Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
https://www.phytojournal.com
JPP 2023; 12(2): 119-127
Received: 18-12-2022
Accepted: 23-01-2023

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Quantitative determination of nutraceuticals in matured unriped fruits of three edible *Musa Species* using GC-MS

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DOI: https://doi.org/10.22271/phyto.2023.v12.i2b.14637

Abstract
The nutraceuticals in fruits and vegetables are among the major contributors of their therapeutic relevance to humans. This study evaluates the relevance of nutraceuticals obtained from the GC-MS analyses of dichloromethane extracts of unripe matured fruits of *Musa paradisiaca*, *Musa acuminata* and *Musa balbisiana*.
Methodology: Unripe matured fruits of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* harvested from their natural habitat and identified at the Plant Science Department of the University of Port Harcourt were separately washed and the epicarp were removed. The sliced mesocarp were dried and ground into fine powder. Ten grams each of the ground samples was weighed into different well stoppered bottle and 40 mls of dichloromethane was added. Each mixture was vigorously agitated and allowed to stand for 96 hours. The crude extracts collected by filtering was purified and concentrated to 2.0 ml for GC-MS analysis.
Result: Results shows 97, 83, and 52 nutraceutical components in *M. paradisiaca*, *M. acuminate* and *M. balbisiana* respectively, with 1,4-Cyclohexadiene,1-methyl-4-(1-methylethyl)-, α-Pinene and Glycerin as highest nutraceutical components with percentage concentrations of 18.379, 11.874 and 17.889 respectively.
Conclusion: The numerous therapeutic potentials of predominant nutraceuticals in these *Musa* species are of prominent in the development of broad-spectrum pharmaceuticals formulations for advancement of human wellbeing.

Keywords: Nutraceuticals, *Musa* species, pharmaceuticals, monoterpenes, sesquiterpenes

Introduction
Plants have made large contributions in the enhancement of human health and wellbeing via its leaves, fruits and roots, which have remained important components of healthy diets. Fruits and other edible plant parts have contributed greatly due to their high content of vitamins, minerals, fiber and beneficial non-nutrient substances often referred to as nutraceuticals (Kumar *et al.*, 2012) [14]. The medicinal benefits of fruits are based on their ability to aid in the body's retention of calcium, nitrogen, iron and phosphorus, all of which work to build healthy organs and regenerated tissues. Consumption of medicinal fruits and plants materials protects and heals a number of ailments and they have been the principal treatment therapy in prehistoric times until the discovery of synthetic drugs. About 40% of the present prescription drugs are derived from herbs and 0.5% of the world's best-selling pharmaceutical preparations are derivatives of natural products of plant origin (Rao *et al.*, 2014) [22].
Traditional medicines which are derived from plant sources have shown to be potent in combating several ailments and diseases. However, there is a paucity of information on the nutraceuticals that actually elicit these therapeutic effects, thereby resulting in the need to scientifically evaluate plant materials to identify the secondary metabolites that elicits these medicinal and nutritive properties. Amongst the medicinal plants use in traditional medicine, *Musa paradisiaca* (Plantain) has been reported to have therapeutic activities such as antilithiatic, antioxidant, antibacterial, anti-diabetic, anti-ulcer, anti-diarrhoeal, hypocholesterolaemic, hepatoprotective, anti-snake venom, wound healing, hair growth promoting, antifungal and antihemorrhagic activity (Lavanya *et al.*, 2016) [15]. These indigenous knowledges, passed through generations have significantly contributed to the development of different traditional medicine (Jachak and Saklani, 2007) [11] as well as helped in exploration of different medicinal plants to find the scientific basis of their traditional uses. Exploration of biologically active nutraceuticals have also played important roles in the

discovery of new chemical compounds. Approximately 28% of chemical compounds discovered between 1981and 2002 were natural products or natural product-derived (Newman *et al.*, 2003) [19]. The aim of this present research is to quantitatively determine the nutraceutical constituents present in selected fruits of *Musa species* (*M. paradisiaca*, *M. acuminata* and *M. balbisiana*) using GC-MS.

Method

Sample Collection and Preparation and Extraction

Unripe matured fruits of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* were harvested from their natural habitat within the University of Port Harcourt community and identified at the Plant Science Department of the University of Port Harcourt. Two fruits of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* each were separately washed under running tap, the epicarp were removed using a sterilized knife. The sliced mesocarp were separately dried at room temperature for one week in a clean, dry and dust free environment. The dried samples were ground into fine smooth powder using a Binatone BLG 450 electric blender and placed in sterilized universal sample bottles and labeled accordingly. A quantity of 10g each of the ground samples was weighed into different well stopper bottle and 40 mls of dichloromethane was added to each sample. The mixtures were vigorously agitated and left to stand for 96 hours. The crude extracts were collected by filtering into a quartz beaker, purified by passing through a pasture pipette packed with silica gel and anhydrous sodium sulphate and air dried to 2 mls for GC-MS analysis.

Gas chromatography and Mass spectrometry of Extracts

The nutraceutical constituents in the extracts were analyzed using Agilent Technology Gas chromatography model HP 6890 and spectrometer model 5973 fitted to a HP-5 MS capillary column (5% phenyimethylsiloxane) 30.0m x 250µm x 0.25µm. Helium gas at initial column temperature of 120 ^{o}C was used as a carrier gas for 5 minutes. The temperature was increase at 5 ^{o}C per minute to 320 ^{o}C and held for 5 minutes. Ionization energy of 70eV was used for mass spectroscopy electron impact ionization. A volume of 2 µL of 98% hexane diluent of the pure extract was auto-injected into mass spectrometer model 5973 (Agilent Technology) and a Microsoft Library connected Chem-office software was used to identify the constituent bioactive components in the extracts, while National Institute of Standards and Technology (NIST) database was employed in the confirmation of structures and names of the nutraceutical constituents.

Results

The chromatogram of the nutraceutical constituents of unripe matured fruits of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* are shown in figures 1a - 1c. The highest peaks in the chromatogram of *M. paradisiaca* (fig. 1a) were observed at retention times of 12.573 mins., 10.585 mins. and 10.439 mins, while retention times of 12.573 mins., 15.263 mins. and 16.916 mins had the highest peaks in the chromatogram of *M. acuminata* (fig. 1b). Highest peaks in the chromatogram of *M. balbisiana* were observed at retention times of 16.916 mins., 16.862 mins. and 12.573 mins (fig. 1c).

