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Antioxidants and Anticancer Activity of Certain Algae and Their Role in Sustainability

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ABSTRACT

This study examined the potential of various Egyptian marine algae as sources of antioxidant and anticancer compounds, offering a sustainable and less toxic alternative to conventional cancer treatments. It addressed the global public health burden of cancer and the limitations of current therapies, highlighting the urgent need for safe, effective, and affordable options derived from natural products. The research outlined the extraction process of bioactive compounds from five types of algae using both methanol and ethyl acetate solvents. These extracts were tested for their efficacy against several human cancer cell lines, as well as for their antioxidant activity. The results reveal that different algal extracts exhibit varying levels of potency against specific cancer cells and demonstrate significant antioxidant capacity, suggesting strong potential for future pharmaceutical development.

INTRODUCTION

Cancer is the second leading cause of death, after cardiovascular disease **(Cadoná *et al.*, 2022)**. It is also an important barrier to increasing life expectancy. Cancer is associated with substantial social and macroeconomic costs that vary in degree across cancer types, geography, and gender **(Azizi *et al.*, 2023)**.

Cancer is a very serious public health problem, with rising rates of occurrence and mortality **(Jang & Lee, 2021)**. It is ranked as one of the major causes of death all over the world **(Toric *et al.*, 2020; Eltamany *et al.*, 2022)** according to the **WHO (2024)**. In 2020, it was estimated that the global cancer burden would rise to 19.3 million new cases and 10.0 million deaths. Approximately one in every five people worldwide develops cancer during their lifetime, whereas one in eight men and one in eleven women die from the disease **(International Agency for Research on Cancer, 2024)**.

Due to the side effects and the high costs of various treatments for cancer, researchers have thought about finding alternative anti-cancer compounds, so that these compounds are safe and inexpensive **(Rahman *et al.*, 2022)**. Recently, several studies have focused on the

antioxidants and the antiproliferative activities of extracts of natural products, especially some algae **(Sharma *et al.*, 2023)**. Antioxidants act as free radical scavengers. They block the activity of the free radicals, preventing their harmful effects **(Leong & Chang, 2024)**. Although hundreds of chemopreventive agents have been developed worldwide during the past decade, only a few new drugs have been approved **(Ren *et al.*, 2025)**. Most natural products are chemopreventive agents **(Boretti, 2022)**. This is attributed to their low toxicity profiles and potential effectiveness. They are considered nutritional therapeutics, which include a variety of nutrients, non-nutrients, and bioactive food components **(Sharma *et al.*, 2024)**.

Chemotherapy drugs can enter the environment through improper disposal and patient excretion **(Hao *et al.*, 2022)**. These drugs can harm aquatic life and disrupt ecosystems. The production and disposal of chemotherapy drugs contribute significantly to healthcare's carbon footprint **(Sharma *et al.*, 2022)**. A carbon footprint is the total amount of greenhouse gases (GHGs) emitted directly and indirectly by human activities. It includes emissions from various sources such as transportation, energy consumption, industrial processes, and agriculture **(Zhang *et al.*, 2025)**.

For instance, the NHS (National Health Service) in the UK has identified that around 25% of its carbon footprint comes from medicines, including chemotherapy **(van Hove *et al.*, 2024)**. The manufacturing process of chemotherapy drugs is resource-intensive, requiring significant amounts of water and energy. These factors highlight the need for more sustainable practices in the production and disposal of chemotherapy drugs to mitigate their environmental impact **(Singh *et al.*, 2024)**.

Environmental waste is diverse and varied, including solid, liquid, and gaseous waste—most of which is man-made. Natural waste also abounds in specific environments, such as freshwater and marine habitats. These wastes include many aquatic plants and weeds that grow profusely, causing an environmental burden because they are not disposed of using sound scientific methods. These plants include reeds, water hyacinth, and others, which have transformed rivers into hiding places for fish, thus hindering fishing operations **(Ogidi & Akpan, 2022)**.

All marine creatures have many chemical defense strategies, using toxic molecules to protect themselves from pathogens or predators, which are widespread in the marine environment **(Hou *et al.*, 2019)**. They produce functional metabolites with chemical defense functions that can defend against natural enemies, avoid attachment of marine organisms and floating debris, and transmit information between species **(Burkhardt *et al.*, 2022; Scesa *et al.*, 2022)**.

A very distinctive group is algae, both freshwater and marine. Since these organisms grow rapidly, they pose a significant environmental burden, especially if they are not controlled using sound scientific methods. For example, waterways may become clogged, as in neglected canals, and beaches may become unsuitable for summer recreation. Coral reefs in some areas may also be harmed. Recently, research has emerged on sound scientific methods for utilizing living and dead algae. Some are edible due to their high nutritional content and are therefore used as human nutritional supplements. They are also used as feed for cattle, fish, and birds, while others are used as fertilizer. Some are being studied to extract safe drugs **(Roy *et al.*, 2022)**.

Harmful algal blooms can discourage people from visiting beaches due to their unpleasant appearance and odor. Some types of algae produce toxins that can cause health issues in humans, viz. skin rashes, respiratory problems, and gastrointestinal illnesses. These toxins can be released into the air or water, posing risks to swimmers, surfers, and other beachgoers **(AbouGabal *et al.*, 2022)**.

