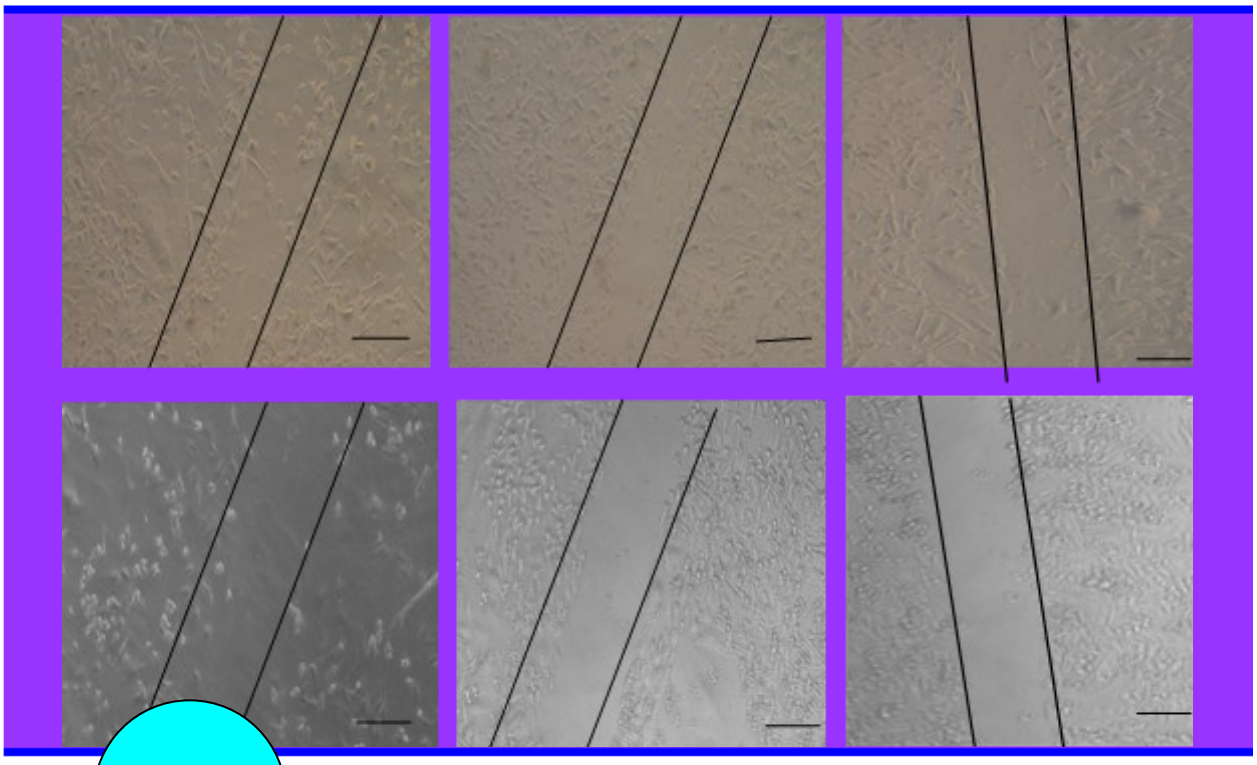

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Anti-cancer potential of crude extracts from *Dictyota bartayresiana* in triple-negative breast cancer

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Abstract

This study aims to isolate and characterize secondary metabolites from the brown algae *Dictyota bartayresiana* and evaluate its cytotoxicity under *in vitro* conditions. Phytochemical analyses were extracted using dichloromethane and ethyl acetate as solvents. The results showed the presence of various compounds such as terpenoids, flavonoids, phenols, and alkaloids. Gas chromatography-mass spectrometry was utilized to characterize the extracts. The cytotoxicity evaluation of the crude extracts by MTT assay showed the inhibitory concentration (IC_{50}) for both extracts in the MDA-MB-231 cell line to be 1 µg/mL. The studies in cell biology indicated a change in cell morphology including detached cells with a round morphology, indicating the induction of apoptosis. Wound healing assay showed that both extracts inhibited the invasion of MDA-MB-231 cells (0.75 µg/mL).

Introduction

Breast cancer has topped lung cancer as the most spotted cancer, with 2.3 million new cases (11.7%) (Sung et al., 2021). The variations between and within tumors, as well as between patients, breast cancer is recognized as a heterogeneous illness (intratumor heterogeneity). This variation is seen in cancer cells as they express hormone receptors, the human epithelial growth factor 2 oncoprotein, and other biomarkers. When taken together, these elements form the foundation for personalized therapies for breast cancer (Turashvili and Brogi, 2017). Hormone receptor-positive/ERBB2 negative (70% of patients), ERBB2 positive (15–25% of patients), and triple-negative (15%) are the three main subtypes of breast cancer based on the above characteristics (Waks and Winer, 2019).