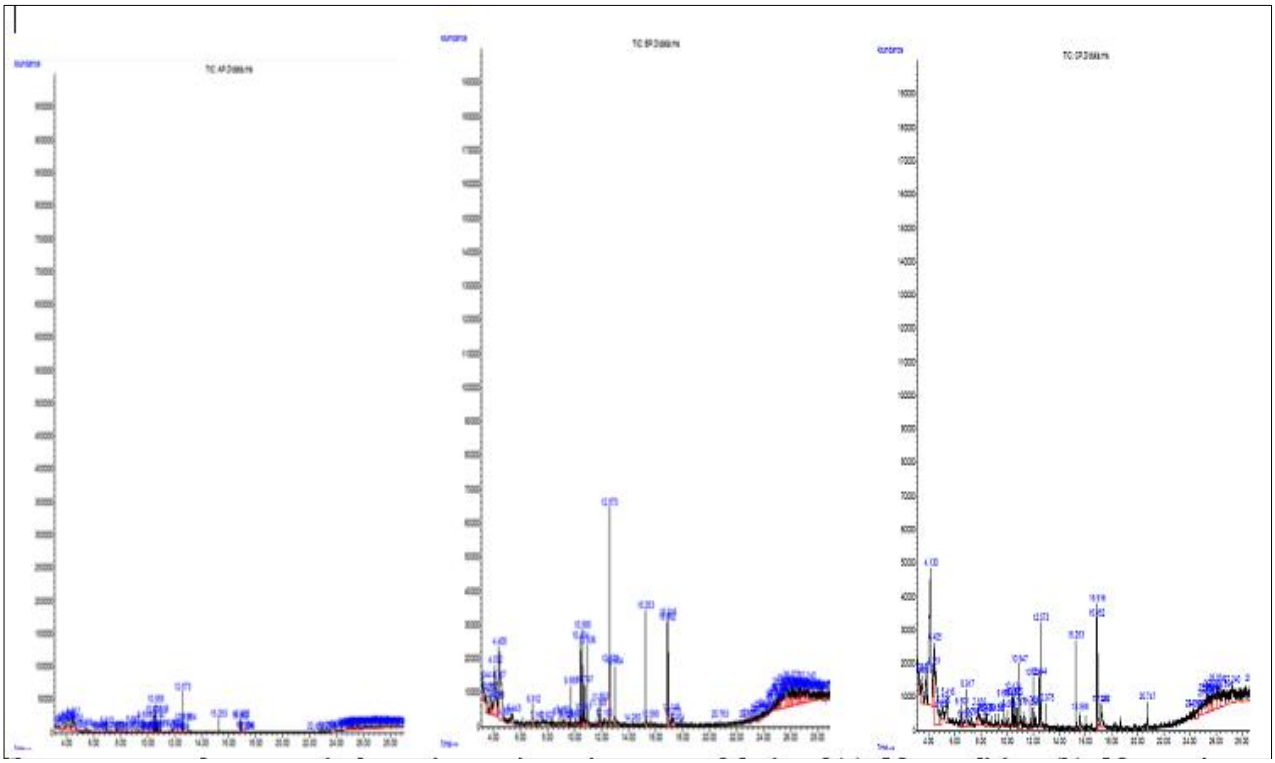

Fig 1: Chromatogram of nutraceutical constituents in unripe matured fruits of (a). *M. paradisiaca* (b). *M. acuminata* and (c). *M. balbisiana* fruits

The nutraceutical constituents obtained from the GC-MS analyses of dichloromethane extract of unripe matured fruits of *M. paradisiaca*, *M. acuminata* and *M. balbisiana* are presented in tables 1-3. Amongst the 97 bioactive components observed in *M. paradisiaca*, 1,4-Cyclohexadiene,1-methyl-4-(1-methylethyl)- had the highest percentage concentration with a total value of 18.379, followed by aR-Turmerone; Cyclohexane,1methylene-4-(1-methylethenyl)-; (1S,2S,6R,7R)-2-Hydroxy-N-methoxy-Nmethylbicyclo[4.1.0]heptane-7-carboxamide; 6-Octadecenoic acid, methyl ester, (Z)- and Cedrene with percentage concentrations of 4.668, 3.125, 3.045, 2.337 and 2,267 respectively (table 1).