In Egypt, algal blooms have been observed in various coastal areas, including the Mediterranean coast and the Red Sea. For instance, beaches in Port Said have experienced sudden gatherings of green algae due to high temperatures, increased organic nutrients, and strong sea currents **(Rashad & El-Chaghaby, 2020)**. Similarly, the Eastern Harbor of Alexandria has witnessed recurrent red tides caused by harmful algae like *Alexandrium minutum*, which can produce toxins that are harmful to marine life and humans. This discourages people from visiting the beaches and affects local tourism **(Ismael, 2021)**.

Numerous methods for removing algae are harmful to the environment. One common method involves the use of chemical algaecides. While effective in killing algae, these chemicals can contaminate water sources, harm non-target aquatic organisms, and disrupt marine ecosystems **(El-Dars *et al.*, 2021)**.

Physical removal methods, such as dredging and mechanical harvesting, can also be damaging. These techniques often disturb the seabed, destroy habitats, and resuspend sediment, which can degrade water quality and harm marine life **(Ge *et al.*, 2025)**.

However, sustainable uses of algae are now being developed. Algae can be used to produce biofuels—renewable and environmentally friendly alternatives to fossil fuels. Their high lipid content makes them ideal for biodiesel production. This approach provides a sustainable energy source and helps reduce greenhouse gas emissions **(Hosny *et al.*, 2025)**. Egypt is actively exploring algae for biofuel, with projects like Rega Green Energy's Algae Modular Automated Plantations (A-MAP) in Hurghada producing algae biomass for green fuel. This initiative is expected to lower carbon emissions and to support a greener economy **(Hosny *et al.*, 2025)**.

Algae can also be employed in wastewater treatment to remove excess nutrients and contaminants. They absorb nitrogen and phosphorus, helping to prevent eutrophication and improve water quality—an efficient and environmentally sustainable solution **(Hosny *et al.*, 2025)**.

Moreover, algae can capture and store carbon dioxide from the atmosphere, contributing to climate change mitigation. Algae-based carbon sequestration is a promising strategy that can complement other environmental management practices **(Roy *et al.*, 2022; Hosny *et al.*, 2025)**.

Using algae as anticancer agents offers significant sustainability advantages. Algae can be cultivated in diverse environments—marine and freshwater—without competing with agricultural land or freshwater used for food production **(Nurkolis *et al.*, 2024)**. They grow rapidly and can be harvested multiple times annually, ensuring a stable supply of raw materials **(Xin *et al.*, 2024)**. Additionally, algae absorb carbon dioxide and release oxygen during cultivation, which helps reduce greenhouse gases **(Sharma *et al.*, 2023)**. These characteristics make algae a promising, eco-friendly source of anticancer agents **(Thaman *et al.*, 2023)**.

Recent studies have further highlighted algae's potential in cancer therapy. For example, a 2024 study investigated *Chlorella* sp. extracts for synthesizing bismuth

nanoparticles (BiNPs) for targeted drug delivery in lung cancer treatment. These BiNPs showed selective toxicity toward A549 lung cancer cells, while sparing normal human fibroblast cells **(Alprol *et al.*, 2023)**. Marine-derived bioactive molecules continue to show promise in biotechnology and cancer medicine **(Hang *et al.*, 2024)**. Additionally, research on the green alga *Bornetella nitida* demonstrated significant cytotoxic effects on MCF-7 breast cancer cells **(Hadisaputri *et al.*, 2024)**.

Therefore, this research aimed to use Egyptian algae for their anticancer and antioxidant properties.

MATERIALS AND METHODS

1. Plant material

A total of five marine algae were collected from different Egyptian marine environments, especially the Mediterranean and the Red Sea, belonging to different algae families, as shown in Table (1).

The collection of algae took place during spring and summer along two consecutive years. *Spirulina platensis* was obtained as a fresh culture from the National Research Centre, Cairo, Egypt.

Table 1. Algae names, their families and spot of collection

	Name	Family	Spot
1	*Corallina officinalis*	Corallinaceae	Hurghada
22	*Laurencia obtusa*	Rhodomelaceae	Abu Kir, Alexandria
33	*Spirulina platensis*	Microcoleaceae	NRC
44	*Galaxaura elongata*	Galaxauraceae	Hurghada
55	*Amphiroa rigida*	Corallinaceae	Al Ain Al Sokhna

Macro- and microalgae collected from different localities (Table 1) were oven-dried at 25–30°C. The dried material was ground, macerated, and then dissolved in an organic solvent (methanol or ethyl acetate). The extracts were filtered, and the solvents were evaporated under vacuum at 35°C. The resulting residues were freeze-dried and stored at −20°C **(Dalaam *et al.*, 2020; Thanigaivel *et al.*, 2023)**.

2. Cell lines and culture

Cell lines included hepatocellular carcinoma (HEPG2), prostate adenocarcinoma (PC3), breast adenocarcinoma (MCF7), colorectal carcinoma (HCT116), an epithelial breast cancer cell line (MDA-MB-231), lung carcinoma (A549), colorectal adenocarcinoma with epithelial morphology (HT29), and immortalized normal epithelial cells (RPE1) using hTERT.

