

Synthesis and Characterization of Hydrocarbon Fuels from Cassava Seed Oil using an Indigenous Salt Catalyst

Martin Muiruri¹, Aloys M. Osano², Bakari Chaka^{3*}

^{1,2,3} Department of Mathematics & Physical Sciences, School of Science, Maasai Mara University, Narok, Kenya. Address; 861-20500, Narok, Kenya

*Corresponding author

Abstract: - Hydrocarbon fuels from cassava seeds oil can supplement fossil fuels hence reducing over-reliance on non-renewable energy sources. This research put emphasis on the extraction of cassava seeds oil from cassava seeds then converting the synthesized oil into hydrocarbon fuels using indigenous salt catalyst. Samples were extracted by soxhlet extraction method using petroleum ether. The samples were then characterized for physical-chemical parameters, functional groups, bio-metal concentrations, acid and free fatty acid values, saponification value and iodine values. Antifungal analysis was conducted using *C. albicans* species. The obtained oil was then esterified using the indigenous salts and the products characterized against a control sample. The percent extraction yields obtained using the solvent petroleum ether was $43.17 \pm 0.00\%$. The oil was pale yellow, odorless and liquid at room temperature with no pH value. The oil had very low electrical conductivity and specific gravity values. The samples had high acid and free fatty acid values, moderate saponification value ($236.32 \pm 0.10 \text{mgOH}$) and low iodine value ($83.50 \pm 2.00 \text{w/w}$). The anti-fungal inhibitions were moderate. The samples had high iron and zinc concentrations. During trans-esterification process, it was observed that carboxylic -OH, acetylenic and amide peaks were removed. Consequently, sp^3 -CH peaks intensified illustrating more saturation in the hydrocarbons formed. The conversion of the oil using the indigenous salts produced combustible gases and liquid. In conclusion, use of the indigenous salt aided in fast production of quality fuels from cassava oil.

Key words: Cassava seeds oil, fuel, indigenous salt

I. INTRODUCTION

Depletion of natural sources of hydrocarbon fuels (fossil fuels) as well as the rapid increase in costs of finding them have raised the need of finding renewable and cheap sources of fuel such as seeds oil. Seeds oil can be transformed into hydrocarbon fuel via various techniques such as catalytic cracking, trans esterification, thermal cracking, hydro processing and fermentation (Frey *et al.*, 2011). Various biofuel oils have been obtained from vegetable and seed oils at varying success rates. Amongst these include cassava seed oil, corn oil, rapeseed oil, avocado seed oil amongst others.

These oils contain several combustible fatty acids with appreciable calorific values, prolonged durability, low specific gravity for them to be easily conveyed and reduced electrical

conductivity to raise flash point values. The oils also have high-energy intensity, low oxygen content, recyclability and renewability (Zhang *et al.*, 2018). The cetane number of most biofuels is however quite low. Most of the synthesized biofuel oils are also quite odorful, deterring potential users from using them. It is thus suitable to refine raw biofuels for optimized performances. Several salts can be used to hasten trans-esterification process, amongst them indigenous salts such as Magadi (Osano, 2013). Indigenous salts have the ability to fasten the digestive as well softening property of food and therefore, find application in cooking tough food materials such as maize and beans (Osano, 2013).

Cassava seeds are rich in oil and some fatty acids with oleic and linolenic acids being the major fatty acids though arachidonic, lauric and stearic acids are still present in small amount (Alves *et al.*, 2014). The oil is pale yellow and liquid at room temperature. In addition, the oil is odorless and tasteless with specific gravity of 0.93 at room temperature (Opaluwa and Oyetunji, 2012). The lipid content and iodine value of cassava seed are 25.2% and 90 w/w respectively (Popoola and Yangomodou, 2006). Cassava seeds oil can be used for the making of soap and other cosmetic products (Ajiwe *et al.*, 1994). Apart from few domestic uses of cassava seed oil, local communities in Nigeria use the oil for treatment of skin rashes and related skin infections caused by bacteria and fungi species (Popoola and Yangomodou, 2006).

