

Original Article

Chemical profile and in vitro biological activities of volatile oil extracted from *Arthrospira platensis*

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Abstract: This study aimed to examine the chemical characteristics and biological actions of the volatile oil extracted from the cyanobacterium *Arthrospira platensis*. The results of gas chromatography-mass spectrometry (GC-MS) showed that the samples have a chemically diverse profile dominated by aliphatic hydrocarbons, terpenoid derivatives, aldehydes, ketones, and fatty acids, including 2-ionone, phytol, and unsaturated fatty acids. The antioxidant activity of the volatile oil was assessed using the DPPH free radical scavenging assay and was found to be concentration-dependent, although the overall activity was rather moderate compared with polar extracts. The antibacterial activity of the volatile oil was evaluated using the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) methods against Gram-positive and Gram-negative bacteria of interest. The findings showed a high level of concentration-dependent antibacterial activity, with inhibitory and bactericidal activities higher against *Escherichia coli* and *Bacillus cereus* than against *Salmonella enterica* and *Staphylococcus aureus*. Assessment by the MTT cytotoxicity assay revealed concentration-dependent and selective cytotoxic activity of the volatile oil against the human hepatocellular carcinoma (HepG2) and breast adenocarcinoma (MCF-7) cell lines, while preserving high cell viability in normal human dermal fibroblast cells. The half-maximal inhibitory concentration values showed good cytotoxicity against cancer cells and low toxicity to normal cells. The results revealed that the volatile oil of *A. platensis* is a potential source of bioactive compounds with moderate antioxidant activity, strong antibacterial effect, and selective anticancer potential, and indicate that the oil can be used as a natural source of biologically active metabolites in the pharmaceutical and biomedical industries.

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Introduction

Microalgae, particularly cyanobacteria, have become attractive biological sources for their natural compounds with diverse pharmacological and biomedical uses. Their variety of bioactive molecules, produced due to their metabolic plasticity, includes hydrocarbons, terpenoids, fatty acids, pigments, and nitrogen-containing compounds, most of which have antioxidant, antimicrobial, and anticancer effects (Sosa-Hernandez et al., 2018; Jung et al., 2022; Gentscheva et al., 2023). In addition, their sustainability, high growth rates, and capacity to grow under controlled environments contribute to their growing popularity as an alternative to terrestrial plants for producing bioactive compounds (Pôjo et al., 2021; Milia et al., 2025).

Arthrospira platensis is one of the most commonly studied cyanobacteria species due to its long-standing safe use as a dietary supplement and its outstanding biochemical composition. Past studies have shown that *A. platensis* is a source of proteins, essential amino acids, phycobiliproteins, carotenoids, polyunsaturated fatty acids, and secondary metabolites that have been proven to possess antioxidant, anti-inflammatory, immunomodulatory, and anticancer activities (Gheda et al., 2021; Braune et al., 2021; ElFar et al., 2022). Most studies on *A. platensis* have focused on its polar fractions, especially phycocyanin and polysaccharides, but recent findings indicate that its lipophilic and volatile compounds may also contribute significantly to its biological activity (Jung et al., 2022; Taiti et al.,

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Natural-origin volatile and semi-volatile compounds are known to have strong biological activities due to their chemical reactivity and their ability to interact with cellular membranes and intracellular targets. Terpenoids, aldehydes, ketones, hydrocarbons, and fatty acids have been reported to have antioxidant effects by free-radical scavenging, antimicrobial action by disrupting the membrane, and anticancer effects by causing oxidative stress and apoptosis in cancer cells (Moran et al., 2022; Ilieva et al., 2024; de Carvalho et al., 2025). Microalgae are not yet considered typical essential oil-producing organisms, but GC-MS analysis has revealed that *A. platensis* contains volatile and semi-volatile compounds, such as 2-ionone, phytol, and long-chain hydrocarbons, that may contribute to its bioactivity (Moran et al., 2022; Nikolova et al., 2024).

One of the primary pathogeneses of many chronic diseases, such as cancer, neurodegenerative diseases, or cardiovascular diseases, is oxidative stress. Overproduction of reactive oxygen species may lead to lipid peroxidation, protein oxidation, and DNA damage, ultimately causing cell dysfunction and cell death. As a result, identifying natural antioxidants that can counteract oxidative stress remains a focus of biomedical research (Gheda et al., 2021; Milia et al., 2025). Selective cytotoxicity for cancer cells and sparing of normal cells is crucial in the design of useful anticancer agents in oncology. Some metabolites found in *A. platensis*, such as terpenoids and fatty acids, have been shown to inhibit cancer cell growth, induce apoptosis, and suppress oxidative stress signaling (Braune et al., 2021; Rungjiraphirat et al., 2025; Zeitler et al., 2024). In addition, the rapid emergence of multidrug-resistant bacterial strains has heightened interest in discovering new antimicrobial agents with a different mechanism of action derived from nature (Martelli et al., 2020; Ilieva et al., 2024).

However, few integrated studies characterize the volatile fraction of *A. platensis* and systematically assess its antioxidant, antibacterial, and cytotoxic properties. Therefore, the current work aimed to describe the volatile oil obtained from *A. platensis*

using gas chromatography-mass spectrometry and to examine its antioxidant, antimicrobial, and cytotoxic effects using DPPH radical scavenging, minimum inhibitory and bactericidal concentrations, and MTT-based cytotoxicity assays against normal and cancerous human cell lines.

