PROXIMATE, PHYTOCHEMICAL AND FTIR ANALYSES OF THE FRUIT EXTRACTS OF *Kigelia africana* AND THE ANTIOXIDANT ACTIVITY

Supported by tetfund TERTIARY EDUCATION TRUST FUND

Elizabeth Adejoke Osibote*, Idris Abiodun Olasupo and Lydia Chilaka
Department of Chemistry, University of Lagos, Nigeria
*Corresponding author: eosibote@unilag.edu.ng

Received: September 18, 2021 **Accepted:** November 15, 2021

Abstract: *Kigelia africana*, a Tropical African plant is commonly called the 'Sausage Tree'. The fruit has been utilized as laxative, treatment for dysentery, acne, wounds and ulcers. Its powdered solution is used as disinfectant. Fruit powder or slices are used for breast firming. In Ghana the fruit, cut and boiled with peppers, is given for constipation and piles while the bark and fruit are used to heal sores and restore taste. The plant is used traditionally in disorders of male reproductive system; this may be due to the secretion of androgenic hormones found in its extract. In this study, the phytochemical screening, proximate analysis and antioxidant activity of *K. africana* fruit extracts were assessed with standard established protocols. The hexane, ethyl acetate and butanol fractions were obtained and purified using column chromatography; the eluted components were analyzed using FTIR. Functional groups obtained were compared with the phytochemicals. Phytochemicals found were alkaloids (10.27 mg/100g), saponins (20.26 mg/100g diosgenin), reducing sugar (80.83 mg/100g glucose), cardiac glycosides (7.23 mg/100g digoxin), steroids (112.35 mg/100g cholesterol), tannins (133.69 mg/100g tannic acid), phenolic compounds (108.06 mg/100g gallic acid), flavonoids (96.23 mg/100g quercetin). The antioxidant effect of the three fractions tested at a concentration of 100 uL/mL in a 1,1-diphenyl-2-picrylhydrazyl assay yielded (46.99% inhibition) hexane (70.44% inhibition) ethyl acetate and (58.30% inhibition) butanol fraction relative to ascorbic acid (84.24% inhibition). *Kigelia africana* have great potential to develop lead compounds for the design and synthesis of potent drugs against diseases caused by reactive oxygen species.

Keywords: DPPH, FTIR, *Kigelia africana* and phytochemicals

Introduction

A natural product is a chemical compound or substance produ ced by plants or any living organism using enzyme-mediated chemical reactions called metabolic pathways. Natural products sometimes have therapeutic benefit as traditional medicines for treating diseases and yielding knowledge to derive active components as lead compounds for drug discovery. Natural products especially within the field of organic chemistry are often defined as primary and secondary metabolites. A more restrictive definition limiting natural products to secondary metabolites is commonly used within the fields of medicinal chemistry and pharmacognosy (Bhat *et al*., 2005). Many thousands of secondary metabolites have been isolated from plants, and many of them have powerful physiological effects in humans and so are used as medicines.Role of secondary metabolites in plants include general protective roles (e.g. as antioxidants, free radical-scavenging), defend the plant against pathogens (viruses, fungi and bacteria) and allelopathic defenders etc. Types of secondary metabolites include alkaloids, terpenoids, flavonoids, tannins, cardiac glycosides, reducing sugar, saponins all of which support bio-activities in plants.

Reactive oxygen species (ROS) are reactive chemical species containing oxygen examples are peroxides, superoxide, hydroxyl radical, singlet oxygen and alpha-oxygen. The reduction of molecular oxygen (O_2) produces superoxide ($^{\bullet}O^{-}_2$) and is the precursor of most other reactive oxygen species: $O_2 + e^- \rightarrow {}^{\bullet}O^-$(Hayyan *et al*., 2016). In a biological context, ROS are formed as a natural byproduct of the normal metabolism of oxygen and have important roles in cell signaling and homeostasis. However, during times of environmental stress (e.g., UV or heat exposure), ROS levels can increase dramatically (Devasagayam *et al*., 2004). This may result in significant damage to cell structures. Cumulatively, this is known as oxidative stress.Oxidative stress results when the balance between the productions of ROS exceeds the antioxidant capability of the target cell. In traditional medicine, several medicinal plants are used in the management of fibroid. Ethnobotanic inquiries have shown that *Kigelia africana* is among the most commonly used plants. The methanol extract of *K. africana* inhibited HeLacervical cancer cell growth, albeit to a lesser extent (81 % of the untreated control growth) (Arkhipov *et al.*, 2014)