Several methods can be used to extract the oil from the cassava seed such as mechanical press methods, solvent extraction with the aid of soxhlet extractor. The extraction of cassava seed oil by solvent extraction as reported by Popoola and Yangomodou, (2006); seem more efficient and economical than the mechanical press methods since recovery rate using the mechanical method is less effective and huge quantity of seeds is needed for the mechanical press designed method. However, catalytic cracking is simple technology, cost effective and can yield higher amount of hydrocarbon biofuel from seeds oil at fairly lower temperature (Zhao *et al.*, 2017).

Kenya has abundant agricultural seeds that can be converted to crude oil. These crude oils can serve as feedstock for

hydrocarbon fuels production. This study aimed at using cassava seed to produce cassava seed oil that will then undergo chemical conversion using indigenous salt catalysts to produce hydrocarbon fuels. This will provide an alternative source of hydrocarbon fuels in Kenya that will replace already depleted fossil fuels and reduce over reliance on fossil fuels importation.

II. MATERIALS AND METHODS

Design of experiment

Cassava seeds were collected from Murang'a county, Kenya (0.7839°S, 37.0400°E) and sun dried for 7 days. The seeds were thereafter crushed to obtain the extracts which were further subjected to Soxhlet extraction using pet-ether. The extracts obtained were characterized for physical chemical parameters, functional groups, bio-metal concentration, oil parameters and antifungal activity. The oil was thereafter thermally cracked by use of an indigenous salt (Magadi). The resultant gas was condensed and analyzed for flammability, functional groups present and pH. Characterization and analysis were done at Maasai mara university, Kenya chemistry and biology labs.

Materials

All chemicals and reagents used were lab grade unless stated. The chemicals were all sourced from Sigma-Aldrich.

The lab grade chemicals and reagents included; petroleum ether, n-hexane, ethyl acetate, absolute ethanol, phenolphthalein indicator, potassium hydroxide pellets, hydrochloric acid, starch solution, iodine solution, sodium thiosulfate, nitric acid, chloroform, sodium hydroxide pellets, sodium thiosulfate, potassium iodide and sodium chloride

The following chemicals were analytical grade (all from Sigma-Aldrich); potassium bromide for IR analysis, copper, chromium, cadmium, cobalt, iron and zinc standards for AAS analysis.

For antimicrobial analysis; Muller-Hinton agar (Sigma-Aldrich), nutrient agar, potato dextrose agar, sterile distilled water, ethanol.

The indigenous salt in question was Magadi salt, a popular rock amongst the Maasai community in Kenya known to contain a lot of trona ($\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 10\text{H}_2\text{O}$).

Access to; Atomic Absorption Spectrometer (PG-990) FTIR (Shimadzu), pH metre (Hanna G114)

Methods

Solvent extraction of cassava seed oil

The dry seeds were ground into fine powder and dried in an air circulating oven at 60°C for 1 hour. A 20g of the powder in 200ml pet ether was subjected to soxhlet extraction at 60-80°C. The extract was allowed to seep through the pores of the thimble and fill the siphon tube, before re-condensing. This process was allowed to continue for 48 hours. The

solvent was then distilled off at 80°C. The percent yield of the oil was calculated from the weight of the oil obtained and the weight of the seeds used.

Characterization of cassava seed oil

Physical-chemical analysis

The extracts were characterised for the pH, conductivity, density, total solids, volatile solids and solubility using conventional methods. A pH meter and conductivity meter were used for pH and conductivity respectively.

Oil parameters of the cassava seed oil

Acid value and free fatty acid value

1.10g of the oil was placed in a dried conical flask. 25ml of absolute ethanol was added to dissolve the oil followed by 2 drops of phenolphthalein. The solution mixture was heated while soaking in a water bath (65%) for 10 minutes after which it was allowed to cool. The solution was titrated against 0.1N potassium hydroxide solution until pink color appeared (end point). The acid value and the corresponding free fatty acid were calculated by the following formula;

$$\text{Acid Value} = \frac{V \times 56.1 \times N}{E(1)}$$

$$\text{Free Fatty acid (\% Oleic acid)} = \frac{V \times \text{MG} \times N}{10 \times E(2)}$$

Where; V is Consumed titrant volume, N is Normality of titrant, E is Sample weight, MG is Molecular weight of fatty acid (oleic acid equivalent).