Table 1: Nutraceutical constituents in unripe matured fruits of *M. paradisiaca*

S/N	Compound	Retention Time (min)	Percentage concentration	Molecular formula	Molecular weight
1	3,3-Dimemethyl-4-methylenebicyclo[3. 1.0]hexan-2-one	3.276	1.137	$C_{12}H_{18}O_2$	194.2700
2	2-Ethyl-3-vinyloxirane	3.357	0.401	$C_6H_{10}O$	98.1430
3	3H-Pyrazol-3-one, 2, 4-dihydro-5-methyl-	3.460	2.767	$C_{17}H_{16}N_2O$	264.3200
4	Cyclohexane, 1 methylene-4-(1-methylethenyl)-	3.752	3.125	$C_{10}H_{16}$	136.2340
5	(1S, 2S, 6R, 7R)-2-Hydroxy-N-methoxy-N methylbicyclo [4.1.0]heptane-7-carboxamide	3.973	3.045	$C_{10}H_{17}NO_3$	199.2500
6	1, 4-Cyclohexadiene, 1-methyl-4-(1-methylethyl)-	4.092	8.003	$C_{10}H_{16}$	136.2340
7	1, 3, 5-Cycloheptatriene, 3, 7, 7-trimethyl-	4.351	2.048	C_7H_8	92.1384
8	1, 4-Cyclohexadiene, 1-methyl-4-(1-methylethyl)-	4.411	10.376	$C_{10}H_{16}$	136.2340
9	3-Bromo-7-methyl-1-adamantanecarboxylic acid	4.632	2.336	$C_{12}H_{17}BrO_2$	273.1660
10	1, 2-Diisopropyltriaziridine	4.800	0.375	$C_9H_{19}N$	141.2600
11	2, 4-Hexadien-1-ol	5.383	1.609	$C_6H_{10}O$	98.1430
12	2-[2'-(Cyclohex-1"-enyl) prop-2'-enyl]-2-methylcyclo hexane-1, 3-dione	5.788	0.245	$C_{16}H_{22}O_2$	246.3500
13	1, 1, 2, 2-Tetracyano-5-methylspiro [2.5] octane	6.350	0.282	C_9H_{16}	124.2200
14	Callydiyne	6.463	0.230	$C_{16}H_{22}$	214.3500
15	3-Cyclohexen-1-one, 4-[2-methyl-4- (2, 6, 6-trimethyl-1-cyclohexen-1-yl)-2-butenyl]-, (E)-	6.496	0.216	$C_{20}H_{30}O$	286.4600
16	2-Heptyn-1-ol	6.685	0.307	$C_7H_{12}O$	112.1696
17	4-methyl-2-[(E)-prop-1-enyl]-1,3-dioxolane	6.917	1.365	$C_8H_{14}O_2$	142.2000
18	2-Propanol, 1, 1'-[1,2-ethanediylbis(thio)]bis-	7.290	0.223	$C_9H_{20}O_4$	192.2527
19	Pentane-1, 2, 3, 4, 5-pentaol	7.690	0.815	$C_5H_{12}O_5$	152.1460
20	1-Hexanol, 6-chloro-	7.771	0.699	$C_6H_{13}ClO$	136.6200
21	1H-Thiepine, 2, 3, 6, 7-tetrahydro-4, 5-didehydro-3, 3, 6, 6-tetramethyl-, 1-oxide	8.003	0.293	$C_{10}H_{16}O_2S$	200.3000
22	1, 2-Pentadiene, 4-methoxy-4-methyl 1	8.219	0.286	$C_7H_{12}O$	112.1700
23	Cyclopentene, 3, 5-diethenyl-4-methoxy-, (3.alpha., 4.alpha., 5.alpha.)	8.770	0.312	$C_{10}H_{14}O$	150.2176
24	Phenol, 2-methoxy-4-(2-propenyl)- 9	8.867	1.040	$C_{12}H_{14}O_3$	206.2378
25	1H-Cyclopropa[a]naphtha lene, 1a, 2, 3, 5, 6, 7, 7a, 7b-octahydro-1, 1, 7, 7a-tetra methyl-, [1aR(1a.alpha., 7. alpha., 7a.alpha., 7b.alpha.)]-	9.121	0.576	$C_{15}H_{24}$	204.3511
26	3, 9-Undecadiyn-1-ol	9.321	0.419	$C_{11}H_{16}O$	164.2500
27	3-(3-butynyl)-2-cyclohepten-1-one 8	9.688	1.829	$C_{10}H_{14}O$	150.2200
28	7-Isopropenyl-2, 3-dimethyltricyclo [5.2.1. 0(3, 8)]decane	9.840	0.383	$C_{10}H_{14}$	134.2182
29	3-Methyl-1 phenylbicyclo [1.1.1] pentane	9.964	0.258	$C_{12}H_{14}$	158.2400
30	1, 5, 8, 8-Tetramethyl-8-bicyclo [8.1.0] undecene-2, 9-diol	10.110	0.536	$C_{15}H_{26}O_2$	238.3700
31	2-Nonynoic acid	10.239	0.352	$C_9H_{14}O_2$	154.2100
32	(3R, 4aS, 5R)-3-isopropenyl-4a, 5-dim ethyl-2, 3, 4, 5, 6, 7-hexahydro-1H-naphthalene	10.380	0.227	$C_{15}H_{24}$	204.3500
33	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	10.439	2.253	$C_{15}H_{22}$	202.3352
34	2-Heptyn-1-ol	10.515	0.290	$C_7H_{12}O$	112.1696
35	(R)-1-Methyl-4-(6-methylhept-5-en-2 yl)cyclohexa-1, 4-diene	10.585	3.592	$C_{15}H_{24}$	204.3511
36	Acora-4(14), 8-diene	10.655	0.499	$C_{15}H_{24}$	204.3511
37	Bergamotene	10.747	1.908	$C_{15}H_{24}$	204.3500
38	Cedrene	10.936	2.267	$C_{15}H_{24}$	204.3570
39	(.+/-.)-Dihydro-ar-turmerone	11.763	0.620	$C_{15}H_{22}O$	218.3346
40	2-(4'-methylphenyl)-propanal	11.893	0.781	$C_{10}H_{12}O$	148.2017
41	2, 5-Pyrrolidinedione, 1-hydroxy-	11.984	0.208	$C_4H_5NO_3$	115.0874
42	2-[2'-(Cyclohex-1"-enyl) prop-2'-enyl]-2-methyl cyclohexane-1, 3-dione	12.190	0.239	$C_{16}H_{22}O_2$	246.3500
43	Propene	12.444	0.256	C_3H_6	42.0800
44	aR-Turmerone	12.573	4.668	$C_{15}H_{20}O$	216.3200
45	(2, 6-Dimethyl-phenyl)-hydrazine	12.616	1.491	$C_8H_{12}N_2$	136.1900
46	Curlone	12.984	1.240	$C_{15}H_{22}O$	218.3346
47	Pentadecanoic acid, 13-methyl-, methyl ester	15.253	1.581	$C_{17}H_{34}O_2$	270.4507
48	9, 12-Octadecadienoic acid (Z,Z)-, methyl ester	16.862	1.505	$C_{18}H_{32}O_2$	280.400
49	6-Octadecenoic acid, methyl ester, (Z)-	16.922	2.337	$C_{19}H_{36}O_2$	296.4879
50	(2S)-2-Methyldecanal	17.154	0.347	$C_{11}H_{22}O$	170.2900
51	1-Allyloxy-octa-2, 7-diene	17.224	0.273	$C_{13}H_{22}O$	194.3100
52	2-Butenal, 2-ethenyl-	17.316	0.235	$C_6H_{10}O$	98.1430
53	Cyclohexanone, 2-(2-propenyl)-	22.454	0.219	$C_9H_{14}O$	138.2069
54	1-isopropenyl-1-(1-propenyl)cyclohexane	23.210	0.275	$C_{12}H_{20}$	164.2900
55	Nickel, bis(1, 1-dimethyl-.pi.-allyl)-bis(ethoxy)bis-	23.399	0.231	$C_{28}H_{20}NiS_4$	543.4000
56	2-methyl-2-(2-methyl-1-propenyl)cyclobutanone	23.842	0.387	$C_8H_{12}O$	124.1800
57	Hexadeca-1, 2, 14, 15-tetraen-4, 13-dione	24.198	0.264	$C_{16}H_{22}O_2$	246.3500
58	7-Oxabicyclo [4.1.0] heptane, 3-(epoxyethyl)-	24.609	0.264	$C_8H_{12}O_2$	140.1800
59	1, 4-Dimethyl 2-(3, 5, 5-tri methyl-4H-pyrazol-1-yl)but-2-enedioate	24.658	0.217	$C_9H_{12}O_2$	152.1900
60	(-)-trans-Verbenol (4, 6, 6-trimethylbicyclo [3.1.1] hept-3-en-2-ol)	24.787	1.046	$C_{10}H_{16}O$	152.2334