All cell lines were of human origin and were kindly provided by Dr. Sting Lander, Karolinska Institute, Sweden.

Cells were cultured in a medium containing 10% fetal bovine serum (FBS) at 37°C, 5% CO_2, and 95% humidity. Subculturing was performed using 0.15% trypsin.

3. Cell viability assay

- ***Seeding***
  MCF7, MDA-MB-231, HCT116, HT29, PC3, A549, and HEPG2 cells were seeded at 10,000 cells per well, while RPE1 cells were seeded at 50,000 cells per well in 96-well plates.
- ***Treatment***
  After 24 hours of seeding, the medium was replaced with serum-free medium containing decreasing concentrations (200, 100, 50, and 25 µg/ml) of the algal extracts. Cells were incubated for 72 hours.
  Cell viability was assessed using the MTT assay, with doxorubicin as the positive control and DMSO as the negative control. IC_{50} values were calculated using SPSS 22.

4. Estimation of antioxidant activity by 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging

All samples were tested at descending concentrations of 500, 250, 125, and 62.5µg/ ml using 0.1 mM DPPH dissolved in methanol. After 30 minutes of incubation in the dark at room temperature, absorbance was measured at 517nm, with a reference wavelength at 690nm. Ascorbic acid (vitamin C) was used as a positive control at concentrations ranging from 11 to 2.7µg/ ml. A DPPH/methanol mixture was used as the negative control.

The DPPH scavenging activity of the samples was calculated using the following equation:

Percentage reduction = (1 - (X / av(NC))) × 100

Where, X is the absorbance of the sample; av is the average absorbance of the control; and NC is the absorbance of the negative control **(Ameen *et al.*, 2023)**.

RESULTS

1. Cell viability assay

1.1. Methanolic extracts

The IC_{50} values obtained for the different algal extracts against various cell lines reveal important insights into their anticancer potential and selectivity.

Corallina officinalis demonstrated the lowest IC_{50} values across most cancer cell lines, particularly against HT29 (117 ± 0.5µg/ ml), indicating high potency. This suggests that *C. officinalis* could be a promising candidate for further investigation, especially for colorectal cancer treatment (Table 2 & Fig. 1).

Amphiroa rigida also exhibited relatively low IC_{50} values against MDA-MB-231 (134.3 ± 1µg/ ml) and A549 (130 ± 0.4 µg/ml), highlighting its effectiveness against breast and lung cancer cells (Table 2 & Fig. 1).

Spirulina platensis showed a high IC_{50} value against HCT116 (722.3 ± 0.6µg/ ml), suggesting lower efficacy for this cell line. Nonetheless, its lower IC_{50} values for A549 (113.26 ± 0.6µg/ ml) and RPE1 (132.3 ± 1.1µg/ ml) indicate potential for lung cancer treatment, though its impact on normal cells should be carefully considered.

Galaxaura elongata showed moderate IC_{50} values across all tested cell lines, with the lowest being 139.2 ± 0.6µg/ ml for RPE1. This suggests a broad spectrum of activity but also raises concerns about its selectivity and potential cytotoxicity to normal cells.

Overall, these results highlight the differing efficacy and selectivity of the algal extracts, with *C. officinalis* and *A. rigida* emerging as particularly potent candidates against specific cancer cell lines (Table 2 & Fig. 1).

Table 2. IC_{50} of the bioactivity for methanolic extracts of some algae on MDA, A549, HCT116, HT29 (human cancerous cell lines) and RPE1(normal cell line)

Algae	IC_{50} µg/ml				
	MDA	A549	HT29	HCT116	RPE1
Galaxaura elongata	152.55±0.9	266.15±0.6	151.5±0.5	230±0.6	139.2±0.6
Amphiroa rigida	134.3±1	130±0.4	166.1±0.3	204.6±0.7	---------
Spirulina platensis	143.9±.05	113.26±0.6	168.9±0.7	722.3±0.6	132.3±1.1
Corallina officinalis	124.6±0.6	116.7±0.5	117±0.5	191.1±0.4	191.1±0.8

(---) not detected value.