Saponification value of the oil

Approximately 2g of the oil was weighed into a 250 conical and 25ml of 0.5N alcoholic potassium hydroxide solution. The flask content was heated on the boiling water for 1 hour with occasion shaking. While the solution was still hot, 3 drops of phenolphthalein indicator was added and the excess potassium hydroxide was titrated with 0.5N hydrochloric acid (V_{ml} of Hydrochloric acid at the end point was represented by S).

The above was repeated without the sample (V_{ml} of hydrochloric acid at the end point in this case was represented with B). Saponification value was calculated using the following formula;

$$\text{Saponification value} = \frac{56.10 (B-S) \times N}{\text{Weight of sample (g)}} \quad (3)$$

Where; B is volume of HCl required by blank (ml), S is HCl volume of sample (ml), N is normality of HCl.

Iodine value of the cassava oil

0.5g of the oil was weighed into an iodine flask and then dissolved in 10ml of chloroform. 25ml of iodine solution was added using a pipette, draining it in a definite time. The

solution was mixed well and allowed to stand in dark for exactly 30 minutes with occasional shaking.

10ml of 15% potassium iodide solution was added, shaken thoroughly and 100ml of freshly boiled and cooled water was added, washing down any free iodine on the stopper.

The solution mixture was the titrated against 0.1N sodium thiosulphate until yellow solution turns almost colorless. Few drops of starch solution were added as an indicator and titrated until the blue color completely disappears. The flask was stopped at the end of the titration and shaken vigorously so that any iodine remaining in solution was taken up by potassium iodide solution.

The blank was then run without the sample using the same procedure. Iodine value was then calculated by the following formula;

$$\text{Iodine Value} = \frac{(B-S) (N \text{ of sodium thiosulfate } (0.127\text{g/meq } (100))}{\text{Weight of sample (g)}(4)}$$

Bio-metal concentrations

For bio-metal analysis, the extracts were serially diluted 200-folds using 20ml aliquots distilled water and filtering using Whatman #42 filter paper at each dilution stage. The bio-metals were analyzed after formulation of calibration curve using standard salts prepared for each of the bio-metal analyzed. **Table 1** below summarizes the conditions used during the bio-metal analysis.

Table 1: AAS conditions used to analyze the bio-metals

Bio-metal	Wavelength	Bandwidth	Lamp current	Flame	Sensitivity
Co	240.7nm	0.4nm	5.0ma	Air/Acetylene	0.05mg/L
Cr	357.9nm	0.4nm	5.0ma	Air/Acetylene	0.05mg/L
Cu	324.7nm	0.4nm	5.0ma	Air/Acetylene	0.03mg/L
Fe	248.3nm	0.2nm	5.0ma	Air/Acetylene	0.05mg/L
Zn	213.9nm	0.4nm	4.0ma	Air/Acetylene	0.01mg/L

Functional groups

For functional group analysis, the extracts were heated slowly at 60°C until all the water was dried. The samples were then cast into pellets using potassium bromide pellet before analyzing for functional groups using fourier transform infrared (FT-IR) Spectrometer.

Antifungal analysis of the cassava seed oil

Antifungal studies were conducted for *C. albicans* strain used for antifungal analysis. All aseptic techniques were considered to minimize the contamination rates.

Media preparation

28.0g of Muller-Hinton's agar media was dissolved into 600ml of sterile distilled water in a media dispensing bottle. The mixture was gradually boiled to completely dissolve the media. Caution was taken not to break the media bottle by loosening the bottle stopper occasionally to avoid pressure build up. The media was then sterilized by autoclaving along with petri-dishes and all apparatus to be used at 121°C and 15 psi pressure for 15 minutes. The media was allowed to cool to 45°C before dispensing in sterile petri dishes. The media plates were allowed to cool, inverted and stored in the refrigerator at 4°C for 24 hours.

Antimicrobial sensitivity tests

Sterile media plates were sub-divided into six equal parts using a marker pen and labelled accordingly. The test microbes were then spread aseptically on different media plates to prevent cross-contamination. Sterile octodiscs

impregnated with different samples were then placed on the surface of the plates. The plates were then inverted and incubated at 37°C for 24 hours. The inhibition zones were noted and recorded in millimeters.