Materials and Methods

Algal material: In this, spirulina powder was purchased in a ready-to-consume form from Algotab Company (Iran). The samples were kept in airtight containers at room temperature and shielded from light until further use.

Volatile compounds extraction: Extraction of volatile compounds was performed using an organic solvent-based procedure, following previously established methods proven effective for extracting volatile compounds prior to further processing with GC-MS (Senila et al., 2025). In short, the spirulina powder (10 g) was placed in 100 mL of ethanol (99) and mixed at room temperature for 24 hours. A 0.45 µm membrane filter was used to filter the mixture, and the filtrate was concentrated under low pressure to one-half its original volume. The extract was placed in dark, gas-tight vials at 4°C until analysis.

Gas chromatographic Analysis: A gas chromatography system fitted with a mass spectrometer (Agilent Technologies) was used to separate volatile compounds using a capillary column (HP-5MS, 5% phenyl 95% dimethylpolysiloxane) with dimensions of 30 m by 0.25 mm internal diameter and 0.25 mm film thickness. The carrier gas was Helium with a constant flow rate of 1.0 mL/min. Injection was performed in split mode, with the injector temperature set to 250°C. The oven program was as follows: the initial temperature was 50°C for 2 min, then heated at 5°C/min to 280°C, where it was held for 10 min to allow high-boiling compounds to elute. The mass spectrometer was set to run in electron ionization (EI) mode at 70 eV, and mass spectra were collected over the m/z range 40-550. Compound identification was performed by matching the obtained mass spectra to reference mass spectral libraries.

Antioxidant activity assay: The DPPH radical-scavenging assay, an established spectrophotometric method for measuring free-radical scavenging ability, was used to evaluate the antioxidant effect of volatile oil samples (Munteanu and Apetrei, 2021). In short, 0.2 mM of DPPH solution in ethanol was combined with various concentrations of the volatile extract and incubated in the dark at room temperature for 1 h. The absorbance was determined at 517 nm using a spectrophotometer. The percent of DPPH radical scavenging activity was calculated using the equation of DPPH scavenging activity (%) = $[1 - (\text{absorbance of sample} / \text{absorbance of sample})] \times 100$. All measurements were done three times, and the results are presented as mean \pm standard deviation (SD).

Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) determination:

MIC was determined using a broth microdilution system in 96-well microplates. The culture medium was Mueller-Hinton broth, and two-fold serial dilutions of the extract were prepared. Each well was inoculated with a standardized bacterial suspension of approximately 1.5×10^8 CFU/mL. As a colorimetric measure of bacterial growth, resazurin solution (0.1%) was added, and the plates were incubated at 37°C for 24 hours. The lowest extract concentration at which the color change was prevented was considered the MIC, indicating that the extract inhibited visible bacterial growth. To determine the minimum bactericidal concentration (MBC), all aliquots from wells with no apparent growth were subcultured onto brain heart infusion (BHI) agar plates and incubated at 37°C for 24 h. The minimum concentration of the agar plates at which no bacterial growth was detected was MBC (Wiegand et al., 2008).

Bacterial strains: Ready-to-use pure bacterial strains were obtained from the Iranian Genetic Resources Center (IGRC) at the University of Tehran. The strains were provided as certified pure cultures and purchased directly from this formally recognized national reference center, which is responsible for preserving and distributing authenticated microbial resources in Iran. The bacterial strains used in this research were internationally recognized reference strains with

global identification codes (PTCC and ATCC). These were *Escherichia coli* (PTCC 1330 / ATCC 8739), *Salmonella enterica* (PTCC 1709 / ATCC 14028), *Staphylococcus aureus* (PTCC 1764 / ATCC 33591), and *Bacillus cereus* (PTCC 1015 / ATCC 11778). These susceptible strains are widely used in antimicrobial screening studies and have been reported to exhibit typical resistance characteristics. The outer membranes of Gram-negative strains of *E. coli* and *S. enterica* act as permeability barriers to numerous antibacterial agents. The ability of *S. aureus* to acquire resistance through various mechanisms, and the high resistance of *B. cereus* due to its sporogenicity and strong cell wall, are well known.

MTT cytotoxicity assay: Cell viability was measured using the MTT assay. In short, cells were seeded in 96-well plates and incubated for 24 h before growth. The volatile extract was then added at varying concentrations to the cells, which were incubated for 72 h. The incubated wells were then supplemented with MTT solution (3, 4, 5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide, and the plates were incubated for another 4 h to allow the formation of purple formazan crystals. These crystals were dissolved in dimethyl sulfoxide (DMSO), and absorbance was measured at 570 nm with a microplate reader. Cell viability relative to untreated control cells was calculated, and the IC₅₀ was determined in a dose-dependent manner (Al-Qubaisi et al., 2011).

Statistical analysis: Each experiment was conducted in triplicate, and the findings are presented as mean \pm SD. The IC₅₀ was calculated using a standard dose-response analysis in GraphPad Prism.

Results

Identification of *A. platensis*: In this study, the cyanobacterium *A. platensis* was used as a biological material. Figure 1 shows the features of the algae on the label of the purchased algal biomass.