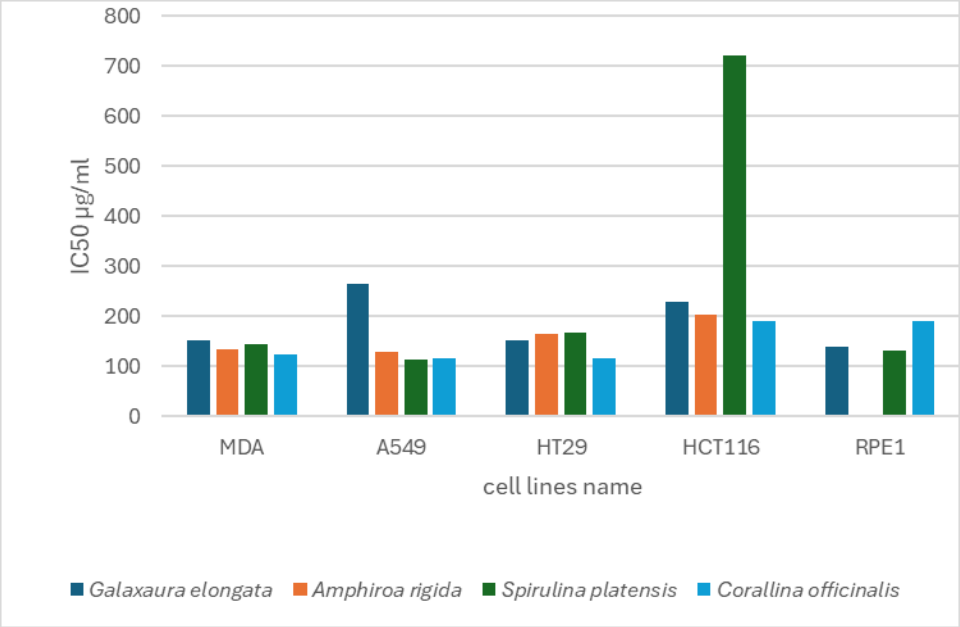

Fig. 1. The difference in IC50 between human cancer cell lines (MDA, A549, HT29, HCT116) and normal cell line

1.2. Ethyl acetate extract

Corallina officinalis showed moderate IC_{50} values across most cell lines, with the highest being 107.06 ± 0.5µg/ ml for RPE1, indicating some effectiveness but also a potential impact on normal cells. It demonstrated particular efficacy against PC3 (177.11 ± 1µg/ ml) and HCT116 (205.49 ± 1.4µg/ ml), suggesting potential for prostate and colorectal cancer treatment.

Laurencia obtusa exhibited low IC_{50} values for HCT116 (113.61 ± 1.1µg/ ml) and MCF7 (91.78 ± 1.2µg/ ml), indicating good potential for colorectal and breast cancer treatment. However, the absence of data for HT29 limits the efficiency of a complete evaluation. The relatively low IC_{50} value of 88.23 ± 0.5µg/ ml for RPE1 suggests that it may also affect normal cells.

Spirulina platensis demonstrated very low IC_{50} values for MCF7 (2.78 ± 0.8µg/ ml) and PC3 (9.81 ± 0.7µg/ ml), indicating strong potency against breast and prostate cancer cells. However, its moderate to high IC_{50} values for other cell lines—such as HCT116 (245.33 ± 1µg/ ml) and A549 (312.93 ± 0.8µg/ ml)—suggest variable effectiveness. The low IC_{50} value for RPE1 (62.96 ± 0.7µg/ ml) indicates a potential cytotoxic effect on normal cells.

Overall, these results highlight the differing efficacy and selectivity of the algal extracts, with *Spirulina platensis* showing the highest potency against specific cancer cell lines. However, further studies are required to confirm these findings and to better assess the safety and selectivity of these extracts (Table 3 & Fig. 2).

Table 3. IC_{50} of the bioactivity for ethyl acetate extracts of some algae on A549, HCT116, HT29, PC3, HEPG2 (human cancerous cell lines) and RPE1 (normal cell line)

Algae	IC50						
	A549	HCT116	HT29	PC3	HEPG2	MCF7	RPE1
Corallina officinalis	295.26±0.6	205.49±1.4	273±1.2	177.11±1	231.77±0.6	264.09±1	107.06±0.5
Laurencia obtusa	302.52±0.4	113.61±1.1	---------	109.76±0.9	142.25±0.9	91.78±1.2	88.23±0.5
Spirulina platensis	321.93±0.8	245.33±1	166.04±1	9.81±0.7	173.92±0.9	2.78±0.8	62.96±0.7

(---) not detected value.

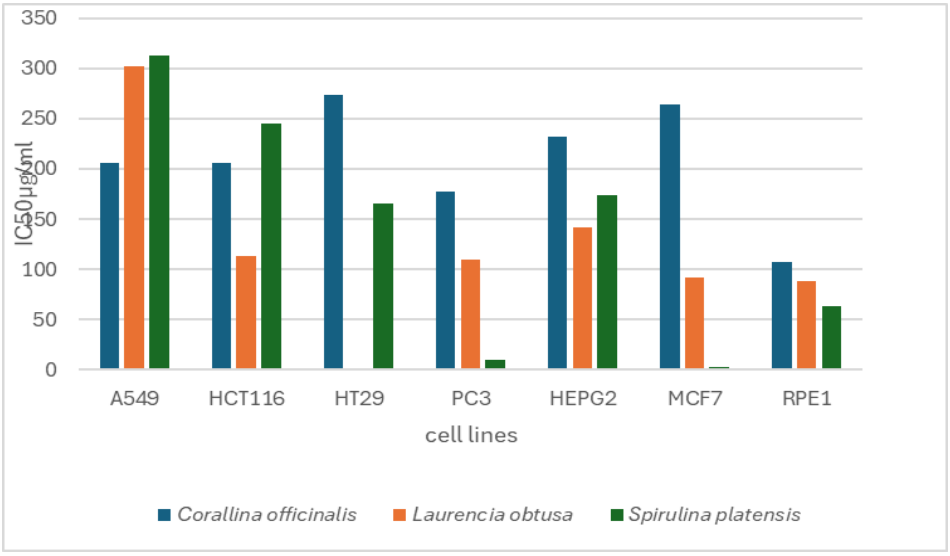

Fig. 2. The difference in IC50 between human cancer cell lines (A549, HCT116, HT29, PC3, HEPG2, MCF7) and normal cell line (RPE1) for ethyl acetate extracts

