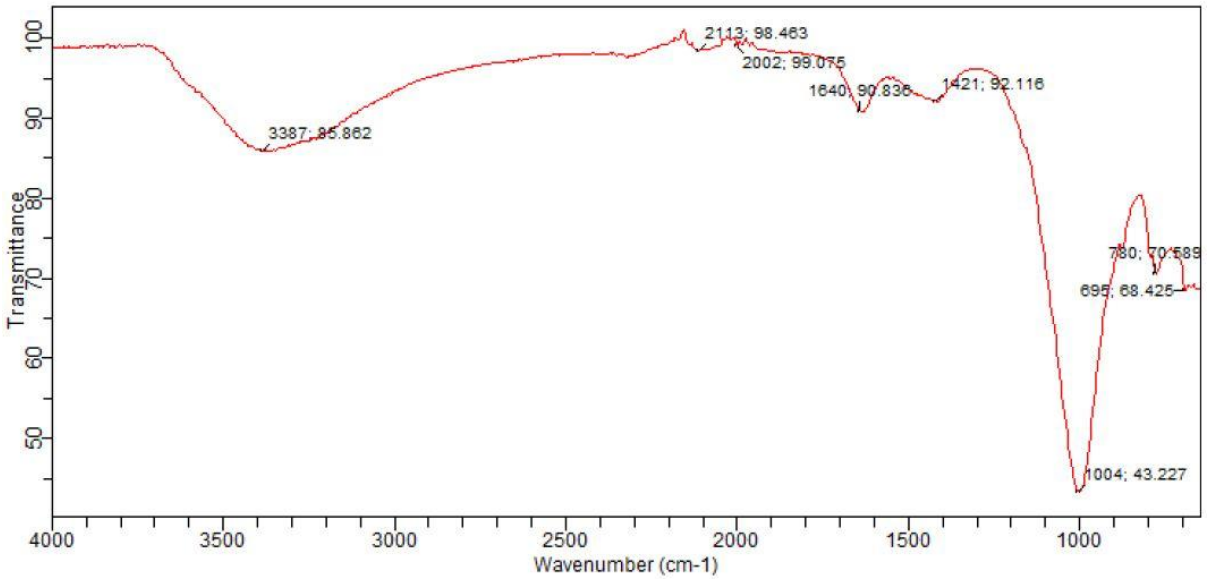

Fig. 3. FTIR spectrum of Palm Bunch (*Elaeis Guineensis) Ash*

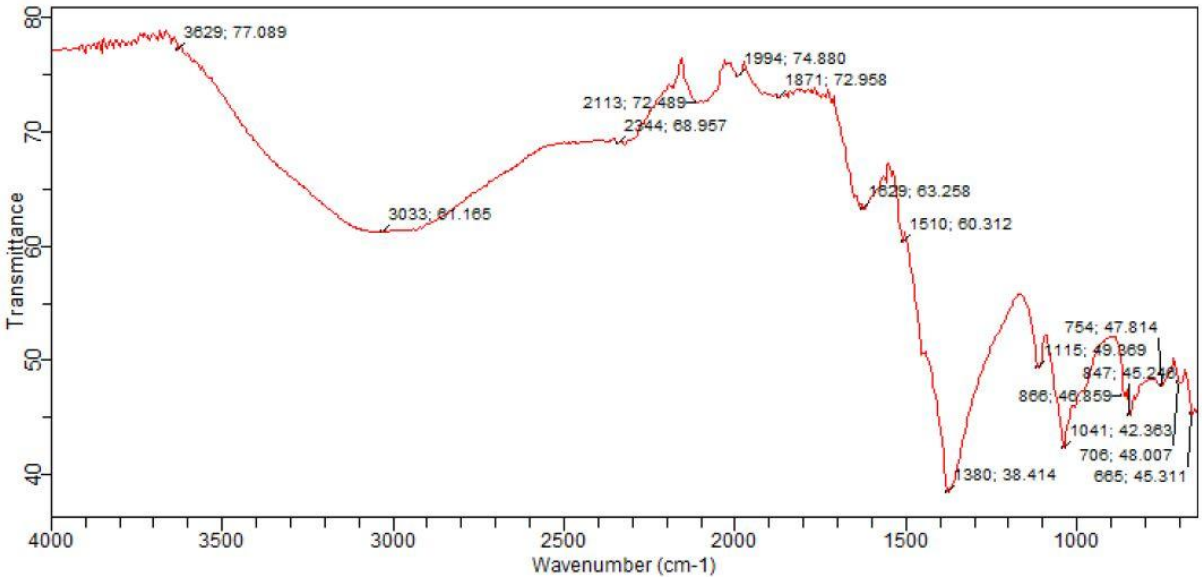

Fig.4. FTIR spectrum of Plantain (*Musa Paradisica*) Peel Ash

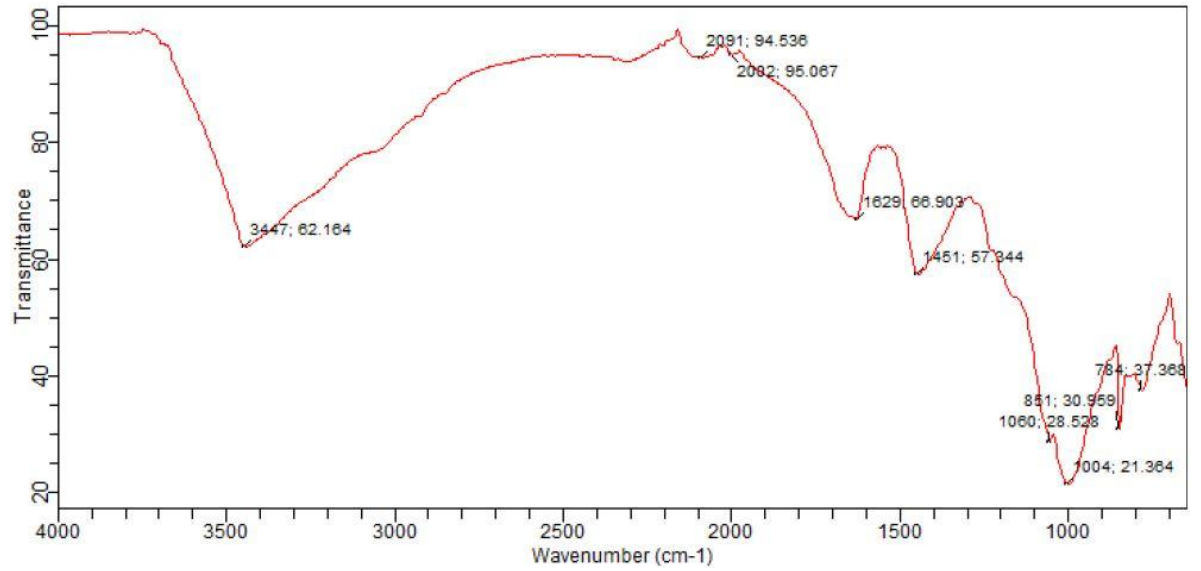

Fig. 5. FTIR spectrum of Potash

The various analysis carried out shows that the selected natural products are indeed suitable natural alkaline chemicals with pH values ranging from 9 to 11 which is within the stipulated pH range as suggested by Sheng, 2011 and they are similarto the pH values of conventional alkali chemicals such as sodium carbonate and sodium metaborate. The phytochemical analysis indicate that they contain flavonoids, alkaloids and saponins which are components needed to be present in alkali chemicals to enable them act during chemical flooding. Furthermore, most alkaline chemicals currently used in the oil and gas industry during recovery pose a major problem as they are most often incompatible with the formation brine in the oil reservoir resulting in scale production which plugs the oil production well thereby reducing the reservoir permeability and restricting the flow of oil giving rise to a low displacement efficiency. However, the development and introduction of these natural alkali chemical solutionthat have scale inhibiting properties is a novel response to the need for non-toxic, eco-friendly yet effective alkaline recovery agents as indicated by Obot et al., 2014; Obuebite et al., 2021 who used Potash in their experimental study for alkaline flooding.

V. CONCLUSION

❖ Assessment of the potentials of the use of *Brophyllum pinnatum* (never die leaf), *Elaeis guineensis* ash (palm bunch ash), *Musa paradisiaca* ash (plantain peel ash) and Potash as natural alkali oil recovery agents indicates their suitability based on their pH values.

❖ The selected natural alkali agents contain high levels of sodium and potassium oxides as well as divalent (calcium and magnesium) ions.

❖ Phytochemical assay of these materials confirms the presence of alkaloids, flavonoids and saponins especially in *Brophyllum pinnatum* (never die leaf) which shows that it has both alkaline and surface-active properties.

❖ The ashing of the natural alkali agents reduces or destroys the organic molecules present in them and produces potassium hydroxides, inorganic carbonates and minerals.