Three plant parts of *Kigelia africana* generally used are leaf, fruit and bark. Fruit extracts have found the widest applications in the treatment of fungal and bacterial skin infections. This may justify the wider usage in skin care formulations. In clinical microbiology, bacterial and fungal susceptibility tests are of paramount importance, as they help detect possible efficacy or resistance of common pathogens to the drug being tested as researched by Reller *et al.* (2009). The susceptibility tests reported by Hussain *et al.* (2016) and Arkhipov *et al.* (2014) revealed that the ethanolic leaf extract showed maximum activity against *E. coli* (22 mm) and moderate activity against *P. vulgaris* and *P. aeruginosa*, respectively. *K. pneumoniae* and *C. amalonaticus* showed resistance with no inhibition zones. For the aqueous leaf extract, maximum antibacterial activity was observed against *C. amalonaticus* (7 mm) and moderate activity against *S. aureus* (5 mm), *P. aeruginosa* (4 mm) and *P. vulgaris* (4 mm). *Klebsiella pneumoniae* showed resistance to the aqueous leaf extract, with no inhibition zone. The n-hexane leaf extract of *K. africana* exhibited maximum activity; zones produced by the fruit of *K. africana* against all bacterial strains were highly significant. Ethanolic and aqueous extracts of bark and leaves of *K. africana* showed remarkable activity against the bacterial strains as compared to n-hexane. *S. aureus* and *E. coli* were proved as highly sensitive strains, while *K. pneumoniae* was the resistant strain, as the extracts formed no inhibition zone against it (Hussain *et al.* 2016). The anti-inflammatory of the methanolic leaf extract of *K. africana* was evaluated and it showed significant anti-inflammatory activity on carrageenan-induced paw edema, which was demonstrated by the reduction in the inflamed hind paw diameter after the extract administration (Kamau*et al.*, 2016). The effect of the extracts on rate of wound closure was investigated using the excision wound model and histopathological investigation of treated and untreated wound tissues performed. The MICs of leaf extract of *K. africana*

against test organisms were 2.5–7.5 mg/mL and stem bark extract were 2.25–7.5 mg/ml. *K. africana* extracts (7.5% w/w) showed significant ($P< 0.05$) wound contraction at day 7 with 72% of wound closure while significant ($P< 0.05$) wound contractions were observed on day 11 for stem bark of *K. africana*. Wound tissues treated with the extracts showed improved collagenation, re-epitheliazition and rapid granulation formation compared with untreated wound tissues. The extracts of *K. africana* exhibited antimicrobial, antioxidant, and enhanced wound healing properties (Agyare *et al.*, 2013). The methanolic extract of *K. africana* fruits, aqueous fruit extract and acetone fruit extract were subjected to antioxidant and anti-inflammatory assays. The extracts had good antioxidant and anti-inflammatory activity and this supports their use as potential anti-inflammatory therapies (Nabatanzi *et al*., 2020).

This research is to investigate the phytochemistry and medicinal use of the *Kigelia africana* fruits. The compounds identified by the analytical procedure are compared with the metabolites detected. Hence it is important to scientifically reveal the compositions of the components of the fruits.The major aim of the present work is to carry out the 50% methanol/water extraction and partition into fractions according to the polarity; to carry out phytochemical screening, assess the total antioxidant content of the extracts. The antioxidant activity of *K. africana* fruits on DPPH and nitric oxide free radical scavenging using 50% methanol extract and partitioned fractions. FTIR analyses of the fractions were carried out to identify the functional groups of the compounds present in the extracts.

Materials and Methods

Plant collection and processing

The plant was bought from Oyingbo market in Lagos between July 2018 and April 2019. It was identified and authenticated at the herbarium of Botany Department, University of Lagos with the voucher number LUH 7993 assigned. Fruits of the plant were cut into tiny pieces, air dried and pulverized.1134 g of wet fruit gave 791.5 g of dried fruit powder.

Extraction of the plant materials: Solvent extraction was carried out on the plant materials

50%v/v methanol/water extraction (maceration)

The 400 g dried powder of the fruits of *Kigeliaafricana* was extracted with 2 litres of 50% methanol-water ratio for 72 h with very frequent agitations in 5 litre conical flasks. The ratio of solvent to plant being 1:3 the conical flasks containing the mixture was made air-tight by covering with foil paper. The mixture was filtered with a sieve of fine sized mesh after 72 h. The residue was soaked again in 1.5 L of 50% methanol/water for another 24 h to remove any extract that may remain in the residue. The two extracts were pooled together and concentrated by rotary evaporation at 40ºC. The concentrated extracts were dried in a freeze dryer. The extract obtained is the crude extract. The 50% methanol/water extraction gave 71g of dried extract obtained from 500 g of the pulverised fruit. The methanol/water extracts had a chocolate brown colour.

Serial solvent partitioning

Aqueous solutions of 50% methanol/water extract of *Kigelia Africana* was obtained by dissolving in 30 mL water with the ratio of extract to water 1:1. The solution was partitioned between the aqueous and the organic solvents (hexane, ethyl acetate, butanol) to obtain non-polar, slightly polar and polar fractions respectively. Hexane was used first for separation followed by slightly polar ethyl acetate and the very polar butanol was used last on the same mixture.

The partitioning was carried out by shaking the aqueous mixture with 10 mL of hexane four (4) times in a separating funnel to remove the non-polar compounds. The aqueous mixture plus solvent was always left to stand each time for a few minutes till two distinct layers were formed in the separating funnel with the hexane fraction being on top while the water fraction was below. The hexane fraction was then removed separately. The ethyl acetate fraction was obtained with the same procedure as hexane in the remaining aqueous mixture with 10 mL of ethyl acetate four (4) times in a separating funnel and the ethyl acetate fraction was collected. The butanol fraction was obtained with the same procedure with 10 mL of butanol four (4) times and the butanol fraction was collected. The fractions were evaporated to dryness by air drying the hexane and ethyl acetate fractions and concentrating the butanol fraction in rotary evaporator.

The colour of the hexane fraction (HKA) was light yellow. The ethyl acetate fraction (EKA) was light brown. The butanol fraction (BKA) was deep brown.