2. Estimation of antioxidant activity by 2,2-diphenyl-1-pcrylhydrazyl (DPPH) radical scavenging activity

2.1 Methanol extract

These results highlight the varying antioxidant capacities of the algal extracts, with *Corallina officinalis* (329.39µg/ ml) being the most potent, followed by *Galaxaura elongata* (353.13µg/ ml), *Amphiroa rigida* (412.80µg/ ml), and *Spirulina platensis* (608.8µg/ ml) (Fig. 3).

2.2. Ethyl acetate extract

These results highlight the varying antioxidant capacities of the algal extracts, with *Corallina officinalis* (395.14µg/ ml) being the most potent, followed by *Laurencia obtusa* (464.63µg/ ml), and *Spirulina platensis* (551.16µg/ ml) (Fig. 3).

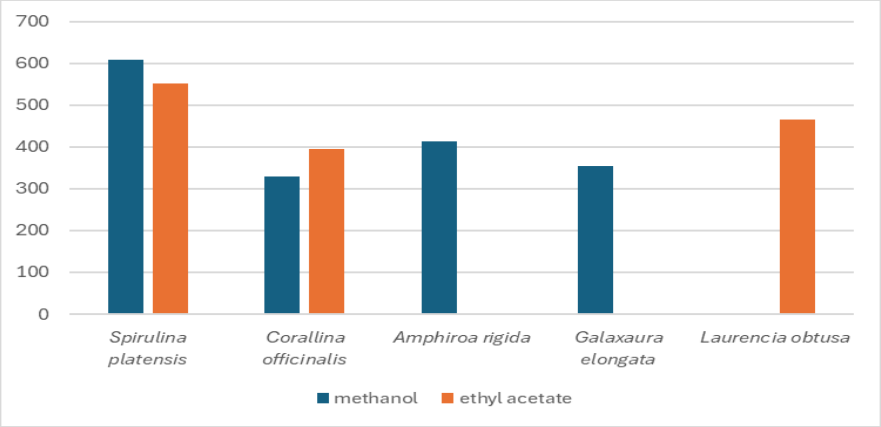

Fig. 3. Differences in antioxidant activity by using DPPH for methanolic and ethyl acetate extracts

DISCUSSION

Algae, including macroalgae (seaweeds) and microalgae, are common on beaches and coastal areas. They play a crucial role in marine ecosystems by providing food and habitat for various marine organisms. However, when algae proliferate excessively, they can form harmful algal blooms (HABs), which can have significant negative impacts on both the environment and human activities **(Rashad & El-Chaghaby, 2020; Ismael, 2021)**.

In the last decade, there has been extensive research on the use of algae as a source of safe chemical compounds for treating tumors, cardiovascular diseases, and infections. These compounds include flavonoids, phenolic acids, alkaloids, and terpenoids. They protect cells from the harmful effects of free radicals, which trigger chain reactions that can damage cell membranes and internal components, opening the door to fatal diseases **(Ahmed *et al.*, 2024)**.

The ease of cultivation and rapid growth of algae in freshwater or marine environments makes them a sustainable source of countless natural compounds **(Diaz *et al.*, 2023)**.

This study was conducted to evaluate the cytotoxic potential of selected marine algae and to explore their unique bioactive productivity, which may introduce novel compounds or serve as substitutes for existing natural products. Utilizing natural products like algae helps reduce waste and encourages global cooperation and innovation in tackling challenges such as climate change and biodiversity loss.

Ethyl acetate, being moderately polar, extracts a different set of compounds, including non-polar substances such as fatty acids, polysaccharides, stigmasterol, and

terpenes **(Behzadnia *et al.*, 2024)**. Studies have shown that ethyl acetate extracts of algae can exhibit strong antioxidant activity—sometimes surpassing that of methanolic extracts **(Quitério *et al.*, 2022)**. Algal terpenes have been found to upregulate the expression and activity of endogenous antioxidant enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase, thereby enhancing the cell's ability to detoxify reactive oxygen species **(Behzadnia *et al.*, 2024)**.

Ethyl acetate extracts of marine algae such as *Nannochloropsis oculata* and *Gracilaria gracilis* have demonstrated significant antioxidant activity, particularly in iron chelation and DPPH free radical scavenging assays **(Ebrahimzadeh *et al.*, 2018)**. Other studies on *Laurencia* sp., *Corallina* sp., *Spirulina platensis*, *Amphiroa* sp., and *Galaxaura* sp. have reported EC_{50} values for DPPH radical scavenging activity of approximately 450, 600, 300, 550, and 500µg/ ml, respectively. These findings are consistent with previously published data **(Chen *et al.*, 2013; Martinez *et al.*, 2020)**.