Trans-esterification of cassava seed oil

The oil obtained was thereafter trans-esterified by dosing 100ml of the oil with 5% of Magadi salt. The products were condensed and the resultant liquid analyzed for flammability, pH and functional group variation with the raw cassava seed oil.

Data analysis

Data obtained from analyzing pH, temperature, total solids, volatile solids, heavy metals was subjected to statistical analysis. Some of these analyses were include; mean, median, standard deviation, variance, correlation and regression, t-test and f-test. The degree of freedom value was maintained at 8 with 95% confidence level being used for the statistics.

The data was analyzed using Ms Excel and Originlab statistical packages.

III. RESULTS AND DISCUSSIONS

The overall extraction efficiency using petroleum ether was 43.17%. These values were higher than those obtained by Popoola and Yangomodou, (2006) using a similar solvent.

Physical chemical analysis of extracted cassava seed oil

The extracted oil was found to have several physical-chemical similarities with other types of oils such as oleic, linoleic,

stearic and other types of oil. The color of the oil was yellow, similar to cassava seed oil extracted using n-hexane and ethyl acetate solvents (Current awareness in flavour and fragrance, 2010). No smell was associated with the oil. Popoola and Yangomodou, (2006); found out that the smell of cassava seed oil was odorless when extracted using n-hexane solvent. However, these findings differed with those of (Current awareness in flavor and fragrance, 2010); who obtained cassava seed oils with a characteristic pleasant odor when extracted using diethyl ether solvent. The extracted oil was found to be a viscous liquid oil at room temperature. However, the oil was not freezeed in refrigerator to determine its freezing point. **Table 2** below summarizes the physical-chemical parameters of cassava seed oil.

Table 2: Physical-chemical parameters of cassava seed oil

Parameter	Observation/value
Color	Pale yellow
Smell	Odorless and free from the smell associated with the plant
State at room temperature	Liquid at room temperature
pH	-
Electrical conductivity	0.72±0.50µS
Solubility	insoluble in water, soluble in n-hexane
Specific gravity	0.86±0.00g/cm ³

This pH coincides with that of most vegetable and petroleum oils. The pH of the oils was not detectable due to the inaqueous nature of the oil. Therefore, hydroxide and proton ions could not dissolve in the cassava oil to be detected. The conductivity of the oil was found to be lower than the set minimum conductivity of cassava seed oil (1.04 µS/cm⁻¹g⁻¹) (Apoku et al., 2017). Like other types of oils, cassava seed oils had trace conductivity values. This can be attributed to their non-polar behavior thus very few ions could dissolve. Absence of ions (polar groups) in a solvent is known to enhance reduced conductivity. This factor increases the suitability of the cassava seed oils as increased charges of oil is responsible for rampant fire outbreaks during storage and transportation of the oil. The extracted oil was found to be soluble in n-hexane and insoluble in water at all temperatures tested. This attests that non-polar solvents only dissolve in similar solvents, and vice-versa; further confirming the purity of the extracted oil. The extracted oil was found to have a specific gravity of 0.86±0.00g/cm³ which is quite lower than that of (Popoola and Yangomodou, 2006) who obtained 0.94 g/cm³ using similar solvents. (Popoola and Yangomodou, 2006) found out that the density of seed and vegetable oils are affected by temperature but are always below 1.00 g/cm³ (density of water).

The oil parameters of cassava seed oil

Petroleum oil and vegetable oils have similar characteristics that distinguish them from other compounds. **Table 3** below

summarizes the analyzed oil parameters in the cassava seed oil.

Table 3: The oil parameters of cassava seed oil

Parameter	Value
Acid value	3.56±0.60mgKOH/g
Free fatty acids value	7.06±0.40%
Iodine value	83.50±2.00wijs
Saponification value	236.32±0.10mgOH/g