Among the newly reported cases of breast cancer, 15–20% are diagnosed as triple-negative. As a result, the prognosis for these patients is dismal, with a low 5-year survival rate and a significant recurrence rate even after adjuvant therapy (de Ruijter et al., 2011). Standard treatments for triple-negative breast cancer include chemotherapy or radiotherapy following surgery. However, these treatments often have severe side effects, and leave the body prone to relapse and a higher risk of infections as they tend to weaken the body's immune system. Moreover, hormonal therapy or trastuzumab-based therapy cannot be used in triple- negative breast cancer treatment due to the lack of the three receptors above.

In recent decades, there has been a rise in the field of marine pharmacology. These organisms have a rich chemical diversity of secondary metabolites with a wide range of bioactive properties and processes, including the ability to halt the cell cycle, induce apoptosis, and inhibit proliferation and metastasis. Their extensive concentrations in the marine ecosystem, aquatic species are currently being explored as a viable source of bioactive compounds. Abectedin, tisotumab

vedotin, plitidepsin, and cytarabine are only a few of the sea-based medicines that are approved by the FDA and the European Medicines Agency (Ruiz-Torres et al., 2017).

The marine brown algae are known as an excellent source of anti-cancerous biopotentials. For instance, many members of the family *Dictyotaceae* produce several secondary metabolites, mainly diterpenes, making Dictyota the richest genus of brown algae in this family (Rushdi et al., 2022). The structural diversity of the cyclic diterpenes produced by this family is exceptional. Antimicrobial, anti-inflammatory, and anti-cancer properties are just some of the many pharmacological properties attributed to diterpenes (Nyirimigabo et al., 2015). Although approximately 225 direct species can be traced back to Dictyota J. V. Lamouroux, only a fraction of them have been analyzed so far.

This paper primarily aims to investigate the brown algae *Dictyota bartayresiana,* popularly termed "forded sea tumbleweed," which is ubiquitous in tropical and warm water (Bogaert et al., 2020). The current study involved the extraction of *D. bartayresiana* using solvents and subsequent experimentation to detect the phytoconstituents present and the algae's anti-cancer efficacy against the MDA-MB-231 cell line.

Materials and Methods

Collection of algae

The marine seaweed *D. bartayresiana* was obtained from the Mandapam coast of Tamil Nadu, India. A voucher specimen (SLS2022001) of the algae was deposited at the School of Life Sciences, BSACIST, Vandalur, India.

Extraction of phytochemicals

The algae *D. bartayresiana* was shade-dried for 2 weeks and grinded to form a coarse powder. The dried algal powder (20 g) was extracted sequentially with dichloromethane (100 mL) and ethyl acetate (175 mL) for 6 days in an incubator shaker at 37°C at 100 rpm. The mixture was filtered using Whatman filter paper (Sigma Aldrich) and evaporated in a rotary evaporator. The crude extracts were further dried until complete solvent evaporation and subsequently stored at a temperature of 4˚C for further analyses. The yield extract was calculated as a percentage using the following formula:

$$\%\text{Yield} = \frac{\text{Dry weight of extract}}{\text{Dry weight of material}} \times 100$$

The extracts were used after being reconstituted in 1 mg/mL of methanol for all analyses.

Phytochemical screening

The obtained dichloromethane and ethyl acetate extracts of *D. bartayresiana* were subjected to phytochemical screening according to the following standard methods (Yadav et al., 2011).

Test for tannins and phenols (Ferric chloride test)

About 2-3 drops of 2% ferric chloride solution were added to 2 mL of the crude extracts. The appearance of blue-green or black color indicated the presence of tannins and phenols.

Test for flavonoids (Shinoda test)

Fragments of magnesium ribbon were added to 2 mL of the crude extracts, followed by a drop-wise addition of

Box 1: Wound healing assay

Principle

The wound healing test (scratch assay) is a conspicuous *in vitro* technique for tracking cell migration and wound healing in a regulated laboratory setting. This method entails forming a "wound" or gap in a monolayer of previously cultured cells, and then tracking and measuring the cells' movement to close the gap over an established period. The fundamental aspects of cell migration, such as polarity, persistence, and speed, are measured using this assay.

Requirements

Benchtop centrifuge; Breast cancer cell line (MDA-MB-231); Centrifuge tube (15 mL); DEDB extract (1 µg/mL); EEDB extract (1 µg/mL); High-glucose DMEM medium; Incubator; Micropipettes (100-1000 µL); PBS medium; T flask (25 mL); 6-Well culture plate

Procedure

Step 1: MDA-MB-231 cells were seeded in a six well plate at a density of 3 x 10^5 cells/well.

