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Evaluation of the nutraceutical potential of *Garcinia kola* Seed Oil

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Abstract
This study investigated antimicrobial and antioxidant activities, mineral and phytochemical compositions of *Garcinia kola* seed oil. Results of the antimicrobial activity showed that the order of susceptibility of the test microbes to the oil was *Salmonella typhi* > *Enterobacter cloacae* > *Staphylococcus aureus* > *Candida albicans* > *Escherichia coli.* The oil showed flavonoid content of 59.42 mg/g, phenolic content of 41.27 mg/g and DPPH scavenging activity with IC50 of <1 mg/mL. The mineral analysis revealed that Calcium (210.90 mg/100 g) and Manganese (0.63 mg/100 g) had the highest and lowest concentrations respectively. Meanwhile, toxic minerals; Pb, Hg, Cd, Co and Ni were not detected. The GC-MS analysis of the oil showed eighteen phytochemicals seven of which have been reported as having antioxidant, antimicrobial, anti-inflammatory, hypocholesterolemic, antiviral, anti-diarrheal, antiproliferative, antiandrogenic and anticoronary activities. Decane (14.68 %) and Tridecanoic acid methyl ester (0.48 %) had the highest and lowest concentrations respectively. Based on the results of this study, *Garcinia kola* seed oil could find useful applications in food, cosmetics and pharmaceutical industries.

Keywords: *Garcinia kola,* seed oil, nutraceutical, antioxidant, antimicrobial, minerals

1. Introduction
Garcina kola is a species of flowering plant belonging to the *Clusiaceae* or *Guttiferae* family. It is often called bitter kola (English), Orogbo (Yoruba), Aka ilu (Igbo) and Namijin goro (Hausa). It is an indigenous medicinal plant found in rain forest of central and western Africa, especially Benin, Cameroon, Democratic Republic of Congo, Cote d'Ivoire, Gabon, Ghana, Liberia, Nigeria, Senegal and Sierra Leone. It is a medium sized evergreen tree, with height of about 15-17m and a fairly narrow crown. The leaves are simple, 6-14 cm long and 2-6 cm across, shiny on both surfaces and spotted with resin glands. The small flowers are covered with short, red hairs [1]. *Garcina kola* fruit is a drupe of 5-10 cm in diameter and weight between 30 to 50 g. The fruit changes colour during maturation from green to orange, and each fruit contains 1-4 smooth elliptically shaped seeds [2].
G. kola is an important component of traditional herbal medicine and has been referred to as "wonder plant" because every part of the plant from the root to its seeds has great medicinal importance [3]. When eaten, the seed has a bitter astringent taste. The use of *G. kola* seed in folk medicine and several herbal formulations have been reported together with its potential therapeutic benefits due mainly to the presence of flavonoids and other bioactive compounds [4, 5, 6, 7]. *G. kola* is used in folklore remedies for medicinal treatment as purgative, antiparasitic, antimicrobial, anti-inflammatory, gastroenteritis, rheumatism, asthma, menstrual cramps, bronchitis, throat infections, headache, coughs and liver disorders [8, 9, 10]. Also the plant has been used as antidiabetic, antioxidant and for the chemoprevention of aflatoxin B1 and antihepatotoxic activities [11, 12].
In the coastal rainforests of south-western and south-eastern parts of Nigeria, the nut is chewed and readily served to visitors as a sign of goodwill. Among the Igbo tribe of Nigeria, it is presented to visitors as a sign of peace and welcome. It is also used to entertain guests during ceremonies and festivities. It is reported that in Western Africa, the root of the plant is used as a bitter chewing stick while many people in southern Nigeria also use the stem serves as a chewing stick [13, 14, 15]. Traditionally, its seeds have been used as sialegogue to stimulate the flow of saliva [16]. In traditional medicine, the dried seeds are ground and mixed with honey to make a traditional cough mixture. The ground seeds may also be mixed with water and given to new born babies to relieve stomach cramps. The seeds have been reported as having pharmacological uses in treating coughs, throat infections, bronchitis, hepatitis and liver

Disorders [12]. Oleic, linoleic and palmitic acids have been reported as the most dominant fatty acids in the seed oil [17].
Although reports exist on various nutritional and pharmacological activities of *G. kola* seed, literature reveals scanty information on the edible oil profile of its seeds. This study therefore aimed to extract oil from *G. kola* seed and analyze its mineral and phytochemical compositions as well as examine its antimicrobial and antioxidant potentials.