The acid value of the seed oil was found to be higher than for most vegetable oils analyzed (Manshad and Rosami, 2015). The cassava seed oil acid value (3.56±0.60mgKOH/g) was higher than that of palm oil, sunflower oil, corn oil and peanut oil (Manshad and Rosami, 2015). Manshad and Rosami, (2015); further reports that perilla oil and camellia oil were analyzed to have similar acid values with that of cassava seed oil in table 3 above. However, (Kardash and Turyan, 2005) affirms that rapeseed oil had more (5.60mgKOH/g) acid value content compared to that of cassava seed oil. Increased acid value of the cassava seed oil implies more alkalinity levels in the oil. Therefore, compared to other vegetable oils, it can be concluded that cassava seed oil have relatively more ability to counter acids when blended with acidic oils. The free fatty acids of cassava seed oil refer to the level of acids formed during its hydrolysis. This factor is therefore temperature and pressure dependent. Judicalet al., (2017); found free fatty acids value of 0.39% in the seeds of *L. kerstingii*. Free fatty acids in oils are attributed to more oleic acid, linoleic acid, cholesterol and other phospholipids. The cassava seed oil samples were found to have an extremely low iodine value (83.50±2.00wijs) compared to other vegetable oils analyzed. (Gunstone, 2011) reported values of up to 94-120wijs (rapeseed oil), 116wijs (sunflower oil) and 136-178wijs for linseed oil. These findings were also lower than those of Popoola and Yangomodou, (2006) who found iodine value of 90wijs in cassava seed oil extracts. This implies that the extracted oil had very low degree of unsaturation. This property was partly the reason why the oil remained in liquid state at diverse temperatures exposed (12-30°C). The low iodine values in the extracted cassava seed oils makes this oil suitable for fuel applications due to increased calorific values associated with saturated oils. The extracted cassava seed oil was found to have higher saponification values than baobab oil, virgin avocado oil, virgin apricot oil and apricot kernel oil (From nature with love, 2019). Sample oils with tandem saponification values to those of the extracted cassava oil include aloe vera butter oil, amla oil and refined avocado oil (From nature with love, 2019). The saponification value of 236.32±0.10mgOH/g is quite moderate implying presence of moderate molecular weight compounds.

Bio-metal analysis of the cassava seed oil

The levels of different types of metals in oil can influence the applicability as well as toxicity of the oil. Increased heavy

metals in the oil require more time and energy during refining process. In the other hand, presence of leaded compounds, cadmium, mercury and other toxic heavy metals can have a positive influence on the octane number of the fuel and its overall combustibility but negative impacts when combusted. Exposure to such metals increase chances of getting cancer and respiratory diseases as well as massively contributing to global warming. There was a large disparity in concentrations of the bio-metals analyzed with iron and zinc having large values as copper, chromium and cobalt had minute values. Whilst most of these bio-metals are as a result of the environment (soil and water), each has varying implications in the oils role as a potential fuel. **Table 4** below summarizes the levels of bio-metal concentration in the extracted cassava seed oil.

Table 4: Bio-metal concentration in cassava seed oil

Bio-metal analyzed	Concentration in cassava seed oil (mg/Kg wet sample)
Copper	39.70±0.03
Chromium	30.28±0.03
Cobalt	1.04±0.05
Iron	77.21±0.50
Zinc	50.38±0.60

d

The copper levels (39.70±0.03 mg/Kg wet sample) were found to be higher than those observed by (Mendil *et al.*, 2009) in edible vegetable oils (0.035 µg/g). In a different study, Innocent and Ugochukwu, (2015); observed copper levels ranging between 0.69-3.44 mg/Kg of copper ions in local and imported vegetable oils. Several seed and vegetable oils have adverse corrosion effects on copper and zinc metals. Like copper, chromium is also a candidate of biofuel corrosion. Only 30.28±0.03mg/Kg of wet sample chromium ions were observed in cassava seed oils analyzed. Abundance

of chromium ions in biofuel oils are responsible for increased conductivity of the oil and flash point of the oil. Oil with a lot of chromium ions is thus unsafe for storage and transportation. Chromium ions in biofuels accelerate cathode poisoning. Mudgal *et al.*, (2014); observed that addition of 300ppm chromium ions to fuels drastically affects corrosion of combustion chambers. Cobalt ions were found to be in trace amounts in the extracted oil (1.04±0.05mg/Kg wet sample). Little is known about the abundance of cobalt in seed oils. Both iron and zinc had significant concentrations (77.21±0.50 and 50.38±0.60mg/Kg wet sample respectively) in the cassava seed oils. Farzin and Mohammad, (2014); reported low values of 7.78-28.93 and 3.58-9.54 µg/g of iron and zinc respectively in several vegetable oils sampled. Iron ions in the cassava seed oils are suitable heterogeneous catalysts essential during transesterification of the oil, to get more refined fuels. Addition of zinc ions thus increase the engine performance of biodiesels.