Methanolic crude extracts of *Padina gymnospora* showed significant anticancer activity, reducing cell viability to $16.41 \pm 7.15\%$ at the highest tested concentration **(Suresh *et al.*, 2021)**. Similarly, the ethyl acetate fraction of *Halymenia durvillei* demonstrated high anticancer activity against lung cancer cells **(Kraokaew *et al.*, 2022)**.

Methanolic extracts of *Cladophora glomerata* exhibited significant anticancer activity, with an IC_{50} value of 28.46 ± 0.65µg/ ml against HT29 colon cancer cells. Ethyl acetate extracts of the same algae showed notable activity as well, with an IC_{50} value of 48.56 ± 1.19µg/ ml on the same cell line. These results align with our own findings on the HT29 cell line, indicating that methanolic extracts may be more effective than ethyl acetate extracts **(Sundaramoorthy *et al.*, 2022)**.

Both methanolic and ethyl acetate extracts can induce apoptosis in cancer cells. This effect is achieved through the activation of caspases, which are key enzymes in the apoptotic pathway **(Sene *et al.*, 2023)**. These extracts can also halt cancer cell proliferation by causing cell cycle arrest at specific checkpoints, thereby preventing uncontrolled cell division **(Ebrahimzadeh *et al.*, 2018)**. Additionally, algal extracts have been shown to inhibit angiogenesis by downregulating pro-angiogenic factors such as VEGF (vascular endothelial growth factor), thereby contributing to reduced tumor growth and metastasis **(Aravindakshah & Thangavel, 2020)**.

Brown algae species like *Sargassum vestitum*, *Hormosira banksii*, and *Padina* sp. are known for their high antioxidant activity, attributed primarily to their rich content of phenolic compounds **(Imchen & Singh, 2023)**.

Red algae, such as **Corallina** and **Laurencia**, have demonstrated significant antioxidant activity, particularly in ethyl acetate extracts. This is attributed to their high content of phenolic compounds and pigments **(Ouahabi *et al.*, 2023)**.

Phycobiliproteins from red algae exhibit strong antioxidant properties by reducing oxidative stress **(Matin *et al.*, 2024)** and inducing apoptosis through the generation of reactive oxygen species (ROS), which damage cellular components. These proteins also modulate the expression of pro-apoptotic and anti-apoptotic genes **(Matin *et al.*, 2024)**.

Fucoxanthin, a pigment found in red algae, has shown potent anticancer effects by inducing apoptosis and causing cell cycle arrest via the mitochondrial pathway. It disrupts the mitochondrial membrane potential, triggering cytochrome c release and caspase activation. Additionally, it downregulates anti-apoptotic proteins such as Bcl-2 **(Nurkolis *et al.*, 2024)**.

In microalgae like *Spirulina platensis*, antioxidant levels can vary with growth phase and genetic factors. High cell densities often result in increased antioxidant production due to elevated metabolic activity **(Pereira *et al.*, 2024)**.

Phycocyanin, a blue pigment-protein complex from *Spirulina*, possesses strong antioxidant and anti-inflammatory properties **(Marjanović *et al.*, 2024)**. Polysaccharides from algae enhance immune function and exhibit anticancer effects **(Panya *et al.*, 2024)**, while phenolic acids contribute potent antioxidant activity **(Spínola *et al.*, 2024)**.

Sulfated polysaccharides like carrageenans, found in red algae such as Corallina, Laurencia, Galaxaura, and Amphiroa, have demonstrated strong antioxidant effects **(Pereira *et al.*, 2023)**. Carrageenans induce apoptosis by activating caspase pathways and inhibiting the PI3K/Akt signaling pathway, reducing cell proliferation, survival, and metastasis **(Denim, 2024)**.

The antitumor effects of *Amphiroa rigida* are largely attributed to its high content of n-hexadecanoic acid and octadecanoic acid. These compounds act as antioxidants and anti-neoplastic agents. Octadecanoic acid, in particular, is known to induce apoptosis **(Janani *et al.*, 2024)**.

Gallic acid and epicatechin gallate in ***Galaxaura elongata*** provide potent antioxidant protection and demonstrate anticancer activity by inhibiting cell proliferation and promoting apoptosis **(Kamel *et al.*, 2022)**.

Alkaloids such as laurene and sagonenyne from *Laurencia obtusa* have shown strong antioxidant effects and anticancer properties, including the inhibition of cancer cell growth and apoptosis induction **(Farhan & Rizvi, 2022)**.

Phytol and its derivatives found in *Spirulina platensis* possess antioxidant activities that help reduce oxidative stress and inflammation. These terpenoids also inhibit tumor growth and boost immune response **(El-Seedi *et al.*, 2025)**.

Tannins, a type of polyphenolic compound present in ***Corallina officinalis***, exhibit strong antioxidant and anticancer activities by neutralizing free radicals and inducing apoptosis in cancer cells **(Burgueño *et al.*, 2024)**.