Phytochemical screening

The phytochemical screening of the crude aqueous methanolic extracts, was carried out to detect the presence (or absence) of alkaloids (Dragendorff, Wagner and Mayer Test), reducing sugar (Fehling Test), flavonoids (Shinoda's Test), tannins (Ferric Chloride Test), cardiac glycoside (Keller Killani's Test), phenolics compound (Lead acetate Test), Saponins (Emulsion Test) and terpenoids (Liebermann Burchard reaction). Quantitative phytochemical analysis was also carried out on all the extracts.

Proximate analysis

The proximate analysis of the crude extract, HKA, EKA and BKA fractions was carried out to estimate the percentage composition, moisture content, total ash, crude protein, crude lipids, crude fibre and nitrogen free extracts present in them.

Total antioxidant capacity

The total antioxidant capacity (TAC) of extracts was assessed by measuring absorbance at 695 nm after 90 min incubation of 0.3 mL of a 1 mg/mL extract solution in methanol mixed with 2.7 mL phosphomolybdenum reagent in capped test tubes. TAC results were expressed as Trolox (Sigma-Aldrich, St. Louis, MO, USA) equivalents (mg TE/g of dry sample). Butylatedhydroxytoluene (BHT; Sigma-Aldrich, St. Louis, MO, USA) and Oligopin (DRT nutraceutical, Vielle-St-Girons, France) were used as reference controls.

DPPH free radical scavenging activity

The free radical scavenging activity of extracts was tested by measuring decrease in absorbance at 516 nm after 30 min incubation of 1.3 mg/mL in methanol of a DPPH (1,1-diphenyl-2-picrylhydrazyl) solution mixed with 1.0 mL of the, HKA, EKA and BKA extracts (tested at concentrations of 10 µg/10mL). The reducing power was expressed as percentage inhibition by comparison with ascorbic acid standards (10 µg/10mL)

Nitric oxide scavenging assay:

Sodium nitroprusside (5 mM) in phosphate buffered saline was mixed with different concentrations of the sample and incubated at 25°C for 150 min. The samples were then mixed with Griess reagent (1% sulfanilamide, 2% H_3PO_4 and 0.1% N-(1-naphthyl ethylenediaminedihydrochloride) (NED). The absorbance of the chromophore formed during diazotization of nitrite with sulfanilamide and subsequent coupling with NED was read at 546 nm using a UV–VIS spectrophotometer. The inhibition of nitric oxide formation was determined with respect to standard potassium nitrite in the same way with Griess reagent. The results is expressed as potassium nitrite equivalent which was used as a standard.

Thin layer chromatography

The fractions were examined by thin layer chromatography. About 5 µL of each extract (100 mg/mL) were deposited on fluorescence silica gel plates (0.2 cm thickness, 60 F254) and migration conducted with various solvent systems. C:D 1:2 solvent system was established for HKA giving three (3)

components; E:D:M 1:1:0.1 was established for EKA, giving four (4) components; M: E:C 0.1:1:1 was established for BKA giving four (4) components. After drying the plates, an UV lamp at 254 and 366 nm was used to view the components (M is used for methanol, H for hexane, E for ethyl acetate, D for dichloromethane, C for chloroform).

Column chromatography

Separation on silica gel column using mixtures of solvent systems established for TLC to elude with UV lamp at 254 and 366 nm to view yielded different number of components for each fraction HKA (2 components), EKA (5 components) and BKA (3 components) which further underwent FTIR analysis to further compare with the results of the phytochemical screening.

Results and Discussions

Phytochemical screening

Table 1 and 2 give the % yield of the aqueous methanol extract and the hexane, ethyl acetate and butanol fractions. Phytochemicals (Table 3) *Kigelia africana*, alkaloids (10.27 mg/100g), saponins(20.26 mg/100g diosgenin), reducing sugar (80.83 mg/100g glucose), cardiac glycosides (7.23 mg/100g digoxin), steroids (112.35 mg/100g cholesterol), tannins (133.69 mg/100g tannic acid), phenolic compounds (108.06 mg/100g gallic acid), flavonoids (96.23 mg/100g quercetin).

Table 1: Masses and % yield of 50% methanol/water extracts

Plant Extract	*Kigelia africana*
Mass of pulverized plants (g)	500
Mass of dried 50% MeOH/H_2O extract (g)	71
% yield of extract	14.2

Table 2: Yield of the fractions obtained from the crude extract of *Kigelia africana* after serial partitioning

Solvent	Hexane	Ethylacetate	Butanol
Volume of water used to dissolve (mL)	50	50	50
volume of organic solvent used (mL)	80	80	80
Mass of hexane fraction (g)	0.126	0.360	0.701
% yield of fraction	0.18	0.51	0.99
Colour of fraction	Light yellow	Light brown	Deep brown

DPPH free radical scavenging activity

At a concentration 100 µg/mL, the fractions HKA, EKA and BKA decreased under the present experimental condition by 47, 70 and 58% the DPPH signal, as compared to 84% decrease with 100 µg/mL ascorbic acid (Table 4).

Nitric oxide free radical scavenging activity

At a concentration 100 µg/mL, the fractions HKA, EKA and BKA decreased under the present experimental condition, 46.44, 60.83 and 50.20% the nitric oxide signal, as compared to 87.18% decrease with 100 µg/mL ascorbic acid (Table 4).

