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The Potential Protective Roles of *Garcinia* Extract as an Antimicrobial and Anticancer Agent Against MCF-7 Breast Cancer, HCT Colon Cancer, and HepG2 Liver Cancer Cells

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Abstract

As the search for novel natural therapeutics intensifies, *Garcinia cambogia* (Gc) emerges as a powerhouse of phytochemical constituents, capable of inhibiting tumor growth. Thus, we aimed to evaluate the phytochemical screening and biological activity of the aqueous ethanolic extract of Gc fruit using HPLC, LC-MS, and GC-MS to identify natural phytochemical constituents. The antimicrobial activity of *Garcinia* fruit extract (GFE) was evaluated against methicillin-resistant *Staphylococcus aureus and Enterococcus faecalis as* Gram-positive bacteria, *Escherichia coli and Pseudomonas aeruginosa as* Gram-negative bacteria, *and Malassezia furfur and Candida albicans* as fungi. HPLC revealed that GFE contained 14 polyphenol compounds, the LC-MS revealed the presence of fifty-six compounds at the positive ionization mode and forty-seven compounds at the negative mode; however, thirty-six compounds were detected using GC-MS. GFE exhibited the strongest inhibitory effects against *E. faecalis*, with a minimum inhibitory concentration (MIC) of 15.36 mg/mL. Where the inhibition zone diameters were 24.7, 21.7, 21.7, 21.3, and 20.7 mm for *E. faecalis*, *S. aureus*, *P. aeruginosa*, *M. furfur*, and *E. coli*, respectively, at the concentration of 500 mg/mL of GFE. In contrast, GFE exhibited no antimicrobial activity against *Candida albicans*. Furthermore, *GFE* was screened against three cancer cell lines, including breast cancer (MCF-7), colon cancer (HCT-116), and liver cancer (HepG2), and demonstrated in vitro cytotoxic activity, with IC50 values of 31.7, 49.87, and 48.99 µg/mL for MCF-7, HCT-116, and HepG2, respectively. These findings indicate

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that GFE is a promising natural antimicrobial agent, while its in vitro cytotoxic activity warrants further investigation.

Keywords: *Garcinia* extract; phenolic compounds; antimicrobial; anticancer cancer

1. Introduction

The human diet includes phytochemicals' bioactive compounds, mainly from fruits and vegetables [1,2]. Phytochemicals are health-promoting bioactive compounds due to their well-known activity against bacteria, viruses, and fungi, as well as acting as anti-coagulants, anti-inflammatories, and lipid-lowering agents [3]. Cancer is the leading cause of death worldwide. Approximately 300 genes with abnormalities have been found in various human cancers [4]. The prevalence of death-related cancer is estimated to be one in eight persons globally [5]. Thus, there is an urgent need to develop therapeutic agents derived from natural products, as chemotherapeutics have drawbacks, including relapse and adverse effects [6].

There is a growing movement towards substituting chemically synthesized preservatives with natural ones. This trend is driven by the growing clean-label movement and consumer awareness of healthier eating and more sustainable foods. Using natural antimicrobials extracted from plants, microbes, and marine sources is advantageous because it is safer for humans and more eco-friendly, and it also offers potential antimicrobial activity. Due to market convergence, consumer demand, and regulatory requirements, food manufacturers are increasingly using natural antimicrobials [7]. Therefore, it is of great importance to extract, identify, and purify effective antimicrobial agents from natural origin [8].

Garcinia cambogia is an Asian fruit that belongs to the *Clusiaceae* family. It has been used in traditional medicine to treat gastrointestinal and rheumatic diseases, parasitic infections, and digestive disorders [9]. Hydroxycitric acid (HCA) is the primary bioactive compound in *Garcinia cambogia*, used to treat weight gain as it lowers appetite, enhances lipid oxidation, and regulates the endogenous lipid synthesis pathways [10]. Moreover, it is commonly used as a bulking agent in the food industry, a preservative compound, and a flavor-enhancing substance. Several organic acids, benzophenones, and xanthones have been identified as key phytochemicals in this plant [11].

Thus, this study aimed to evaluate the antimicrobial activity of the aqueous ethanolic extract of *Garcinia cambogia* fruit against two Gram-positive bacteria, two Gram-negative, and two fungal isolates. Additionally, the cytotoxic effects of GFE on breast cancer (MCF7), colon cancer (HCT), and liver cancer (HepG2) cell lines were also compared.

2. Materials and Methods

2.1. Materials

2.1.1. Dried *Garcinia* and Chemicals

Dried *Garcinia* fruits were purchased from a local herbal market in Cairo, Egypt. The chemicals and reagents utilized in this study were sourced from the suppliers: El-Gamhouria Chemicals and Drugs Co., Ltd. (Cairo, Egypt); Tokyo Chemical Industry Co., Ltd. (Kita-Ku, Tokyo, Japan); and Sigma-Aldrich Co., Ltd. (St. Louis, MO, USA).

2.1.2. Microorganisms and Cancer Cell Lines

Assessment of the antimicrobial efficacy of GFE against six microbes: two Gram-positive bacteria, *Staphylococcus aureus* (*S. aureus*) (ATCC 33591) and *Enterococcus*

faecalis (*E. faecalis*) (ATCC 29212); two Gram-negative bacteria, *Escherichia coli* (*E. coli*) (ATCC 43888) and *Pseudomonas aeruginosa* (*P. aeruginosa*) (ATCC 27853); and two fungal species, *Malassezia furfur* (*M. furfur*) (ATCC 12078) and *Candida albicans* (*C. albicans*) (NRRL-Y 477). The microbial strains used in this study were obtained from the Central Laboratory, Faculty of Science (Girls), Al-Azhar University (Cairo, Egypt). The breast cancer (MCF-7), colon cancer (HCT-116) and liver cancer (HepG2) cell lines were acquired from the National Cancer Institute, Cairo, Egypt (NCI, Cairo University, Giza, Egypt).

2.2. Methods

2.2.1. Preparation of *Garcinia* Fruit Extract (GFE)

100 g of *Garcinia* fruit was mixed with 200 mL ethanol 70% and incubated for 24 h at 25 °C and the process was repeated twice. The obtained suspension was filtered using Whitman filter paper No. 4, and the filtrate was concentrated using a rotary evaporator at 35 °C before being dissolved in 30 mL distilled water.

2.2.2. High-Performance Liquid Chromatography (HPLC)

An Agilent 1260 HPLC was employed for qualitative and quantitative analysis of phytochemical constituents in GFE. The analysis was performed using HPLC on a Zorbax Eclipse Plus C_{18} column (250 mm × 4.6 mm, 5 µm) (Agilent Technologies, Santa Clara, CA, USA). The mobile phases A (water) and B (0.05% trifluoroacetic acid in acetonitrile) were used in a gradient: 0 min (82% A); 0–1 min (82% A); 1–11 min (75% A); 11–18 min (60% A); 18–22 min (82% A); 22–24 min (82% A) at 0.9 mL/min flow rate. The multi-wavelength detector was monitored at 280 nm. Subsequently, 5 µL of each sample was injected, and the column temperature was set at 40 °C [12]. Additionally, Caffeic acid, (+)-Catechin, p-Coumaric acid, Chlorogenic acid, Rosmarinic acid, Quercetin, syringic acid, ellagic acid, vanillin, naringenin, Gallic acid, Rutin, Apigenin, and Kaempferol were used as standards to identify and quantify the phenolic compounds in the GFE. Quantification was performed using an external analytical service provider where calibration curves, LOD, and LOQ were pre-established according to the standard operating procedures of the analytical facility.

2.2.3. Liquid Chromatography–Mass Spectrometry Analysis (LC-ESI-MS/MS)

The phytochemical constituents were identified using LC-ESI-MS/MS with an ExionLC AC system, and SCIEX Triple Quad 5500+ MS/MS system (Waters Corporation Co., Milford, MA, USA), equipped ESI for the separation and detection, respectively. MS-DIAL software "version 4.9" was used to identify the tentatively identified compounds with ReSpect library. Chromatographic separation was conducted on an Ascentis® Express 90 Å C_{18} (150 mm × 2.1 mm, 2.7 µm) column (Sigma-Aldrich, Burlington, MA, USA). The mobile phases consisted of 5 mM ammonium formate (A) and acetonitrile (B) at 0.3 mL/min flow rate. Subsequently, 5 µL of each sample was injected. For MS/MS analysis, the parameters were used while applying the negative ionization mode with a scan with EMS-IDA-EPI was as follows: for MS1 (from 100 to 1000 Da) curtain gas, 25 psi; Ion Spray voltage, 5500; source temperature, 500 °C; and for MS2 (from 50 to 1000 Da) ion source gas 1 and 2, 45 psi; declustering potential, 80V; collision energy, 35.