Step 2: The cells were allowed to adhere for 24 hours in a CO_2 incubator.

Step 3: Cell confluency was checked under a microscope. When the cells reached 70% confluency the media was removed.

Step 4: A thin straight scratch was made in each well with the help of a 200 µL micropipette tip.

Step 5: The detached cells were removed by consequent washing with PBS medium.

Step 6: The cells were treated with 0.75 µg/mL of DEDB and EEDB extracts.

Step 7: The cell migration rate was monitored by taking images at hour 0 and hour 24 after incubation.

Step 8: The cells that have not been treated with DEDB and EEDB extracts served as control, and the images that taken at specific intervals were compared to the control.

Reference

Cory, 2011

concentrated HCl. The development of pink, red or orange color confirmed the presence of flavonoids.

Test for terpenoids (Salkowski test)

Chloroform (2 mL) was mixed with 2 mL of the extracts and about 3 mL of concentrated H_2SO_4 was added carefully to form a layer. The formation of a reddish-brown color indicated the presence of terpenoids.

Test for saponins (Froth test)

Distilled water (1 mL) was added to 2 mL of the extracts and shaken vigorously. The formation of stable froth or foam indicated the presence of saponins.

Test for alkaloids

About 2 mL of 1% HCl was added to 2 mL of the extracts. The mixture was heated gently before adding 2 mL of Mayer's and Wagner's reagents. Turbidity and resulting precipitate indicated the presence of alkaloids.

Test for cardiac glycosides (Keller-Kilani test)

A mixture of 2 mL of glacial acetic acid containing 1-2 drops of a 2% $FeCl_3$ solution was added to 2 mL of the crude extracts. The mixture was then transferred to a test tube containing 2 mL of concentrated H_2SO_4. The appearance of a brown ring at the interphase confirms the presence of cardiac glycosides.

Test for amino acids (Ninhydrin test)

The crude extracts (2 mL) were boiled with 2 mL of 0.2%ninhydrin. The formation of a violet color indicated the presence of amino acids.

Test for carbohydrates (Molisch's test)

Molisch's reagent (2-3 drops) was mixed with 2 mL of the crude extracts, followed by the careful addition of 2 mL of concentrated H_2SO_4 along the side of the test tube. The appearance of a violet or purple ring at the interface of the two liquid layers confirmed the presence of carbohydrates.

GC-MS analysis

For the identification of the algal constituents and chemical composition of *D. bartayresiana*, the extracts were characterized by employing the use of GC-MS (Shimadzu, QP2010) plus equipped with a thermal desorption analyser (TD-20) and a liquid autosampler. The pressure was maintained at 51.5 kPa, with 54.0 mL/min flow volume. The ion source of the mass spectrometer was held at 250°C with an interface temperature of 260°C. The threshold was set at 0 with solvent cut time being 2 min. The unknown peaks in the mass spectra of the compounds were collected and then by compared their retention time, area under the peak, peak height, and mass fragmentation spectra with that of established compounds found in the National Institute of Standards and Technology (NIST) collection, the phytoconstituents were determined.

Cell culture

The study relied on MDA-MB-231 cell lines which were offered for the study by Dr. P. Ashok Kumar, School of Life Sciences, BSACIST, Chennai. The cells were subcultured in a high-glucose DMEM (HiMedia, USA) enriched with 10%FBS (HiMedia, USA) and 1%antibiotic cocktail (HiMedia, USA) and subsequently incubated at 37°C with 5%carbon dioxide incubator (Eppendorf, USA).

In vitro analysis of cell viability

For the cell viability assay, 4 x 10^3 cells/well were sown in a 96-well plate, and the plate was left for the cells to adhere. The cells were treated with different concentrations of dichloromethane or ethyl acetate extract (0.1-5 µg/mL). The cells were incubated for 24 hours, and then their vitality was evaluated using the MTT assay. To carry out the essay, MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) reagent was added to the cells and left for incubation at 37°C for 2 hours. During this period, MTT undergoes reduction to form formazon crystals. Following this, isopropanol was added as a solubilizing agent to facilitate the extraction of the formazon product from cells for further quantitative analysis. Doxorubicin was used as the standard reference, while the cells that were not treated were considered the control (Begum et al., 2017).

Cell biology study

The cells were analysed for morphological changes under phase contrast microscope after treatment with algal extracts. The cells were subcultured (4 x 10^5 cells/well) in a 6-well plate, and treated with the inhibitory concentration (IC_{50}) of dichloromethane or ethyl acetate extract. The cells were then left for incubation for 24 hours. After incubation, the cells were again observed, and images were captured.