Total antioxidant capacity

Table 4 gives the total antioxidant content in the three extracts considered in this study. The results are given as mg of ascorbic acid equivalent per gram extract. The highest values were recorded in the EKA extracts, amounting to 18.24 mg.

Thin layer chromatography

C:D 1:2 solvent system was established for HKA giving three (3) components (R_f 0.22,0.32,0.35); E:D:M 1:1:0.1 was established for EKA, giving four (4) components (R_f 0.28,0.32,0.35,0.37) ; M: E:C 0.1:1:1 was established for BKA giving four (4) components (R_f 0.38,017 0.43,0.45,0.48). After drying the plates, revelation was conducted using an UV lamp at 254 and 366 nm. (Using M for methanol, H for hexane, E for ethyl acetate, D for dichloromethane, C for chloroform).

Column chromatography

The HKA fraction eluted two components with Rf values 0.92 (0.0118 g), and 0.79 (0.0072 g); BKA eluted five components with Rf values 0.96 (0.0423 g), 0.94 (0.0049 g,), 0.88 (0.1012 g), 0.52 (0.0725 g) and 0.31 (0.0058 g) and BKA eluted 3 components with Rf values 0.88 (0.0099 g), 0.81 (0.2881 g), 0.65 (0.1126 g)

The FTIR analysis of the components eluted from column chromatography for all fractions showed that hexane fraction contained terpenoids, alkaloids and cardiac glycosides,:the ethyl acetate fraction of *Kigelia africana* gave the highest number of components which showed bands whose functional groups correspond to tannins, phenolic compounds, flavonoids, alkaloids and terpenoids. The butanol fraction contains reducing sugars, fatty acids, phenolics and flavonoids. The FTIR result is reported in Table 5. The presence of these functional groups support the reported bioactive activities of the plant.

This study reports the composition of phytochemicals present in the 50% methanol-water extracts of *Kigelia africana* which include tannins, flavonoids, alkaloids, reducing sugar, steroids, phenolic compounds and terpenoids which are known for their strong medicinal values providing scientific evidence for the therapeutic usage of the plant. The crude extract were partitioned into hexane, ethyl acetate and butanol to give different fractions which were purified with column chromatography and analyzed with FTIR to further support the results obtained from the phytochemical screening. The in vitro antioxidant assay indicated that the plant extract has potent antioxidant activity relative to the antioxidants present in ascorbic acid.

The proximate analysis shows the number of macronutrients in descending order as moisture content (30%) =carbohydrates (30%)> crude fiber (15%)>crude protein=crude fat (9%)>total ash (7%) therefore it is safe to say that this fruit is a good source of macronutrients in human diet.

Table 3: Results of phytochemical screening on extract from fruits of *Kigelia africana*

Test	Method	Qualitative	Quantitative	Unit
Alkaloids	Mayer's Test	-	10.27	(mg/100g)
	Dragenderoff's Test	+		
	Wagner's Test	-		
Saponins	Emulsion Test	++	20.66	(mg/100g diosgenin)
Reducing Sugar	Fehling's Test	+ +	80.83	(mg/100g glucose)
Cardiac glycosides	Keller Killani's Test	+ +	7.23	(mg/100g Digoxin)
Terpenoids	Liebermaan Burchard	+ ++		
Steroids	Salkowki Test	+ +	112.35	(mg/100g cholesterol)
Tannins	Ferric Chloride Test	+++	133.69	(mg/100g Tannic acid)
Phenolic Compounds	Lead acetate Test	+++	u108.06	(mg Gallic Acid Equivalent/100g extract)
Flavonoids	Shinoda's Test	++	56.23	(mg Quercetin Equivalent/100g extract)

Heavily detected: + + +; detected: + +; slightly detected: +; not detected: –

Table 4: Results of antioxidant assays of n-hexane, ethyl-acetate and butanol fractions of *Kigelia africana*

Sample	Nitric oxide assay				DPPH assay				TAC Ascorbic acid Equivalent (mg/mg extract)
	25 ug/ml	50 ug/ml	75 ug/ml	100 ug/ml	25 ug/ml	50 ug/ml	75 ug/ml	100 ug/ml	
HKA	18.46 ±0.14	25.72±0.01	33.56 ±0.34	46.44 ±0.76	25.57 ±0.46	32.96±0.3	39.40 ±1.05	46.99±1.25	9.33
EKA	27.75 ±0.74	36.35±1.35	48.90 ±2.79	60.83 ±0.84	42.99 ±1.98	55.68±0.76	61.05 ±1.91	70.44±0.37	18.24
BKA	17.43 ±0.58	26.94±0.82	34.05 ±0.51	50.20 ±0.43	42.67 ±0.94	50.37±1.43	55.98 ±1.61	58.30±1.75	10.11
Ascorbic acid	73.10 ±0.35	79.99±0.41	84.45 ±0.20	87.18 ±0.26	64.30 ±0.83	69.11±0.32	74.54±0.83	84.24±0.77	