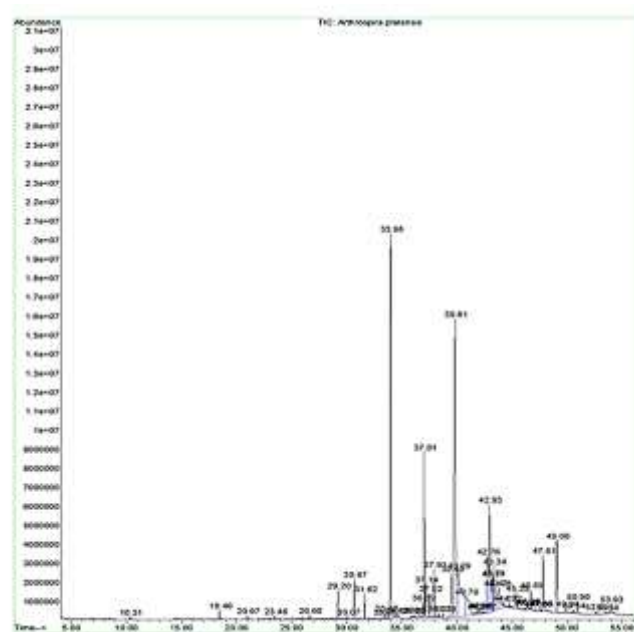
Volatile oil extraction of *A. platensis*: The chemical profile of the volatile oil extracted from *A. platensis* using GC-MS is shown in Table 1, and Figure 2 indicates that the oil contained aromatic compounds, such as p-xylene, and aliphatic hydrocarbons,

Table 1. Chemical composition of the volatile oil extracted from *Arthrospira platensis* as identified by GC-MS analysis.

RT (min)	Identified compound	Compound class	Molecular formula
10.30	p-Xylene	Aromatic hydrocarbon	C ₈ H ₁₀
20.97	Dodecane	Aliphatic hydrocarbon	C ₁₂ H ₂₆
26.61	Tetradecane	Aliphatic hydrocarbon	C ₁₄ H ₃₀
29.20	4-(2,6,6-Trimethylcyclohex-1-en-1-yl)-3-buten-2-one (β-Ionone derivative)	Terpenoid ketone	C ₁₃ H ₂₀ O
30.67	Benzofuranone derivative	Oxygenated aromatic	~C ₈ H ₈ O ₂
31.61	Hexadecane	Aliphatic hydrocarbon	C ₁₆ H ₃₄
33.35	Z,Z-10,12-Hexadecadienal	Unsaturated aldehyde	C ₁₆ H ₂₈ O
33.48	8-Heptadecene	Unsaturated hydrocarbon	C ₁₇ H ₃₄
33.72	β-Ionone	Terpenoid ketone	C ₁₃ H ₂₀ O
33.98	Heptadecane	Aliphatic hydrocarbon	C ₁₇ H ₃₆
35.89	Acetic acid, 3,7,11,15-tetramethyl- (terpenoid acid)	Terpenoid derivative	C ₁₂ H ₂₄ O ₂
36.11	Octadecane	Aliphatic hydrocarbon	C ₁₈ H ₃₈
36.36	2-Pentadecanone, 6,10,14-trimethyl-	Terpenoid ketone	C ₁₈ H ₃₆ O
36.75	3,7,11,15-Tetramethyl-2-hexadecene	Terpenoid hydrocarbon	C ₂₀ H ₄₀
38.33	2-Heptadecanone	Ketone	C ₁₇ H ₃₄ O
39.49	Z-7-Hexadecenoic acid	Unsaturated fatty acid (semi-volatile)	C ₁₆ H ₃₀ O ₂
39.82	n-Hexadecanoic acid (Palmitic acid)	Fatty acid (semi-volatile)	C ₁₆ H ₃₂ O ₂
42.76	Phytol	Diterpene alcohol	C ₂₀ H ₄₀ O
43.17	Linoleic acid (Z,Z-9,12-octadecadienoic acid)	Polyunsaturated fatty acid	C ₁₈ H ₃₂ O ₂
43.34	Linoleic acid ethyl ester	Fatty acid ester	C ₂₀ H ₃₆ O ₂
44.72	Oleic acid	Unsaturated fatty acid	C ₁₈ H ₃₄ O ₂

Figure 1. *Arthrospira platensis* was used in the present study.

including dodecane, tetradecane, hexadecane, and octadecane. Moreover, terpenoid compounds of biological significance were identified, including 2-ionone and its derivatives and phytol. In addition, there were saturated and unsaturated fatty acids, including palmitic, oleic, and linoleic acids. The results indicate the biochemical richness of the

Figure 2. GC-MS chromatogram of the volatile oil extracted from *Arthrospira platensis*.

volatile oil in *A. platensis*.

Antioxidant activity using the DPPH Assay: The DPPH free radical scavenging assay was used to determine the antioxidant activity of the volatile oil extracted from *A. platensis*. The results showed a significant concentration-related antioxidant effect, as evidenced by a progressive decline in absorbance with