61	14.alpha.-Cheilanth-12-enic MethylEster	24.944	0.548	$C_{26}H_{42}O_2$	386.6000
62	3-Pentenoic acid, 2, 4-dimethyl-, 2-furanylmethyl ester, (S)-	24.998	0.505	$C_7H_{12}O_2$	128.1700
63	2-Phenyl-3-(propylsulfanyl)imidazo [2, 1-b] [1, 3]selenazole	25.101	0.504	$C_{10}H_{12}ClN_3$	209.6800
64	14.alpha.-Cheilanth-12-enic Methyl Ester	25.176	0.562	$C_{19}H_{32}O_2$	292.5000
65	N-Formyl-calycinine	25.209	0.26	$C_{19}H_{17}NO_5$	339.3500
66	4H-Bis[1, 2, 5]oxadiazolo [3, 4-b:3', 4 '-f]azepine-8, 9-diamine	25.246	0.585	$C_8H_{10}N_8O_2$	250.2200
67	3, 5-Dimethylbenzaldehyde thiocarbamoylhydrazone	25.392	1.332	$C_{10}H_{13}N_3S$	207.3000
68	Heptasiloxane, 1, 1, 3, 3, 5, 5, 7, 7, 9, 9, 11, 11, 13, 13-tetradeca methyl-	25.479	0.654	$C_{14}H_{44}O_6Si_7$	505.0940
69	Naphtho[2, 1-b]furan,dodeca hydro-6,9a-dimethyl-, [3aS-(3a.alpha.,5a.alpha., 6.beta., 9a.beta., 9b.alpha.)]-	25.527	0.856	$C_{16}H_{26}O_3$	266.3800
70	Spiro[4.5]decane-6,10-dione	25.646	1.988	$C_{10}H_{14}O_2$	166.2200
71	14.alpha.-Cheilanth-12-enic Methyl Ester	25.841	1.323	$C_{19}H_{32}O_2$	292.5000
72	14.alpha.-Cheilanth-12-enic Methyl Ester	26.084	1.995	$C_{19}H_{32}O_2$	292.500
73	2-Phenyl-3-(propylsulfanyl) imidazo[2, 1-b][1,3] selenazole	26.181	1.158	$C_{10}H_{12}ClN_3$	209.6800
74	Silicic acid, diethyl bis (trimethylsilyl) ester	26.289	0.663	$C_{10}H_{28}O_4Si_3$	296.5800
75	Cheilanth-13(14)-enic Methyl Ester	26.375	0.235	$C_{26}H_{42}O_2$	386.6000
76	2H-3, 9a-Methano-1-benzoxepin, octahydro-2, 2, 5a, 9-tetramethyl-, [3R-(3.alpha., 5a.alpha., 9.alpha., 9a.alpha.)]-	26.424	1.642	$C_{15}H_{26}O$	222.3663
77	3-Methylindole-2-carboxylic acid, 4, 5, 6, 7-tetrahydro-, ethyl ester	26.591	0.693	$C_{12}H_{15}NO_3$	221.2500
78	(E)-2-chloro-3'-fluoro-4,4'-dihydroxybiphenyl-3-carbaldehyde oxime	26.678	1.031	$C_{13}H_9ClFNO_3$	281.6700
79	2, 7-dimethyl-3, 8-dioxaspiro [4.4]no nane-4, 9-dione	26.808	0.302	$C_9H_{12}O_4$	184.1900
80	5-(4-Nitrophenyl)-1, 3, 4-oxadiazol- 2(5H)-one	26.840	0.611	$C_8H_5N_3O_4$	207.1430
81	Silicic acid, diethyl bis (trimethylsilyl) ester	26.948	0.758	$C_{10}H_{28}O_4Si_3$	296.5800
82	2-Acetyl-2-{bis[4-(dimethyl amino)p henyl]methyl} cyclopentanone	27.045	0.921	$C_{25}H_{31}N_3O$	389.5000
83	2-Butynal	27.240	0.953	C_4H_4O	68.0740
84	14.alpha.-Cheilanth-12-enic MethylEster	27.353	0.327	$C_{19}H_{32}O_2$	292.5000
85	2-Amino-4-(2-methyl propenyl)-pyrimidin-5- carboxylic acid	27.407	0.361	$C_6H_7N_3O_2$	153.1400
86	4-Dehydroxy-N-(4, 5-methylenedioxy-2 nitrobenzylidene)tyramine	27.456	0.309	$C_{16}H_{14}N_2O_4$	298.2900
87	2-Phenyl-3-(propylsulfanyl) imidazo [2, 1-b] [1, 3] selenazole	27.650	0.270	$C_{10}H_{12}ClN_3$	209.6800
88	14.alpha.-Cheilanth-12-enic Methyl Ester	27.737	0.209	$C_{19}H_{32}O_2$	292.5000
89	2-Hexyn-1-ol	27.802	0.399	$C_6H_{10}O$	98.1430
90	N-[(2, 3, 6-Trimethoxy-10-phenanthryl)methyl]propylamine	27.942	0.302	$C_{21}H_{25}ClNO_3$	374.8900
91	Naphtho [2, 1-b] furan, dodecahydro-6, 9a-dimethyl-, [3aS- 3a.alpha., 5a.alpha., 6.beta., 9a.beta., 9b.alpha.)]-	28.077	0.208	$C_{16}H_{26}O_3$	266.3800
92	1-Cyclohexene-1-methanol	28.126	0.208	$C_7H_{12}O$	112.1700
93	2-Nonynoic acid	28.196	0.290	$C_9H_{14}O_2$	154.2100
94	4H-Dibenz[de,g]isoquinoline, 5,6,6a,7-tetrahydro-1,2,9,10-tetramethoxy-5-methyl-,(.+-.)-	28.407	0.240	$C_{21}H_{25}NO_4$	355.4300
95	(-)-trans-Verbenol (4, 6, 6-trimethylbicyclo [3.1.1] hept-3-en-2-ol)	28.536	0.354	$C_{10}H_{16}O$	152.2334
96	14.alpha.-Cheilanth-12-enic Methyl Ester	28.644	0.369	$C_{19}H_{32}O_2$	292.5000
97	14.alpha.-Cheilanth-12-enic Methyl Ester	28.871	0.464	$C_{19}H_{32}O_2$	292.5000

α-Pinene had the highest concentration amongst the 83 nutraceutical constituents observed in unripe matured fruits of *M. acuminata*, with a percentage concentration of 11.874%. α-Phellandrene, dimer was second highest with percentage concentration of 5.722%, followed by alpha.- aR-Turmerone; n-Propyl 11-octadecenoate; 7,10-Octadecadienoic acid, methyl ester; 4-(2',6'-Dichlorophenyl methylene)-1,2,3,4-tetraisoquinoline-1,3-dion; Hexadecanoic acid, methyl ester with percentage concentrations of 5.404%, 4.100%, 2.885%, 2.751% and 2.721% respectively (table 2).

Table 2: Nutraceutical constituents in unripe matured fruits of *M. acuminate*

S/N	Compound	Retention Time (min)	Percentage concentration	Molecular formula	Molecular weight
1	1,4-Cycloheptadiene, 6-(1,3-butadienyl)-, (Z)-(.+-.)-	3.244	1.177	$C_{11}H_{14}$	146.2300
2	3-Bromo-7-methyl-1-adamantanecarboxylic acid	3.428	2.447	$C_{12}H_{17}BrO_2$	273.1660
3	8-Methylene-7-methyl-1-oxaspiro[4.4]non-3-en-2-one isomer	3.757	1.678	$C_{10}H_{12}O_2$	164.2000
4	Duroquinone	3.925	1.181	$C_{10}H_{12}O_2$	164.2041
5	.alpha.-Phellandrene, dimer	4.092	5.722	$C_{20}H_{32}$	272.4681
6	(1S,6R,7R)-Bicyclo[4.1.0] hept-2-ene-7-carboxylic acid	4.281	0.658	$C_8H_9N_3O$	163.1800
7	Benzene, 1-ethyl-2,4-dimethyl-	4.357	1.755	$C_{10}H_{14}$	134.2200
8	2-Pinene	4.405	11.874	$C_{10}H_{16}$	136.2400
9	6,7-Dioxabicyclo [3.2.2] nonane	4.805	0.256	$C_7H_{12}O_2$	128.1690
10	11-Oxatricyclo (5.4.1.0)dodecan-9-one	5.443	1.050	$C_{15}H_{26}O$	222.3700
11	2-Hexenal, (E)-	6.912	1.208	$C_6H_{10}O$	98.1430
12	1-[3-(1-cyclohexenyl)-1-ethoxyprop -2-ynyl] Benzotriazole	7.160	0.293	$C_{17}H_{19}N_3O$	281.3600
13	2-hydroxy-1,4,6,7- tetramethyleneoctane	7.922	0.258	$C_{10}H_6O_3$	174.1500
14	2-Allyl-4-methoxyphenol	8.867	0.334	$C_{10}H_{12}O_2$	164.2000
15	3-Methyl-1-phenyl bicycle [1.1.1] pen tane	9.121	0.588	$C_{12}H_{14}$	158.2400
16	3-Ethynyl-3-methoxypenta-1, 4-diene 2	9.321	0.26	$C_8H_{10}O$	122.1600
17	(3aR, 7aR)-7a-but-3-ynyl-3a-methyl- 1, 2, 3, 4,6, 7-hexahydroinden-5-one	9.689	1.153	$C_{10}H_{14}N_2O_2$	194.2304
18	(1E, 8E)-1, 8-bis(bromanyl) cyclotetradeca-1, 8-diene	9.851	0.260	$C_{14}H_{22}Br_2$	350.1400