Table 5: FTIR results for *Kigelia africana*

Fractions	Bands present	Functional groups	Likely compound
N-Hexane	3440.24cm^{-1}	OH stretching	Terpenoid/
***Kigelia africana* 1**	1732 cm^{-1}	C=O stretching	Alkaloid
	1633.97cm^{-1}	Aromatic Streching C=C	
	1462.43 cm^{-1}	CH_2 bending or C-N Stretching	
	1260.71cm^{-1}	C-O Asymmetric stretching	
	794.86 cm^{-1}	aromatic out of plane bending	
	663cm^{-1} (broad)	N-H wag	
N-Hexane	3440.40 cm^{-1}	OH stretching	Cardiac glycoside/
***Kigelia africana* 2**	1727.61 cm^{-1}	C=O stretching,	Steroid due to absence of C=C bands
	(1628.69 cm^{-1}	C=C stretching	Of aromatic bands
	1259.6cm^{-1}	C-O Asymmetric stretching	
Ethyl-Acetate	3405.60 cm^{-1}	OH stretching	Tannins due to the
***Kigelia africana* 1**	1650.23 cm^{-1}	C=O stretching	presence of the –COO-
	1452.95 cm^{-1}	CH_2 bending or C-N Stretching	Bands
	1404.90 cm^{-1}	COO Symetric stretching	
Ethyl-Acetate	3432.59 cm^{-1}	OH stretching	Phenolic/
***Kigelia africana* 2**	1636.63 cm^{-1}	Aromatic C=C stretching	Flavonoid
	1517.57 cm^{-1}	Aromatic C=C stretching	
	1279.47cm^{-1}	C-O Asymmetric stretching	
	3437.95 cm^{-1}	OH stretching	
Ethyl-Acetate	2924.63 cm^{-1}	CH_2 stretching	Reducing sugar due to
***Kigelia africana* 3**	2854.11 cm^{-1}	CH_3 stretching	Absence of C=C
	1758.03 cm^{-1}	C=O stretching	Bands
	1452.7 cm^{-1}	CH_2 bending	
	1374.46 cm^{-1}	CH_3 bending	
	1243.65cm^{-1}	C-O Asymmetric stretching	
	3437.58 cm^{-1}	OH stretching	
Ethyl-Acetate	2924.10 cm^{-1}	CH_2 stretching	Phenolic
***Kigelia africana* 4**	2853.98 cm^{-1}	CH_3 stretching	Flavonoid
	1758 cm^{-1}	C=O stretching	
	1635.71 cm^{-1}	C=C stretching	
	1456.04 cm^{-1}	aromatic C=C stretching	
	1377.62 cm^{-1}	CH_3 bending	
	1244.36 cm^{-1}	C-O Asymmetric stretching	
Ethyl-Acetate	3440cm^{-1}	OH stretching	Alkaloid /
***Kigelia africana* 5**	1750.10cm^{-1}	C=O stretching	Terpenoids
	1634cm^{-1}	C=C stretching	
	1243.67cm^{-1}	C-O stretching	
	621.44cm-1 (b	N-H wagging	
Butanol	3438.54 cm-1	OH stretching	Reducing sugar due to
***Kigelia africana* 1**	1758.49 cm-1	C=0 stretching	Absence of C=C bands
	1243.73 cm^{-1}	C-O Asymmetric stretching	
Butanol	3260 cm^{-1}	O-H stretching	Phenolic/
	1745 cm^{-1}	C=O stretching	Flavonoid
***Kigelia africana* 2**	1633.95 cm^{-1}	C=C stretching	
	1459.56 cm^{-1}	CH_2bending, aromatic C=C stretching	
	1295.0 cm^{-1}	C-O Asymmetric stretching	
	3430.49, cm^{-1}	OH stretching	
Butanol	(1634.98) cm^{-1}	C=O stretching	Fatty Acid
***Kigelia Africana* 3**	(1277.06) cm^{-1}	C-O stretching	

The potency of the N-Hexane, ethyl-acetate and butanol fractions of *Kigelia africana* (Figs. 1 – 10). *Kigelia africana* were tested and it was observed that of all the extracts, the ethyl-acetate fraction showed the best antioxidant and free radical scavenging activities while the hexane and butanol fractions showed minimal antioxidant activity (Figs. 11 – 12).