2. Materials and Method

2.1 Sample Collection and Oil Extraction

Fresh *Garcina kola* seeds were purchased from Ilishan market in Ogun state, Nigeria. The seeds were chopped into smaller sizes with the aid of a stainless steel knife and oven dried at 50 ^{o}C for 72 hours. It was thereafter pulverized with a laboratory blender (LEXUS MG-2053 OPTIMA).
Solvent extraction was carried out on 50 g of pulverized sample with Soxhlet apparatus for the duration of 8 hours with n-hexane as the extraction solvent. The solvent was removed *in vacuo* using rotary evaporator (Eyela N-1001) at 40 ^{0}C to recover the seed oil. The oil was placed on a water bath at 50 ^{0}C to ensure complete removal of residual solvent. The seed oil was then stored in a glass vial and analyzed using standard methods.

2.2 Antioxidant Activities

2.2.1 Flavonoid Content

Analysis of total flavonoid content of the oil was done with the modified method of [18] which is based on formation of a flavonoid-aluminum complex. The oil sample (10 mg/mL) in methanol was used for the analysis. To 0.2 mL of the sample was added 5 % Sodium nitrite (0.4 mL) solution and allowed to react for 5 mins. Thereafter, 10 % Aluminum trichloride in methanol (0.4 mL) and 1 M methanolic Sodium hydroxide solution (2 mL) were added and then allowed to stand at room temperature for 20 min. The absorbance of the resulting mixture was read at 510 nm against reagent blank on a UV-Visible spectrophotometer (JENWAY 6305, Staffordshire, UK). Reagent blank, containing 0.2 mL methanol in place of the oil sample was concomitantly prepared and treated in the same manner as the sample. The same procedure was replicated for the standard solutions of quercetin to obtain a calibration curve. The concentration of flavonoid was determined from quercetin calibration curve and results expressed as mg of quercetin equivalent per gram of sample (mg QE g-1). Results are means of three replicates.

2.2.2 Phenolic Content

The spectrophotometric method described by [19] was used to determine the phenolic content of the oil. The oil sample (10 mg/mL) in methanol was used for the analysis. The reaction mixture was made by mixing methanolic solution of the oil (0.5 mL), 10 % aqueous Folin-Ciocalteu's reagent (2.5 mL) and 7.5 % aqueous Sodium hydrogen carbonate solution (2.5 mL). Blank was concomitantly prepared with methanol (0.5 mL), 10 % aqueous Folin-Ciocalteu's reagent (2.5 mL) and 7.5 % aqueous Sodium hydrogen carbonate solution (2.5 mL). The sample was thereafter incubated in a thermostat at 45 ^{0}C for 45 mins. The absorbance was determined using a UV-Visible spectrophotometer (JENWAY 6305, Staffordshire, UK) at a wavelength of 765 nm. The same procedure was repeated for the standard solutions of gallic acid to obtain a calibration curve. Based on the measured absorbance of the oil sample, its phenolic content was estimated from the calibration curve and expressed in terms of gallic acid equivalent (mg of GA/g of extract). Results are means of three replicates.

2.2.3 DPPH Free Radical Scavenging Activity

The ability of *Garcina kola* oil to scavenge free radicals was assayed according to the 2, 2-diphenyl-2-picrylhydrazyl (DPPH) radical spectrophotometric method described by [20]. 0.3 mM methanolic DPPH solution (1 mL) was added to methanolic solution of the oil sample (2.5 mL) at various concentrations (3, 6, 9, 12 and 15 mg/mL) and allowed to stand at room temperature for 30 mins. Different concentrations of gallic standard solutions (2, 4, 6, 8 and 10 µg/mL) were prepared and treated in the same manner as the sample. The absorbance of the resulting mixture was read at 518 nm on a UV- Visible spectrophotometer (JENWAY 6305, Staffordshire, UK) and converted to percentage antioxidant activity (AA %), using the formula:

$$AA\ \% = \left[\frac{(Abs_{control} - Abs_{sample})}{Abs_{control}} \times 100\right]$$

Methanol (1.0 mL) plus oil solution (2.5 mL) was used as blank while a mixture of 0.3 mM DPPH solution (1 mL) and methanol (2.5 mL) was used as control. Standard solutions of gallic acid served as positive controls. This assay was carried out in triplicates for each sample and concentration. The IC_{50} value represented the concentration of the sample which scavenged 50 % of the DPPH free radical and this was extrapolated from the standard calibration curve.