Functional group analysis of raw and refined cassava seed oil

There was total transformation in the appearance of the FT-IR spectra of the raw and refined cassava seed oil. The FT-IR spectra of the raw cassava seeds oil appeared to be similar to the spectra of the other vegetables oil such as peanut oil, soybean oil and sunflower oil (Joana *et al.*, 2015). It was clear from the spectra that there were carboxylic acids present, basically fatty acids as a result of the oil. Some of the dominant peaks in the spectra depicting presence of fatty acids included the wide valley between 2900-3500cm⁻¹ as a result of carboxylic -OH, carbonyl peak at 1750cm⁻¹ and -C-OH_{vibration} peak at 1035cm⁻¹. Presence of long chain hydrocarbons was observed in both raw and refined cassava seed oil spectra due to the sharp peaks at 3100cm⁻¹ (sp²-C-H_{stretch}), sp³-C-H_{stretch} at 2850cm⁻¹ and increased activity at the fingerprint region especially in the refined oil sample. The collated FT-IR spectra of the raw and trans-esterified cassava seed oil samples are illustrated in **figure 1** below.

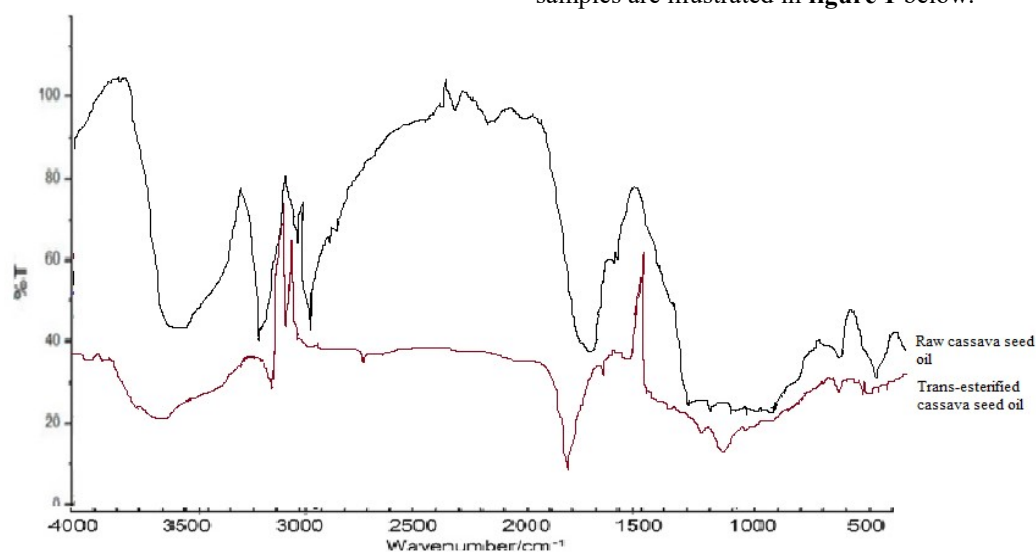


Fig 1 FT-IR spectra of raw (black) and trans-esterified (red) cassava seed oil

From the two spectra, there is loss in carboxylic -OH group from the raw to the refined oil sample. This implies less fatty acids in the trans-esterified cassava oil. On the other hand, the peaks as a result of sp^3 -C-H intensified in the trans-esterified sample showing higher degree of saturated compounds. Acetylenic and amide bonds present in the raw sample (2400cm^{-1} and 2200cm^{-1} respectively) were significantly removed after trans-esterification. Linear FT-IR spectra are characteristic of saturated hydrocarbons. The sharp peak at 1750cm^{-1} as a result of carbonyl groups was not affected by trans-esterification while the shallow -C-OH peak at 1050cm^{-1} intensified. Trans and cis double bonds as well as benzylic peaks between $1500\text{-}900\text{cm}^{-1}$ were also reserved in the process.