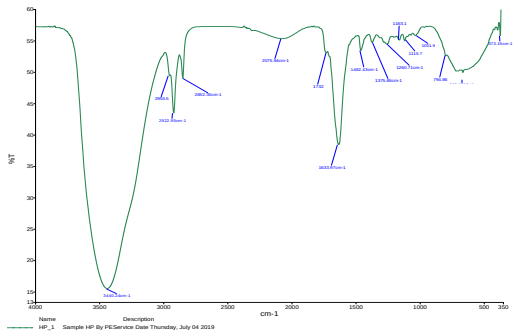

Fig. 1: N-Hexane component 1 K.A

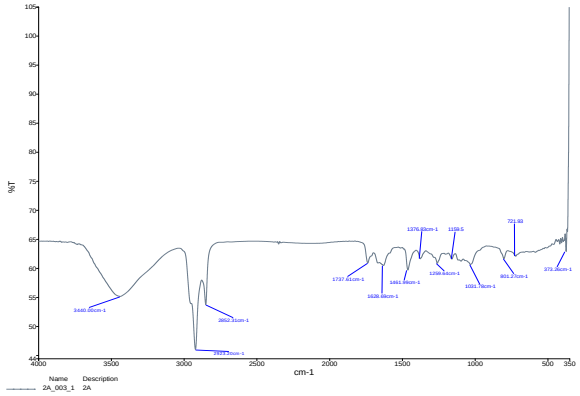

Fig. 2: N-Hexane component 2 K.A

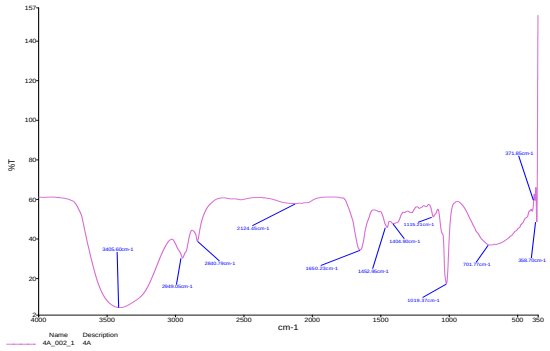

Fig. 3: Ethyl-Acetate component 1 K.A

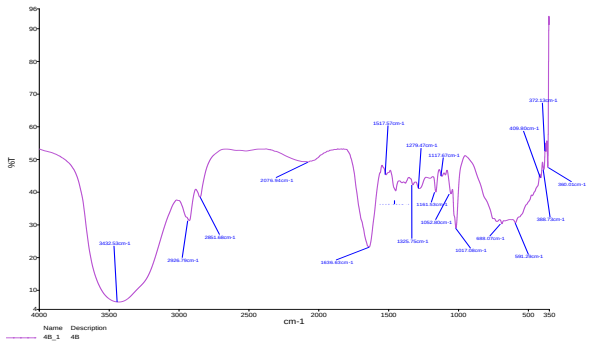

Fig. 4: Ethyl-Acetate component 2 K.A

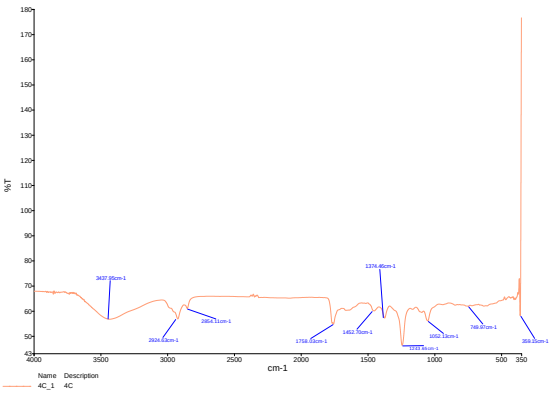

Fig. 5: Ethyl-Acetate component 3 K.A

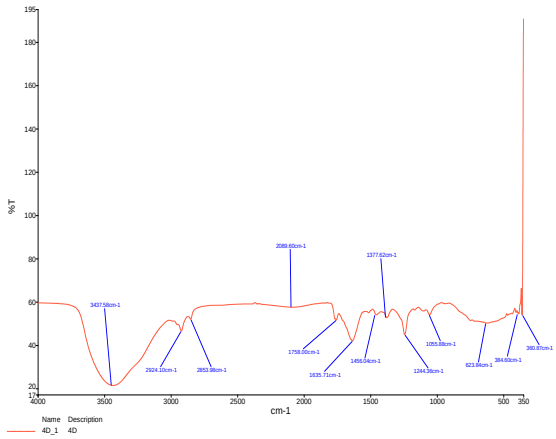

Fig. 6: Ethyl-Acetate component 4 K.A

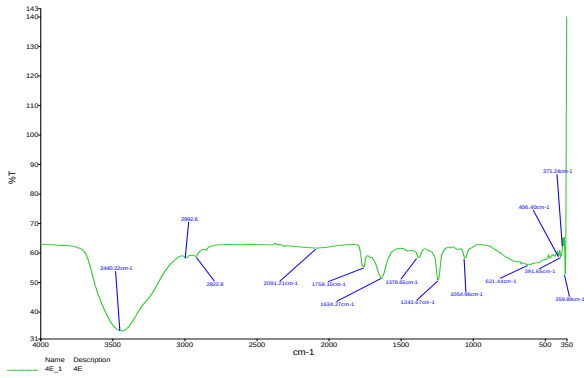

Fig. 7: Ethyl-Acetate component 5 K.A

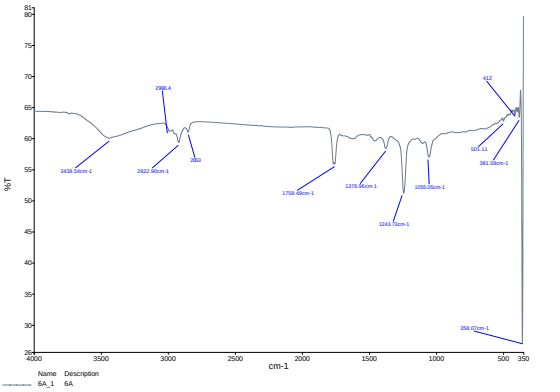

Fig. 8: Butanol component 1 K.A

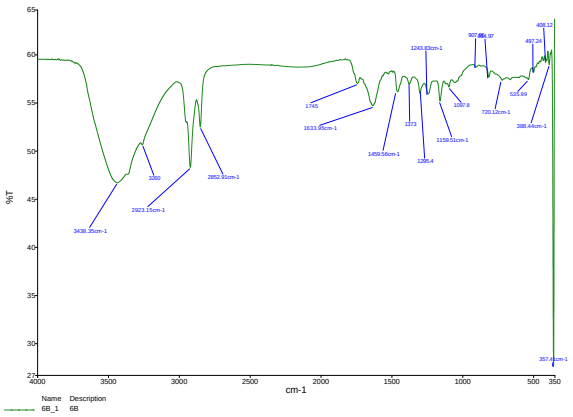

Fig. 9: Butanol component 2 K.A

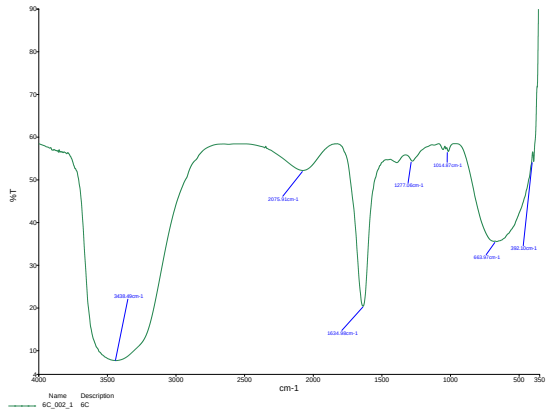

Fig. 10: Butanol component 3 K.A

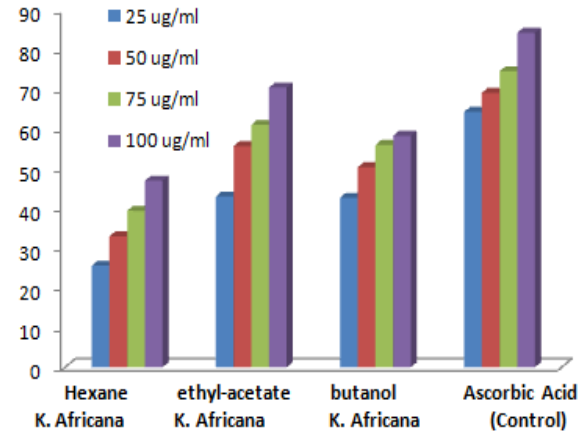

Fig. 11: A pictorial representation of the antioxidant activity of *Kigelia aficana* compared to ascorbic acid In DPPH free scavenging Assay

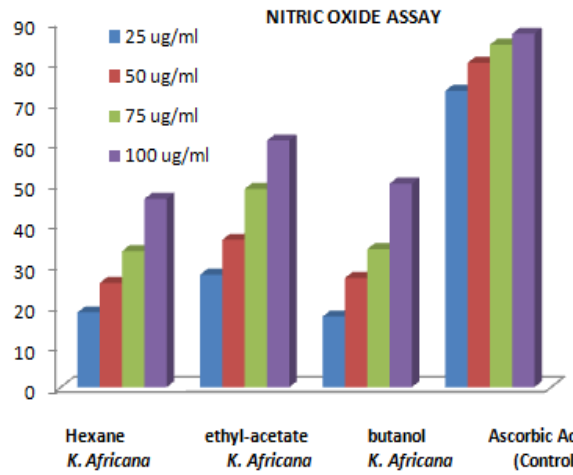

Fig. 12: A pictorial representation of the antioxidant activity *Kigelia africana* compared to ascorbic acid In Nitric Oxide free radical scavenging assay The proximate and elemental analyses showed that the plant possesses nutritional properties