2.3 Antimicrobial Activity

The test organisms used (*Enterobacter cloacae*, *Escherichia coli*, *Salmonella typhi*, *Staphlylococcus aureus* and *Candida albicans)* were clinical isolates from stock cultures that were obtained from the Department of Microbiology, Babcock University, Ilishan-Remo, Ogun State, Nigeria. Sterilization of work bench and consumables was carried out in line with standard procedures.

2.3.1 Antimicrobial Assay

The antimicrobial sensitivity was done using agar diffusion technique. Five concentrations of *Garcina kola* oil: 20 mg/mL, 40 mg/mL, 60 mg/mL, 80 mg/mL and 100 mg/mL were dissolved in dimethylsulfoxide (DMSO) as the antimicrobial. The clinical isolates, *Enterobacter cloacae, Staphylococcus aureus, Salmonella typhi, Escherichia coli* and *Candida albicans* were introduced into the sterile medium using streaking method. Holes were made using 6mm core borer where the various concentrations of *Garcina kola* oil were introduced using 100 µL Pasteur pipette. This was done in duplicates and incubated at 37 ^{o}C for 24 hours. The zones of inhibition were measured using calibrated meter rule.

2.4 Elemental Composition

The mineral content of the oil sample was analyzed by modified AOAC method [21]. One gram of the sample was weighed and transferred into a 100 mL micro digestion tube. Fifty mL of 10 % Nitric acid solution was added and the tube was heated in a digester block at 250 °C for 30 min when appearance of clear solution indicated complete digestion. The tube was taken out and allowed to cool. The resulting digest was filtered and the volume was made up to 20 mL with 10 % Nitric acid solution. Reagent blank was prepared by using 50 mL of 10 % Nitric acid solution.
Twelve mineral elements (Ca, Mg, K, Na, Mn, Fe, Co, Zn,

Hg, Cd, Pb and Ni) were determined in the digest solution and blank by using Atomic Absorption Spectrophotometer (Buck Scientific Model 2010 VGP) after calibration of the equipment with 100 mg/L of the standard solution of each element determined while P was determined with the use a UV- visible spectrophotometer (LabMed SPECTRO SC Spectrophotometer).

2.5 Phytochemical Analysis

2.5.1 Methylation of Oil Sample

As sample pre-treatment prior to GC-MS analysis, methylation of oil was carried out thus; 0.2 g of oil sample was weighed into a 250 mL quick fit conical flask. Six mL of methanolic Sodium hydroxide was added and refluxed for 10 mins. 10 mL of methanolic Hydrochloric acid was further added and refluxed for another 10 mins. Thereafter, 10 mL of n-hexane was added to the resulting mixture and refluxed for 2 mins. The mixture was allowed to cool and 10 mL of distilled water was added and the phase separation was done in a separating funnel. The methylated oil was then subjected to GCMS analysis.

2.5.2 GC-MS Analysis

The identification of chemical compounds present in the oil was done by using SHIMADZU QP- 2010 Plus GC-MS equipment. The GC-MS was equipped with a split injector and an ion-trap mass spectrometer detector with a fused-silica capillary column having a thickness of 1.00 µm, dimensions of 30m x 0.25mm (Agilent DB-5MS) and temperature ranges of 60 ºC and 325 ºC. The column temperature was programmed between 60 ºC and 250 ºC at a flow rate of 3.0 mL/min. The temperature of the injector and detector were at 250 ºC and 200 ºC respectively. Helium gas was used as a carrier gas at a flow rate of 46.3 cm/ sec. Components were identified by computer-aided matching of their spectra with spectra of known compounds from the Library of spectra from the National Institute of Standards and Technology [22]. The fragmentation patterns of the identified compounds were then examined for consistency with known data from literature [23]. In addition, the hit quality which indicated how closely matched the compound is with the library data was used to further verify the identity of the compound in the samples.