Statistical analysis

The experiments were carried out thrice in triplicates and the values were expressed as mean ± SD. IBM SPSS 23 Student *t*-test was used to observe the level of significance, with a p-value of <0.05 indicating statistical significance.

Results

Phytochemicals identified

The dry weights of the dichloromethane and ethyl acetate extracts obtained from the extraction process were 0.47 g (yield, 1.5%) and 0.11 g (yield, 0.4%), respectively. The decrease in yield percentage could be attributed to the difference in polarity between the

solvents – dichloromethane < ethyl acetate. The phytochemical analysis verified the presence of secondary metabolites in both extracts. Terpenoids, steroids, flavonoids, phenols, and cardiac glycosides were identified in the crude extracts. Both dichloromethane and ethyl acetate were positive for terpenoids and saponins. However, ethyl acetate extract showed the presence of flavonoids and phenols whereas dichloromethane was positive for cardiac glycosides and alkaloids (Table I).

Table I

Phytochemical analysis of the crude extracts of *Dictyota bartayresiana*

Phytoconstituent	Dichloromethane	Ethyl acetate
Tannins	-	-
Flavonoids	-	+
Terpenoids	+	+
Saponins	+	+
Cardiac glycosides	+	+
Carbohydrates	-	+
Amino acids	-	-
Phenols	+	+
Alkaloids	-	-

+ Presence, - Absence

GC-MS analysis to identify the phytoconstituents

Fifty-four peaks that designate various phytoconstituents were spotted in the GC-MS chromatogram of dichloromethane extract (Table II). Out of 54 compounds, pentadecanoic acid exhibited a higher prevalence with a peak area of 40.5% while the remaining compounds' peak area fell shorter than 5.0%. Such other compounds include 5,9-methanobenzo-cycloocten -5(1H)-ol,2,3,4,6,7,8,9,10-octa-hydro-2,2,8,8,9-pentamethyl- with a peak area of 4.2%, L-ascorbic acid with 3.5% peak area, decaethylene glycol with 3.0% peak area and hexadecenoic acid with 2.6% peak area.

In a correspondent manner, 56 compounds were found in the chromatographic profile of the ethyl acetate extract (Table II). Among these, the compound registered the highest peak area of 9.2%, demonstrating its abundance, was 1-methyl-3-(2,6,6-trimethyl-1-cyclohexen-1-yl) propyl acetate. This was followed by n-hexadecanoic acid with an 8.4% peak area, 3,5-di-tert-butyl-4-hydroxy-phenyl propionic acid with a 6.8% peak area, thunbergol with a 6.3% peak area. The compounds that had peak area as low as 0.05% and below include heptadecane, 2-isopropyl-5-methyl-1-

Table II

GC-MS profile of compounds in two different extracts of *Dictyota bartayresiana*

Retention time (min)	Name of the compound	Molecular formula	Molecular weight	%Present
Dichloromethane extract				
5.851	2-Bromo-3,3,3-trifluoropropyl fluorosulfate	$C_3H_3BrF_4O_3S$	274	0.17
6.085	Phosphorothioic acid, o,o-dimethyl s-[2-(methylamino)-2-oxoethyl] ester	$C_5H_{12}NO_4PS$	213	0.47
10.141	[1,3,5]-Triazine-2-carbonitrile, 4-methoxy-6-(pyrrolidin-1-yl)-	$C_9H_{11}N_5O$	205	0.48
13.257	5-Chloro-3-(4-chloro-phenyl)-benzo[c]isoxazole	$C_{13}H_7C_{12}NO$	263	1.81
16.384	Heptasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13-tetradecamethyl-	$C_{14}H_{44}O_6Si_7$	504	1.03
17.271	1-Dodecanol, 3,7,11-trimethyl-	$C_{15}H_{32}O$	228	0.66
19.366	Proscillaridin	$C_{30}H_{42}O_8$	530	0.19
20.02	Pentadecanoic acid	$C_{15}H_{30}O_2$	242	40.48
20.38	3,6,9,12-Tetraoxatetradecan-1-ol,14-[4-(1,1,3,3-tetramethylbutyl) phenoxy]-	$C_{24}H_{42}O_6$	426	2.34
21.315	7-Hexadecenal, (Z)	$C_{16}H_{30}O$	238	1.37
23.68	Valeric acid, 2,3-epoxy-3,4-dimethyl-, ethyl ester, cis-	$C_{9}H_{16}O_3$	172	1.23
Ethyl acetate extract				
18.491	Neophytadiene	$C_{20}H_{38}$	278	2.76
20.313	3,5-Di-tert-Butyl-4-hydroxyphenylpropionic acid	$C_{17}H_{26}O_3$	278	6.82
20.675	Linalol oxide,trifluoroacetate	$C_{12}H_{17}F_3O_3$	266	0.3
22.225	α– Santalol	$C_{15}H_{24}O$	220	0.65
22.526	1-Methyl-3-(2,6,6-trimethyl-1-cyclohexan-1-yl) propyl acetate	$C_{15}H_{26}O_2$	238	9.23
22.646	1H-Purin-6-amine, [(2-fluorophenyl) methyl]-	$C_{12}H_{10}FN_5$	243	0.6
23.626	4,8,13-Cyclotetradecatriene-1,3-diol, 1,5,9-trimethyl-12-(1-methylethyl)-	$C_{20}H_{34}O_2$	306	3.14
24.245	Testolactone	$C_{19}H_{24}O_3$	300	5.91
26.007	Thunbergol	$C_{20}H_{34}O$	290	6.34

