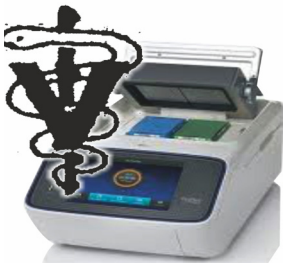
Journal of Veterinary and Biomedical Sciences
Vol. 7(2). PP 409-423, May, 2025
ISSN:2659-0743 **DOI: 10.36108/jvbs/5202.70.0241**



Mineral composition and GC-MS analysis of Fatty acid methyl esters, carotenoids and sterols in stem bark and leaves of *Boswellia dalzielli* Hutch.

Frank C. Okeke[1] Deborah Chidinma Okeke[2] and Victoria Chinweike Abraham[3]

[1]Department of Botany, Faculty of Biological Sciences, University of Abuja, Nigeria.

[2]Department of Public Health, Madonna University, Elele, Rivers State, Nigeria.

[3]Department of Biochemistry and Industrial Chemistry, College of Pure and Applied Sciences, Caleb University, Imota, Lagos.

Corresponding author: frankokeke2015@gmail.com

Abstract

The mineral analysis of *Boswellia dalzielli* stembark was performed following standard procedures. The results of the studies revealed that some macroelements found include calcium (98.64 mg/g extract), sodium (11.71mg/g extract) and Iron (8.46mg/g extract); while the microelements seen include manganese (0.52mg/g extract) and lead (0.32mg/g extract). Other microelements present were copper, chromium, cadmium, zinc, nickel and cobalt. Mineral analysis of *Boswellia dalzielli* leaf detected potassium (4521.8 ppm), magnesium (3315.9ppm) and calcium (1825.4ppm). Gas chromatography-mass spectrometry (GC-MS) analysis of *Boswellia dalzielli* leaves for fatty acid methyl esters (FAME) unveiled the presence of significant amounts of omega-3 and omega-6 fatty acids among others, appreciable amounts of sitosterol (4.95 mg/100g) and beta-carotene (12.78µg/100g).

1.0 INTRODUCTION

The challenges of human and animal health have been met mostly with herbal resources used in the management of different diseases and health conditions [1][2]. Among medicinal plants, *Boswellia species* are considered to be quite outstanding. They are indigenous to Africa, found growing extremely slowly in the rocky, arid regions of East, West, Central and North East Africa but are also found in the Arabian Penninsula, India, China and tropical regions of the Americas[3]. Disparities in growth environments viz soil and climate and even in harvest techniques give rise to differences in their content quality even within the same species [4]. Every part of the Boswellia shrub or tree- root, bark, bud, flower, fruit and resin is medicinally useful [5]. A number of the species have been listed among the endangered to critically endangered plants due to overharvesting [6]. In West Africa, the predominant species is *Boswellia dalzielli* Hutch. (West African frankincense tree). Local names in Nigeria include *Hanu* or *ararabi*. In Nigeria the local demand far outstrips its supply due to over exploitation. The plant and its products provide a multi-dimensional, multi-utility alternative medical health package employed for diverse health challenges ranging from mental, cardiovascular, respiratory, skeletal, blood, dental, deep systemic diseases-cancer, leprosy, inflammatory diseases, immune boosting, etc. [5,7]. The traditional applications of Boswellia are numerous. The stembark [5,6,8] is employed for: (1). In bone setting: the region of the skin is aseptically cleansed with decoction of the fresh bark or the powdered bark mixed with water. The splints made from Boswellia wood are placed over the region. Strips of stembark on top the splints and around the region. This setup is held in place by wrapping with a bandage soaked in softened frankincense resin. Upon drying, the resin provides a firm support like a plaster for the ossification of the broken ends. (2). As a calming ointment for swellings (edema) when powdered and converted in to a caustic paste. (3). Boiled and consumed as a blood cleanser and nerve tonic (4). As a first aid for wounds, burns and an antiseptic to cleanse and dress dirty and infected sores when powdered and sometimes singed and prepared into a paste with water. The fresh bark may also be employed for this purpose; (5). Powdered bark is incorporated in lotions and ointments for treatment of skin sores, wounds, chapped skin, etc. (6). Twigs of young plants are chewed for gastrointestinal disorders.

Pharmacologically, Boswellia leaves contain bioactive constituents which exhibit anti-carcinogenic, antimicrobial, antifungal, antineoplastic, anti-inflammatory, anti-mutagenic, and anti-allergic properties [3,5,8].

This study was designed to determine the mineral constituents and carry out Gas chromatography-mass spectrometry (GC-MS) characterization of the fatty acid methyl esters, sterols and carotenoids of *Boswellia dalzielli* stem bark and leaf extracts.

2.0 MATERIALS AND METHOD

2.1 Collection and identification of plant

Fresh stem and leaves of the plant samples were obtained from the rocky and arid forest of Makaya in Kibiya Local Government Area, Kano state, Nigeria. The plant was identified and authenticated at the Faculty of Science, University of Abuja, Abuja, Nigeria.

2.2. Preparation of stem bark extracts

The stem bark was cut into smaller sizes and air-dried under shade for 20 days. Thereafter, the dried samples were pounded to powder using wooden mortar and pestle. About 250 gram of the stembark were placed in five different containers each containing 1.5 L of the solvents. These were left soaked for 24 hours (maceration). Thereafter the contents were separately filtered using muslin cloth. The filtrate was evaporated to dryness using a rotatory evaporator (RE 300, Bibby Scientific, UK) set at 40 ^{0}C and low pressure. The crude extracts obtained were stored in a sterile airtight container and kept in a refrigerator at low temperature [9].

Preparation of leaf extracts

Fresh leaves of *B. dalzielli* were washed and air-dried under shade for 20 days. Thereafter, the dried samples were pulverized to powder using wooden mortar and pestle. The powdered leaves were taken, poured and pressed into a soxhlet extractor and extracted exhaustively for 72 hours using methanol. The extract collected was filtered using a Whatmann filter paper No. 42. The filtrate was concentrated using rotary evaporator and thereafter transferred to a water bath set at 40^{o}C to evaporate the solvent. The concentrated extract of the leaves was put in airtight containers and stored at low temperature (4 ^{0}C) for further studies [10].