2.2.4. Gas Chromatography–Mass Spectrometry Analysis (GC-MS)

The sample was prepared by acidification with HCl, then extracted with diethyl ether and ethyl acetate, and evaporated at 40 °C under vacuum. Before GC analysis, the sample was reconstituted in 50 µL of bis (trimethylsilyl) trifluoroacetamide (BSTFA) + trimethylchloro-silane (TMCS) 99:1 silylation reagent and 50 µL of pyridine to derivatize

the sample's functional groups to trimethylsilyl groups (TMS). Analyses were carried out using a gas chromatograph (7890B) and an MS detector (5977A). The GC was equipped with a DB-5MS column (30 m × 0.25 mm × 0.25 μm). Hydrogen was used as the carrier gas at a 1.0 mL/min flow rate, 1 μL of the solution was injected and the temperature program was as follows: 60 °C for 1 min; rising at 10 °C /min to 320 °C held for 10 min. The injector and detector were held at 300 °C and 320 °C. Using a spectral range of *m*/*z* 50–800 and a solvent delay of 3.9 min, mass spectra were obtained by electron ionization (EI) at 70 eV. The mass temperature was 230 °C and Quad 150 °C. The spectrum fragmentation pattern was compared to the data from the NIST Mass Spectral Library and Wiley, Davies NW. 1990, to identify the various constituents.

2.2.5. Antimicrobial Activity of GFE

The antimicrobial activity of GFE was evaluated using the agar well diffusion method, with slight modifications. The extract was dissolved in sterile distilled water to prepare solutions at final concentrations of 500, 250, and 125 mg/mL. The tested bacterial strains were cultured in Nutrient broth and incubated for 24 h, while the fungi were cultured in Sabouraud dextrose broth and incubated for 48 h. The inoculum suspensions were adjusted by 0.5 McFarland standards. to achieve a final working inoculum concentration of 5 × 105 CFU/mL in strict accordance with CLSI guidelines [13,14]. Then, the inoculum suspensions were spread over the surface of MHA plates for bacterial strains and SDA for fungal strains and the plates were left for 3–5 min to enable the absorption of additional moisture present on their surfaces. A sterile cork borer (6.0 mm) was used to make holes in the inoculated agar plates. 100 μL of the three varying concentrations of GFE were placed into the holes. Levofloxacin and ketoconazole discs were used as positive controls for bacterial and fungal isolates, respectively. After the incubation period of 24 h for bacterial species and 48 h for fungal species, the inhibition zones were measured in mm.

Determination of Minimum Inhibitory Concentration (MIC) of GFE

The minimum inhibitory concentration (MIC) of GFE was assessed by the broth microdilution method using sterile polystyrene 96-well plates [15]. A volume of 200 μL of autoclaved Mueller-Hinton broth for bacterial strains and Sabraud dextrose broth for fungal strains supplemented with different concentrations of GFE (500–0.24 mg/mL) was added to each well. Finally, 5 μL of the adjusted spore was added. The plates were incubated at 37 °C for 24 h and 48 h for bacterial and fungal species, respectively. MIC was defined as the lowest concentration of the extract at which the microbes showed no visible growth.

Determination of the Minimum Bactericidal Concentration (MBC) and the Minimum Fungicidal Concentration (MFC) of GFE

The broth microdilution assay was performed, and MBC and MFC were determined by subculturing 100 μL from wells at or above the MIC onto TSA plates, which were then incubated for 48 h at 37 °C. The concentration at which no microbial growth occurs post-incubation is considered the MBC for bacterial species and the MFC for fungal species. The MBC and MFC were defined as the minimum concentrations of GFE required to kill more than 99.99% of the microbes present. Three replicates were performed for each organism [16].

2.2.6. Cytotoxicity Assay of GFE

The Cytotoxicity assay of GFE was performed on MCF-7 breast cancer, HCT colon cancer, and HepG2 liver cancer cell lines. DMEM medium supplemented with streptomycin (100 mg/mL), penicillin (100 units/mL), and heat-inactivated fetal bovine serum (10%) was used to keep the cells at 37 °C in a humidified atmosphere with 5% CO_2 (*v*/*v*).

For the Sulforhodamine B (SRB) assay, 100 µL of aliquot suspension containing (5×10^3) cells was seeded into 96-well plates before being incubated in complete media for 24 h. Subsequently, the cells were treated with an additional 100 µL aliquot of medium containing various concentrations of GFE. Following exposure, 150 µL of 10% trichloroacetic acid (TCA) was added to the medium to fix the cells, and the cells were then incubated for an hour at 4 °C. The TCA solution was removed, and the cells were washed with distilled water in five rounds. Thereafter, 70 µL of 0.4% SRB solution (*w*/*v*) was added, and the mixture was incubated in the dark at 25 °C for 10 min. Following three washes with 1% acetic acid, the plates were left to air-dry overnight. Then, 150 µL of 10 mM Tris base was added. Finally, the absorbance was detected at 540 nm**.** The IC_{50} values of the samples were calculated by plotting log concentration vs. percentage cell survival and analysed using GraphPad Prism version 8.0.

2.2.7. Statistical Analysis

The experiments were performed at least three times, and values are measured as mean ± standard deviation (SD). The data were analyzed using one-way ANOVA.

3. Results and Discussions

3.1. Determination of Polyphenol Compounds in Garcinia Fruit Extracts Using HPLC

HPLC analysis identified and quantified various phenolic compounds in *Garcinia* fruit extract (GFE), as shown in Table 1. The chromatograms of the standard phenolic compounds (A) and the detected compounds in the GFE (B) are shown in Figure 1. Here, the fractionation of the GFE identified a total of 18 phenolic compounds and flavonoids. The major characterized compounds were chlorogenic acid, gallic acid, and catechin, which were found at concentrations of 17210.22, 1019.24 and 372.74 µg/g of GFE, respectively. In addition, the GFE also contained other compounds such as, caffeic acid, syringic acid, ellagic acid, vanillin, naringenin, rosmarinic acid, quercetin, and kaempferol at lower concentrations of 17.33, 63.03, 27.48, 22.04, 27.60, 26.02, 17.92, and 26.49 µg/g GFE, respectively.

Among the characterized compounds, chlorogenic acid, the most abundant compound detected in the GFE, is a phenolic compound reported in various sources, including tea leaves, coffee beans, berry fruits, citrus fruits, and grapes [17]. It has many therapeutic benefits, especially those connected to age-related disorders and chronic metabolic diseases. Furthermore, it exhibits a variety of multifaceted properties, including anti-inflammatory, antioxidant, antidiabetic, hepatoprotective, neuroprotective, and anticancer activities [18–21]. At the molecular level, its integrative functions work mechanistically by regulating metabolic homeostasis and anti-inflammatory/oxidation processes. It can inhibit inflammatory components at several levels, including by reducing NF-κB pathways to counteract pro-inflammatory factors, preventing the spread of inflammation, and reducing tissue damage. Moreover, chlorogenic acid simultaneously increases levels of essential antioxidants and scavenges excess cellular free radicals. To preserve and restore the metabolic equilibrium between lipids and glucose, it activates AMPK pathways. Beyond its metabolic effects, chlorogenic acid targets ion channels and neuroreceptors, demonstrating neuromodulatory effects [22].