Antifungal activity of the cassava seed oil

The extracted oil was found to have moderate inhibition towards *C. albicans* fungi strain. An inhibition zone of diameter $10.60\pm 1.00\text{mm}$ was recorded after 24 hours incubation period. This implies that the extracted oil can be used to mitigate fungi effects. These findings do not concur with those of Popoola and Yangomodou, (2006) who got a smaller inhibition zone diameter using cassava seed oil.

Properties of the trans-esterified cassava seed oil

The liquid condensed after trans-esterification was found to have no pH value. This is because the sample was not aqueous thus acidic or basic ions could not be detected. The liquid burnt with a yellow sooty flame showing high degree of unsaturation or mixed compounds. **Figure 2** below illustrates a sample of the liquid being burnt.



Fig 2 Combustion of trans-esterified cassava seed oil

The liquid continued to burn with production of heat and less soot even after removing the ignition source until the liquid was completely consumed. The extent of combustion and the heat released during combustion was found to be dependent on the amount of liquid used. This suggests that the liquid can be used as a fuel.

IV. CONCLUSION

A high extraction efficiency of 43.17% was obtained during solvent extraction of oil from cassava seeds using pet ether. The extracts conformed to other cassava seed oils in terms of

physical appearance observed i.e yellow, odorless liquids with no pH detection and very little electrical conductivity ($0.72\pm 0.50\mu\text{S}$) and specific gravity ($0.86\pm 0.00\text{g/cm}^3$) values. The oil was also insoluble in water and soluble in n-hexane. The liquid state of the extracted oil did not condense beyond 12°C . The samples had a lot of iron and zinc content, moderate copper and chromium ions but extremely low cobalt levels. The extracted cassava seed oil had moderate antifungal activity against *C. albicans*. Characterization of oil parameters in the extracted oil led to speculation of high oleic acid content. The samples had quite high acid and free fatty acid values, moderate saponification value ($236.32\pm 0.10\text{mgOH/g}$) and extremely low iodine values ($83.50\pm 2.00\text{wijs}$) citing low degrees of unsaturation. These findings were supported by the FT-IR spectra of both raw and trans-esterified cassava seed oil which depicted high degree of saturation in the oil. During trans-esterification process, it was observed that carboxylic -OH, acetylenic and amide peaks were removed. Consequently, sp^3 -CH peaks intensified illustrating more saturation in the hydrocarbons formed.

Use of the indigenous salt, Magadi was therefore found to successfully aid in trans-esterification of cassava seed oil.

ACKNOWLEDGEMENT

The authors wish to thank Maasai mara university chemistry and biology labs for provision of facilities and personnel used in the research.

CONFLICTS OF INTEREST

The authors declare to have no conflicts of interest whatsoever

SOURCES OF FUNDING

No funding was received for this research.

DATA AVAILABILITY STATEMENT

All data used is enclosed within the manuscript and supplementary sheets attached.

REFERENCES

- [1]. Ajiwe, V., Umerie, S., Okeke, C., Oburota, V. (1994). Extraction and utilisation of cassava seed oil. *Bioresource Technology*, Vol: 47, Page: 85-86.
- [2]. Alves, A., Manthey, L., Isbell, T., Ellis, D., & Jenderek, M. M. (2014). Diversity in oil content and fatty acid profile in seeds of wild cassava germplasm. *Industrial Crops & Products*, 60, 310-315.
- [3]. Current awareness in flavour and fragrance. (2010). *Flavour and Fragrance Journal*, 25, 183-194.
- [4]. Farzin, L. and Mohammad, E. (2014). Determination of Metal Contents in Edible Vegetable Oils Produced in Iran Using Microwave-assisted Acid Digestion. *Journal of Applied Chemical Research*, 8, 35-43.
- [5]. Fréty, R., Rocha, M., Brandão, S., Pontes, Luiz, A., Padilha, J., Borges, L. & Gonzalez, W. (2011). Cracking and hydrocracking of triglycerides for renewable liquid fuels: alternative processes to transesterification. *Journal of the Brazilian Chemical Society*, 22, 1206-1220.
- [6]. From nature with love (August 24, 2019). Saponification chart. Retrieved from <https://www.fromnaturewithlove.com/resources/sapon.asp>