19	2-Chloro-5-hydroxy-1, 3-dimethylbenzene	10.088	0.354	C_8H_9ClO	156.6100
20	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	10.434	2.172	$C_{15}H_{22}$	202.3352
21	1, 3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-, [S-(R*,S*)	10.585	2.462	$C_{15}H_{24}$	204.3511
22	3, 3-Dimethyl-2-methylene-4, 7-oxo-cyclopentane [a] cyclohept-5-ene	10.661	0.381	$C_{10}H_{16}O$	152.2300
23	4,4-Dimethyl-2-(4'-methyl cyclohexen-1'-yl)-1, 5-hexadiene	10.747	1.490	$C_{15}H_{24}$	204.3600
24	(E,Z)-.alpha.-Farnesene	10.936	2.079	$C_{15}H_{24}$	204.3511
25	Diethyl [(2'-bicyclo[3.1.0]hex -6'- ylidene)ethyl]-malonate	11.758	0.508	$C_{10}H_{16}$	136.2340
26	7-Methoxymethyl-2, 7-dimethylcyclohepta-1, 3, 5-triene	11.893	0.786	$C_{11}H_{16}O$	164.2400
27	N-phenyl-3-ureido-1-diazo-4-phenyl-butan-2-one	12.190	0.249	$C_{10}H_{12}O_2$	164.2011
28	aR-Turmerone	12.573	5.404	$C_{15}H_{20}O$	216.3200
29	2-Cyclopropyl-2 chloropropane	12.622	1.686	$C_6H_{11}Cl$	118.6100
30	Benzenesulfonamide, N-(2, 5-dimethylphenyl)-4-(1-methylethyl)-	12.984	1.791	$C_{22}H_{29}NO_3S$	387.4706
31	1-Propanamine, 2-methyl-	14.280	0.242	$C_8H_{19}N$	129.2432
32	Hexadecanoic acid, methyl ester	15.253	2.721	$C_{17}H_{34}O_2$	270.4500
33	2-Heptenal, (E)-	15.598	0.366	$C_7H_{12}O$	112.1696
34	7,10-Octadecadienoic acid, methyl ester	16.862	2.855	$C_{19}H_{34}O_2$	294.4721
35	n-Propyl 11-octadecenoate	16.916	4.100	$C_{21}H_{40}O_2$	324.5000
36	Decanedioic acid, dimethyl ester	17.149	0.379	$C_{12}H_{22}O_4$	230.3007
37	1-(4'-pentenyl)-1,2-epoxycyclopentane	17.273	1.106	$C_7H_{10}O_2$	126.1500
38	Cyclopropane, 1,1'-ethenylidenebis	17.484	0.266	C_8H_{12}	108.1809
39	1-[2'-Methoxyphenyl]-2-nitro-2-ethylethene	20.763	0.263	$C_{11}H_{13}NO_3$	207.2300
40	1-isopropenyl-1-(1-propenyl)cyclohexane	22.837	0.259	$C_{12}H_{20}$	164.2900
41	1-Decyne	23.053	0.404	$C_{10}H_{18}$	138.2500
42	14.alpha.-Cheilanth-12-enic Methyl Ester	23.658	0.445	$C_{19}H_{32}O_2$	292.5000
43	1-isopropenyl-1-(1-propenyl)cyclohexane	23.734	0.411	$C_{12}H_{20}$	164.2900
44	14.alpha.-Cheilanth-12-enic Methyl Ester	23.945	0.343	$C_{19}H_{32}O_2$	292.5000
45	Cheilanth-13(14)-enic Methyl Ester	24.134	0.419	$C_7H_{14}OS$	146.2500
46	Cyclohexene, 3-cyclohexyl-	24.290	0.257	$C_{12}H_{20}$	164.2872
47	[1, 2, 4] Triazolo [1, 5-a] pyrimidine-6 –carboxylic acid, 4, 7-dihydro-7-imino-, ethyl ester	24.798	0.315	$C_{10}H_{12}N_4O_3S$	268.2900
48	Cheilanth-13(14)-enic Methyl Ester	24.852	0.273	$C_7H_{14}OS$	146.2500
49	14.alpha.-Cheilanth-12-enic Methyl Ester	24.944	0.562	$C_{19}H_{32}O_2$	292.5000
50	Ethyl 4, 4, 6, 6, 8, 8-hexa methyl-11-oxo-3, 5, 7, 9, 12-pentaoxa-4, 6, 8-trisil atetradecan-1-oate	25.041	0.499	$C_{18}H_{40}O_8Si_3$	468.7600
51	(1S,2S)-2-Isopropyl-1-phenylsulfanylmethylspiro[4.5]decan-6-one	25.160	0.899	$C_{15}H_{26}O$	222.3663
52	7-Morpholin-4-yl-1, 2, 3, 5, 8, 8a-hexa hydro-indolizine	25.203	0.418	$C_{25}H_{23}NO_3S$	417.5000
53	14.alpha.-Cheilanth-12-enic Methyl Ester	25.241	0.481	$C_{19}H_{32}O_2$	292.5000
54	2-Amino-4-(2-methyl propenyl)-pyrimidin-5-carboxylic acid	25.290	1.344	$C_6H_7N_3O_2$	153.1400
55	4-(2',6'-Dichlorophenyl methylene)- 1,2,3,4-tetra isoquinoline-1,3-dion	25.403	2.751	$C_{10}H_{13}NO_2$	179.2200
56	14.alpha.-Cheilanth-12-enic Methyl Ester	25.641	1.621	$C_{19}H_{32}O_2$	292.5000
57	Silicic acid, diethyl bis(trimethylsilyl) ester	25.754	1.440	$C_{10}H_{28}O_4Si_3$	296.5800
58	Ethyl 4, 4, 6, 6, 8, 8-hexamethyl -11-oxo-3, 5, 7, 9, 12-pentaoxa-4, 6, 8-trisil	25.846	1.128	$C_{18}H_{40}O_8Si_3$	468.7600
59	2-Myristynoyl-glycinamide	25.933	1.076	$C_{16}H_{28}N_2O_2$	280.4100
60	4-Dehydroxy-N-(4,5-methyl enedioxy- 2-nitrobenzyli dene)tyramine	26.078	2.025	$C_{16}H_{14}N_2O_4$	298.2900
61	5-(4-Chlorophenyl)-3-(3-phenylsydnon-4-yl)-1H-[1, 2, 4]triazole	26.165	0.415	$C_{19}H_{13}N_7O_5$	419.3600
62	(1S, 2S)-2-Isopropyl-1-phenylsulfanylmethylspiro [4.5]decan-6-one	26.219	2.244	$C_{11}H_{20}O$	168.2800
63	14.alpha.-Cheilanth-12-enic Methyl Ester	26.424	1.223	$C_{19}H_{32}O_2$	292.5000
64	Cheilanth-13(14)-enic Methyl Ester	26.554	1.028	$C_7H_{14}OS$	146.2500
65	Cyclopropane, 1,1'-ethenylidenebis	26.592	0.287	C_8H_{12}	108.1809
66	Cheilanth-13(14)-enic Methyl Ester	26.624	0.833	$C_7H_{14}OS$	146.2500
67	(1S,2S)-2-Isopropyl-1-phenylsulfanylmethylspiro [4.5]decan-6-one	26.710	0.879	$C_{15}H_{26}O$	222.3663
68	N-Formyl-calycinine	26.775	1.134	$C_{19}H_{17}NO_5$	339.3500
69	(-)-trans-Verbenol (4,6,6-tri methylbicyclo[3.1.1]hept-3-en-2-ol)	26.867	1.096	$C_{10}H_{16}O$	152.2334
70	14.alpha.-Cheilanth-12-enic Methyl Ester	26.991	0.460	$C_{19}H_{32}O_2$	292.5000
71	14.alpha.-Cheilanth-12-enic Methyl Ester	27.035	0.428	$C_{19}H_{32}O_2$	292.5000
72	3, 5-Dimethylbenzaldehyde thiocarbamoylhydrazone	27.110	0.993	$C_{10}H_{13}N_3S$	207.3000
73	2', 4'-Dimethyloxanilic acid N'-veratrylidenehydrazide	27.240	1.483	$C_{19}H_{21}N_3O_4$	355.3900
74	1-[1-(2-Fluorenyl)ethylidene] semic arbazide	27.396	0.646	$C_4H_9N_3O$	115.1300
75	2-Methoxy-1,3-bis (trimethylsilyl)benzene	27.477	0.483	$C_{13}H_{24}OSi_2$	252.5000
76	5, 6-Dimethoxy-3,4-dihydro-1H-quinolin-2-one	27.607	1.103	$C_{11}H_{13}NO_3$	207.2300
77	4-(2' 6'-Dichlorophenyl methylene)- 1, 2, 3, 4-tetraisoquinoline-1,3-dion	27.758	0.627	$C_{10}H_{13}NO_2$	179.2200
78	Silane, trimethyl [4-[1-[(trimethylsilyl)oxy]ethenyl-2, 2-d2] phenoxy]-	27.893	0.361	$C_{14}H_{222}D_2O_2Si_2$	282.5300
79	1,1'-bi(cyclohexan)-1'-en-2-one	28.045	0.266	$C_{12}H_{18}O$	178.2710
80	N-[(2, 3, 6-Trimethoxy-10-phenanthry l)methyl]propylamine	28.153	0.754	$C_7H_{19}NO_3Si$	193.3162
81	14.alpha.-Cheilanth-12-enic Methyl Ester	28.347	1.221	$C_{19}H_{32}O_2$	292.5000
82	14.alpha.-Cheilanth-12-enic Methyl Ester	28.531	0.418	$C_{19}H_{32}O_2$	292.5000
83	2-Propyn-1-amine, N-2-propynyl-	28.720	0.433	C_6H_7N	93.1265