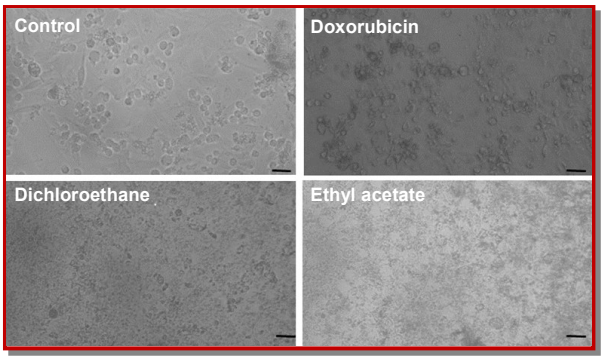

Figure 1: Phase contrast microscopic views after exposure to dichloromethane and ethyl acetate extracts *D. bartayresiana*. Doxorubicin was used as standard. Magnification at 10x

Table III

Cytotoxic activity of extracts of *D. bartayresiana* against MDA-MB-231 cell line

	%Cell viability	
Concentration (µg/mL)	Dichloromethane	Ethyl acetate
0.5	79.7 ± 2.2[a]	59.8 ± 3.4
0.75	51.0 ± 4.0[a]	58.4 ± 2.3
1	50.1 ± 0.5	50.8 ± 2.1
1.5	46.4 ± 1.3	33.5 ± 0.5[a]
2	43.2 ± 1.5	33.4 ± 0.9
2.5	42.5 ± 1.7	32.1 ± 0.7
3	41.4 ± 1.1	28.3 ± 0.8

Data are mean ± SD. For standard doxorubicin (1 µg/mL) cell viability (%) = 50.8 ± 0.6; Superscript "a" means $p<0.05$ compared to control group

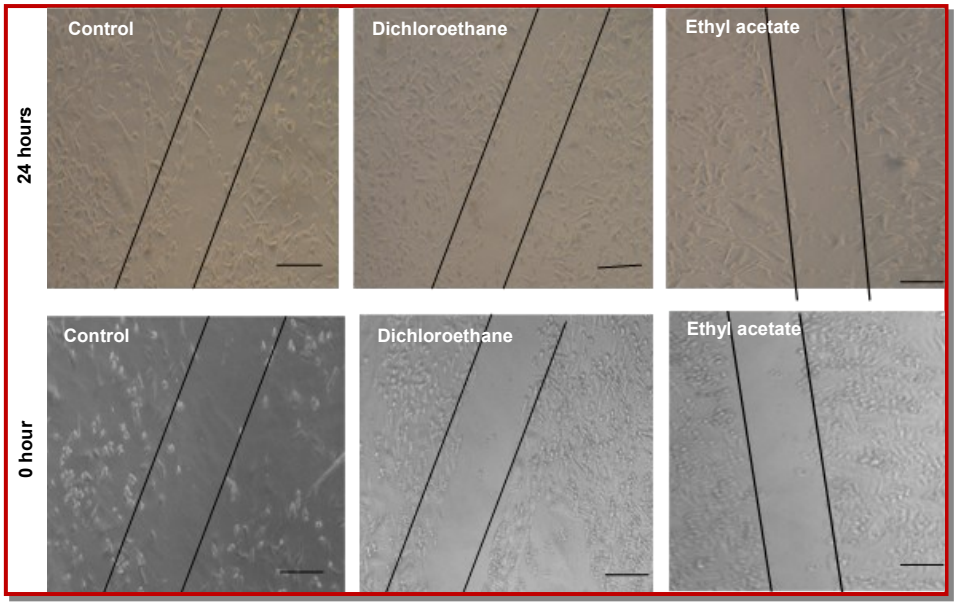

Figure 2: Wound healing assay. The assay was carried out to test the anti-migratory effect of dichloromethane and ethyl acetate extracts of *D. bartayresiana*. The migration of cells into the wound region was observed in control and dichloromethane and ethyl acetate-treated cells at 0 and 24 hours. Magnification at 10x

heptanol, and 3-isopropoxy-1,1,1, 7,7,7-hexamethyl-3,5,-5-tris(trimethyl-siloxy)tetrasiloxane. Further, compounds such as neophytadiene, testolactone and octadecanoic acid had peak areas ranging between 2 and 5%.