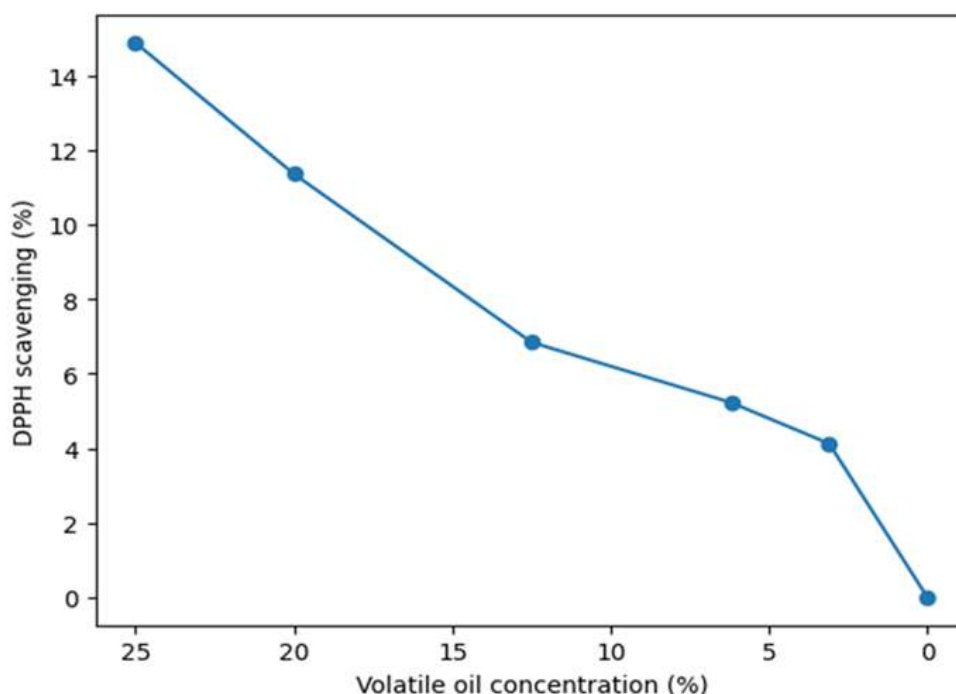


Figure 3. Effect of different concentrations of volatile oil extracted from *Arthrospira platensis* on antioxidant activity determined by the DPPH

increasing oil concentration. The maximum free radical scavenging was 14.88% at a concentration of 25%. The scavenging activity decreased to 11.36 at 20%. Additional dilution reduced the scavenging activities to 6.84, 5.23, and 4.12% at concentrations of 12.5, 6.2, and 3.1, respectively. The control sample showed no antioxidant activity. These results show that the antioxidant properties of the volatile oil of *A. platensis* are low and highly concentration-dependent (Table 2, Figs. 3-4).

Antibacterial activity of *A. platensis*

Minimum inhibitory concentration assay: The minimum inhibitory concentration assay using resazurin dye was used to determine the antibacterial activity of the volatile oil from *A. platensis*. At higher concentrations, the dye's blue color remained in the wells, and it completely inhibited bacterial growth. Intermediate concentrations produced partial color changes, whereas lower concentrations produced a distinct shift to pink or red, indicating active bacterial growth. These results indicate a concentration-dependent antibacterial effect of the volatile oil (Fig. 5).

Minimum bactericidal concentration: The minimum bactericidal concentration data showed that

the volatile oil of *Arthrospira platensis* exhibited bactericidal activity at concentrations similar to those required for inhibition. It was found that a strong bactericidal effect was observed against *E. coli* and *B. cereus*, but higher concentrations were required to achieve bactericidal activity against *S. enterica* and *S. aureus*. The lack of bacterial growth at bactericidal levels is evident in the relevant Figure 6.

Cytotoxic effects of volatile oil of *A. platensis* against human cell lines

Human dermal fibroblast cells: The MTT assay was used to determine the cytotoxic effect of the volatile oil isolated from *A. platensis* on human dermal fibroblast cells (HDF). As indicated in Table 3, cell viability gradually declined as oil concentration increased, but it remained quite high across all oil concentrations tested. The highest cell viability was detected at the lowest concentration (3.1-99.71%), and the lowest viability was obtained at the highest concentration (25-85.09%). Figure 7 shows the changes in cell viability with increasing concentrations, whereas the dose-response behaviour is shown in Figure 8. The half-maximal inhibitory concentration was not achieved because cell viability did not decline to less than 50 percent at any tested

Table 2. Minimum inhibitory concentration and minimum bactericidal concentration values of volatile oil extracted from *Arthrospira platensis* against selected bacterial strains.

No.	Bacterial species	Algae	Abbreviation	Test	Volatile oil Concentration									Control treatment		
					1	2	3	4	5	6	7	8	9	10	11	12
					100 %	50 %	25 %	12.5 %	6.2 %	3.1 %	1.5 %	7.8 %	3.9 %	Bacteria Control	Culture medium control	Algae control
1	<i>E. coli</i>	<i>Arthrospira platensis</i>	E.c-G	MIC	-	-	-	-	+	+	+	+	+	+	-	-
				MBC	-	-	-	-	+	+	+	+	+			
2	<i>S. Enteric</i>	<i>Arthrospira platensis</i>	SI/G	MIC	-	-	-	+	+	+	+	+	+	+	-	-
				MBC	-	-	-	+	+	+	+	+	+			
3	<i>S. aureus</i>	<i>Arthrospira platensis</i>	SI/G	MIC	-	-	-	+	+	+	+	+	+	+	-	-
				MBC	-	-	-	+	+	+	+	+	+			
4	<i>B. cereus</i>	<i>Arthrospira platensis</i>	B.C/G	MIC	-	-	-	-	+	+	+	+	+	+	-	-
				MBC	-	-	-	-	+	+	+	+	+			

(+) Presence of bacterial growth, (-) Absence of bacterial growth.