Amongst the 52 nutraceutical constituents observed in M. *balbisiana*, Glycerin had the highest percentage concentration, with a value of 17.889 followed by gamma.-Terpinene; 14.alpha.-Cheilanth-12-enic methyl ester; 3-Isopropoxy-1, 1, 1, 5, 5, 5-hexamethyl-3-(trimethylsiloxy) trisiloxane (3aS, 4R, 11aS)-4-Methyl-; 2, 3, 3a, 4, 10, 11-hexahydrocyclopenta [d]-pyrido[1, 2-c] [1, 3]oxazin-6 (1H)-

one with percentage concentrations of 11.380, 6.001, 5.613, 3.965 and 3.836 respectively (table 3).

Table 3: Nutraceutical constituents in unripe matured fruits of *M. balbisiana*

S/N	Compound	Retention Time (min)	Percentage concentration	Molecular formula	Molecular weight
1	1-[(1E)-3-methylbuta-1,3-dienyl]-2-pyrrolidinone	3.244	1.112	$C_9H_{13}NO$	151.2100
2	Propene	3.444	1.847	C_3H_6	42.0800
3	Cyclopropane, 1-(1-methylethenyl)- 2-(2-methyl-1-propenyl)-, (1R-trans)-	3.773	1.722	$C_{10}H_{16}O_2$	168.2328
4	Glycerin	4.130	17.889	$C_3H_8O_3$	92.0938
5	2,6-Dimethyl-1,3,5,7-octatetraene, E,E-	4.351	1.291	$C_{10}H_{14}$	134.2182
6	.gamma.-Terpinene	4.405	11.380	$C_{10}H_{16}$	136.2300
7	6,7-Dioxabicyclo[3.2.2]nonane	4.902	1.147	$C_7H_{12}O_2$	128.1690
8	Oxirane, methyl-, (S)-	5.075	0.828	C_3H_6O	58.0791
9	Propane	5.416	2.438	C_3H_8	44.1000
10	Butyraldehyde, 4-(methylenecyclopropyl)-	6.501	0.966	$C_8H_{12}O$	124.1800
11	Cyclopropane, 1,1'-ethenylidenebis 12	6.685	0.757	C_8H_{12}	108.1809
12	2-Butyn-1-ol	6.917	1.522	C_4H_6O	70.0898
13	Ethyl(dimethyl)isopropoxysilane	7.290	0.363	$C_7H_{18}OSi$	146.3030
14	d-Glycero-d-ido-heptose	7.765	0.725	$C_7H_{14}O_7$	210.1800
15	2,5-Dihydroxy-3,6-dimethylhydroxy- 1,4-dioxane	7.830	1.549	$C_3H_4N_4O_2$	128.0905
16	3-chloranyl-4-methyl-pent-4-en-2-one	8.133	0.653	C_6H_9ClO	132.5900
17	2-(2'-Methyl-2'-butenyl)-4-methylfuran	8.306	0.387	$C_{10}H_{14}O$	150.2176
18	.+/-.-Tetrahydro-3-furanmethanol	8.435	0.471	$C_5H_{10}O_2$	102.1317
19	1,5,9-Cyclododecatriene, 3-[(phenylthio)methyl]-, (E,E,E)-	9.116	0.434	$C_{12}H_{18}$	162.2713
20	(-)-Elema-1,3,11(13)-trien-12-ol 25	9.327	0.491	$C_{15}H_{24}O$	220.3505
21	(1aR*,2S*,4aR*,7aS*)-4a-But-3'-ynyl-octahydro-2H-cyclopropa[d]inden-2-ol	9.689	0.729	$C_{14}H_{18}O$	202.2899
22	2,3,4-Trimethyl-5-(1'-methylallyl)cyclopentadiene	10.040	0.368	C_8H_{12}	108.1800
23	.beta.-Guaiene	10.369	0.578	$C_{15}H_{24}$	204.3511
24	Benzene, 1-methyl-4-(1-methylethenyl)-	10.434	0.602	$C_{10}H_{12}$	132.2023
25	(1R,5R)-2-Methyl-5-((R)-6-methylhept-5-en-2-yl) bicyclo[3.1.0]hex-2-ene	10.585	0.799	$C_{15}H_{24}$	204.3511
26	8-Methylene-7-methyl-1-oxaspiro[4. 4]non-3-en-2-one	10.747	0.657	$C_{10}H_{12}O_2$	164.2000
27	4-Isopropyl-1,6-dimethyl-1,2, 3,4-tetrahydronaphthalene	10.947	2.174	$C_{15}H_{22}O$	218.3346
28	1-Phenyl-5-(isopropylamino) -1H-tetrazole	11.763	0.510	$C_{15}H_{21}NO$	231.3300
29	Porninsal	11.898	0.442	$C_{32}H_{54}O_2$	470.7638
30	1,2,4-Metheno-1H-indene, octahydro-1,7a-dimethyl-5-(1-methylethyl)-, [1S-(1.alpha.,2.alpha.,3a. beta.,4.alpha.,5.alpha.,7a. beta.,8S*)]-	12.022	0.941	$C_{15}H_{24}$	204.3500
31	(1aR,4R,4aR,7aR,7bR)-1,1,4-trimethyl-7-methylene-2,3,4, 4a,5,6,7a,7b-octahydro-1aH-cyclopropa[e]azulene	12.444	1.295	$C_{15}H_{24}$	204.3500
32	aR-Turmerone	12.573	2.486	$C_{15}H_{20}O$	216.3200
33	benzenamine, N-(1-methyl-2-phenoxyethyl)-	12.978	0.516	$C_{10}H_{11}N$	145.2000
34	Hexadecanoic acid, methyl ester	15.253	1.629	$C_{17}H_{34}O_2$	270.4507
35	9,10-Anthracenediol, 1,4,4a, 5,8,8a,9,9a,10,10a-decahydro -2,3,6,7-tetramethyl-, mono (4-methylbenzenesulfonate), (4a.alpha., 8a.beta., 9.beta., 9a.beta., 10.alpha.,10a.alpha.)-	15.598	0.654	$C_{21}H_{15}NO_3$	329.3490
36	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	16.862	1.925	$C_{19}H_{34}O_2$	294.4721
37	Methyl 9,9-dideutero-octadecanoate	16.916	2.625	$C_{19}H_{362}D_2O_2$	300.5000
38	Methyl 14-methylheptadecanoate	17.149	0.387	$C_{19}H_{38}O_2$	298.5040
39	9-Octadecenoic acid (Z)-, methyl ester	17.262	1.619	$C_{19}H_{36}O_2$	296.4879
40	16-Pregnen-3,20-dione	20.747	0.548	$C_{21}H_{30}O_2$	314.5000
41	14.alpha.-Cheilanth-12-enic Methyl Ester	24.290	0.453	$C_{19}H_{32}O_2$	292.5000
42	2-(N-methylanilino)benzonitrile	24.512	0.827	$C_{14}H_{12}N_2$	208.2600
43	Isolongifolan-8-ol	25.252	3.836	$C_{15}H_{26}O$	222.3663
44	Cyclobarbital	25.284	1.058	$C_{12}H_{16}N_2O_3$	236.2700
45	1H-imidazole-2-methanol, 1-decyl-	25.592	1.806	$C_{14}H_{26}N_2O$	238.3700
46	(1aS, 4aS, 5S, 7aR, 7bR)-3, 3, 7b- hyl-5-methylol-1, 1a, 2, 4, 4a, 6, 7, 7a-octahydrocycloprop [e]azulen-5-ol	25.657	0.751	$C_{15}H_{26}O_2$	238.3700
47	Silicic acid, diethyl bis (trimethylsilyl) ester	25.711	0.831	$C_{10}H_{28}O_4Si_3$	296.5800