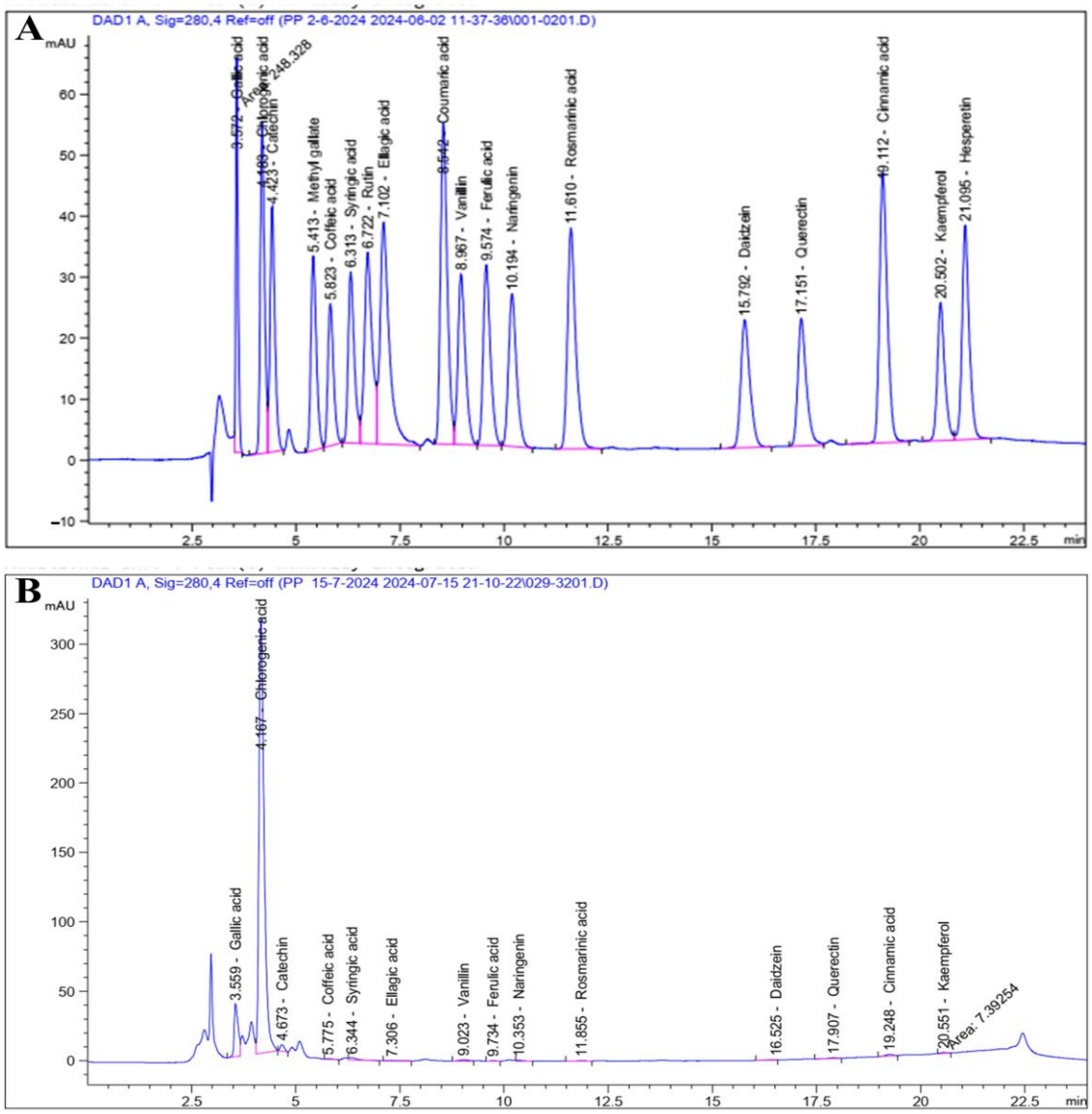


Figure 1. HPLC chromatogram of standard phenolic compounds and phenolic compounds identified in *Garcinia* fruit extract.

Table 1. Phenolic compounds identified in *Garcinia* fruit extract (GFE) using HPLC.

Identified Compounds	Conc. (µg/g)
Gallic acid	1019.24
Chlorogenic acid	17,210.22
Catechin	372.74
Caffeic acid	17.33
Syringic acid	63.03
Ellagic acid	27.48
Vanillin	22.04
Ferulic acid	4.80
Naringenin	27.60
Rosmarinic acid	26.02
Daidzein	8.40
Quercetin	17.92
Cinnamic acid	12.06
Kaempferol	26.49

Gallic acid is the second most abundant phenolic compound found in the GFE. It is a widely distributed plant phenolic acid, abundant in fruits, tea, and many medicinal plants, and is recognized as a key bioactive constituent with pharmacological properties. Gallic acid has three phenolic hydroxyl groups, which efficiently scavenge reactive oxygen species, inhibit lipid peroxidation, chelate metal ions, and up-regulate endogenous antioxidant defenses. It is also reported to exhibit a wide range of biological and pharmacological properties, such as antimicrobial, anti-inflammatory, and anticancer activities, as well as effects on gastrointestinal and cardiovascular diseases [23].

The third bioactive compound detected in GFE is catechin. The beneficial properties of catechins against microbes, viruses, inflammation, allergy, and cancer development are well documented. Catechins enhance the effectiveness of healthy functional meals and biocosmetics by increasing their absorption and penetration into the body and skin. Additionally, several in vitro and in vivo studies have reported the antioxidant effects of catechins [24]. Findings in the current study are broadly in line with a previous study by Rana and colleagues (2023) reported that the major phenolic compounds in *Garcinia gummi gutta* using HPLC were quercetin (251.44 µg/gm), chlorogenic acid (6.517 µg/gm), rutin (637.78 µg/gm), gallic acid (2.114 µg/gm), fumaric acid (0.363 µg/gm), HB acid (3.515 µg/gm), benzoic acid (57.53 µg/gm), coumaric acid (505.91 µg/gm), and kaempferol (17.03 µg/gm) [25].

3.2. Analysis of Garcinia Fruit Extract (GFE) Using LC-MS

The LC-MS data showed that the GFE comprises numerous phytocompounds, including flavonoids, phenolics, amino acids and derivatives, glycosides, organic acids, and alkaloids, in correspondence with previous reports [26,27]. The analysis revealed the presence of 56 tentatively annotated metabolites in positive ionization mode across many chemical classes. The identified compounds are listed in Table 2 and Figure 2, along with their retention times, mass-to-charge ratios (*m*/*z*), metabolite names, peak heights, and peak areas. These metabolites belonging to eleven different classes: flavonoids and phenolic compounds (11 metabolites), carbohydrates and glycosides (10 metabolites), nucleic acid derivatives (9 metabolites), vitamins and cofactors (6 metabolites), amino acids and derivatives (7 metabolites), lipids (3 metabolites), alkaloids (4 metabolites), carboxylic acids (2 metabolites), organic acids (2 metabolites), peptides (1 metabolite), and phosphorus-containing compounds (1 metabolite).

One of the top available components in the GFE is harmaline, with a remarkably high peak area of 5.26×10^8 at *m*/*z* 214.9715. Harmaline is an alkaloid extensively investigated for its beneficial roles, such as antimicrobial activity against various pathogenic microorganisms, like *Escherichia coli*, *Staphylococcus aureus*, *Xanthomonas oryzae*, *Pectobacterium atroseptica*, *and Xanthomonas axonopodis*, and suppresses fibrosarcoma, breast cancer, myeloma, esophageal squamous cell carcinoma, hepatocellular carcinoma, and hepatic carcinoma [28–30]. Similarly, myricetin (1.41×10^8) with *m*/*z* 318.9057, is a flavonoid that acts as an antioxidant, antimicrobial, and anti-inflammatory compound [31].

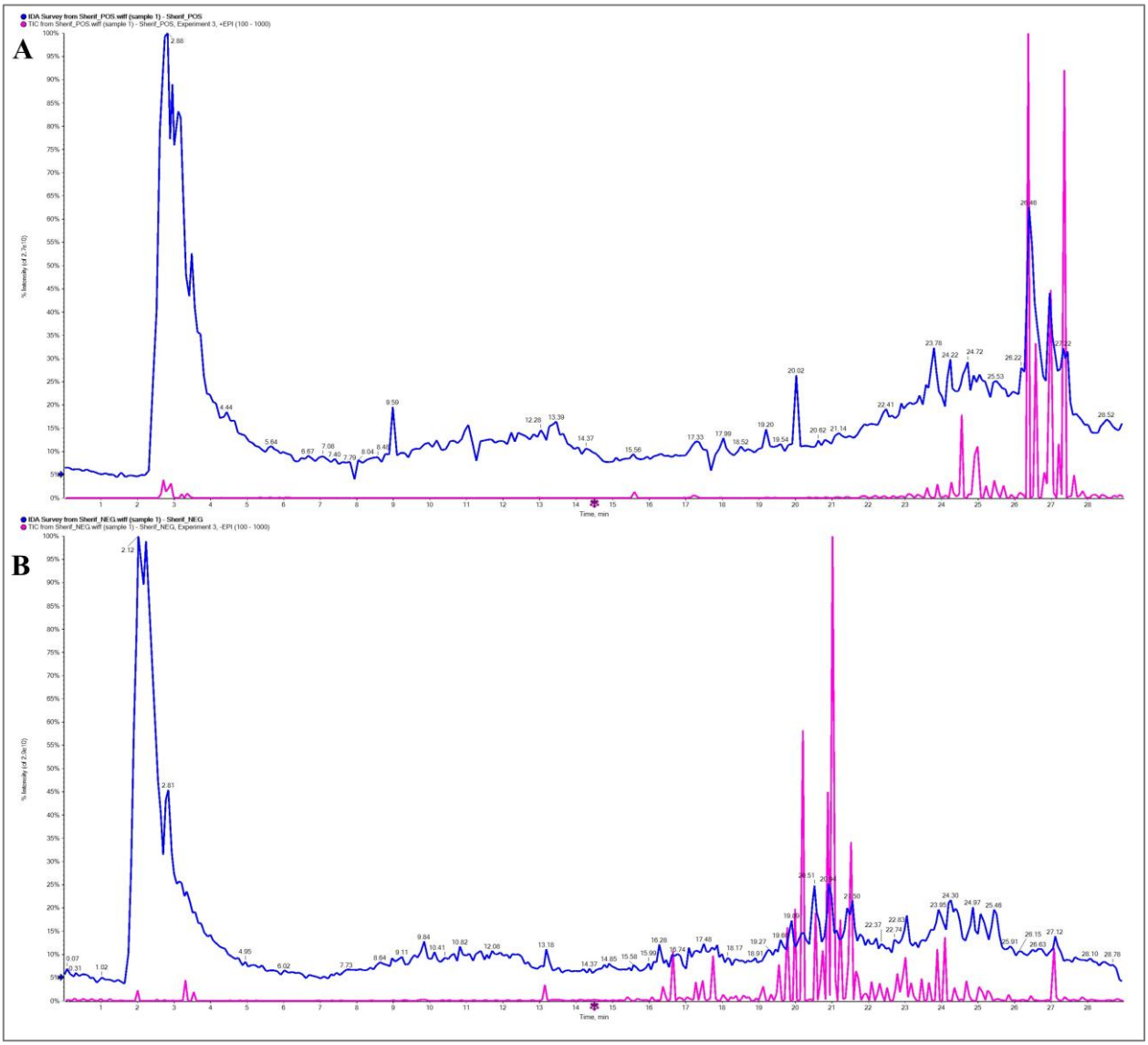


Figure 2. LS-MS positive and negative chromatograms of *Garcinia* fruit extract.

Table 2. LC-MS data (Positive ionization mode) for compounds detected in *Garcinia* fruit extract.