CONCLUSION

The study highlights the significant antioxidant and anticancer properties of methanolic and ethyl acetate extracts from selected algae, including *Laurencia obtusa*, *Corallina officinalis*, *Spirulina platensis*, *Amphiroa rigida*, and *Galaxaura elongata*. These extracts contain bioactive compounds such as phenolics, flavonoids, alkaloids, and terpenes, which exert their effects through mechanisms including free radical scavenging, metal ion chelation, and modulation of cellular signaling pathways. The IC_{50} values obtained for these algae reflect their strong antioxidant capacities, while their anticancer activity has been demonstrated against multiple human cancer cell

lines. These findings support the potential of algal extracts as promising sources of natural antioxidants and anticancer agents, paving the way for further research and development in pharmaceuticals, nutraceuticals, and sustainable drug discovery.

REFERENCES

AbouGabal, A.A.; Khaled, H.M.; Aboul-Ela, H.M.; Aly, M.H.; Diab, O.K. and Shalaby, S. (2022**)**. Marine macroalgal biodiversity, spatial study for the Egyptian Mediterranean Sea, Alexandria Coast. Thalassas: Int. J. Mar. Sci., 38**(**1**)**: 639–646.

Ahmed, N.; Sheikh, M.A.; Ubaid, M.; Chauhan, P.; Kumar, K. and Choudhary, S. (2024**)**. Comprehensive exploration of marine algae diversity, bioactive compounds, health benefits, regulatory issues, and food and drug applications**.** Food, 100163.

Alprol, A.E.; Mansour, A.T.; Abdelwahab, A.M. and Ashour, M. (2023**)**. Advances in green synthesis of metal oxide nanoparticles by marine algae for wastewater treatment by adsorption and photocatalysis techniques. Catalysts, 13**(**5**)**: 888.

Ameen, F.; Al-Maary, K.S.; Almansob, A. and AlNadhari, S. (2023**)**. Antioxidant, antibacterial and anticancer efficacy of Alternaria chlamydospora-mediated gold nanoparticles. Appl. Nanosci., 13**(**3**)**: 2233–2240.

Appu, A.; Sadanandan, R. and Ravichandran, S. (2023**)**. Screening of antibacterial, antifungal and antioxidant activity of methanolic extract from marine algae, Hypnea indica. A.Z.B., 11**(**4**)**: 239–245.

Aravindakshah, A.S. and Thangavel, S.E.K.A.R. (2020**)**. Analysis of bio-active compounds present in the leaves and stems of Trichosanthes Roxb. using GC-MS technique with respect to its anti-inflammatory actions. Int. J. Pharm. Sci., 13**(**2**)**: 7–13.

Azizi, N.; Zangiabadian, M.; Seifi, G.; Davari, A.; Yekekhani, E.; Safavi-Naini, S.A.A.; Berger, N.A.; Nasiri, M.J. and Sohrabi, M.R. (2023**)**. Gastric cancer risk in association with underweight, overweight, and obesity: a systematic review and meta-analysis. Cancers, 15**(**10**)**: 2778.

Behzadnia, A.; Moosavi-Nasab, M. and Oliyaei, N. (2024**)**. Anti-biofilm activity of marine algae-derived bioactive compounds. Front. Microbiol., 15: 1270174.

Boretti, A. (2022**)**. Natural products as cancer chemo preventive agents: Where we stand. Nat. Prod. Commun., 17**(**12**)**: 1934578X221144579.

Burgueño Sandoval, G.M.; Saad, J.F.; Narvarte, M.A. and Firstater, F.N. (2024**)**. Short-term responses of Corallina officinalis **(**Rhodophyta**)** to global-change drivers in a stressful environment of Patagonia, Argentina. Mar. Biol., 171**(**1**)**: 5.

Burkhardt, I.; de Rond, T.; Chen, P.Y.T. and Moore, B.S. (2022**)**. Ancient plant-like terpene biosynthesis in corals. Nat. Chem. Biol., 18**(**6**)**: 664–669.

Cadoná, F.C.; Dantas, R.F.; de Mello, G.H. and Silva-Jr, F.P. (2022**)**. Natural products targeting into cancer hallmarks: An update on caffeine, theobromine, and **(**+**)**-catechin. Crit. Rev. Food Sci. Nutr., 62**(**26**)**: 7222–7241.

Chen, Z.; Bertin, R. and Froldi, G. (2013**)**. EC50 estimation of antioxidant activity in DPPH assay using several statistical programs. Food Chem., 138**(**1**)**: 414–420.

Dalaam, N.M.; Abdelmordy, M. and Mahmoud, K. (2020**)**. In vitro assessment of some non-edible parts of edible plants on some cancer cell lines. Egypt. J. Exp. Biol. **(**Zoo.**)**, 16**(**1**)**: 57–63.

Denim, Y. (2024**)**. Revealing the function of red algae extract formulated with nanotechnology in cancer treatment. Arch. Surg. Oncol., 10: 97.

Diaz, C.J.; Douglas, K.J.; Kang, K.; Kolarik, A.L.; Malinovski, R.; Torres-Tiji, Y.; Molino, J.V.; Badary, A. and Mayfield, S.P. (2023**)**. Developing algae as a sustainable food source. Front. Nutr., 9: 1029841**.**

Ebrahimzadeh, M.A.; Khalili, M. and Dehpour, A.A. (2018**)**. Antioxidant activity of ethyl acetate and methanolic extracts of two marine algae, Nannochloropsis oculata and Gracilaria gracilis—an in vitro assay. Braz. J. Pharm. Sci., 54**(**1**)**: e17280.