2.3 **Mineral Analyses**

A given quantity (0.5g) of the pulverized sample was weighed into a pre-cleaned borosilicate 250 ml capacity beaker for digestion. A volume (20 ml) of nitric acid was added in to the weighed sample in the beaker. The sample with the digesting solvent was placed on the hot plate for digestion in the fume cupboard. The beaker and its content were allowed to cool to room temperature after the digestion. The mixture was filtered in to a-250 ml volumetric capacity borosilicate container. The filtrate was made up to the mark with de-ionised water. All the digested samples were sub-sampled in to pre-cleaned borosilicate glass containers for Atomic Absorption spectrophotometric analysis. Standards of Copper, Iron, Zinc, Chromium, Manganese, Selenium, Sodium, Potassium and Calcium solutions of 0.2, 0.4, 0.6. 0.8 and 1.0 mg/l were made from each of the heavy metals solutions as 1000 mg/L stock solutions of the analytes. The set of standard solutions and the filtrate of the digested samples were analyzed by Atomic Absorption spectrophotometry (AAS). The detection limit of the metals in the samples was 0.0001mg/L by means of UNICAM 929 London, Atomic Absorption Spectrophotometer powered by the SOI AAR software. Copper, Iron, Zinc, Chromium, Manganese, Selenium. Sodium, Potassium and Calcium cathode lamps were used for the analysis of the respective ions in the standards and the filtrate of the samples. Gas mixtures of compressed air and acetylene were used in the generation of the flame with the exception of Selenium in which Nitrous oxide was applied [11]

2.4 **Crude Fat** (AOAC Official Method 920.39 (A), 2006)

A fixed volume (250 ml) capacity extracting flask was dried in an oven at the temperature of 105^{o}C, transferred to the desiccator to cool at laboratory temperature and the weight of the flask was measured. A quantity (2.5 g) of the sample was weighed into the labeled porous thimble. Two hundred milliliter (200 ml) of petroleum ether was measured and added to the 250 ml capacity flask. The covered porous thimble with the sample were placed in the condenser of the soxhlet extractor arrangement that had been assembled. The sample was extracted for 5 hours. The porous thimble was removed with care and the petroleum ether in the top container (tube) was collected for recycling and reuse. The extraction flask was removed from the heating mantle arrangement when it was almost free of petroleum ether. The extraction flask with the oil was oven-dried at 105^{o}C until it was almost free of petroleum ether for the period of one hour. The flask containing the dried oil was cooled in a desiccator and the weight of the cooled flask with the dried oil were measured [12].

2.5 **Fatty Acid Methyl Ester (FAME) Analysis**

Gas Chromatography Mass Spectrometry (GC-MS) analysis method [13]: C:\HPCHEM\1\ METHODS\FAME-AS.M

A quantity (50 mg) of the extracted fat content was saponified (esterified) for 5 minutes at 95^{o}C with 3.4 ml of 0.5M KOH in dry methanol. The mixture was neutralized by using 0.7M HCl. 3 ml of 14% boron triflouride in methanol which was added. The mixture was heated for 5 minutes at 90^{o}C to achieve complete methylation process. The Fatty Acid Methyl Esters were thrice extracted from the mixture with redistilled

n-hexane. The content was concentrated to 1 ml for gas chromatography (GC) analysis and 1 µl was injected in to the injection port of the GC.

2.6 **Phytosterols Extraction and Analysis** The phytosterol extraction and analysis were carried by the following modified method AOAC 994.10 and AOAC 970.51 Official methods[14]. The hexane was concentrated to 2 ml in Agilent vial for gas chromatography analysis.

2.7 **Carotenoids Extraction and Analysis** The carotenoid extraction was carried out by following the method of Shigeaki Takagi as described in: Determination of Green Leaf carotenoids (Agric. Biol. Chem. 1984. 49(4): pp. 1211-1213)[15].

2.8 Data analysis

The experiments were carried out in triplicates and the results expressed as mean ± standard error of the mean. The obtained results were subjected to statistical analysis using the statistical program SPSS/PC+, version 17 (SPAA Inc., Chicago, IL, USA). Descriptive statistics was employed in the data analyses.

3.0 RESULTS

3.1 Mineral analyses of Boswellia dalzielli stem bark and leaf

Mineral analysis of *Boswellia dalzielli* stembark revealed the presence of some macroelements: calcium (Ca) had the highest concentration of 98.64 mg/g extract followed by sodium (Na) 11.71 mg/g extract, iron (Fe) 8.46 mg/g extract, potassium 6.26 mg/g, magnesium (Mg) 5.29 mg/g. Microelements detected in trace amounts include manganese (Mn) (0.52 mg/g extract), lead (Pb) (0.32 mg/g extract). Other microelements include cobalt (Co) 0.01, cadmium (Cd) 0.11, nickel (Ni) 0.013, chromium (Cr) 0.012, zinc (Zn) 0.08, and copper (Cu) 0.15 mg/g in the extract (Figure 1).