ID	RT (min)	*m/z*	Type	Metabolite Name	Peak Area
Flavonoids and Phenolic Compounds					
1	2.42255	182.969	$[M+H]^+$	Syringaldehyde *	1.06×10^8
2	2.5217	305.1527	$[M+H]^+$	(±)-Taxifolin *	4.52×10^7
3	3.179333	317.189	$[M+H]^+$	3 3′ 4′ 5-Tetrahydroxy-7-methoxyflavone *	7.61×10^7
4	3.244967	318.9057	$[M+H]^+$	Myricetin *	1.41×10^8
5	3.3274	421.1833	$[M+H\ H_2O]^+$	E-4,5′-Dihydroxy-3-methoxy-3′-glucopyranosylstilbene *	1.92×10^8
6	4.544734	316.9799	$[M+H]^+$	Petunidin *	4.01×10^8
7	10.0698	218.9482	$[M+H]^+$	7-Acetoxy-4-Methylcoumarin	2.25×10^8
8	11.57553	355.2085	$[M+H]^+$	Chlorogenic acid *	1.79×10^8
9	15.3615	138.9731	$[M+H]^+$	p-Hydroxybenzoic acid *	9.70×10^7
10	21.96215	407.1805	$[M+H]^+$	E-3,4,5′-Trihydroxy-3′-glucopyranosylstilbene *	3.22×10^8
11	26.61208	655.3389	$[M+2H]^{2+}$	Malvidin-3, 5-di-*O*-glucoside chloride *	9.31×10^7
12	1.434017	117.9637	$[M+H]^+$	Indole	3.63×10^7
13	2.307083	128.1759	$[M+H]^+$	Isoguvacine *	2.49×10^7

14	3.1134	214.9715	$[M+H]^+$	Harmaline *	5.26×10^8
15	11.27063	168.0366	$[M+H]^+$	Phenylephrine	49800000
16	0.715583	160.9319	$[M+H]^+$	L-beta-homoglutamine-HCl	1.2×10^8
17	2.610167	104.1846	$[M+H]^+$	N,N-Dimethylglycine	1.06×10^9
18	3.56755	190.9527	$[M+H]^+$	DL-alpha,epsilon-Diaminopimelic acid *	1.07×10^9
19	11.89153	399.1938	$[M+H]^+$	S-Adenosyl-L-methionine *	1.92×10^8
20	14.44653	176.9423	$[M+H]^+$	N-Carbamoyl-L-Aspartic acid *	4.25×10^7
21	15.00652	197.9745	$[M+H]^+$	3,4-Dihydroxy-L-Phenylalanine *	1.15×10^8
22	17.0915	175.1185	$[M+H]^+$	L-Arginine *	4.66×10^7
23	1.764783	135.9697	$[M+H]^+$	Adenine	7.05×10^7
24	2.610167	365.1231	$[M+2H]^{2+}$	Xanthosine-5′-monophosphate *	1.66×10^8
25	3.484117	335.1716	$[M+H]^+$	Beta-nicotinamide mononucleotide *	4.95×10^8
26	5.497617	126.9683	$[M+H]^+$	Thymine	3.03×10^8
27	6.5826	346.0137	$[M+H]^+$	Guanosine-3′,5′-cyclic monophosphate *	7.03×10^8
28	9.195833	243.9686	$[M+H]^+$	Cytidine *	1.22×10^8
29	9.955883	388.1477	$[M+H]^+$	2′-Deoxycytidine-5′-diphosphate *	2.20×10^8
30	13.65185	428.927	$[M+H]^+$	Inosine-5′-diphosphate *	8.02×10^7
31	17.0915	228.0939	$[M+H]^+$	2′-Deoxycytidine *	1.28×10^8
32	2.42255	244.9476	$[M+H]^+$	Alpha-L-(-)-Fucose 1-phosphate bis(cyclohexylammonium) salt	2.01×10^8
33	2.42255	244.9476	$[M+H]^+$	Alpha-L-(-)-Fucose 1-phosphate bis(Cyclohexylammonium) salt *	2.01×10^8
34	2.954317	230.8959	$[M+H]^+$	D-Ribose 5-phosphate *	1.02×10^9
35	9.955883	259.9049	$[M+H]^+$	D-Glucosamine-6-phosphate *	9.31×10^7
36	12.83758	606.1862	$[M+H]^+$	Guanosine 5′-diphosphate-d-mannose *	8.93×10^7
37	13.55442	437.2325	$[M+H]^+$	Phlorizin *	8.97×10^7
38	13.94435	341.2173	$[M+H]^+$	Esculin *	4.79×10^7
39	16.52398	342.9745	$[M+H]^+$	D-(+)-Maltose *	3.69×10^7
40	18.02895	387.1043	$[M+H]^+$	1-*O*-B-D-Glucopyranosyl sinapate	1.65×10^8
41	27.44507	625.2605	$[M+2H]^{2+}$	Isorhamnetin-3-*O*-rutinoside *	1.83×10^8
42	3.244967	393.2001	$[M+H]^+$	Sodium deoxycholate *	3.24×10^8
43	9.844283	172.9624	$[M+H]^+$	Glycerophosphate (2) *	1.91×10^8
44	19.08603	302.2093	$[M+H]^+$	Dihydrosphingosine *	7.05×10^7
45	2.8242	377.2352	$[M+H]^+$	(-)-Riboflavin *	3.85×10^8
46	10.5524	170.0472	$[M+H]^+$	Pyridoxine *	8.11×10^7
47	10.66313	265.9861	$[M+H]^+$	Thiamine *	8.62×10^7
48	13.35835	768.127	$[M+NH_4]^+$	Coenzyme A *	9.29×10^7
49	21.88877	666.2419	$[M+H]^+$	NADH *	1.03×10^8
50	28.00722	411.4659	$[M+H]^+$	Gamma-tocotrienol *	4.29×10^7
51	2.610167	203.0061	$[M+H]^+$	Sebacate *	9.88×10^8
52	4.544734	185.0176	$[M+H]^+$	3,4-Dihydroxymandelate *	3.68×10^8
53	4.069133	109.0126	$[M+H]^+$	1,4-Benzoquinone	1.78×10^9
54	28.67488	114.0843	$[M+H]^+$	Creatinine	1.71×10^8
55	22.15912	427.2719	$[M+H]^+$	Leupeptin hemisulfate salt *	1.61×10^8
56	13.03333	206.9637	$[M+H]^+$	Etidronate *	1.20×10^8

* Tentatively annotated metabolites.

Another detectable component with a high peak area (3.85×10^8) and *m*/*z* 377.2352 is Riboflavin, vitamin B2, which has been shown to be effective in chemotherapy while avoiding its toxic side effects [32]. Remarkably, a key polyphenol metabolite, chlorogenic

acid, was detected at (1.79 × 10^8) with *m*/*z* 355.2085. It has been shown to possess potential antimicrobial and anticancer effects in the Caco-2 cell line [32–34].

Malvidin 3,5-di-O-glucoside was identified at 9.31 × 10^7 with *m*/*z* 655.3389 and has been shown to protect against infection with *Helicobacter pylori* and safeguard against cardiovascular disease, type 2 diabetes, metabolic disorders, and oral cancer [35]. Additionally, the extract's therapeutic potential may be due to the presence of petunidin (4.01 × 10^8) observed at *m*/*z* 316.9799, an anthocyanin with well-known antioxidant and anticancer properties [36].

The compounds extracted from *Garcinia* identified by LC-MS in negative ionization mode are displayed in Table 3 and Figure 2. The analysis identified forty-seven tentatively annotated metabolites in the extract categorized into the following groups: flavonoids and phenolic compounds, carboxylic acids, nucleic acid derivatives, lipids, carbohydrates and derivatives, amino acids and derivatives, terpenoids, peptides, purine derivatives, and miscellaneous. Phenolic compounds, such as chlorogenic acid, *p*-hydroxybenzoic acid, salicylic acid, and 3-(4-Hydroxy-3-methoxyphenyl) prop-2-enoic acid, exhibited the deprotonated molecule $[M-H]^-$ at *m*/*z* 353.0125, 137.0449, 136.9373, and 193.087, respectively. Studies have shown that plant phenolic compounds exhibit potential anticancer activity and broad-spectrum antibacterial properties [1,37].

Table 3. LC-MS data (Negative ionization mode) for compounds detected in *Garcinia* fruit extract.