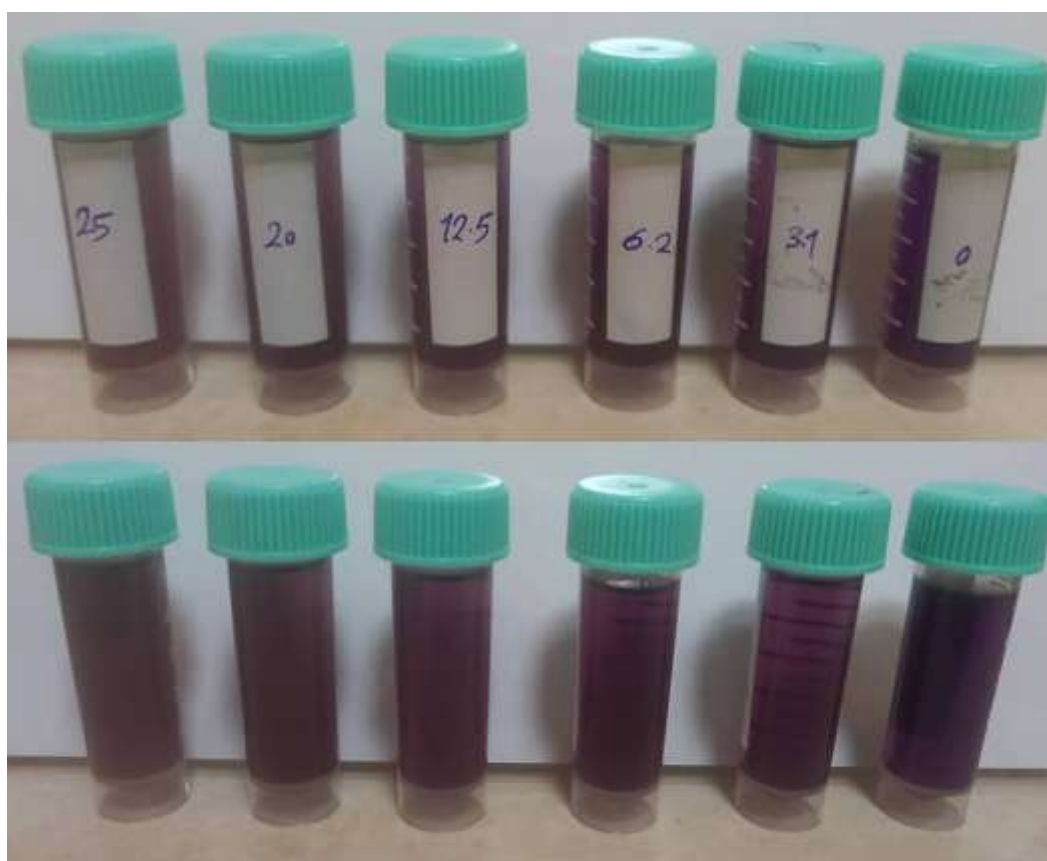


Figure 4. Effect of different concentrations of volatile oil extracted from *Arthrospira platensis* on antioxidant activity determined by the DPPH assay.

concentration in HDF cells.

Human hepatocellular carcinoma cells: A strong, concentration-dependent decline in cell viability was observed with the volatile oil from *A. platensis* on human hepatocellular carcinoma cells (HepG2). As shown in Table 4, the highest percentage was cell viability (47.83) at the lowest concentration (3.1%),

followed by a steep reduction to 14.45 at the highest concentration (25%). Figure 9 shows a clear decrease in cell viability with increasing concentration, whereas the dose-response curve (Fig. 10) shows the cytotoxic nature and the half-maximal inhibitory concentration. The half-maximal inhibitory concentration was determined to be 2.986, indicating



Figure 5. Inhibitory effect of volatile oil extracted from *Arthrospira platensis* against *Escherichia coli*, *Salmonella enterica*, *Staphylococcus aureus*, and *Bacillus cereus* on the microplate assay, minimum inhibitory concentration.