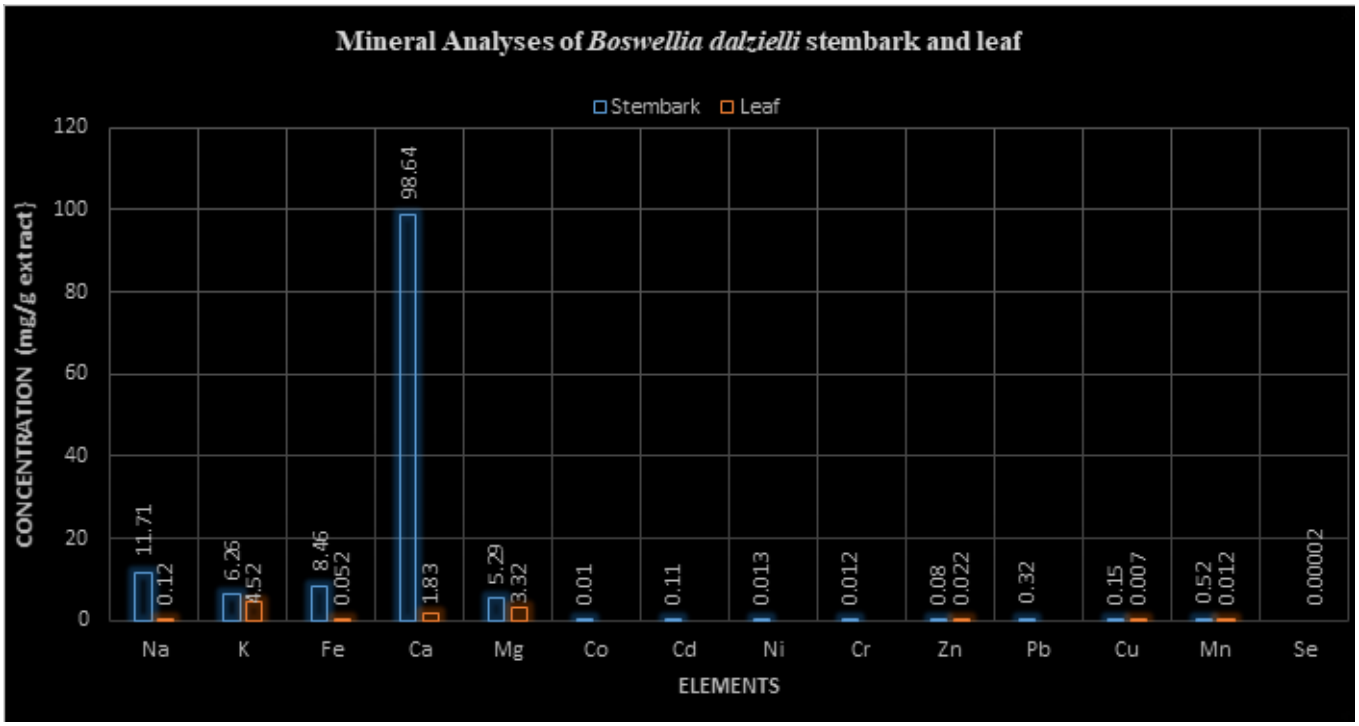
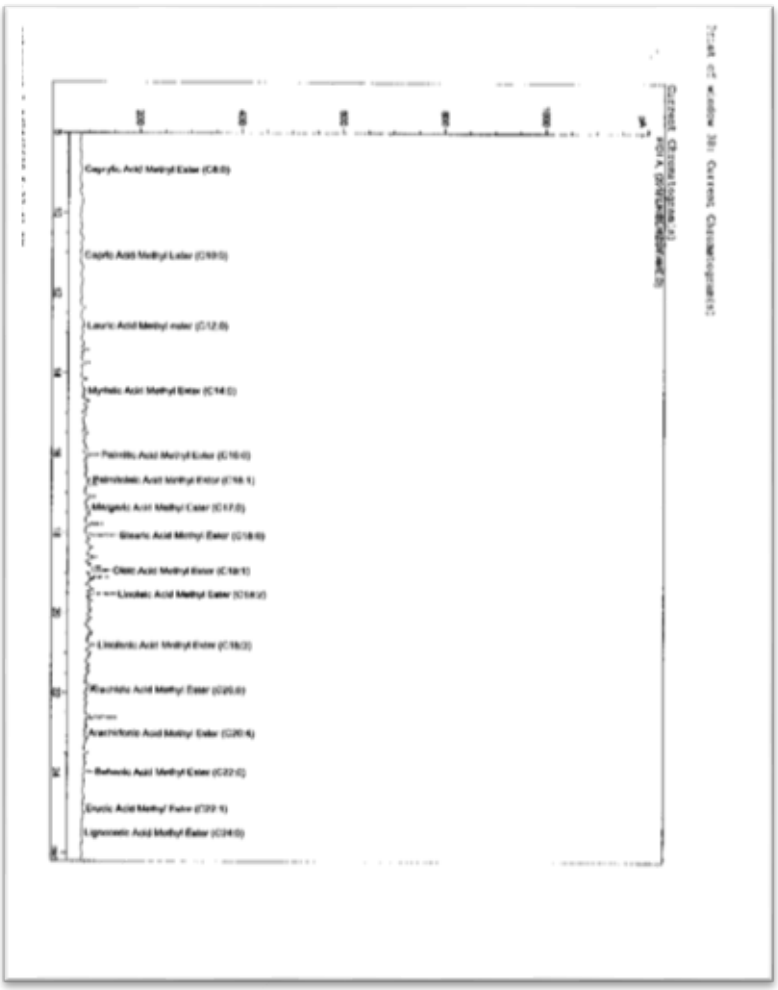


Figure 1. Mineral Analyses of *B. dalzielli* stembark and leaf

3.2 **GC-MS analysis of *Boswellia dalzielli* leaf for Fatty acids methyl esters (FAME)**

GC-MS) analysis of *Boswellia dalzielli* leaf for fatty acid methyl esters (FAME) revealed the presence of significant amounts of Linolenic C18:3 (29.09%), Palmitic acid C16:0 (28.58%), Lineoleic acid C18:2 (23.09%), Oleic acid C18:1 (11.44%) (Figures 3, 4). Other fatty acids seen include: Stearic acid C18:0 (4.48%), Palmitoleic acid C16:1 (1.29%), Lignoceric acid C24:0 (0.79%), Arachidic acid

C20:0 (0.41%), Behenic acid C22:0 (0.29%), Myristic acid C14:0 (0.22%), Erucic acid C22:1 (0.21%) (Figures 2, 3).