ID	RT (min)	*m*/*z*	Type	Metabolite Name	Peak Height	Peak Area
				Flavonoids and Phenolic Compounds		
1	0.54425	109.1627	$[M-H]^-$	1,2-Benzenediol	1,667,813	2.71 × 10^7
2	0.54425	353.0125	$[M-H]^-$	Chlorogenic acid	12,50,000	3.50 × 10^7
3	1.54715	137.0449	$[M-H]^-$	*p*-Hydroxybenzoic acid	8,408,711	1.96 × 10^8
4	3.9198	286.9522	$[M-H]^-$	3′ 4′ 5 7-Tetrahydroxyflavanone *	5,449,360	1.40 × 10^8
5	4.245667	163.2066	$[M-H]^-$	Hinokitiol *	4,021,228	1.71 × 10^8
6	6.3391	207.0536	$[M-H]^-$	Sinapyl aldehyde *	8,232,345	3.16 × 10^8
7	11.92887	193.087	$[M-H]^-$	3-(4-Hydroxy-3-methoxyphenyl) prop-2-enoicacid *	4,348,874	1.01 × 10^8
8	12.421	285.1505	$[M-H]^-$	Luteolin *	2,775,804	5.04 × 10^7
9	16.27673	253.0544	$[M-H]^-$	Daidzein	5,185,810	7.91 × 10^7
10	22.91063	653.3021	$[M-H]^-$	Malvidin-3, 5-di-o-glucoside chloride *	6,271,499	1.27 × 10^8
11	23.9953	609.043	$[M-2H]^-$	Delphinidin-3-O-(6″-O-alpha-rhamnopyranosyl-beta-glucopyranoside)	771,142.6	1.26 × 10^7
12	24.44005	267.1546	$[M-H]^-$	Formononetin	2,751,173	4.27 × 10^7
13	24.64995	136.9373	$[M-H]^-$	Salicylic acid	5,180,722	1.30 × 10^8
14	26.64462	269.1835	$[M-H]^-$	Apigenin	3,589,086	5.86 × 10^7
15	27.81547	138.0394	$[M-H]^-$	Para nitro phenol	2,387,897	5.49 × 10^7
				Carboxylic Acids		
16	1.898733	145.131	$[M-H]^-$	2-Methylglutaric acid *	2,221,483	2.06 × 10^7
17	2.0916	132.8535	$[M-H]^-$	D-(+)-Malic acid *	1.48 × 10^7	1.67 × 10^8
18	2.635367	100.8704	$[M-H]^-$	2-Oxobutyric acid	2,356,581	1.99 × 10^7
19	13.9637	191.1569	$[M-H2O-H]^-$	Citrate *	1,698,884	6.29 × 10^7
20	14.0541	173.054	$[M-H]^-$	(-)-Shikimic acid *	7,979,362	2.95 × 10^8
21	23.36137	116.9321	$[M-H]^-$	Succinic acid *	1.32 × 10^7	4.93 × 10^8
22	23.78573	117.1628	$[M-H2O-H]^-$	3-Hydroxyisovaleric acid *	1.25 × 10^7	2.53 × 10^8
23	25.29147	117.05	$[M-H]^-$	D-Alpha-hydroxyisovaleric acid *	1.68 × 10^7	2.67 × 10^8
24	26.74392	116.9473	$[M-H]^-$	Methylmalonic acid *	2.53 × 10^7	6.64 × 10^8
				Lipids		

25	13.9637	209.1586	$[M-H]^-$	(±)-Jasmonic acid *	4,972,069	1.52×10^8
26	14.29797	535.3734	$[M-H]^-$	1,2-Dilauroyl-sn-glycero-3-phosphate *	958,406.3	2.01×10^7
27	14.44762	170.9469	$[M-H]^-$	Glycerophosphate (2) *	3,888,621	6.75×10^7
28	21.9901	277.1923	$[M-H]^-$	Gamma-linolenic acid	1.30×10^7	1.78×10^8
				Nucleic Acid Derivatives		
29	2.166367	321.1666	$[M-H]^-$	Thymidine-5′-monophosphate *	6,440,993	7.09×10^7
30	3.138683	111.0011	$[M-H]^-$	Uracil	4,252,342	1.24×10^8
31	3.430983	480.9848	$[M-H]^-$	Thymidine-5′-triphosphate sodium salt *	604,511	6,860,695
32	11.3949	242.1778	$[M-H]^-$	Cytidine *	2,482,549	4.32×10^7
33	17.08492	606.1583	$[M-H]^-$	Uridine 5′-diphospho-n-acetylglucosamine	1,432,130	2.28×10^7
34	22.13442	227.2301	$[M-H]^-$	2′-Deoxyuridine	7,630,809	1.18×10^8
35	23.78573	241.2349	$[M-H]^-$	Thymidine	5,804,076	8.48×10^7
36	24.25535	267.2068	$[M-H]^-$	Inosine	3,119,752	5.53×10^7
37	26.18513	604.2341	$[M-H]^-$	Guanosine-5′-diphosphoglucose sodium salt *	733,015.7	6727890
				Amino Acids and Derivatives		
38	1.898733	189.1317	$[M-H]^-$	Dl-Alpha, epsilon-diaminopimelic acid*	2.73×10^7	3.35×10^8
39	2.842583	217.203	$[M-H]^-$	L-Beta-homotryptophan-HCL*	5.22×10^7	9.67×10^8
				Peptides		
40	11.6173	171.0661	$[M-H]^-$	Glycyl-l-proline	3.22×10^7	5.33×10^8
				Terpenoids		
41	4.317467	263.0352	$[M-H]^-$	(±)-Cis, Trans-Abscisic acid *	3,969,537	9.12×10^7
42	23.78573	135.1124	$[M-H]^-$	Gamma-terpinene	8,354,649	1.48×10^8
				Carbohydrates and Derivatives		
43	2.701417	198.9707	$[M-H]^-$	D-Erythrose-4-phosphate sodium salt *	625,440.1	5251235
44	8.909233	168.9438	$[M-H]^-$	Dl-Glyceraldehyde 3-phosphate *	3,908,919	1.05×10^8
45	16.466	170.936	[M-H]-	Glycerol-2-phosphate *	2,376,994	3.75×10^7
				Purine Derivatives		
46	10.82132	195.1249	$[M-H]^-$	1,3-Dimethylurate *	3,250,968	6.71×10^7
				Miscellaneous		
47	6.693717	163.0177	$[M-H]^-$	Methyl 5-chloro-5-oxovalerate	2,125,757	5.54×10^7

* Tentatively annotated metabolites.

The highly abundant carboxylic acids detected were methylmalonic acid, succinic acid, (-)-shikimic acid, and D-alpha-hydroxy isovaleric acid, presented the deprotonated molecule $[M–H]^-$ at *m*/*z* 116.9473, 116.9321, 173.054, and 117.05, respectively. In particular, succinic acid has been shown to exhibit antibacterial activity by damaging the cell membranes of *S. aureus and P. fluorescens* [38]. Another detected metabolite was gamma-terpinene at *m*/*z* 135.1124, a monoterpene existing in several pharmacologically active plants, which has been reported to have antibacterial activity and inhibit breast cancer [39]. These findings highlight that the *Garcinia* extract is abundant in phenolics, flavonoids, and other phytochemical constituents. Therefore, the significant existence of these phytochemical constituents in GFE endows it with promising antimicrobial and anticancer applications. This is because various phytochemicals work synergistically, producing effects greater than the sum of their individual effects, thereby strengthening the extract's therapeutic potential while reducing the likelihood of resistance.

3.3. Bioactive Analyses of *Garcinia* Fruit Extract Using GC-MS

The GFE was analyzed using GC-MS to identify phytochemical constituents. The active compounds, along with their retention times (RT), concentrations (peak area %), and molecular formulas, are displayed in Table 4 and Figure 3, which show the presence of 34 phytochemical constituents in the GFE. The GC-MS analysis revealed the presence of several distinct phytochemical classes, primarily organic acids (29.45%), oxygenated

compounds (3.16%), alcohols (24.09%), fatty acids (both saturated and unsaturated, 19.85%), phenolics (3.61%), terpenoids (0.24%), and sterols and thiols (0.55%) in the ethanolic extract of *Garcinia cambogia* fruit.

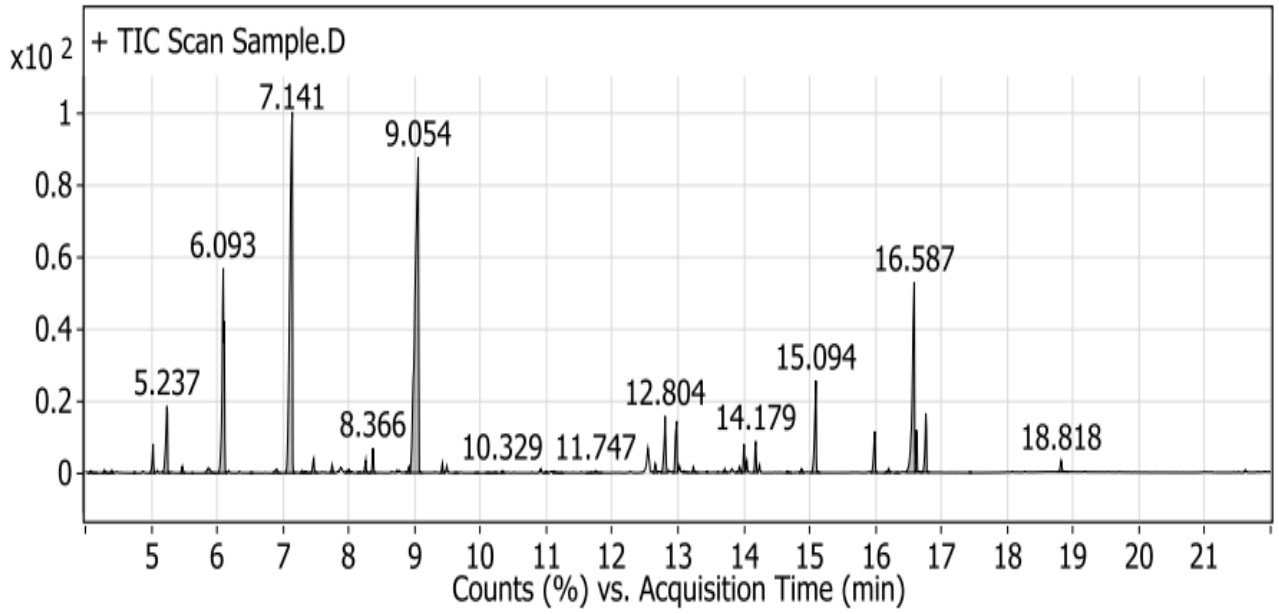


Figure 3. GC-MS chromatogram of *Garcinia* fruit extract.