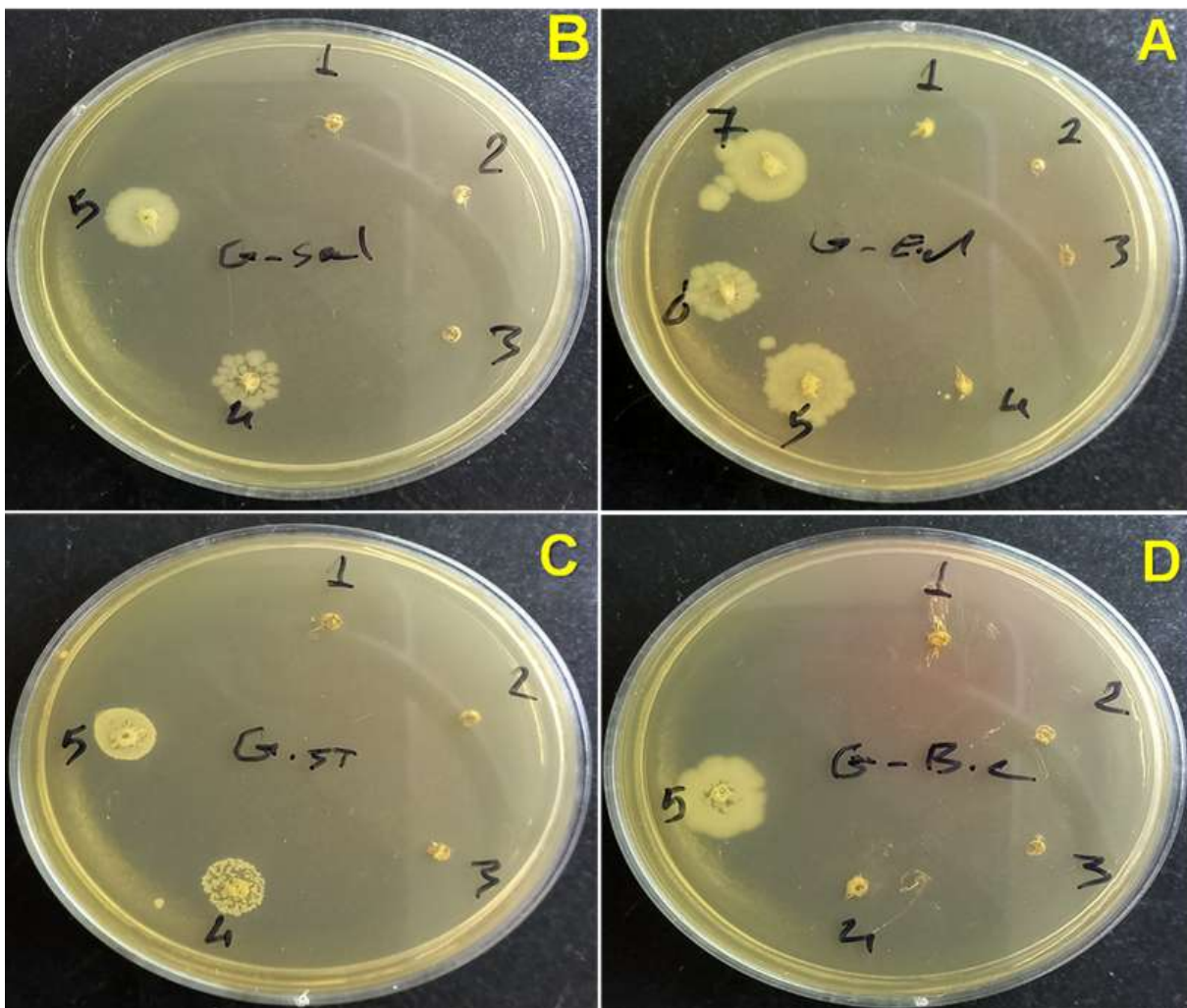


Figure 6. A minimal bactericidal concentration assay of volatile oil produced by *Arthrospira platensis* against *Escherichia coli* (A), *Salmonella enterica* (B), *Staphylococcus aureus* (C), and *Bacillus cereus* (D) was used to determine its bactericidal effect.

a significant cytotoxic effect of the volatile oil on HepG2 cells.

Human breast adenocarcinoma cells: The cytotoxic effect of volatile oil obtained through the extraction of

Arthrospira platensis was also observed to be clearly concentration-dependent in its cytotoxicity on human breast adenocarcinoma cells (MCF-7). According to Table 5, cell viability decreased, with the lowest

Table 3. The MTT assay was used to establish the cytotoxic effect of volatile oil extracted using *Arthrospira platensis* on human dermal fibroblast cells.

Concentration (%)	OD1	OD2	OD3	Avg OD	Cell Viability (%)
0	0.341	0.348	0.337	0.342	100
3.1	0.333	0.348	0.342	0.341	99.71
6.2	0.339	0.339	0.341	0.3397	99.32
12.5	0.319	0.328	0.326	0.3243	94.83
20	0.311	0.299	0.301	0.3037	88.79
25	0.298	0.291	0.284	0.291	85.09

Table 4. The MTT assay identified the cytotoxic effect of the volatile oil extracted on human hepatocellular carcinoma cells.

Concentration (%)	OD1	OD2	OD3	Avg OD	Cell Viability (%)
0	0.623	0.676	0.639	0.646	100
3.1	0.304	0.312	0.311	0.309	47.83
6.2	0.269	0.271	0.278	0.2727	42.21
12.5	0.195	0.192	0.199	0.1953	30.24
20	0.114	0.116	0.119	0.1163	18.01
25	0.09	0.1	0.09	0.0933	14.45

Table 5. The MTT assay demonstrated the cytotoxic effects of the extracted volatile oil on human breast adenocarcinoma cells.

Concentration (%)	OD1	OD2	OD3	Avg OD	Cell Viability (%)
0	0.591	0.596	0.571	0.586	100
3.1	0.311	0.319	0.309	0.313	53.41
6.2	0.277	0.278	0.291	0.282	48.12
12.5	0.191	0.184	0.185	0.1867	31.85
20	0.114	0.118	0.112	0.1147	19.57
25	0.09	0.1	0.09	0.0933	15.93