Effects on cell viability

MDA-MB-231 cells were treated with increasing concentrations of dichloromethane extract and EEDB, ranging from 0.1 to 5 µg/mL for 24 hours and cell death was measured with the help of MTT assay. Cell viability assay results displayed that both the extracts exhibited a dose-dependent response and induced 50% cytotoxicity in the MDA-MB-231 cell line. The IC_{50} that caused 50% cell death was determined as 1 µg/mL for dichloromethane and ethyl acetate extracts. The IC_{50} for doxorubicin was also identified as 1 µg/mL. Cell viability seemed to decrease with concentrations >1 µg/mL of both extracts (Table III).

Under a phase contrast microscope, cells treated with both extracts shrunk in size, indicating the loss of cell morphology with alterations in the cell shape and size as compared to the untreated control cells (Figure 1).

Effects on the migration of cells

The wound healing assay showed extract-treated cells had fewer cells migrating into the wound than the control cells, suggesting that both extracts have anti-migratory properties. The percent migration was calculated as 65% for dichloromethane extract and 51.3% for ethyl acetate extract (Figure 2).

Discussion

The findings of this study show the potent cytotoxic

and anti-migratory effects of the crude extracts from the brown algae *D. bartayresiana* on the triple negative breast cancer cell line MDA-MB-231. With an IC_{50} of 1 µg/mL, the dichloromethane and ethyl acetate extracts demonstrated a significant ability to induce apoptosis and inhibit migration of the cancer cells. Both extracts exhibited dose-dependent cytotoxicity, altering the morphology of MDA-MB-231 cells and reducing their migratory abilities in the wound healing assay. Moreover, the phytochemical screening revealed the presence of diverse bioactive compounds such as terpenoids, flavonoids, phenols, and alkaloids, with the ethyl acetate extract being specifically rich in terpenoids. These findings suggest that *D. bartayresiana* holds promise as a potential candidate for the development of novel therapeutic agents targeting triple-negative breast cancer cell lines.

The *Dictyota* genus has been explored generously for a variety of its properties. For instance, *D. dichotoma*, being one of the highly researched species in this genus, has been tested on various grounds for its anti-cancerous property among many (El-Shaibany et al., 2022, Usolteva et al., 2018, Malyarenko et al., 2019). Moreover, the genus is known for its rich reserve of terpenes (Rushdi et al., 2022). Terpenoids, in particular, have shown immense potential in inducing apoptosis and inhibiting proliferation across various cancer models, and they have been attributed to the genus's therapeutic potential. However, the species *D. bartayresiana* has not been analyzed for its cytotoxic activity, specifically against triple-negative breast cancer cell lines, and further, remains to be deeply unexplored. Previously, only two studies were found to have examined its anti-cancer effects against HT29 (Bharathi et al., 2022) and DLA (Antonysamy et al., 2015) cell lines using nanoparticles synthesized from the algae. In another study (Dubey et al., 2022), the group explicitly isolated and extracted fucoidans from *Dictyota bartayresiana.* Fucoidans, being polar compounds, are generally extracted using aqueous solvents under slightly acidic conditions. By employing such techniques, the research group isolated the sulfated polysaccharide effectively, and further investigated its antioxidant and cytotoxic potential in the SK-Hep-1 cell line, producing significant results indicating the same. Moreover, the study further showed that fucoidan treatment induced not only apoptosis but also activated autophagy in the cancer cell. In contrast, our analysis did not detect the presence of sulfated polysaccharides or fucoidans in the extracts since we employed ethyl acetate and dichloromethane for extraction. These solvents are non-polar and therefore not ideal for extracting polar compounds like fucoidans. Despite the lack of relevant data on *D. bartayresiana* to draw conclusive findings, the results of this study align with the more generalized characteristics found in the genus.