3. Results and Discussion

3.1 Antimicrobial activity

The ability of a plant extract to inhibit microorganisms especially those of serious health importance depends largely on the presence of important phytochemical compounds with significant antimicrobial potency. The results of the inhibition of the test organisms by *Garcinia kola* seed oil are presented in Table 1. The results showed that the inhibition of *Salmonella typhi*, *Enterobacter cloacae* and *Staphylococcus aureus* which showed susceptibility to the seed oil was concentration dependent. *Salmonella typhi* was most susceptible to the oil with diameter zone of inhibition of 27 mm while *Escherichia coli* was the least susceptible with diameter zone of inhibition of 12 mm at the same concentration of 100 mg/mL. *Escherichia coli* and *Candida albicans* showed resistance to *G. kola* seed oil at 20 - 80 mg/mL concentrations and were slight susceptibility at 100 mg/mL. Of the few studies available, the antimicrobial activity of *G. kola* seed oil against *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Klebsiella pneumonia*, *Candida albicans, Aspergillus niger, Rhizopus stolonifer* and *Penicillum notatum* at concentrations ranging from 3.125 to 100 % V/V has been reported [24]. He found that all the test organisms except *Salmonella typhi* were susceptible to the oil at 12.5, 25, 50 and 100 % concentrations. The antimicrobial quality shown by *G. kola* seed oil in this study implies that the oil has potential to be used in cosmetic industry either in the manufacture of antiseptic creams or soaps.

Table 1: Diameter of Zones of Inhibition (mm) of Bacterial and fungal isolates by *G. kola* seed oil

Oil concentration (mg/ml)	Salmonella typhi	Enterobacter cloacae	Escherichia coli	Staphylococcus aureus	Candida albicans
20	12±0.02	11±0.01	R	R	R
40	15±0.04	13±0.01	R	R	R
60	25±0.11	14±0.03	R	11±0.01	R
80	25±0.13	15±0.02	R	14±0.21	R
100	27±0.14	19±0.05	12±0.02	16±0.02	13±0.10

Data are expressed as mean ± standard error of three replicates. R= resistant

Table 2: Flavonoid and phenolic contents of *G. kola* seed oil

Samples	Flavonoid content (mg/g)	Phenolic content (mg/g)
Garcina kola	59.42 ± 0.11	41.27 ± 0.20

Data are expressed as mean ± standard error of three replicates.

3.2 Antioxidant activity

Table 2 shows the flavonoid and phenolic contents of the edible oil of *G. kola.* This results show that the oil contained significant amount of these two important phytochemicals which are known for their antioxidant and antimicrobial functions. It is important to note that the flavonoid content was higher than the phenolic content. Results of the oil's ability to scavenge DPPH free radical are presented in Table 3. The oil showed significant free radical scavenging strength in a concentration dependent manner. That is, the higher the concentration of the seed oil; the higher its DPPH free radical scavenging capacity. Its radical scavenging strength was also reflected in its IC 50 value of < 1 mg/mL. The seed oil's radical scavenging activity can be attributed to the presence of pharmaceutically important phytochemicals such as flavonoid and phenolic compounds in it. Several studies have reported the pharmaceutical importance such as antioxidant, anti-inflammatory, antimicrobial, anticancer and anti-atherosclerotic activities of flavonoid and phenolic compounds found in natural products [25, 26, 27, 28, 29]. This suggests that *G. kola* seed oil could be a potential natural antioxidant and antimicrobial source and could therefore find relevance in the pharmaceutical industry.

Table 3: Antioxidant activity of *G. kola* seed oil

Concentration (mg/mL)	% DPPH scavenging activity	IC 50 (mg/mL)
3	79.40±0.22	<1
6	87.07±0.31	
9	87.92±0.01	
12	89.56±0.04	
15	91.05±0.12	

Data are expressed as mean ± standard error of three replicates.