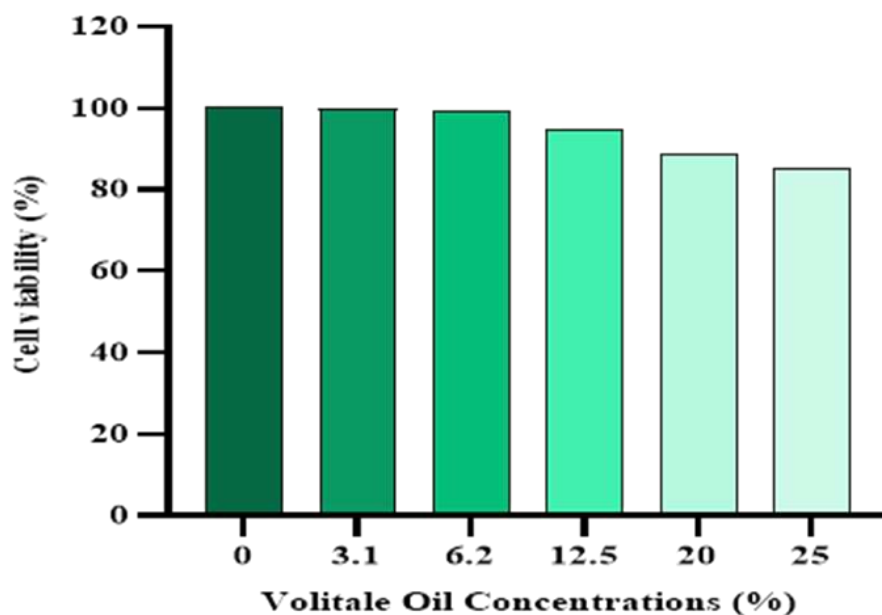


Figure 7. Cell viability response of human dermal fibroblast cells to different concentrations of volatile oil extracted from *Arthrospira platensis*.

concentration at 3.1% (53.41% of the initial) and the highest at 25% (15.93% of the initial). The reducing tendency of cell viability with the increase of concentration (Fig. 11) and the dose-response curve

(Fig. 12), and the determination of half-maximal inhibitory concentration. The half-maximal inhibitory concentration for MCF-7 cells was 4.236 percent, confirming the volatile oil's cytotoxic effect on these

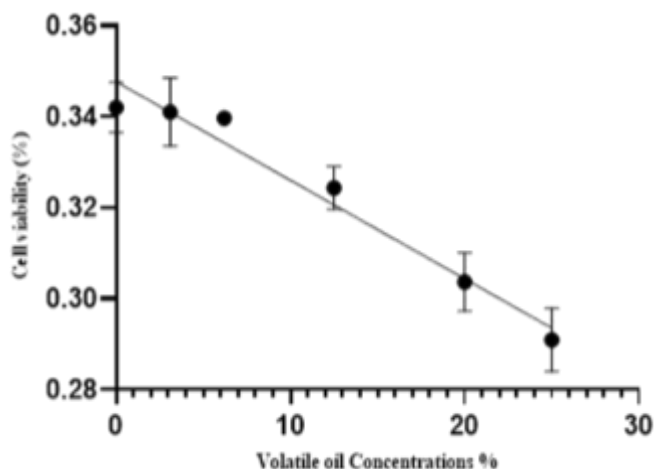
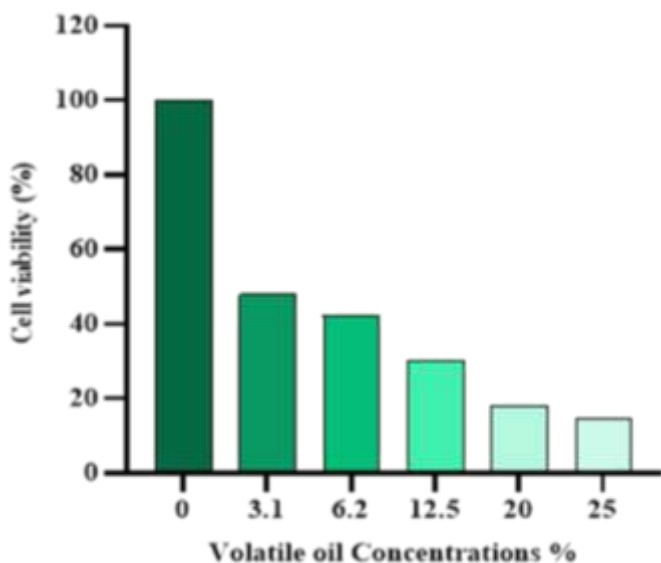


Figure 8. Cytotoxicity evaluation of volatile oil extracted from *Arthrospira platensis* on human dermal fibroblast cells using the MTT assay.



cells.

Discussions

Chemical composition of the volatile oil: According to the results, the volatile oil extracted from *A. platensis* is a chemically heterogeneous mixture, with major components including aliphatic hydrocarbons, terpenoid derivatives, aldehydes, ketones, and fatty acids. The volatility of the long-chain hydrocarbons (dodecane, tetradecane, hexadecane, heptadecane, and octadecane) is in agreement with the literature that reported lipid-derived volatile metabolites in cyanobacteria and microalgae (Moran et al., 2022; Jung et al., 2022; de Carvalho et al., 2025). These compounds have been

proposed to have a role in antimicrobial activity and are typically linked to fatty acid biosynthesis and degradation pathways, and are thought to interact with lipid membranes.