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FATTY ACID METHYL ESTER ANALYSIS

Normalized Percent Report

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11.064	1	VV	36.70364	0.00000	0.000000		Capric Acid Methyl Ester (C10:0)
12.830	1	VV	48.21856	0.00000	0.000000		Lauric Acid Methyl ester (C12:0)
14.440	1	VV	164.76036	2.17149e-7	0.226837		Myristic Acid Methyl Ester (C14:0)
16.044	1	VV	228.15479	1.99348e-5	20.582341		Palmitic Acid Methyl Ester (C16:0)
16.677	1	VV	164.86308	1.24787e-6	1.292857		Palmitoleic Acid Methyl Ester (C16:1)
17.367	1	VV	137.89392	3.82330e-8	0.033131		Margaric Acid Methyl Ester (C17:0)
18.059	1	VV	279.69427	2.55130e-6	4.484374		Stearic Acid Methyl Ester (C18:0)
18.939	1	VV	242.95360	7.49454e-6	11.442610		Oleic Acid Methyl Ester (C18:1)
19.526	1	VV	261.26129	1.40661e-5	23.094295		Linoleic Acid Methyl Ester (C18:2)
20.795	1	VV	288.07730	1.60684e-5	29.089587		Linolenic Acid Methyl Ester (C18:3)
21.913	1	VV	106.28904	6.18259e-7	0.412963		Arachidic Acid Methyl Ester (C20:0)
23.000	1	VV	86.39158	9.36377e-8	0.050837		Arachidonic Acid Methyl Ester (C20:4)
23.972	1	VV	126.60468	3.90725e-7	0.292500		Behenic Acid Methyl Ester (C22:0)
24.893	1	VV	57.57678	5.85874e-7	0.211987		Erucic Acid Methyl Ester (C22:1)
25.487	1	VV	49.79545	2.52117e-6	0.787482		Lignoceric Acid Methyl Ester (C24:0)

Totals : 100.000000

Results obtained with enhanced integrator!

Figure 2**:** GC-MS analysis of Fatty Acid Methyl Esters (FAME) in *B. dalzielli* leaf

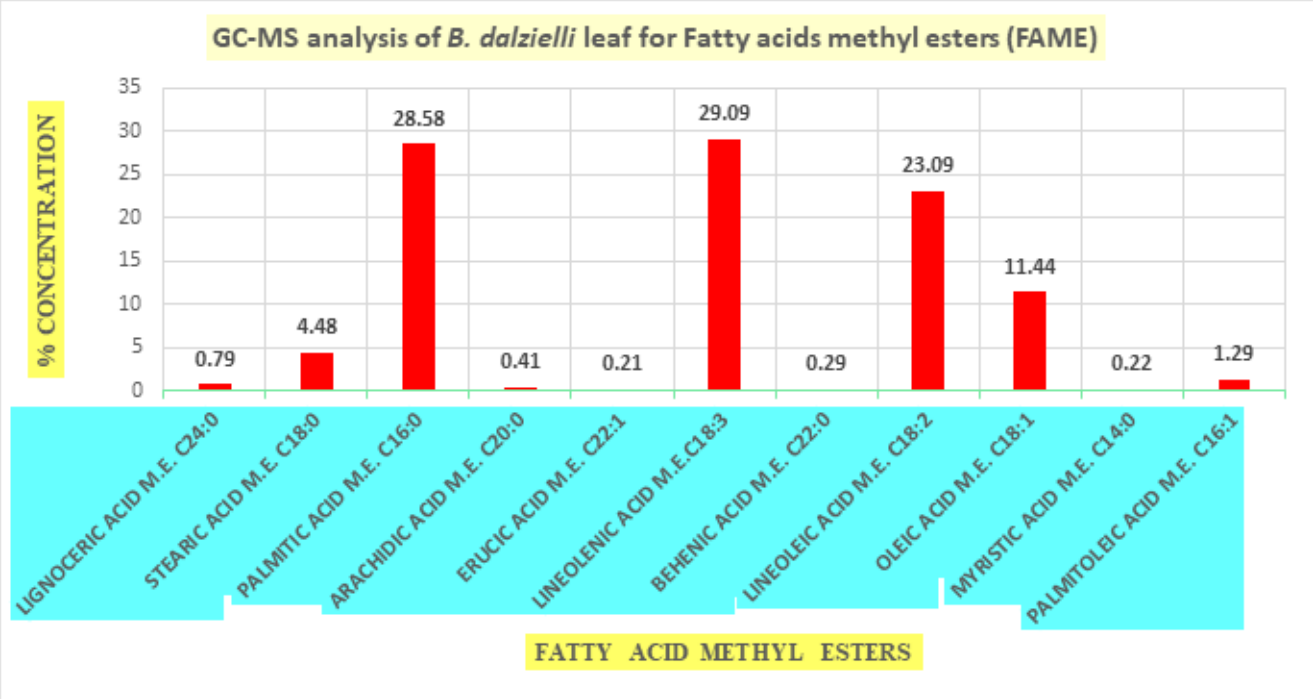
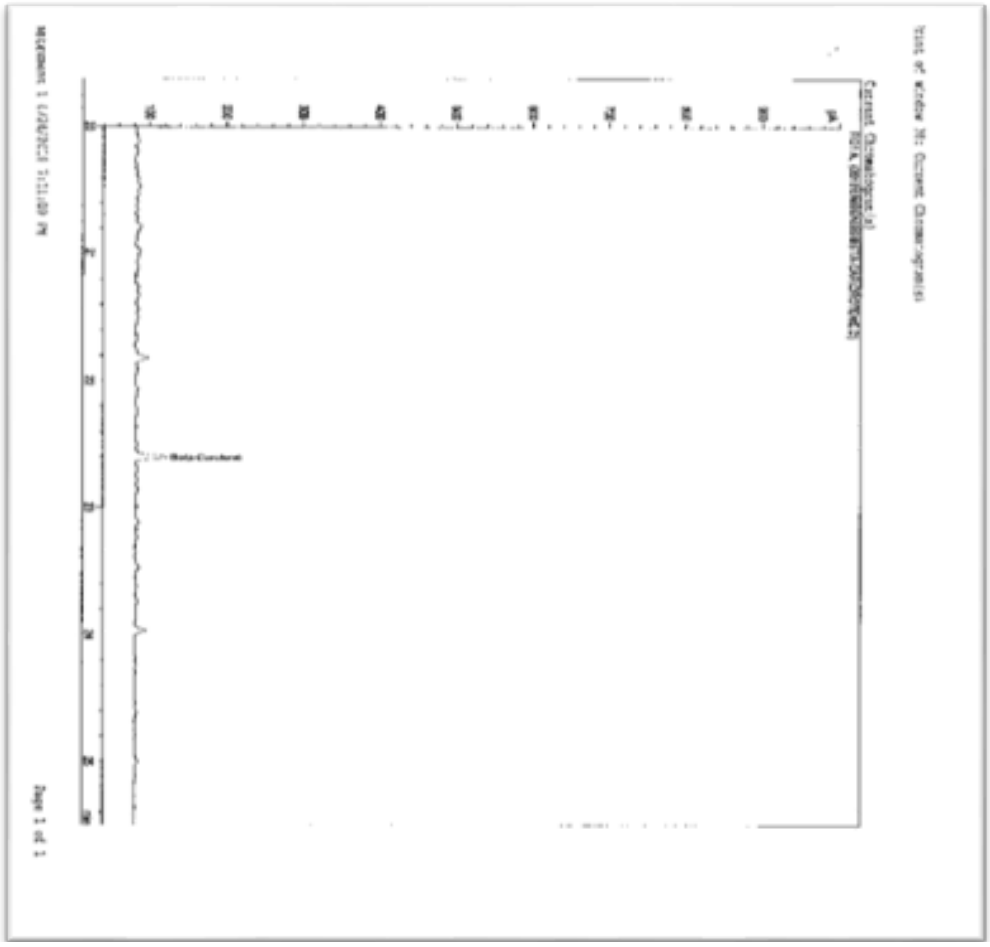
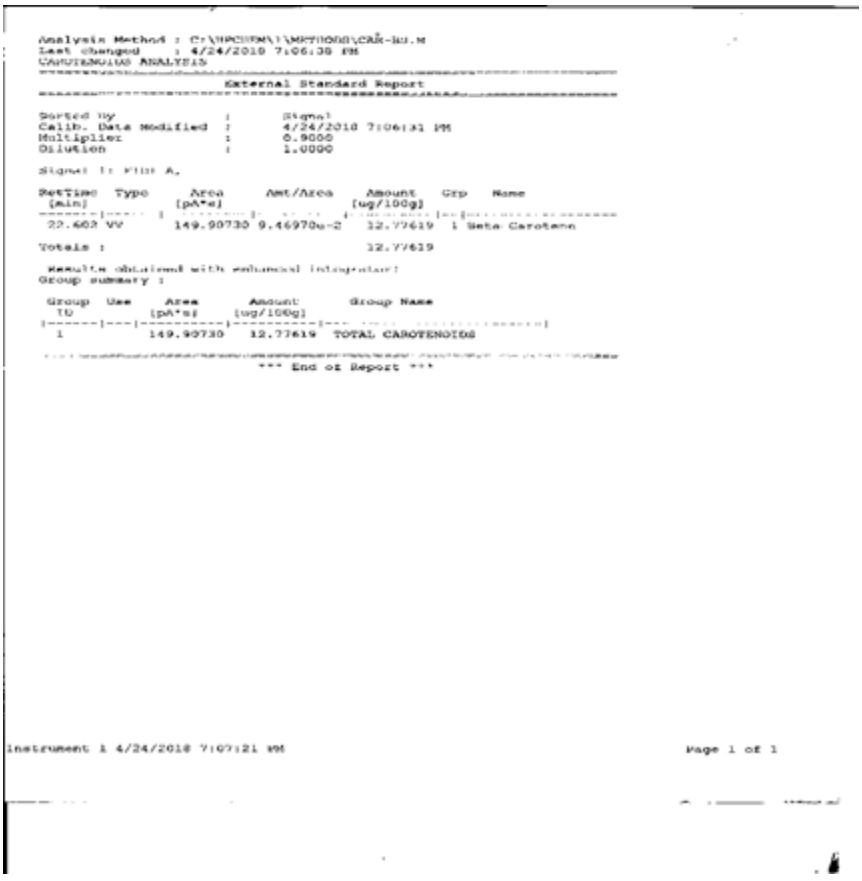