Table 4. GC-MS data for components detect in *Garcinia* fruit extract.

NO.	Rt	Identified Compound	Chemical Classification of Compounds	Molecular Formula	Area %
1	4.079	Lactic Acid	Organic acids	$C_3H_6O_3$	0.11
2	4.289	Glycolic acid	Organic acids	$C_2H_4O_3$	0.09
3	5.027	2-Ethoxyethanol (Oxitol)	Oxygenated compounds	$C_4H_{10}O_2$	0.88
4	5.472	3-Bromo-4-fluorobenzenethiol	Thiols	C_6H_4BrFS	0.2
5	5.866	4-Methylcyclohexaneacetic acid	Phenolic acids	$C_9H_{16}O_2$	0.41
6	6.906	1-Hexadecanol	Fatty alcohol	$C_{16}H_{34}O$	0.22
7	7.141	Trimethylolpropane	Alcohol	$C_6H_{14}O_3$	23.87
8	7.292	Catechol	Phenolic acids	$C_6H_6O_2$	0.07
9	7.343	Butanedioic acid	Organic acids	$C_4H_6O_4$	0.07
10	7.468	5-Hydroxymethyl-2-Furaldehyde	Oxygenated compounds	$C_6H_6O_3$	0.57
11	7.745	1,2-Dimethyl-3,5-bis(1 methyl ethenyl) cyclohexane	Monoterpenoids	$C_{14}H_{24}$	0.23
12	8.005	Phenoxyethanol	Phenolic acids	$C_8H_{10}O_2$	0.17
13	8.257	Ethyl 6-chloropiperonylate	Oxygenated compounds	$C_{10}H_9ClO_4$	0.39
14	8.366	Hydroquinone	Phenolic compounds	$C_6H_6O_2$	0.7
15	9.054	2-Phenyl-5-pyrimidine carboxylic acid	Organic acids	$C_{11}H_8N_2O_2$	28.81
16	9.423	Malic acid	Organic acids	$C_4H_6O_5$	0.26
17	11.227	Dodecanoic acid	Saturated fatty acids	$C_{12}H_{24}O_2$	0.02
18	11.747	3-Isopropylcatechol	Phenolic acids	$C_9H_{12}O_2$	0.08
19	12.653	Ethyl 2-oxopropanoate;2-hydroxypropane-1,2,3-tricarboxylate	Oxygenated compounds	$C_{11}H_{13}O_{10}$	0.34
20	12.804	2-Pentenedioic acid	Unsaturated fatty acids	$C_5H_6O_4$	2.36
21	12.98	Protocatecatechuic acid	Phenolic acids	$C_7H_6O_4$	2.18

22	13.232	Myristic acid	Saturated fatty acids	$C_{14}H_{28}O_2$	0.17
23	13.601	Geranylgeraniol	Diterpenoids	$C_{20}H_{34}O$	0.01
24	13.71	Citric acid	Organic acids	$C_6H_8O_7$	0.11
25	14.179	D-Gluconic acid	Oxygenated compounds	$C_6H_{12}O_7$	0.98
26	14.658	Hexadecanoic acid	Saturated fatty acids	$C_{16}H_{32}O$	0.05
27	15.094	Palmitic Acid	Saturated fatty acids	$C_{16}H_{32}O_2$	3.59
28	15.991	1-Octadecanol	Fatty alcohol	$C_{18}H_{38}O$	1.65
29	16.201	Ethyl Oleate	Fatty acid ester	$C_{20}H_{38}O_2$	0.16
30	16.587	Oleic Acid	Unsaturated fatty acids	$C_{18}H_{34}O_2$	10.34
31	16.621	11-Octadecenoic acid, (Z)	Unsaturated fatty acids	$C_{18}H_{34}O$	1.17
32	16.763	Stearic acid	Saturated fatty acids	$C_{18}H_{36}O_2$	2.15
33	18.818	(Z)-Docos-9-enenitrile	Fatty acid nitrile	$C_{22}H_{41}N$	0.45
34	24.137	β-Sitosterol	Sterol	$C_{29}H_{50}O$	0.35
Fatty acids (alcohol, ester, nitrile) 2.26%			Oxygenated compounds 3.16%	Organic acids 29.45%	
Alcohols 24.09%			Saturated fatty acids 5.98%	Unsaturated fatty acids 13.87%	
Phenolic 3.61%			Terpenoids 0.24%	Sterol and thiol 0.55%	

Notably, among the characterized phytocompounds, 2-phenyl-5-pyrimidine carboxylic acid, 5-hydroxymethyl-2-Furaldehyde, hydroquinone, catechol, and oleic acid have antioxidant, antimicrobial, antitumor, and anti-inflammatory properties [40–43]. Furthermore, protocatechuic acid, a powerful bioactive compound, is recognized for its strong antioxidant activity, antimicrobial and anti-inflammatory properties, and antitumor potential, as well as antiapoptotic and antihyperglycemic activities [44]. β-Sitosterol also has potent anti-inflammatory and anticancer activity against various cancers, including leukaemia, lung, breast, colon, and prostate cancer, and possesses antioxidant and antimicrobial properties [45].

Similarly, Rahman and coworkers (2024) various compounds were identified in the n-hexane extract of *Garcinia cowa* stems by GC-MS, including fatty acid esters, hydrocarbons, steroids, and substituted hydrocarbons [46]. In parallel with this study, GC-MS identified compounds in *Garcinia schomburgkiana* were catechol, 5-hydroxymethyl-2-furaldehyde, myristic acid, palmitic acid, oleic acid, and stearic acid, which align with the current findings [47].

3.4. Antimicrobial Activity of Garcinia Fruit Extract Against Pathogenic Microorganisms

The GFE was investigated as an antimicrobial agent against Gram-positive (*Staphylococcus aureus*, *Enterococcus faecalis*), and Gram-negative bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*), as well as fungi (*Malassezia furfur* and *Candida albicans*) by the well diffusion method. This method measures the diameter of the inhibition zone (mm) against the test microorganisms, as shown in Table 5 and Figure 4.

In the case of *Staphylococcus aureus*, GFE at 500, 250, and 125 mg/mL exhibited inhibition zone diameters of 21.7 ± 0.3, 16.7 ± 0.3, and 15.3 ± 0.3, respectively, while Levofloxacin disc was (31.3 ± 0.3). Notably, the GFE gave the best results among the tested bacteria, with inhibition zone diameters ranging from 17.3 ± 0.3 to 26.3 ± 0.3 mm against *Enterococcus faecalis*, while Levofloxacin disc was (26.3 ± 0.3). Regarding *Escherichia coli*, the GFE at concentrations of 500, 250, and 125 mg/mL exhibited inhibition zone diameters of 20.7 ± 0.3, 15.7 ± 0.3, and 12.7 ± 0.3, respectively, while Levofloxacin disc was (21 ± 0.3). In *Pseudomonas aeruginosa*, the diameter ranged between 21.7 and 11.7 mm while Levofloxacin disc was (24.3 ± 0.3). Surprisingly, GFE at various concentrations exhibited superior antifungal activity against *Malassezia furfur*. In contrast, GFE at different concentrations exhibited weak antifungal activity against *Candida albicans*.