This is especially in the identification of terpenoid compounds, such as 2-ionone and its derivatives, phytol, and terpenoid ketones, which are reported to have antioxidant, antimicrobial, and anticancer effects, mostly due to the effect of moderating oxidative stress and apoptosis-related signaling (Taiti et al., 2023; Thangsiri et al., 2024). Phytol is a diterpene alcohol produced during the metabolism of chlorophylls and has been widely reported to have antimicrobial and cytotoxic properties and to induce apoptosis in cancer cells (Braune et al., 2021; Gheda et al., 2023). The identification of unsaturated aldehydes and fatty acids, e.g., linoleic and oleic acids, also supports the biological applicability of the volatile oil, because these compounds have been reported to affect microbial membranes and oxidative and inflammatory events in mammalian cells (Ilieva et al., 2024; Jung et al., 2022).

Antioxidant activity: The DPPH radical-scavenging assay showed that the volatile oil exhibited concentration-dependent antioxidant activity, with higher concentrations yielding greater radical-scavenging activity. Nevertheless, the antioxidant activity was relatively low compared with that of polar extracts of *A. platensis*, including methanolic and aqueous extracts that contain high levels of phenolic compounds and phycobiliproteins (Gheda et al., 2021; Milia et al., 2025). This finding is consistent with earlier research showing that the volatile and lipophilic fractions lack appropriate DPPH scavenging activity due to a minimal number of strong hydrogen-donating antioxidants (Moran et al., 2022; Taiti et al., 2023).

However, the free radical scavenging activity of terpenoids and unsaturated fatty acids (which can neutralize free radicals and prevent lipid peroxidation) can be considered the reason behind the antioxidant effect observed in the present study. Concentration-dependent antioxidant trends are also similar to volatile fractions obtained with microalgae and other

natural sources, and they are more or less biologically relevant with antioxidant potential (Nikolova et al., 2024; Milia et al., 2025).

Antibacterial activity: The unstable oil of *A. platensis* exhibited concentration-dependent antimicrobial activity against Gram-negative and Gram-positive bacteria. The effectiveness of the salts against *Escherichia coli* and *Bacillus cereus* was stronger and greater than that against *Salmonella enterica* and *Staphylococcus aureus* and could be attributed to variations in the architecture of the cell wall and the composition of the membrane, which determine the sensitivity to hydrophobic compounds (Martelli et al., 2020; Ilieva et al., 2024).

This bacterial killing effect is probably due to a combination of the action of hydrocarbons, terpenoids, aldehydes, and fatty acids contained in volatile oil. These substances have been noted to affect bacterial membranes, increase membrane permeability, disrupt metabolic processes, and ultimately cause cell death (Taiti et al., 2023; Ilieva et al., 2024). A closer relationship between bactericidal concentrations and inhibitory levels in this study further supports a membrane-targeting mode of action, as suggested for volatile and lipophilic natural compounds (Martelli et al., 2020; Thangsiri et al., 2024).

Cytogenomics on human cell lines (Cytosytic effects): The MTT test showed that the volatile oil had a significant selectivity for cancer cells over normal human dermal fibroblasts. An excellent viability profile of normal cells across all tested concentrations suggests a good safety profile, consistent with previous studies reporting low toxicity of *A. platensis*-derived compounds to non-cancer cells (Braune et al., 2021; Zeitler et al., 2024). On the contrary, the volatile oil induced a high degree of concentration-dependent cytotoxicity to HepG2 and MCF-7 cells, as the half-maximal inhibitory concentration was low.

The high level of cytotoxicity on the HepG2 cells could be associated with the fact that the hepatocellular carcinoma cells are sensitive to lipid-derived and terpenoid compounds, which can initiate oxidative stress, mitochondrial dysfunction, and

apoptosis (Braune et al., 2021; Rungjiraphirat et al., 2025). These mechanisms have been also described in the case of phytol and 2-ionone that can induce intrinsic apoptotic processes and prevent the growth of cancer cells (Gheda et al., 2023; Thangsiri et al., 2024). The identified cytotoxic effect on MCF-7 cells further confirms the extensive anticancer potential of the volatile oil and provides evidence of the sensitivity of breast cancer cells to the bioactive compounds in *A. platensis* (Zeitler et al., 2024; Rungjiraphirat et al., 2025).

Overall, the combination of chemical characterization and biological tests indicates that the volatile oil of *A. platensis* exhibits moderate antioxidant activity, high antibacterial activity, and selective cytotoxicity against cancer cells. The data support the potential of *A. platensis* volatile constituents as a source of natural bioactive compounds and align with subsequent studies on their mechanisms of action and therapeutic value.

Conclusion

This research study has shown that the volatile oil of *Arthrospira platensis* consists of a wide range of volatile and semi-volatile compounds as established by GC-MS analysis, which include hydrocarbons, terpenoid derivatives, and fatty acids. These substances are what cause the observed biological actions of the volatile oil. The antioxidant assay showed that the DPPH radical scavenging ability was concentration dependent, but the total antioxidant activity was average in comparison with polar extracts. The antibacterial tests demonstrated inhibitory and bactericidal effects on the Gram-positive and Gram-negative bacteria, with the greatest susceptibility being to *Escherichia coli* and *Bacillus cereus*. The evaluation of cytotoxicity revealed that the volatile oil produced concentration-dependent, selective cytotoxic effects on the HepG2 and MCF-7 cancer cell lines, although the volatile oil was very viable in normal human dermal fibroblast cells. Such selective activity is an indication of a good safety profile. Comprehensively, the results reflect that volatile oil of *Arthrospira platensis* has moderate

antioxidant properties, good antibacterial potential, and selective anticancer effect, which supports its potential of being used as a natural source of biologically active compounds in future pharmaceutical and biomedical studies.

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