The MDA-MB-231 cell line was found to be sensitive to both the extracts' cytotoxicity, and the extracts further displayed anti-migratory ability. This could be attributed to the identified bioactive compounds. A major component in dichloromethane extract, pentadecanoic acid, is known to modulate lipid metabolism and induce apoptosis. The cytotoxicity of pentadecanoic acid has further been linked to the inhibition of the Jak2/Stat3 signaling pathway in a prior study (To et al., 2020). However, several compounds found in dichloromethane extract have not been thoroughly investigated in prior research, which indicates the likelihood that any of these compounds could be responsible independently or synergistically for the biological activity noted in this study. The high incidence of terpenoids in the ethyl acetate extract raises the possibility of the biological activity exhibited by ethyl acetate in this study being accredited to its rich terpenoid content. These included thunbergol, α-santalol, neophytadiene, linalool oxide, isoaromadendrene epoxide, heptatriacotanol. Thunbergol, also referred to as isocembrol, is a monocyclic diterpene alcohol that has been exploited in the treatment of cancer and was previously claimed as a TNF inhibitor (Li et al, 2020). Another intriguing terpenoid found here is α-santalol, which is a naturally occurring sesquiterpene that is generally derived from sandalwood oils. In a prior investigation, alpha-santalol derived from sandalwood oil was tested against human prostate cancer cells, and reports of apoptosis induction in the cell line through caspase-3 activation (Bommareddy et al., 2012) were made. The compound, neophytadiene is also a diterpene, which has also been reported in a previous study to possess anti-inflammatory, antioxidant and cardioprotective properties (Bhardwaj et al., 2020). Linalol oxide, a monoterpene compound, is known for its aromatic power and antimicrobial properties (Griffin et al., 1999). Findings from the above prior investigations into these compounds only reinforce their role in promoting cell death.

However, ethyl acetate extract was more effective in inhibiting cell migration by around 13% than dichloromethane extract. This difference could be attributed to their distinct chemical compositions. According to the GCMS results, ethyl acetate extract contained a more diverse array of compounds. In contrast, the majority of dichloromethane extract's composition is taken up by pentadecanoic acid which accounted for approximately 40% of its content. This high concentration of pentadecanoic acid likely contributes to its cytotoxic effects but may also be accredited to the difference observed in its anti-migratory effects. The polarity of the solvents could be linked to the difference in these chemical compositions between the extracts since by utilizing solvents with varying polarity, it is possible to extract

diverse classes of phytocompounds (Wakeel et al., 2019). Being a nonpolar solvent, dichloromethane extracted compounds like pentadecanoic acid, which are less polar. With its comparatively higher polarity, ethyl acetate extracted a wider range of bioactive molecules, including diverse terpenoids. A few compounds such as 3-Isopropoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris (trimethylsiloxy)tetrasiloxane and hexadecenoic acid overlapped in both the extracts. The selective solubility of compounds explains the minimal overlap in their GCMS profile and further points to a polarity-driven extraction process which hints at the importance of sound solvent selection for isolating compounds with specific bioactivities.

However, this study has a few limitations. The lack of comparative studies conducted on the same species, (*D. bartayresiana)* against a broad range of breast cancer cell lines, severely limits the generalizability of the findings. Secondly, while GC-MS analysis revealed rich reserves of phytocompounds, the specific bioactive compounds responsible for the observed effects remain unidentified, which warrants further purification and characterization studies. Thirdly, the underlying mechanisms through which the compounds exert their effects were unexplored in this study; however, investigating these mechanisms in future research could provide profound insights and enhance our understanding. Finally, the study was not conducted on animal models due to limited research conditions.

Conclusion

Both dichloromethane and ethyl acetate extracts of *D. bartayresiana* contain active phytoconstituents, with the ethyl acetate extract being particularly rich in terpenes. The MDA-MB-231 cell line was sensitive to the extract's cytotoxicity, and the extracts displayed anti-migratory ability.

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Ethical Issue

Not applicable.

Conflict of Interest

Authors declare no conflict of interest

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References

Antonysamy JMA, Thangiah S, Irulappan R. Green synthesis of silver nanoparticles using *Dictyota bartayresiana* JV Lamouroux and their cytotoxic potentials. Int Biol Biomed J. 2015; 1: 112-18.

Bauer KR, Brown M, Cress RD, Parise CA, Caggiano V. Descriptive analysis of estrogen receptor (ER)-negative, progesterone receptor (PR)-negative, and HER2-negative invasive breast cancer, the so-called triple-negative phenotype: A population-based study from the California cancer registry. Cancer. 2007; 109: 1721-28.

Begum SF, Priya S, Sundararajan R, Hemalatha S. Novel anticancerous compounds from *Sargassum wightii*: *In silico* and *in vitro* approaches to test the antiproliferative efficacy. J Adv Pharm Educ Res. 2017; 7: 272-77.

Bhardwaj M, Sali VK, Mani S, Vasanthi HR. Correction to: Neophytadiene from *Turbinaria ornata* suppresses LPS-induced inflammatory response in RAW 264.7 macrophages and Sprague Dawley rats. Inflammation 2020; 43: 951-52.

Bogaert KA, Delva S, De Clerck O. Concise review of the genus Dictyota JV Lamouroux. J Appl Phycol. 2020; 32: 1521-43.