Figure 3: Chart analysis of Fatty Acid Methyl Esters (FAME) in *B. dalzielli* leaf

3.3 **Reversed-Phase High Performance Liquid Chromatography (RP-HPLC) Analysis of carotenoids in *Boswellia dalzielli* leaf**

Analysis of the carotenoids in *Boswellia dalzielli* leaf revealed the presence of only Beta-carotene at 12.776 µg/100 g (Figures 4,5).





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CAROTENOIDS ANALYSIS

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22.602	VV	149.90730	9.46970e-2	12.77619	1	Beta Carotene

Totals : 12.77619

Results obtained with enhanced integrator!
Group summary :

Group ID	Use	Area [pA*s]	Amount [ug/100g]	Group Name
1		149.90730	12.77619	TOTAL CAROTENOIDS

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Instrument 1 4/24/2018 7:07:21 PM Page 1 of 1

Figure 4: RP-HPLC analysis of carotenoids in *B. dalzielli* leaf

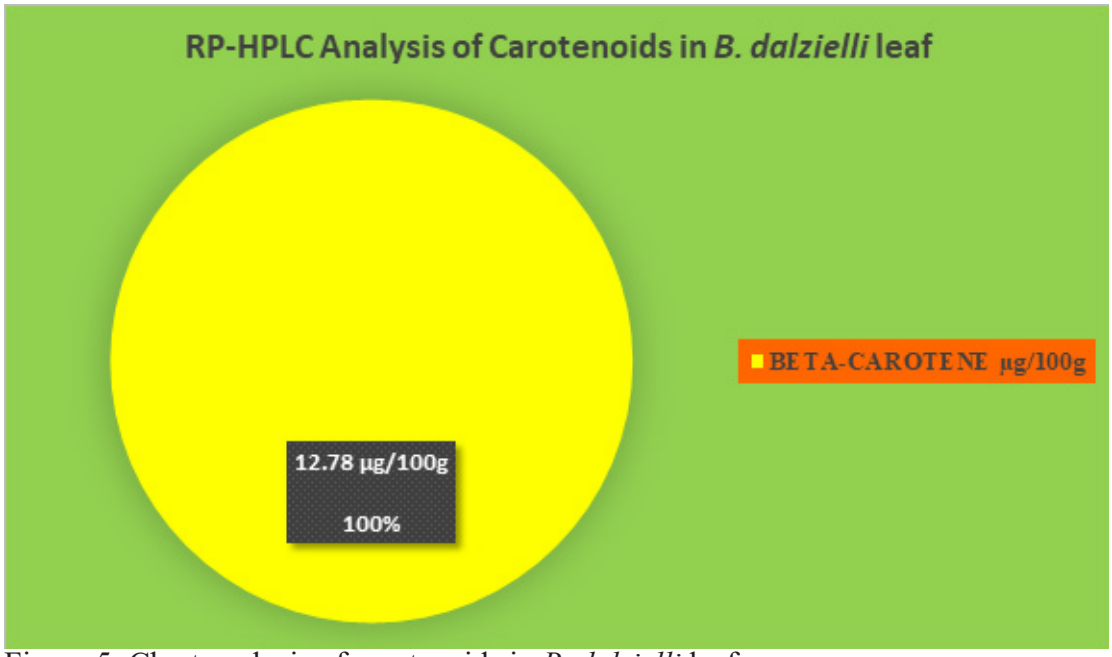

Figure 5: Chart analysis of carotenoids in *B. dalzielli* leaf

3.4 **GC-FID Analysis of sterols in *Boswellia dalzielli leaf***

Analysis of sterols in *Boswellia dalzielli* leaf yielded β-sitosterol (4.95 mg/100g), savenosterol and others (Figures 6,7).

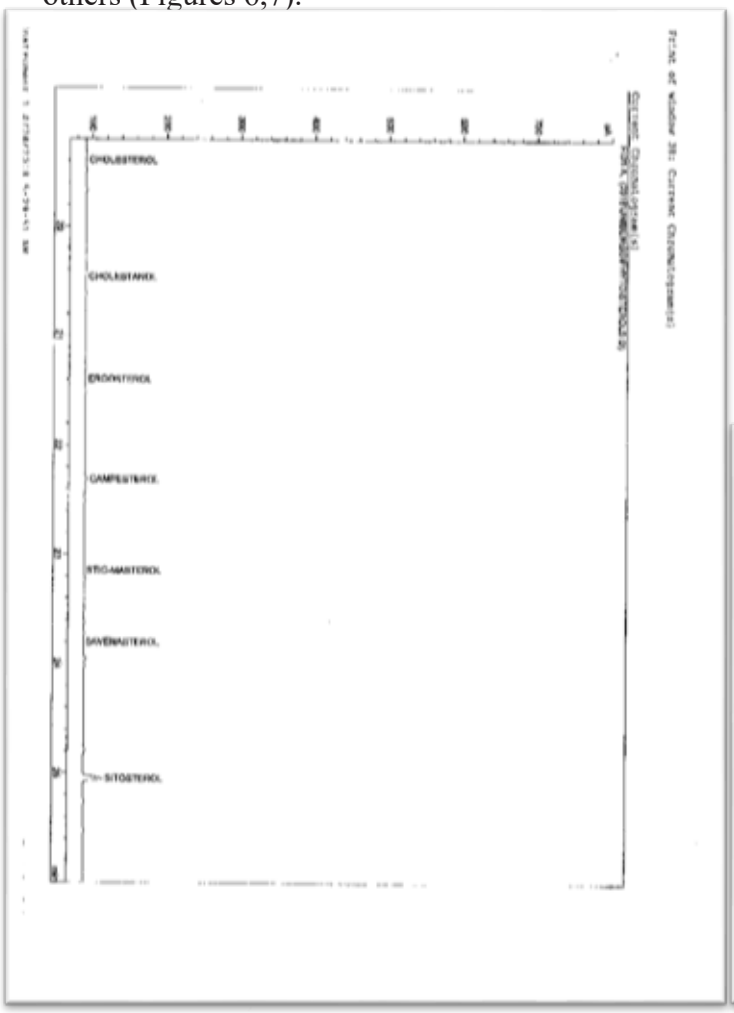

Figure 6: Gas chromatography with Flame Ionization Detector (GC-FID) analysis of sterols in *B. dalzielli* leaf

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STEROL ANALYSIS

External Standard Report

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Dilution : 1.0000

Signal 1: FID1 A,

RetTime [min]	Sig	Type	Area [pA*s]	Amt/Area	Amount [mg/100g]	Grp	Name
19.395	1	VV	1.67579	1.07329e-3	1.79805e-3	1	CHOLESTEROL
20.440	1	VV	1.31960	6.80180e-6	7.61532e-6	1	CHOLESTANOL
21.394	1	VV	5.41741e-1	3.37674e-3	1.82932e-3	1	ERGOSTEROL
22.511	1	VV	7.07149	6.61079e-7	1.64141e-1	1	CAMPESTEROL
23.146	1	VV	2.58194e-1	2.20256	5.68170e-1	1	STIG-MASTEROL
23.798	1	VV	1.38244e-1	5.89967	8.15594e-1	1	SAVENASTEROL
25.261	1	VV	3.49757	1.41624	4.95360	1	SITOSTEROL
Totals :					6.80494		

Results obtained with enhanced integrator!
Group summary :