❖ These natural alkalis contain chemical components that are responsible for their scale inhibiting properties, and their suitability as oil recovery agents during alkaline flooding.

❖ These natural alkalisare suitable substitute to synthetic alkaline chemicals which are toxic and susceptible to hard brine.

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DECLARATIONS

Availability of data and materials

All data generated or analyzed during this study are provided.

Competing interests

The authors declare they have no competing interests.

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Authors contributions
OAA provided conceptualization, bench work, data curation, draft manuscript preparation, and data analysis. EW provided data analysis and interpretation, OOO provided manuscript preparation, data curation and interpretation. All authors read and approved the final manuscript.

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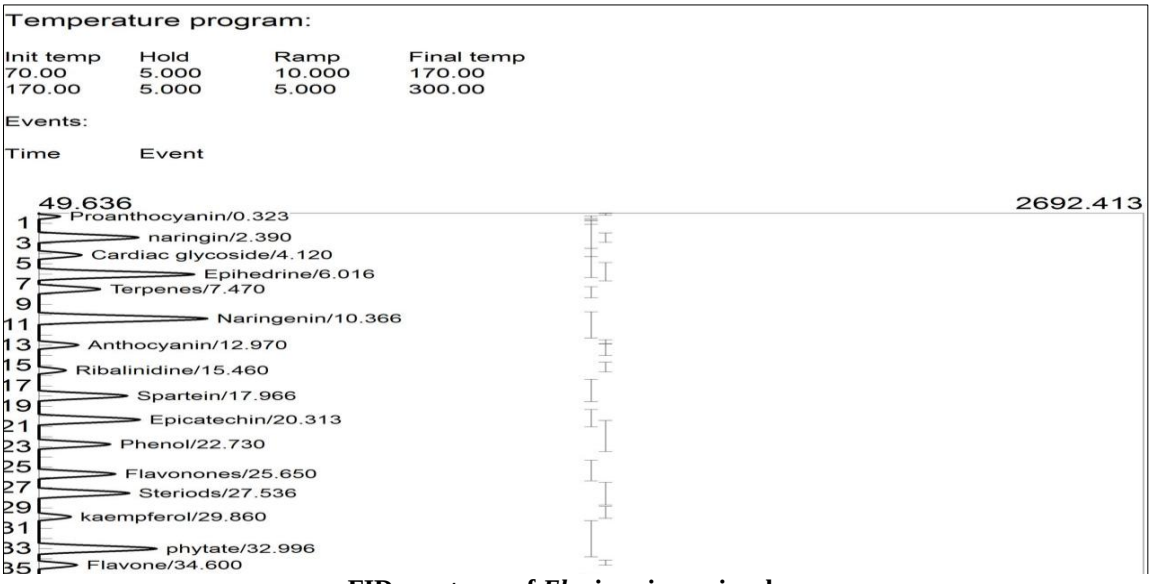
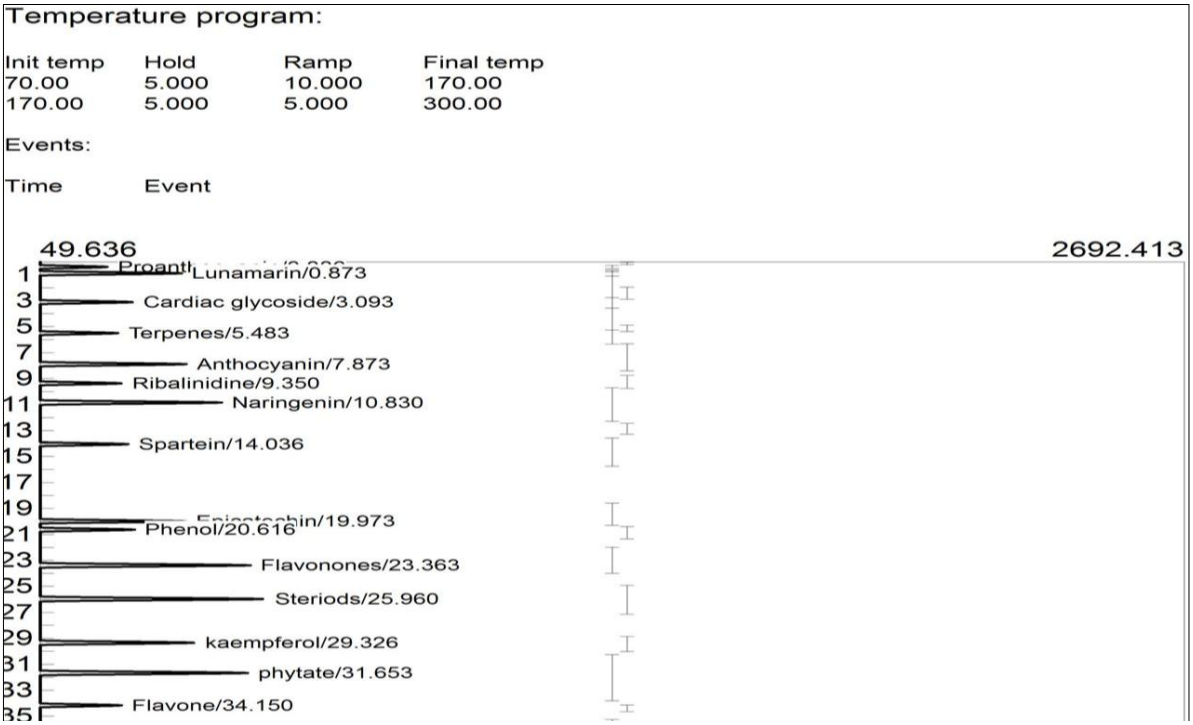
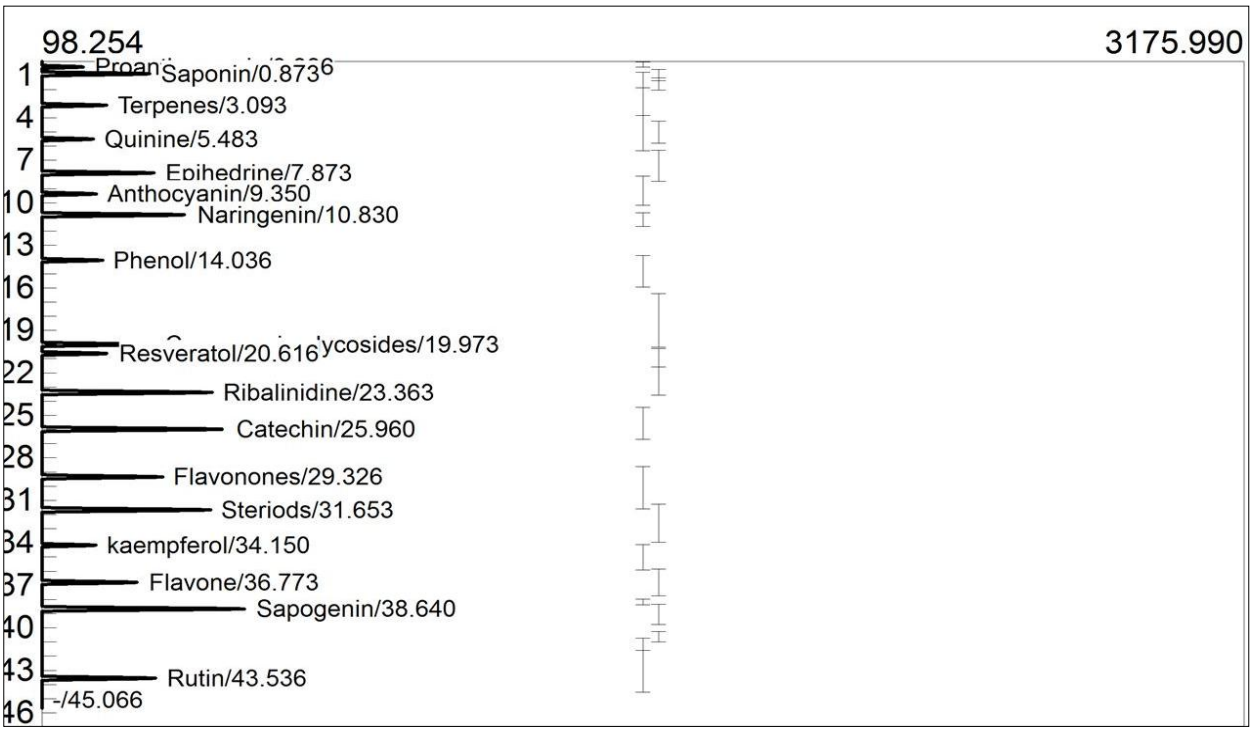
APPENDIX



FID spectrum of *Elaeis guineensis* ash



FID spectrum of Potash



FID Spectrum of*Musa paradisiaca* ash

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