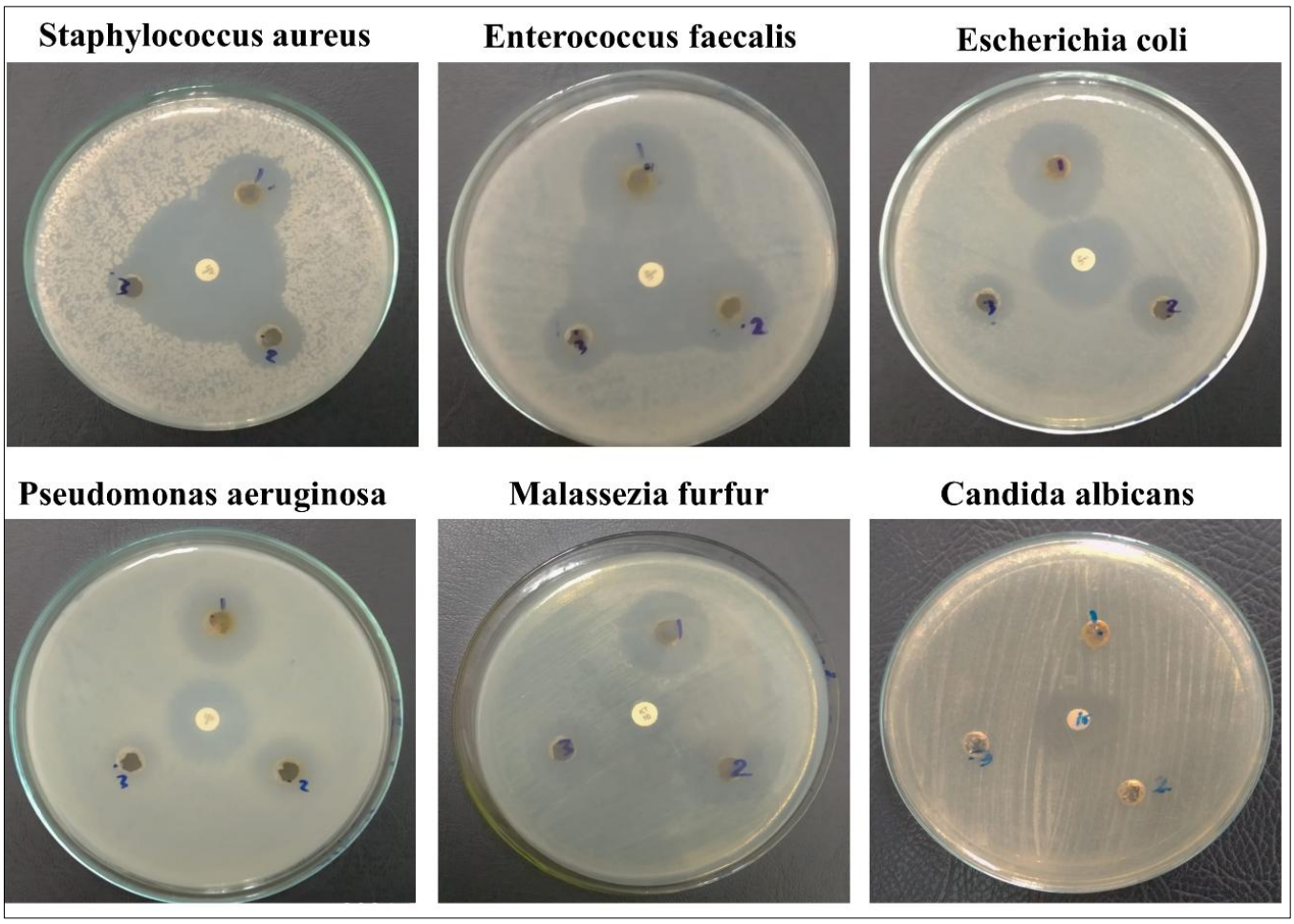


Figure 4. Zone of inhibition for ethanolic *Garcinia* fruit extract (GFE) against *Staphylococcus aureus*, *Enterococcus faecalis*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Malassezia furfur* and *Candida albicans*. 1—GFE 500 mg/mL, 2—GFE 250 mg/mL, 3—GFE 125 mg/mL. Levofloxacin and ketoconazole discs were used as a control positive for bacterial and fungal isolated, respectively.

Table 5. Antimicrobial activities of the 500, 250, and 125 mg/mL of *Garcinia* fruit extract against different pathogenic organisms.

Pathogenic Bacteria	Inhibition Zone Diameter (mm)			Control
	500 mg/mL	250 mg/mL	125 mg/mL	
Gram-positive bacteria				Levofloxacin
Staphylococcus aureus (ATCC 6538)	21.7 ± 0.3	16.7 ± 0.3	15.3 ± 0.3	31.3 ± 0.3
Enterococcus faecalis (ATCC 29212)	24.7 ± 0.3	26.3 ± 0.3	17.3 ± 0.3	26.3 ± 0.3
Gram-negative bacteria				Levofloxacin
Escherichia coli (ATCC 43888)	20.7 ± 0.3	15.7 ± 0.3	12.7 ± 0.3	21 ± 0.3
Pseudomonas aeruginosa (ATCC 27853)	21.7 ± 0.6	15.7 ± 0.3	11.7 ± 0.3	24.3 ± 0.3
Fungi				ketoconazole
Malassezia furfur (ATCC 12078)	21.3 ± 0.3	19.7 ± 0.3	17.3 ± 0.3	9.3 ± 0.3
Candida albicans (*C. albicans*) (NRRL-Y 477)	weak	weak	weak	14.3 ± 0.3

These results align with previous studies of Ayanda et al. (2025), who reported effective antimicrobial activity of *Garcinia kola* against *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Bacillus cereus*, with minimum inhibitory concentration (MIC) values <500 mg/mL [48]. Similarly, Hart & Cock (2016) reported that *Garcinia*

cambogia fruit extracts exhibited strong inhibitory activity, with MIC values <1000 μg/ml against many bacteria [49]. The *Garcinia mangosteen* peel extract exhibited substantial antimicrobial activity against a range of bacteria and fungi, including *S. epidermidis*, *B. cereus*, *B. siamensis*, and *E. indicum*, with minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values ranging from 0.015 mg/mL to 0.061 mg/mL [50].

Moreover, the results indicate that GFE exhibits a strong killing effect, with the MBC/MFC values consistently being half of the corresponding MIC values for all organisms with quantifiable results (Figure 5). The most susceptible organism was *Enterococcus faecalis*, which required the lowest concentration of GFE to achieve a bactericidal effect (MBC = 15.63 mg/mL). Conversely, *Pseudomonas aeruginosa* demonstrated the highest resistance, necessitating the maximum tested concentration of 62.5 mg/mL to achieve a complete kill. MRSA (methicillin-resistant *Staphylococcus aureus)* exhibited antibacterial activity at 31.25 mg/mL indicating the strong therapeutic activity of GFE. The fungicidal activity was also notable, with an MFC of 31.25 mg/mL. The observation that the MBC/MFC was significantly higher than the MIC and the ratio between MIC/MBC or MFC was less than 4 and this indicates the strong bactericidal and antifungal efficacy for most organisms and this suggests that GFE capable of killing more than 99.99% of the microbial population.

3.5. Anticancer Potential of Garcinia Fruit Extract Against Three Cancer Cell Lines: Breast Cancer (MCF-7), Colon Cancer (HCT-116), and Liver Cancer (HepG2)

Morphological assessment revealed cellular alterations in GFE-treated cells compared with untreated controls (Figure 6A–F). GFE-treated MCF-7 cells showed reduced cell density and morphological alterations. Similarly, GFE-treated HCT-116 cells showed changes in cell morphology and reduced cell density. The corresponding conditions for HepG2 cells demonstrated changes in cell number and morphology following GFE treatment. Dose-dependent cytotoxicity was quantified, and the results are presented in the survival curves in Figure 6G. All three cell lines exhibited a decrease in the surviving fraction with increasing concentrations of GFE. The MCF-7 cell line was the most sensitive, with a calculated IC50 value of 31.7 μg/mL. HepG2 and HCT-116 cells showed IC50 values of 48.99 μg/mL and 49.87 μg/mL, respectively. In the context of screening crude plant extracts for cytotoxic activity, an IC50 value below 30 μg/mL has been widely used as a criterion for notable in vitro cytotoxicity [51]. The IC50 value for MCF-7 approached this threshold, whereas higher values were observed for HCT-116 and HepG2.