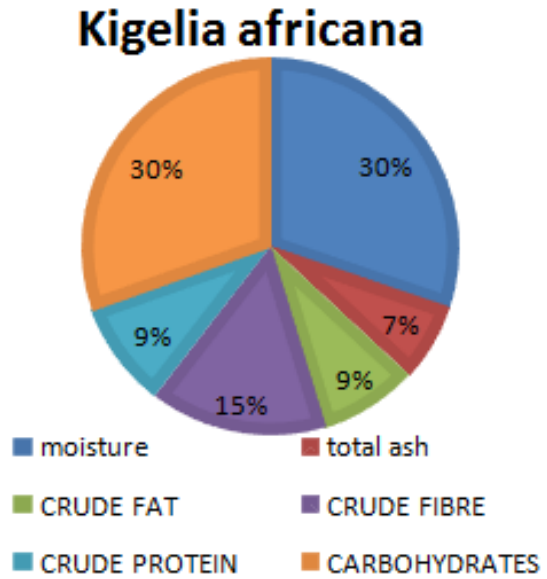

Fig. 13: A pictorial representation of the proximate analysis of *Kigelia africana*

Kigelia africana

The proximate analysis shows the number of macronutrients in descending order as moisture content (30%) =carbohydrates (30%)> crude fiber (15%)>crude protein=crude fat (9%)>total ash (7%) (Fig. 13). Therefore it is safe to say that this fruit is a good source of macronutrients in human diet.

Conclusion

Finally, *Kigelia africana* can be used an important source of new bio-active compounds. The plant has great potential to develop lead molecules for the design and synthesis of potent drugs by pharmaceutical industries against diseases caused by reactive oxygen species. The presence of phenolics compounds like flavonoids which are good antioxidants may be giving the plant good radical scavenging properties. The proximate analysis gave a high crude protein; high

carbohydrate and crude fiber which makes the fruits contribute to the nutritional and energy requirements of humans. It is suggested that the fruits of *K. africana* could be used as additive in the food industry providing good protection against oxidative damage.