- [7]. Gunstone, F. (2011). *Vegetable Oils in Food Technology: Composition, Properties and Uses*, Second Edition. 10.1002/9781444339925.ch1.
- [8]. Innocent, C. and Ugochukwu, E. (2015). Comparative study of trace metal (Cd, Cr, Cu, Fe, K, Mg, Na, and Zn) contents of local and imported vegetable oil brands consumed in Nigeria. *Asian Journal of Plant Science and Research*, 5:22-29.
- [9]. Joana V., Luis C. & José, M. (2015) Investigation of adulteration of sunflower oil with thermally deteriorated oil using Fourier transform mid-infrared spectroscopy and chemometrics, *Cogent Food & Agriculture*, 1:1,doi: 10.1080/23311932.2015.1020254
- [10]. Judicaël, T., Patrice, B., Adjima, B., Nèbpawindé, K., Anne, M., Amadé O. and Imaël H.(2017). "Chemical Composition, Physicochemical Characteristics, and Nutritional Value of *Lanneakerstingii* Seeds and Seed Oil," *Journal of Analytical Methods in Chemistry*, vol.2017; 6 pages, 2017. <https://doi.org/10.1155/2017/2840718>.
- [11]. Kardash, E., &Tur'yan, Y. (2005). Acid Value Determination in Vegetable Oils by Indirect Titration in Aqueous-alcohol Media. *CroaticaChemica Acta*. 78. 99-103.
- [12]. Manshad, A, Rostami, H. (2015) Prediction of Wax Precipitation in Crude Oil Systems Using Gaussian Processes. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 37: 84-91.
- [13]. Mendil, D., Uluözlü, O., Tuzen, M. and Soylak, M. (2009). Investigation of the levels of some element in edible oil samples produced in Turkey by atomic absorption spectrometry. *Journal of Hazardous Materials*, 165, 724
- [14]. Mudgal, D., Surendra, S., and Satya, P. (2014). "Corrosion Problems in Incinerators and Biomass-Fuel-Fired Boilers," *International Journal of Corrosion*, vol. 2014, 14 pages <https://doi.org/10.1155/2014/505306>.
- [15]. Opaluwa, A. &Oyetunji, A. (2012). Evaluating the baked compressive strength of produced sand cores using cassava starch as binder for the casting of aluminium alloy T-joint pipe. *Journal of Emerging Trends in Engineering and Applied Sciences*, 3, 25-32.
- [16]. Opoku, N., Banful, B., Manu-Aduening, J., Tandoh, P. and Owusu, S. (2017). Germination and Vigour Responses of Seeds of Three Cassava Varieties to Pre-germination Treatments and Storage Durations. *Asian Journal of Advances in Agricultural Research*. 3: 1-9.
- [17]. Osano A., Okong'o E., Oyaro N. and Kiptoo J. (2013). Compositional and Structural Characterization of indigenous Salts in Kenya: A case study of 'Para', 'Magadi' and 'Lebek' crystalline salts. *International Journal of BioChemPhysics*, Vol. 20, 56-61.
- [18]. Popoola, T. and Yangomodou, O. (2006). Extraction, Properties and Utilization Potentials of Cassava Seed Oil. *Biotechnology*, 5: 38-41.
- [19]. Zhang, Y., Wu, H., Sun, M., Peng, Q., & Li, A. (2018). Photosynthetic physiological performance and proteomic profiling of the oleaginous algae *Scenedesmus acuminatus* reveal the mechanism of lipid accumulation under low and high nitrogen supplies. *Photosynthesis Research: Official Journal of the International Society of Photosynthesis Research*, 138, 73-102.
- [20]. Zhao, X., Wei, L., Cheng, S., Julson, J. (2017). Review of heterogeneous catalysts for catalytically upgrading vegetable oils into hydrocarbon biofuels. *Catalysts*, 7, 83; <https://doi.org/10.3390/catal7030083>.

^a Parameters used for Atomic Absorption Spectrometer

^b Physical chemical parameters of cassava seed oil

^c Oil parameters of cassava seed oil

^d Bio-metal concentration of cassava seed oil