Group ID	Use	Area [pA*s]	Amount [mg/100g]	Group Name
1		14.25213	6.80494	STEROL

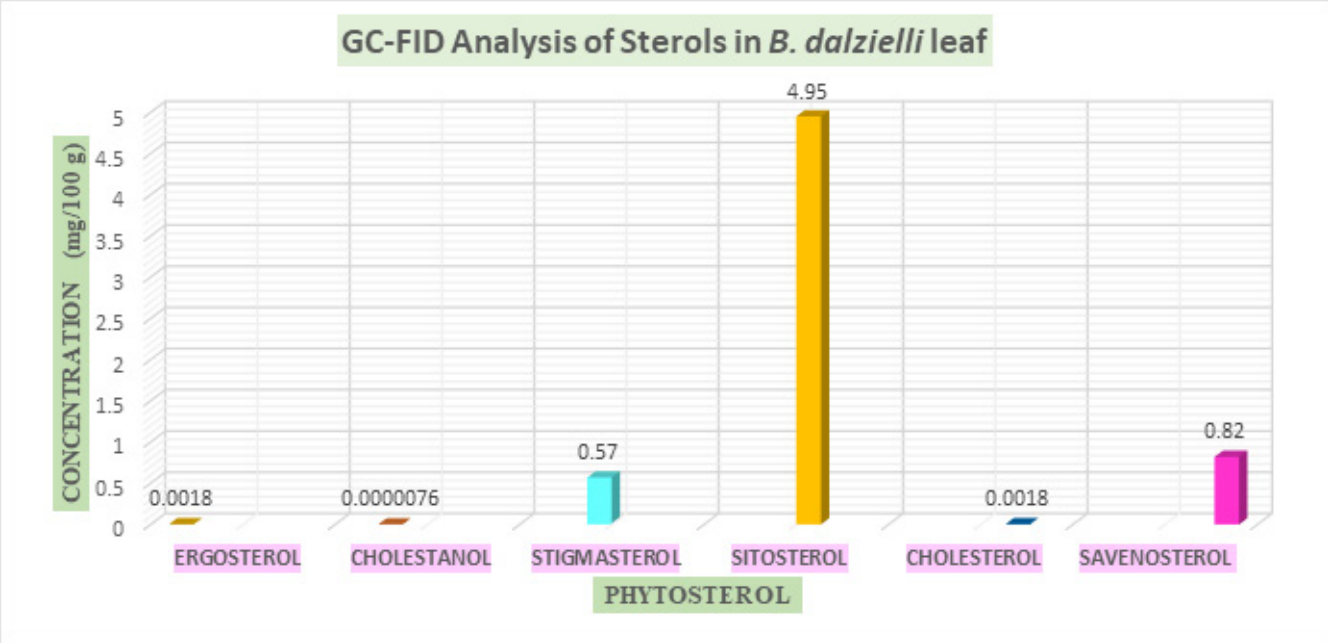

Figure 7: Chart analysis of sterols in *B. dalzielli* leaf

4.0 **DISCUSSION**

The mineral analysis of *Boswellia dalzielli* stembark revealed the following elements: macro-elements: calcium (Ca) had the highest concentration of 98.64 mg/g extract followed by sodium (Na) 11.71 mg/g extract, iron (Fe) 8.46 mg/g extract, potassium 6.26 mg/g, magnesium (Mg) 5.29 mg/g. Microelements present in trace amounts include manganese (Mn) (0.52 mg/g extract), lead (Pb) (0.32 mg/g extract). Other microelements include cobalt (Co) 0.01, cadmium (Cd) 0.11, nickel (Ni) 0.013, chromium (Cr) 0.012, zinc (Zn) 0.08, copper (Cu) 0.15 mg/g extract (Figure 1).

Yakubu *et al*.[16] found sodium at 0.72 mg/g in *B. dalzielli* stem bark extract. Also they and Mamza *at al*.[17] did not detect lead in all the plant parts analyzed. Yakubu *et al*.[18] obtained manganese at 31.24±0.114 mg/kg and zinc 5.82±0.021 mg/kg concentrations from the stem bark *B. dalzielli*.

Mineral analysis of the leaf revealed the presence of the following elements: potassium (4521.79 ppm; 4.52 mg/g), magnesium (3315.8 ppm; 3.32 mg/g), calcium (1825.37 ppm; 1.83 mg/g), sodium (116.38 ppm; 0.12 mg/g), iron (52.19 ppm; 0.052 mg/g), zinc (21.95 ppm; 0.022 mg/g) (Figure 2). Others include Mn 11.7 ppm (0.012 mg/g), Cu 6.95 ppm (0.007 mg/g), Se 0.0172 ppm (1.72×10^{-5} mg/g), Cr 0.0024 ppm (2.4×10^{-6} mg/g) (Figure 1).

In this study, potassium was seen at 4.52 mg/g (4521.79 ppm) in the leaf while Arowora *et al*.[19] found it at 13.29 mg/g. Recommended daily allowance for Potassium is 3500 mg per day[20]. Very essential for normal cell function being the most abundant cation in the intracellular fluid, potassium deficiency could lead to cardiovascular malfunction specifically hypertension and its sequel; it could also lead to diabetes [21]. Yakubu *et al*. [16] working on *B dalzielli* leaf found potassium at 0.0046 mg/kg (4.62E-03 mg/kg).

In this study, calcium was found in the leaf at 1.83 mg/g (1825.37 ppm). The human skeleton is composed most of calcium and serves two main purposes: provision of strength and a calcium pool whereby the intracellular and extracellular calcium balance is maintained [22]. Calcium homeostasis is necessary for harmonious metabolic function viz blood clotting, muscle contraction, normal heart rhythm, proper bone development and function, reducing the risk of osteoporosis, osteomalacia, rickets, kidney failure and facilitates proper nerve function [22]. Yakubu *et al*. [16] working on *B dalzielli* leaf found calcium as the most abundant element at 0.77 mg/g extract (7.70 E-01 mg/g) while Arowora *et al*. [19] found it at 3.37 mg/g.

In the present study, iron concentration in the leaf was 0.052 mg/g (52.19 ppm). Iron plays essential roles in metabolism of living organisms. Upsetting the iron balance could elicit an array of metabolic disorders including iron deficiency anemia, iron overload, neurodegenerative disorders including cognitive function, lower mental capacity and immune system malfunction [23]. Arowora *et al*.[19] found iron in the leaf at 0.9 mg/g.

The concentration of magnesium seen in the leaf in this study was 3.32 mg/g (3315.8ppm). Magnesium is a divalent cation essential for normal electrolyte balance. Its deficiency could lead to hypokalemia, hypocalcaemia disorganizing the entire nervous system leading to spasms and convulsions, and cardiovascular malfunction. Magnesium plays a crucial role in the synthesis of nucleic acids and proteins and in transport systems[24]. Yakubu *et al*. [16] working on *B dalzielli* leaf found magnesium at 0.35 mg/kg (3.45E-01 mg/kg) while Arowora *et al*.[19] found magnesium in the leaf at 0.043 mg/g.

The concentration of manganese seen in the leaf was 0.012 mg/g (11.7 ppm) while it was 0.52 mg/g in the stembark extract. Manganese is an essential microelement which is involved in the synthesis and activation of enzymes, proteins, vitamins C and B, regulating the endocrine activities; assist in immune function and reduces oxidative stress [25]. Arowora *et al*.[19] found manganese in the leaf at 0.1 mg/g.

In this work sodium was seen at 0.12 mg/g (116.38 ppm) in the leaf while Arowora *et al*.[19] found sodium at 4.44 mg/g. Optimum sodium balance is imperative for normal cellular homeostasis, maintenance of the extracellular fluid and electrolyte volume necessary for normal excitability of nerves and muscle, transport and the regulation of blood pressure [26]. Yakubu *et al*. [16] working on *B dalzielli* leaf found sodium at 0.77 mg/kg (7.65 E-01 mg/kg).