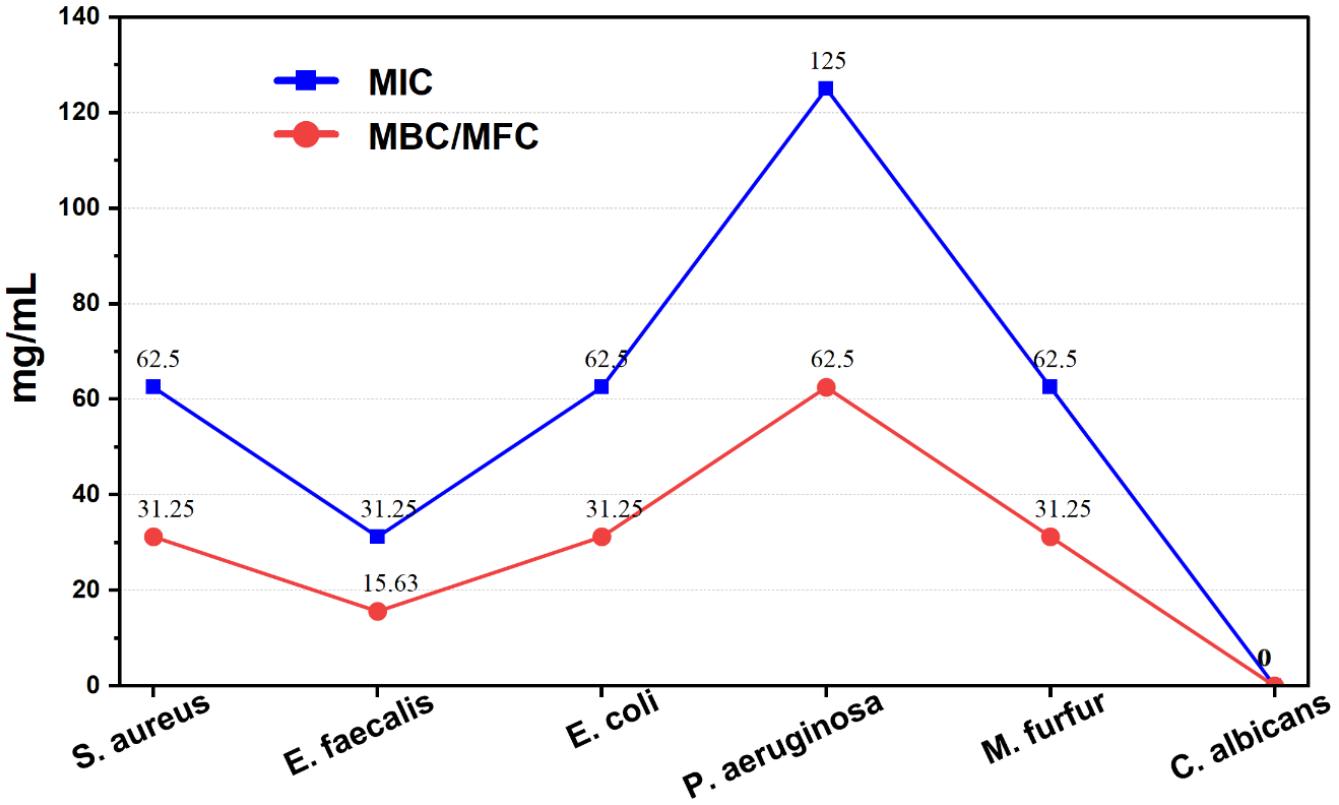


Figure 5. Minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC) and the minimum fungicidal concentration (MFC) of *Garcinia* fruit extract against pathogenic microorganisms.

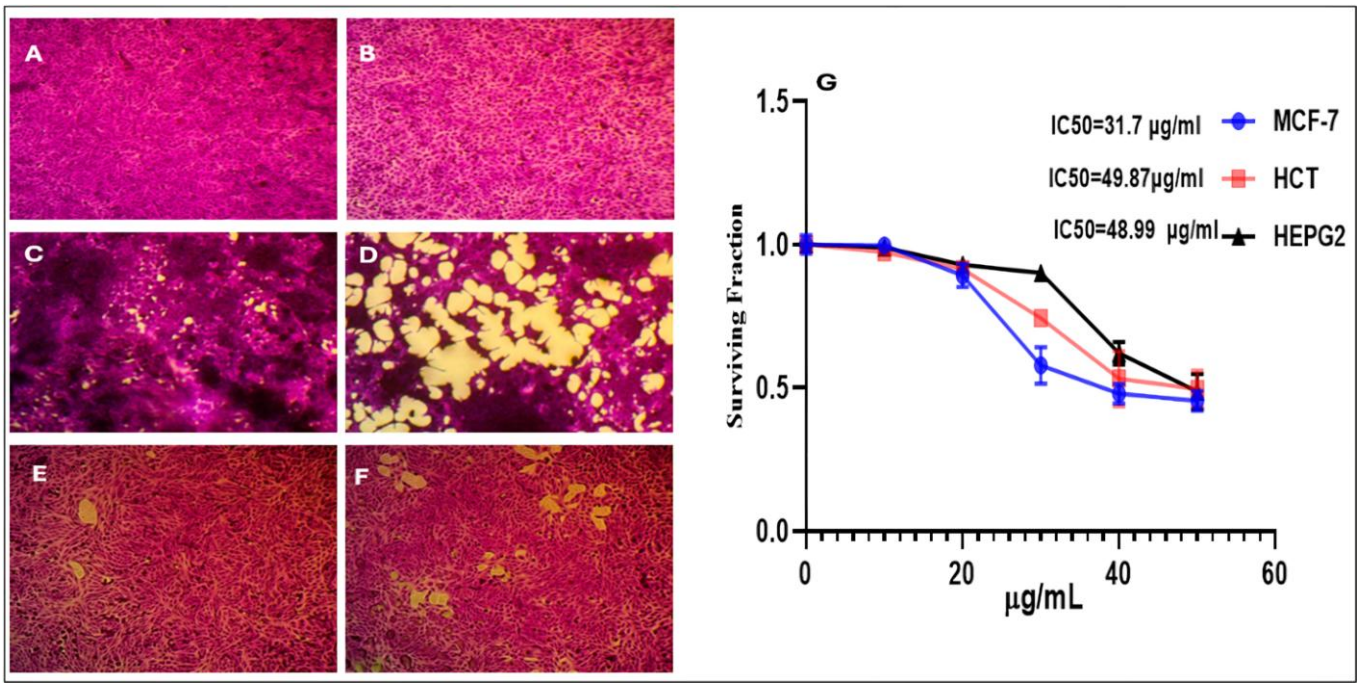


Figure 6. Cytotoxic effects of Garcinia fruit extract on MCF-7, HCT-116, and HepG2 cancer cell lines. Representative images showing the morphological appearance of (**A**,**B**) MCF-7 breast cancer cells, (**C**,**D**) HCT-116 colon cancer cells, and (**E**,**F**) HepG2 liver cancer cells under control and GFE-treated conditions. Compared with the corresponding untreated controls, treated cells showed reduced cell density and morphological alterations. (**G**) Concentration-response curves showing the surviving fraction of MCF-7, HCT-116, and HepG2 cells following treatment with in-

creasing concentrations of GFE. The calculated IC50 values were 31.7 μg/mL for MCF-7, 49.87 μg/mL for HCT-116, and 48.99 μg/mL for HepG2 cells. IC50 values were determined through non-linear regression analysis of log concentration versus percentage cell survival. Data are presented as the mean ± SD of three experiments, each performed in triplicate.

Although the IC50 values obtained for the tested cell lines were above this threshold, the results demonstrate in vitro cytotoxic activity of GFE and warrant further investigation. For crude plant extracts, the observed biological effects may arise from the combined action of multiple constituents rather than a single compound. Therefore, the cytotoxic effects observed across the three cancer cell lines may reflect contributions from several constituents of the extract.

Our phytochemical analysis revealed several polyphenolic compounds in GFE, including chlorogenic acid, gallic acid, and catechin. Chlorogenic acid, a major phenolic compound in the extract, has been widely studied for its antioxidant and anticancer properties. It has been reported to mitigate oxidative stress by scavenging reactive oxygen species (ROS) and regulating redox homeostasis [51]. Chlorogenic acid has also been reported to inhibit cell proliferation, induce apoptosis, and suppress tumor angiogenesis in various cancer models, including breast, hepatic, and colon cancer, supporting its possible contribution to the cytotoxic activity observed with *Garcinia* extract [52,53].

Similarly, gallic acid, another prominent polyphenol in the extract, has been extensively studied for its anticancer properties. It modulates several signaling pathways, including the PI3K/Akt and MAPK pathways, to inhibit cancer cell proliferation, migration, and invasion [54].

Catechin, a flavonoid compound has been reported to affect processes associated with cancer cell invasion [55]. Ref. [56] demonstrated that green tea catechins inhibit the activity of matrix metalloproteinase-7 (MMP-7), an enzyme involved in extracellular matrix degradation. This activity may contribute to the biological effects associated with catechin-containing extracts.

4. Conclusions

In conclusion, *Garcinia* fruit extract contains a range of natural bioactive compounds, including phenolic and flavonoid compounds, carboxylic acids, derivatives of nucleic acids, lipids, carbohydrates, amino acids, terpenoids, and peptides, with gallic acid, catechin, and chlorogenic acid. GFE demonstrated antibacterial activity against S. aureus, E. faecalis, E. coli, P. aeruginosa, and M. furfur, while its activity against Candida albicans was ineffective under the tested conditions. GFE also demonstrated in vitro cytotoxic activity against MCF-7 breast, HCT-116 colon, and HepG2 liver cancer cell lines. The presence of polyphenolic compounds, particularly chlorogenic acid, gallic acid, and catechin, may be associated with the observed cytotoxic activity based on their previously reported biological properties. Future research should focus on isolating and characterizing the bioactive constituents responsible for these effects and investigating their molecular pathways and possible interactions. Further in vivo studies are warranted to evaluate the safety and biological relevance of *Garcinia cambogia* extract before any therapeutic implications can be established.

Author Contributions: A.A.G.: Conceptualisation, Methodology, Resources, Formal analysis, Writing—original draft. J.S.: Conceptualization, Supervision, Writing—review and editing. J.X.: Supervision, Writing—review and editing. X.L.: Software, Supervision, Writing—review and editing. M.R.: Writing—review and editing, Formal analysis. Y.Z.: Data curation, Writing—review and editing. K.M.: Writing—review and editing, Formal Analysis. J.Y.: Writing—review and editing. E.G.A.: Methodology, Resources, Writing—original draft. M.M.H.S.: Methodology, Writ-

ing—review and editing. M.M.E.: Data curation, Writing—review and editing. M.I.M.I.: Methodology, Resources, Writing—review and editing. M.M.D.: Software, Writing—review and editing. E.H.: Visualisation, Writing—original draft, Writing—review and editing. M.A.-G.: Writing—review and editing, Formal analysis. A.H.E.-D.: Methodology, Formal analysis, Writing—original draft. D.H.D.: Writing—original draft, Data curation., G.N.A.-R.; J.Y.; O.P.; G.W.; data analysis, Writing—review and editing, final manuscript review. L.Y.: Resources, Data curation, Review of the final version. S.R.: Conceptualisation, Writing—original draft, visualisation, supervision and final review. All authors have read and agreed to the published version of the manuscript.

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