Bommareddy A, Rule B, VanWert AL, Santha S, Dwivedi C. α-Santalol, a derivative of sandalwood oil, induces apoptosis in human prostate cancer cells by causing caspase-3 activation. Phytomedicine 2012; 19: 804-11.

Cory G. Scratch-wound assay. Methods Mol Biol. 2011; 769: 25-30.

de Ruijter TC, Veeck J, de Hoon JP, van Engeland M, Tjan-Heijnen VC. Characteristics of triple-negative breast cancer. J Cancer Res Clin Oncol. 2011; 137: 183-92.

Dubey A, Sivaraman J. Evaluation of the cytotoxicity, apoptosis, and autophagy induction by fucoidan in human hepatic adenocarcinoma cells. Indian J Pharm Educ Res. 2022; 56: 756-64.

El-Shaibany A, Al-Habori M, Al-Maqtari T, Al-Mahbashi H. The Yemeni brown algae *Dictyota dichotoma* exhibits high in vitro anticancer activity independent of its antioxidant capability. Biomed Res Int. 2020; 2020: 2425693.

Griffin SG, Wyllie SG, Markham JL, Leach DN. The role of structure and molecular properties of terpenoids in determining their antimicrobial activity. Flavour Fragr J. 1999; 14: 322-32

Li G, Li H, Tang W, Yao LG, Liang LF, Guo YW. Further polyoxygenated cembranoids from South China Sea soft coral *Sarcophyton ehrenbergi*. Bioorg Chem. 2020; 101: 103993.

Luo M, Liu Y, Liu N, Shao W, Ming L, Liu J, Xie Y.

Proscillaridin A inhibits hepatocellular carcinoma progression through inducing mitochondrial damage and autophagy. Acta Biochim Biophys Sin (Shanghai). 2021; 53: 19-28.

Nyirimigabo E, Xu Y, Li Y, Wang Y, Agyemang K, Zhang Y. A review on phytochemistry, pharmacology and toxicology studies of Aconitum. J Pharm Pharmacol. 2015; 67: 1-19.

Roulot A, Hequet D, Guinebretiere JM, Vincent-Salomon A, Lerebours F, Dubot C, Rouzier R. Tumoral heterogeneity of breast cancer. Ann Biol Clin (Paris). 2016; 74: 653-60.

Ruiz-Torres V, Encinar JA, Herranz-Lopez M, Perez-Sanchez A, Galiano V, Barrajon-Catalan E, Micol V. An updated review on marine anticancer compounds: The use of virtual screening for the discovery of small-molecule cancer drugs. Molecules 2017; 22: 1037.

Rushdi MI, Abdel-Rahman IAM, Attia EZ, Saber H, Saber AA, Bringmann G, Abdelmohsen UR. The biodiversity of the genus Dictyota: Phytochemical and pharmacological natural products prospectives. Molecules 2022; 27: 672.

Sangpairoj K, Settacomkul R, Siangcham T, Meemon K, Niamnont N, Sornkaew N, Tamtin M, Sobhon P, Vivithanaporn P. Hexadecanoic acid-enriched extract of *Halymenia durvillei* induces apoptotic and autophagic death of human triple-negative breast cancer cells by upregulating ER stress. Asian Pac J Trop Biomed. 2022; 12: 132-40.

Semba M, Takamatsu S, Komazawa-Sakon S, Miyoshi E, Nishiyama C, Nakano H, Moriwaki K. Proscillaridin A sensitizes human colon cancer cells to TRAIL-induced cell death. Int J Mol Sci. 2022; 23: 6973.

Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2021; 71: 209-49.

To NB, Nguyen YT, Moon JY, Ediriweera MK, Cho SK. Pentadecanoic acid, an odd-chain fatty acid, suppresses the stemness of MCF-7/SC human breast cancer stem-like cells through JAK2/STAT3 signaling. Nutrients 2020; 12: 1663.

Wakeel A, Jan SA, Ullah I, Shinwari ZK, Xu M. Solvent polarity mediates phytochemical yield and antioxidant capacity of *Isatis tinctoria*. PeerJ. 2019; 7: e7857.

Waks AG, Winer EP. Breast cancer treatment: A review. JAMA. 2019; 321: 288-300.

Yadav RN, Agarwala M. Phytochemical analysis of some medicinal plants. J Phytol. 2011; 3: 14.

Zhu S, Jiao W, Xu Y, Hou L, Li H, Shao J, Zhang X, Wang R, Kong D. Palmitic acid inhibits prostate cancer cell proliferation and metastasis by suppressing the PI3K/Akt pathway. Life Sci. 2021; 286: 120046.

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