The zinc content of *Boswellia dalzielli* leaf from the analysis was 0.022 mg/g (21.95 ppm) (Figure 1). This property probably contributes to its role as an anti-inflammatory, antioxidant, anticancer, anti-mutagenic, immune-boosting as exploited in traditional applications [27]. These and other phytochemical properties have been displayed pharmacologically in *B. dalzielli*. Arowora *et al*.[19] found in the leaf zinc at 0.2 mg/g extract. Working on *B. dalzielli* leaf, Arowora *et al*.[19] found copper at 0.1 mg/g concentration however in this work copper was 0.007 mg/g (6.95 ppm).

Gas Chromatography-mass spectrometry (GC-MS) analysis of *Boswellia dalzielli* leaf for fatty acid methyl esters (FAME) revealed the presence of significant amounts of Linolenic C18:3 (29.09%), Palmitic acid C16:0 (28.58%), Lineoleic acid C18:2 (23.09%), Oleic acid C18:1 (11.44%) (Figures 3, 4). Other fatty acids seen include: Stearic acid C18:0 (4.48%), Palmitoleic acid C16:1 (1.29%), Lignoceric acid C24:0 (0.79%), Arachidic acid C20:0 (0.41%), Behenic acid C22:0 (0.29%), Myristic acid C14:0 (0.22%), Erucic acid C22:1 (0.21%) (Figures 2, 3).

The genus Boswellia comprises species which have been found efficacious in the healing of several systemic disorders [28]. GC-MS analysis revealed its content of essential and non-essential fatty acids. Polyunsaturated fatty acids (PUFA) imperative for human health but cannot be synthesized by the human body are termed essential since they must be obtained extraneously [29]. *B. dalzielli* leaf contains the two essential fatty

acids: 23.09% of Lineoleic acid (C18:2; LA)- an omega-6 fatty acid and 29.09% of α-linolenic fatty acid (C18:3; ALA), an omega-3 fatty acid. These are two families of essential fatty acids (EFA) - the omega-3 family and the omega-6 family [30]. As linoleic acid (LA) constitutes approximately 90% of dietary omega-6 poly-unsaturated acid, it is the most abundant dietary poly unsaturated fatty acid[31]. Bentsen [32] noted that EFAs and their derivatives constitute 15% to 30% of the dry weight of the human brain. Lower incidence of dementia is recorded in cultures where diets high in omega-3 are consumed [33]. Omega-3 fatty acids have been used in treating symptoms of bipolar disorder, depression, Attention deficit hyperactivity disorder (ADHD) and psychosis [34]. The symptoms are also treated with the *B. dalzielli* resin. Oleic acid exhibited anti-inflammatory, antimicrobial, anti-carcinogenic properties [35]. Ahmed *et al*. [36] carried out GC/MS analysis of volatile oils of *B. serrata* resin and identified twenty two fatty acids including Oleic acid (C18:1) 30.05% as the highest proportion, Palmitoleic acid (C16:1) 22.41%, Lauric acid (C12:0) 9.39%.

In this present study, 28.58% of palmitic acid was obtained. Palmitic acid (PA) is the most common saturated fatty acid (SFA) in the human body constituting 20-30% of total fatty acid in the body [37]. Though it can be synthesized endogenously via de novo lipogenesis (DNL) this may not be sufficient on a long term and so must be taken in the diet for optimal concentration. Palmitic acid plays many valuable biochemical roles at both cellular and tissue levels and a disruption of its homeostatic balance has manifested in systemic breakdown as neurodegenerative disorders, atherosclerosis and cancer [37]. Stearic acid (C18:0) seen at 4.48% in this work plays a role in the regulation of the mitochondria within the cell [38].

Analysis of the carotenoids in *Boswellia dalzielli* leaf revealed the presence of only Beta-carotene at 12.776 µg/100g (Figures 4,5). Symmetric cleavage of one molecule of β-carotene gives two molecules of retinol (Vitamin A) [39]. Some physiological functions of *Boswellia dalzielli* which may be contributed by its content of beta-carotene may include its use in strengthening the immune system, in brain and neural development and in the detoxification process [40]. β-carotene plays essential roles in embryonic development, integrity of epithelial cells and in the development of the hind brain, limbs, heart, eyes, ears [41], in prevention of xerophthalmia and night blindness [42]. It functions as an antioxidant, and enhances the immune response [40] Anti-obesity, anti-diabetic [43], stimulatory effect on bone formation and inhibitory effect on bone reabsorption[44].

Analysis of sterols in *Boswellia dalzielli* leaf yielded β-sitosterol (4.95 mg/100g), savenosterol and others (Figures 6,7). The active roles of *Boswellia dalzielli* in cancerous growths in the brain and breast have been reported with the resin and essential oil. Beta-sitosterol has been a traditional mainstay in Europe for the treatment of enlarged prostrate but probably best known for reducing high blood cholesterol [45]. As in *Boswellia dalzielli*, it exhibits tumor cell-specific cytotoxicity in prostrate cancer cells as well as pro-apoptotic, anti-invasive and anti-proliferative actions [46]. Phytosterols are also known to reduce total and low-density lipoprotein (LDL), cholesterol [47]. They regulate inflammation and the immune system; function as antioxidant, antiulcer, antibacterial and antifungal, in wound healing promotion, and inhibition of platelet aggregation [48].

Conclusion

In conclusion, the results of this work confirm the wide traditional applications of *Boswellia dalzielli* in several health disorders. The significant concentrations of vital elements, vitamins, sterols, beta carotene and key fatty acids in this plant positions it as a resource of immense benefit medicinally and nutritionally. These constituents are easily obtainable by eating the raw leaves or chewing the gum resin. The increasing unavailability of this plant is becoming a major hindrance to its employment. There is need to seek other drug compoundment protocols in or-

der to overcome the recurring challenge of anti-microbial resistance. More so, the traditional methods of herb application do not lead to drug resistance. Concerted efforts must be made to conserve these and other threatened medicinal plants.

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