Table 4: Elemental composition of *G. kola* seed oil

S/N	Mineral	Amount (mg/100g)	DV
1	Magnesium	117.88±0.22	310-420 mg[30]
2	Calcium	210.90±0.11	1000-1200 mg[30]
3	Potassium	15.75±0.12	4.7 g[31]
4	Phosphorus	55.83±0.10	700 mg[30]
5	Sodium	20.05±0.04	1.3-1.5 g[31]
6	Iron	1.65±0.02	8-18 mg[32]
7	Zinc	14.76±0.13	8-11 mg[32]
8	Manganese	0.63±0.01	1.8-2.3 mg[32]
9	Lead	ND	-
10	Mercury	ND	-
11	Cadmium	ND	-
12	Cobalt	ND	-
13	Nickel	ND	-

ND: Not detected DV= Daily value or requirement 30 = Institute of Medicine, 1997, 31 = Institute of Medicine, 2004 32 = Institute of Medicine, 2001,

3.3 Mineral composition

Table 4 represents the results of the mineral composition of *G. kola* seed oil. Eight essential minerals (Mg, Ca, K, P, Na Fe, Zn and Mn) were present at various concentrations while five toxic ones (Pb, Hg, Cd, Co and Ni) were not detected. Of all the essential minerals, Calcium had the highest concentration (210.90 mg/100 g) followed by Magnesium (117.88 mg/100 g) while Manganese had the lowest concentration (0.63 mg/100 g). Others were; Potassium (15.75 mg/100 g), Phosphorus (55.83 mg/100 g), Sodium (20.05 mg/100 g), Iron (1.65 mg/100 g) and Zinc (14.76 mg/100 g). The results of its mineral analysis showed that *G. kola* seed oil would be a very good source of essential minerals. Also, the absence of toxic minerals in the oil showed that the oil would be safe for consumption.

Meanwhile, the importance of each of the essential minerals present in *G. kola* seed oil has been presented in literature. Adequate amount of calcium in the body supports growth as well as the maintenance of strong bone and teeth. Calcium ion has been linked to proper and good functioning of the muscles and nerve. It also helps in regulating the passage of nutrients through the cell walls [33]. Potassium is important for maintaining cellular water balance, pH regulation in the body, and also associated with protein and carbohydrate metabolism [34]. Together with sodium, potassium aids the regulation of water balance and acid-base balance in the blood and tissues [35]. Magnesium is necessary in the plasma and extracellular fluid production which is necessary in maintaining the osmotic equilibrium of our system. The lack of magnesium is associated with abnormal irritability of muscle and convulsions while excess magnesium causes depression of the central nervous system which can both result in death [36]. Adequate amount of phosphorus in the body has been linked to proper functioning of the kidney and growth of the cell [37]. Phosphorus is essential in maintaining the pH of the body. It acts as buffer to maintain the acid-base balance of cellular fluid because of their ability to combine with hydrogen ion [38]. Sodium helps in the regulation of blood pressure and blood volume in the body. It also aids the body in regulating the balancing of fluid and also helps in the proper functioning of the nerves and muscles [39]. Iron is vital in the formation of Hemoglobin and myoglobin, which function in oxygen-transport. Iron is necessary for proper spinal cord myelination and the cerebellar folds white matter in brain, and also a cofactor for most of the enzymes that are involved in synthesis and packaging of neurotransmitter [40]. Zinc has been linked to improving the health of human hair and its presence in adequate amount in the body actively contribute to the normal functioning of few sense organs i.e. it helps in smelling, tasting and sensing [39]. It helps to bring about the production of deoxyribonucleic acid and ribonucleic acid which is essential for production of cell and also assist in coordinating vitamin A from its production site to the liver. It is important in the metabolism of carbohydrate and protein. Deficiency of manganese has been linked to retardation of growth, reproduction and skeletal anomalies. However, excess of it poisons the central nervous system and weakens the body [38].