48	(1S,2S)-2-Isopropyl-1-phenylsulfanylmethyl spiro[4.5]decan-6-one	25.824	2.437	$C_{15}H_{26}O$	222.3663
49	Heptasiloxane, 1, 1, 3, 3, 5, 5, 7, 7, 9, 9, 11, 11, 13, 13-tetra decamethyl-	26.084	2.968	$C_{14}H_{44}O_6Si_7$	505.0941
50	3-Isopropoxy-1, 1, 1, 5, 5, 5-hexamethyl-3-(trimethyl siloxy)trisiloxane	26.694	5.613	$C_{12}H_{34}O_4Si_4$	354.7400
51	(3aS,4R,11aS)-4-Methyl- 2, 3, 3a, 4, 10, 11-hexahydro cyclopenta[d]-pyrido[1, 2-c] [1, 3] oxazin-6(1H)-one	27.240	3.965	$C_{12}H_{17}NO_2$	207.2700
52	14.alpha.-Cheilanth-12-enic Methyl Ester	28.893	6.001	$C_{19}H_{32}O_2$	292.5000

Discussion

Amongst the 97 nutraceutical constituents observed in dichloromethane extract of unripe fruit of *M. paradisiaca*, 1,4-Cyclohexadiene,1-methyl-4-(1-methylethyl)- was predominant. 1, 4-Cyclohexadiene,1-methyl-4-(1-methylethyl) (gamma-terpinene) is one of the three isomeric

monoterpenes, which exits naturally as volatile oil components in most plants. As a plant metabolite, 1,4-Cyclohexadiene,1-methyl-4-(1-methylethyl) plays a role as an analgesic and also as an orally active antioxidant compound, with direct scavenging potentials on free radicals (Sun *et al*., 2020) [28]. There are convincing evidence that administration of gamma-terpinene via oral route exert antinociception effect (Hajhashemi, 2010) [9]. Its administration through central (intracerebroventricular and intrathecal) and peripheral pathways also produces antinociception by the involvement of the opioid system through K^+ATP channels and also through the cholinergic system (Flávia, 2015) [7]. The high concentration of 1,4-Cyclohexadiene,1-methyl-4-(1-methylethyl) observed in this study indicates that the consumption of *M. paradisiaca* fruit may cause antinociception effect and also serve as both an analgesic and antioxidant if not metabolized or conjugated within the alimentary canal and intestinal absorption system respectively.

Ar-turmerone is the second most predominant bioactive compound in *M. paradiasica* fruit and also a major sesquiterpenes. Most sesquiterpenes act as allelopathy, thereby causing behavioral and developmental modifications to parasitic plants, insects and microbes by making them profitable to the sesquiterpenoid producing plant (Chadwick *et al*., 2013) [4]. They also reported the ability of some sesquiterpenoid lactones to disrupt the cell wall of fungi and invasive bacteria thereby serving as antimicrobial agents, while other sesquiterpenoid serves as protective agents to the plants against environmentally induced stress that could tantamount to oxidative damage (Chadwick *et al*., 2013) [4]. Ar-Turmerone has been reported to suppress the growth of cancer cells in a dose-dependent manner with half-maximal inhibitory concentration (IC50) ranging between 11.0 to 41.81 g/mL (Yue *et al*., 2010) [33]. It also induces neural stem cell proliferation in both *in-vitro* and *in-vivo* conditions (Hucklenbroich *et al*., 2014) [13]. The protective efficacy of curcumin against human intestinal epithelial colorectal adenocarcinoma Caco-2 cells, human colonic cancer cells (HCT-116 and HT-29) and human umbilical vein endothelial cells (HUVEC) are synergistically enhanced by both α-turmerones and ar-turmerones (Yue *et al*., 2010; Nair *et al*., 2019) [33, 18]. Aside its anti-cancer properties, ar-turmerone has also been reported to have a high in-vitro antioxidant property, which may be as a result of its ringed portion and a 13-unsaturated ketone portion (Baik *et al*., 1993; Jayaprakasha *et al*., 2002; Sacchetti *et al*., 2005; Liju *et al*., 2011) [3, 12, 24, 17]. Sohrabi *et al*., (2017) [26] also reported anti-inflammatory potential of ar-turmerone through its ability to attenuate microglial activation. A study by Liao *et al*., (2013) [16], revealed that oral administration of 2.5 - 5.0 mg/kg of turmerone improves the concentration of 5-hydroxytryptamine in the cortex, striatum, hippocampus, and hypothalamus. They also reported the ability of ar-turmerone to cause an elevation of norepinephrine in striatum and hippocampus, 4-hydroxy-3-methoxyphenylglycol and 3,4-dihydroxyphenylacetic acid in hypothalamus, the level of 5-hydroxyindole-3-acetic acid in striatum and the level of dopamine in striatum, hippocampus and hypothalamus, there by serving as a depression inhibition to the mice (Liao *et al*., 2013) [16]. Since an enhanced dopamine concentration remains promising in reducing symptoms of Parkinson disease (Liao *et al*., 2013) [16], it indicates that the consumption of *M. Paradisiaca* may also be prominent in managing Parkinson disease related conditions due to its high concentration of ar-turmerone.