Conflict of Interest

All authors hereby declare that the work has not been published before and that the manuscript was read through and the final version approved by all the authors. The authors disclose that there is no actual or potential conflict of interest including any financial, personal or other relationships in any way with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence the work.

References

Agyare C, Dwobeng AS, Agyepong N, Boakye YD, Mensah KB, Ayande PG & Adarkwa-Yiadom M 2013. Antimicrobial, Antioxidant, and Wound Healing Properties of *Kigelia africana* (Lam.) Beneth. and *Strophanthushispidus* DC. Hindawi Publishing Corporation Advances in Pharmacological Sciences Volume 2013, Article ID 692613, 10 pages http://dx.doi.org/10.1155/2013/692613

Ahmad IM, Abdalla MY, Mustafa NH, Qnais EY & Abdulla FA 2009. *Datura* aqueous leaf extract enhances cytotoxicity via metabolic oxidative stress on different human cancer cells. *Jordan J. Biol. Sci*., 2: 9-10.

Anandjiwala S, Bagul MS, Parabia M & Rajani M 2008. Evaluation of free radical scavenging activity of an Ayurvedic formulation, panchvalkala. *Indian J. Pharm. Sci.*, 70:31–5

Arkhipov A, Shalom J, Matthews B & Cock IE. 2014 Metabolomic profiling of *Kigeliaafricana* extracts with anti-cancer activity by high resolution tandem mass spectroscopy. *Pharmacogn. Commun*., 4: 10–32.

Arkhipov A, Sirdaarta J, Rayan P, McDonnell PA & Cock IE 2014. An examination of the antibacterial, antifungal, anti-Giardial and anticancer properties of *Kigeliaafricana* fruit extracts. *Pharmacognosy Communications*, 4(3): 62-76.

Bhat SV, Nagasampagi BA & Sivakumar M 2005. Chemistry of Natural Products. Berlin, New York: Springer.

Devasagayam TP, Tilak JC, Boloor KK, Sane KS, Ghaskadbi SS & Lele RD 2004. Free radicals and antioxidants in human health: Current status and future prospects. *The J. Assoc. Physicians of India*, 52: 794–804.

Hayyan M, Hashim MA & AlNashef IM 2016. Superoxide Ion: Generation and chemical implications. *Chemical Reviews*, 116(5): 3029–3086.

Hussain T, Fatima KF, Rafay M, Shabir S, Akram M & Bano S 2016 Evaluation of antibacterial and antioxidant activity of leaves, fruit and bark of *Kigelia africana*. *Pak. J. Bot*., 48: 277–283.

Kamau KJ 2016. Antipyretic and Anti-Inflammatory Properties of Methanolic Extracts of *Kigelia africana* (Lam.) Benth and Acacia hockii de Wild in Animal Models. Master's Thesis, School of Pure and Applied Sciences, Kenyatta University, Nairobi, Kenya.

Li JW & Vederas JC 2009. "Drug discovery and natural products: end of an era or an endless frontier? *Science*, 325(5937): 161–5.

Micheli V, Sanogo R, Mobilia MA & Occhiuto F 2019. Effects of *Kigelia africana* (Lam.) Benth. fruits extract on the development and maturation of the reproductive system in immature male rats Natural Product ResearchFormerly Natural Product Letters Volume 34, 2020-Issue 1: Ethnomedicine and Foods Sources: Novel Perspectives, pp. 162-166 Guest Editor: Nicola Cicero https://doi.org/10.1080/14786419.2019.1579809

Nabatanzi A, Nkadimeng SM, Lall N, Kabasa JD & McGaw LJ 2020. Antioxidant and Anti-Inflammatory Activities of *Kigelia africana* (Lam.) Benth.

Hindawi Evidence-Based Complementary and Alternative Medicine Volume 2020, Article ID 4352084, 11 pages https://doi.org/10.1155/2020/4352084

Oyaizu M 1986. Studies on products of browning reactions: Antioxidant Activities of Products ofbrowning reaction prepared from glucose amine. *Jpn. J. Nutr*., 44: 307–315.

Pichersky E & Gang DR 2000. Genetics and biochemistry of secondary metabolites in plants: an evolutionary perspective. *Trends in Plant Science*, 5: 439-445.

Prieto P, Pineda M & Aguilar M 1999. Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: Specific application to the determination of Vitamin E1. *Anal. Biochem*., 269: 337–341.

Reller LB, Weinstein M, Jorgensen JH & Ferraro, JM. 2009 Antimicrobial susceptibility testing: A review of general principles and contemporary practices. *Arch. Clin. Infect. Dis*., 49: 1749–1755.

Samuelson G 1999. Drugs of Natural Origin: A Textbook of Pharmacognosy. *Taylor & Francis Ltd.*, 22: 232

Tannin-Spitz T, Grossman S, Dovrat S, Gottlieb HE & Bergman M 2007. Growth inhibitoryactivity of cucurbitacinglucosides isolated from *Citrulluscolocynthis* on human breast cancer cells. *Biochemical Pharmacology*, 73(1): 56–67. doi:10.1016/j.bcp.2006.09.012