Table 5: Chemical composition of *G. kola* seed oil

Peak No	Compound	RT	MF	MM	% Peak area
1.	1,4-dimethylbenzene	3.038	C_8H_{10}	106	8.97
2.	Isobutylcyclohexane	3.275	$C_{10}H_{20}$	140	5.77
3.	1-ethyl-3-methylbenzene	3.621	C_9H_{12}	120	8.83
4.	Decane	3.832	$C_{10}H_{22}$	142	14.68
5.	1,2,3-trimethylbenzene	3.975	C_9H_{12}	120	12.03
6.	1-ethyl-2-methylbenzene	4.316	C_9H_{12}	120	6.54
7.	Undecane	4.971	$C_{11}H_{24}$	156	9.07
8.	2-ethyl-1,3-dimethylbenzene	5.500	$C_{10}H_{14}$	134	1.26
9.	(1E)-1-butenylbenzene	5.770	$C_{10}H_{12}$	132	0.93
10.	1-methyl-2-propenylbenzene	5.931	$C_{10}H_{12}$	132	1.61
11.	Azulene	6.253	$C_{10}H_8$	128	1.48
12.	1-Undecanol	9.991	$C_{11}H_{24}O$	172	1.63
13.	Tridecanoic acid methyl ester	12.786	$C_{14}H_{28}O_2$	228	0.48
14.	Hexadecanoic acid methyl ester	14.872	$C_{17}H_{34}O_2$	270	4.08
15.	9-Octadecenoic acid methyl ester	16.564	$C_{19}H_{36}O_2$	296	12.42
16.	Stearic acid methyl ester	16.770	$C_{19}H_{38}O_2$	298	2.33
17.	9,12-Octadecadienoic acid (Z,Z)	17.200	$C_{18}H_{32}O_2$	280	5.04
18.	Ricinoleic acid methyl ester	18.376	$C_{19}H_{36}O_3$	312	2.84

RT: Retention time MF: Molecular formula MM: Molecular mass

3.4 Phytochemical composition

Over the years, plant-based therapeutics have been proven to be effective in the treatment and management of diseases and used extensively in ethnomedicinal and even ethnoveterinary practices [41]. The presence of a wide variety of chemical compounds in plants which are used to perform essential biological functions has been the basis for the use of plants for effective treatments of various diseases. The presence of phytochemical compounds in extracts from various plant parts have been reportedly linked to the biological or pharmacological activities of such plants [42, 43]. The GC-MS chromatogram is shown in Fig 1 while the chemical compounds are presented in Table 5. Eighteen compounds were identified in the seed oil. The compounds belong to five classes of compounds; alkanes (29.52 %), sesquiterpenes (1.48 %), aromatics (40.17 %), alcohols (1.63 %) and fatty acids (27.20 %). Three compounds were found to be prominent in the oil sample and these were; Decane (14.68 %), 9-Octadecenoic acid methyl ester (12.42 %), and 1, 2, 3-trimethylbenzene (12.03 %).

Table 6: Biological activities of compounds in *G. kola* seed oil

Peak No	Compound	Class of compound	Biological Activity	References
1.	1,4-dimethylbenzene	Aromatic hydrocarbon	NF	-
2.	Isobutylcyclohexane	Cycloalkane	NF	-
3.	1-ethyl-3-methylbenzene	Aromatic hydrocarbon	NF	-
4.	Decane	Acyclic alkane	NF	-
5.	1,2,3-trimethylbenzene	Aromatic hydrocarbon	NF	-
6.	1-ethyl-2-methylbenzene	Aromatic hydrocarbon	NF	-
7.	Undecane	Acyclic alkane	Mild sex attractant for various types of moths and cockroaches, an alert signal for a variety of ants.	44
8.	2-ethyl-1,3-dimethylbenzene	Aromatic hydrocarbon	NF	-
9.	(1E)-1-butenylbenzene	Aromatic hydrocarbon	NF	-
10.	1-methyl-2-propenylbenzene	Aromatic hydrocarbon	NF	-
11.	Azulene	Polycyclic aromatic	NF	-
12.	1-Undecanol	Fatty alcohol	Flavor and perfumery	45
13.	Tridecanoic acid methyl ester	Fatty acid ester	Antibacterial, antifungal	46
14.	Hexadecanoic acid methyl ester	Fatty acid ester	Anti-oxidant, anti-inflammatory, Antifungal, Hypocholesterolemic Nematicide, Pesticide, Antiandrogenic Flavour, Haemolytic, 5-Alpha Reductase Inhibitor,Potent Antimicrobial Activity	47
15.	9-Octadecenoic acid methyl ester	Fatty acid ester	Antioxidant Activity, Anticarcinogenic, Dermatitigenic, Anti inflammatory,Antiandrogenic, Cancer preventive, Dermatitigenic, Hypocholesterolemic, 5-Alpha reductase inhibitor, Anemiagenic, Insectifuge	48, 49
16.	Stearic acid methyl ester	Fatty acid ester	Antiviral, antibacterial, antioxidant, Anti-diarrheal, and antiproliferative activity	50, 51
17.	9,12-Octadecadienoic acid (Z,Z)	Unsaturated fatty acid	Antiinflammatory, Hypocholesterolemic, Cancer Preventive, Hepatoprotective, Nematicide, Insectifuge, Antihistaminic, Antieczemic, Antiacne, 5-Alpha Reductase Inhibitor, Antiandrogenic, Antiarthritic, Anticoronary, Insectifuge	52, 53
18.	Ricinoleic acid methyl ester	Fatty acid ester	NF	-