Cyclohexane,1methylene-4-(1-methylethenyl) was also observed in high concentration in *M. Paradisiaca* fruit. It is also a sesquiterpene, but its synthesis occurs mainly as a response to both microbial and insect pest attack (Holopainen, 2004). Also called pseudolimonene, its main biological action is to serve as a protective compound to the plant by acting as a phytoalexins and an anti-herbivorous compound. Its aromatic smell also makes it an attractant to predators of plants insect pests (Holopainen, 2004) [10]. 6-Octadecenoic acid, methyl ester(Z)- (also called petroselinic acid) was also observed in high concentration in *M. paradisiaca* fruit. It is a monounsaturated positional isomer of oleic acid and has enjoyed wide application in cosmetic formulations as skin moisturizing and anti-aging agents. It also serves as a reducing agent in α-hydroxy acid induced skin-irritation (Alaluf *et al*., 2016). The presence of cedrene in *M. paradisiaca* fruit is to serve as a natural pest repellent, while also serving as an attractant to pollinators and other organisms that are beneficial to the plant. As a terpene, cedrene also serves as a natural anti-bacterial and anti-fungal agent, thereby protecting entire plant and its fruit from been infected by pathogenic organisms (Yu-Chang, 2012) [32]. Reports have also revealed some therapeutic relevance of cedrene, which include anti-inflammatory, anti-bacterial, anti-fungal, analgesic, anti-cancer and anti-tumor properties (Desai, *et al*., 2008) [6]. Cedrene also works as an astringent (e.g., for toothaches), in promoting digestion and alleviation of coughs (Zhang, 2017) [35].

Pinenes are well-known representatives of monoterpenes and are found in many plants' essential oils (Salehi, 2019) [2]. α - Pinene had the highest concentration amongst the 83 nutraceutical components observed in unriped matured fruits of *M. acuminata*. In plants, this compound is mainly responsible for the various odor profiles (Zebib, *et al*., 2015) [34]. It is highly bioavailable and readily absorbed via pulmonary uptake with immediate metabolism and redistribution in humans (Zebib, *et al*., 2015) [34]. Other therapeutic activities of α-Pinene, including antibiotic resistance modulation, anticoagulant, antitumor, antimicrobial, antimalarial, antioxidant, anti-inflammatory, anti-*Leishmania*, and analgesic effects (Salehi *et al*., 2019) [2]. Its anti-inflammatory response is mediated through PGE1 pathway (Salehi *et al.*, 2019) [2]. They also reported its role as an acetylcholinesterase inhibitor and positive modulator of GABAA receptors (Salehi *et al*., 2019) [2]. Its potential to inhibit acetylcholinesterase makes it vital in the reduction of memory deficits commonly reported as a side-effect of THC consumption (Salehi *et al.*, 2019) [2]. Acetylcholinesterase is an enzyme known to improve memory and increase alertness. Rufino *et al*., (2014) [23], also reported anti-inflammatory effects of α-pinene in human chondrocytes, which inhibits antiosteoarthritic activity.

α-Phellandrene also observed in high concentration in *M. acuminata* are synthesized in plants mainly as biopesticides larvicidal and insecticidal activity solely for plant protection, while its pleasing aromas makes it a major stake in fragrance production (Radice, 2022) [20]. *α*-Phellandrene has also shown some promising biological functions as antimicrobial and antitumoral agents, however, further investigations are required on its threshold values to distinguish the boundary between its beneficial and toxic effects (Radice, 2022) [20]. The high concentration of ar-Turmerone in *M. acuminata* (as also observed in *M. paradisiaca*) also indicates that *M.*

acuminata may also be of relevant in the treatment of cancer. As stated earlier, ar-Turmerones has the ability to suppress the growth of cancer cells in a dose-dependent manner (Yue *et al*., 2010) [33]. Methyl hexadecanoic acid, (also known as methyl palmitate or hexadecanoate methyl ester), is a fatty acid methyl ester (Aparna *et al*., 2012) [30]. The initiating steps of inflammation, entails the hydrolysis of ester bonds of membrane phospholipids by Phospholipase A (2) (Aparna *et al*., 2012) [30]. This enzymatic hydrolysis converts methyl hexadecanoic acid to n-hexadecanoic acid which subsequently acts as end product competitive inhibitor of phospholipase A (2), thereby inducing anti-inflammatory potentials. This validates the use of n-hexadecanoic acid and its esters in the treatment of rheumatoid arthritis.

Glycerin observed as the most predominant nutraceutical components in *M. balbisiana* is a sweet colorless and odorless liquid that is totally miscible with water but insoluble in oil. Its unique chemical property makes it prominent in the drug industry as an excellent vehicle for drug administration as it helps to maintain both moisture and smoothness of drugs (Van Rosendal *et al*., 2012) [29]. It also acts as a skin moisturizer, by forming a water layer on the skin surface, thereby preventing topical evaporation of water (Fluhr *et al*., 2008) [8]. In humans, Glycerin is widely used as a suppository to relieve occasional constipation and to clear the bowels before a rectal examination (Song, *et al*., 2008) [27]. It also works well as a laxative when administered rectally by enhancing the water retention ability of the intestines thereby causing the expansion of bowels and subsequent release of the blockage (Sardi *et al*., 2018) [25]. Gamma-Terpinene was also of high concentration in *M. balbisiana*. It is a major component of essential oils with strong antioxidant activity. γ-Terpinene has a particularly beguiling aromatic blend of lime and tropical sweetness that is frequently utilized in fragrances (Ramalho *et al*., 2015) [21]. Therapeutically, γ-Terpinene has enjoyed numerous benefits as antifungal compound (Waller *et al*., 2017) [31]. Its antioxidant properties have been reported to retard the progression of diabetes and Alzheimer's disease in humans (Conforti *et al*., 2014) [5]. As an anti-inflammatory compound, γ-terpinene has not only been reported to suppress inflammatory parameters like edema and pro-inflammatory cytokine release, it also retards cell migration to inflamed regions (Ramalho *et al*., 2015) [21].

Conclusion

The numerous therapeutic potentials of most predominant nutraceuticals observed in this study shows that the fruits of these *Musa* species hold promising curative potentials. The extraction and purification of these nutraceuticals may be prominent to the development of novel broad-spectrum pharmaceuticals for the treatment and management of various human ailments.

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