NF: Not found

The compound with the highest concentration was Decane (14.68 %) with no reported biological activity while the least occurring compound was Tridecanoic acid methyl ester (0.48 %) with reported antibacterial and antifungal activities (Chandrasekaran *et al*., 2011) [46]. Other compounds with relatively high concentrations were; 1, 4-dimethylbenzene (8.97 %), Isobutylcyclohexane (5.77 %), 1-ethyl-3-methylbenzene (8.83 %), 1-ethyl-2-methylbenzene (6.54 %), Undecane (9.07 %), Hexadecanoic acid methyl ester (4.08 %), and 9, 12-Octadecadienoic acid (Z, Z) (5.04 %). Biological activities which include; antioxidant, antimicrobial, anti-inflammatory, hypocholesterolemic, antiviral, anti-diarrheal, antiproliferative, antiandrogenic and anticoronary activity amongst others have been reported for seven out of the eighteen compounds found in *G. kola* seed oil as shown in Table 5. The antimicrobial effects reported for the seed oil may be because of the presence of fatty acid ester and aliphatic chains which are known to accumulate in the mitochondria and cell membrane (lipid layer), thus disturbing the cell structure integrity and resulting in cell death [54]. Although no reported biological activity was found for its methyl ester, ricinoleic acid has been reported for its antimicrobial and anti-inflammatory activities [55]. Since 1-Undecanol is reportedly used in flavoring and perfumery, it may also find application in aromatherapy. However, more study should be geared towards determining the biological activities of the compounds with no reported activities.

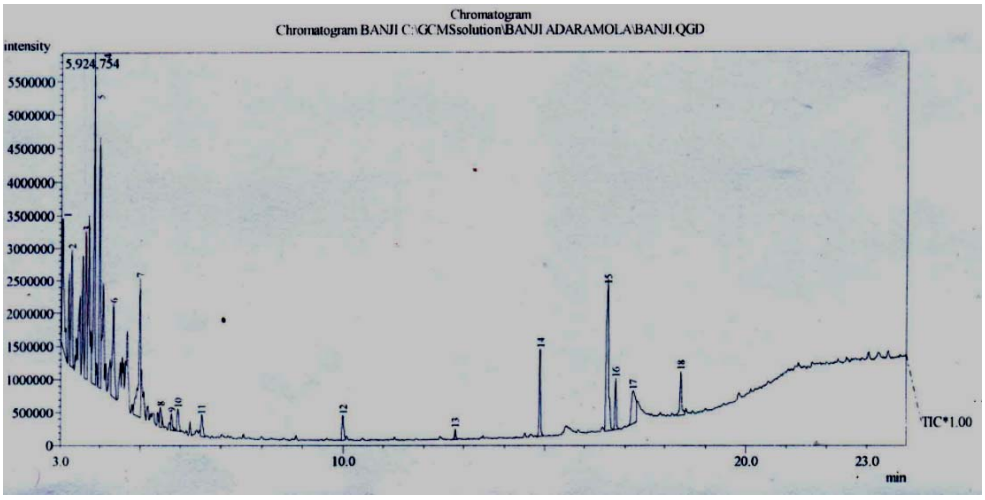

Fig 1: GC-MS Chromatogram of *Garcinia kola* seed oil

4. Conclusion

The presence of nutritionally and pharmacologically important substances in the seed oil of *G. kola* suggests that it would be useful in the food, cosmetics and pharmaceutical industries. However, further elucidation of the mechanisms underlying the bioactivity of the constituting chemical compounds is essential in order to evaluate the potential of the seed oil for future drug development.

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