El-Dars, F.M.S.E.; Abdel Rahman, M.A.M.; Salem, O.M.A. and Abdel-Aal, E.S. (2021**)**. Algal control and enhanced removal in drinking waters in Cairo, Egypt. J. Water Health, 13**(**4**)**: 1060–1072.

El-Seedi, H.R.; Refaey, M.S.; Elias, N.; El-Mallah, M.F.; Albaqami, F.M.; Dergaa, I.; Du, M.; Salem, M.F.; Tahir, H.E.; Daglia, M. and Yosri, N. (2025**)**. Marine natural products as a source of novel anticancer drugs: an updated review **(**2019–2023**)**. NPB, 15**(**1**)**: 13.

Eltamany, E.E.; Goda, M.S.; Nafie, M.S.; Abu-Elsaoud, A.M.; Hareeri, R.H.; Aldurdunji, M.M.; Elhady, S.S.; Badr, J.M. and Eltahawy, N.A. (2022**)**. Comparative assessment of the antioxidant and anticancer activities of Plicosepalus acacia and Plicosepalus curviflorus: Metabolomic profiling and in silico studies. Antioxidants, 11**(**7**)**: 1249–1270.

Farhan, M. and Rizvi, A. (2022**)**. Understanding the prooxidant action of plant polyphenols in the cellular microenvironment of malignant cells: Role of copper and therapeutic implications. Front. Pharmacol., 13: 929853.

Ferdous, U.T. and Yusof, Z.N.B. (2021**)**. Medicinal prospects of antioxidants from algal sources in cancer therapy. Front. Pharmacol., 12: 593116.

Ge, Z.; Chen, X. and Fan, J. (2025**)**. Efficient removal of harmful algae from eutrophic natural water by Mg**(**OH**)**$_2$ coated nanoscale zero-valent iron. FESE, 19: 55.

Hadisaputri, Y.E.; Soekamto, N.H.; Pudjiastuti, P.; Aristokrat, A.; Bahrun, B.; Abdullah, F.F. and Okino, T. (2024**)**. Antimicrobial and cytotoxic effect of Bornetella nitida green algae isolate on MCF-7 breast cancer. Breast Cancer: 555-565.

Hang, S.; Lu, H. and Jiang, Y. (2024**)**. Marine-derived metabolites act as promising antifungal agents. Mar. Drugs, 22**(**4**)**: 180.

Hao, M.L.; Wang, T.; Zhu, J.Q.; Song, Y.J.; Gong, T.J.; Zou, L.K.; Liu, J. and Yan, J.F. (2022**)**. Evaluation of external contamination on the vial surfaces of some hazardous drugs that commonly used in Chinese hospitals and comparison between environmental contamination generated during robotic compounding by IV: dispensing robot vs. manual compounding in biological safety cabinet. J. OPP, 28**(**7**)**: 1487-1498.

Hosny, S.; Elshobary, M.E. and El-Sheekh, M.M. (2025**)**. Unleashing the power of microalgae: a pioneering path to sustainability and achieving the sustainable development goals. ESPR: 1-31.

Hou, X.M.; Wang, C.Y.; Gerwick, W.H. and Shao, C.L. (2019**)**. Marine natural products as potential anti-tubercular agents. Eur. J. Med. Chem., 165: 273-292.

Huang, T.H.; Liu, B.H.; Hsu, C.H.; Wu, C.J.; Liao, K.W.; Lin, C.S. and Chan, Y.L. (2023**)**. The synergistic effects of Corbicula fluminea and Sarcodia montagneana on alleviating systemic inflammation and osteoarthritis progression. Antioxidants, 12**(**12**)**: 2068

Imchen, T. and Singh, K.S. (2023**)**. Marine algae colorants: Antioxidant, anti-diabetic properties and applications in food industry. Algal Res., 69: 102898.

International Agency for Research on Cancer (2020**)**. Latest global cancer data: Cancer burden rises to 19.3 million new cases and 10.0 million cancer deaths in 2020. World Health Organization.

Ismael, A.A. (2021**)**. Climate change and its impact on harmful algae in the Egyptian Mediterranean waters. In International Conference on Innovation in Urban and Regional Planning **(**pp. 411-417**)**. Cham: Springer International Publishing.

Janani, G.; Girigoswami, A.; Deepika, B.; Udayakumar, S. and Girigoswami, K. (2024**)**. Unveiling the role of nano-formulated red algae extract in cancer management. Molecules, 29**(**9**)**: 2077.

Jang, E. and Lee, J.H. (2021**)**. Promising anticancer activities of Alismatis rhizome and its triterpenes via p38 and PI3K/Akt/mTOR signaling pathways. Nutrients, 13**(**7**)**: 2455.

Kamel, A.K.A.; Hozayen, W.; El-Kawi, S.H.A. and Hashem, K.S. (2022**)**. Galaxaura elongata extract **(**GE**)** modulates vanadyl sulfate-induced renal damage via regulating TGF-β/smads and Nrf2/NF-κB pathways. Biol. Trace Elem. Res.: 1-18.

Kraokaew, P.; Manohong, P.; Prasertsuksri, P.; Jattujan, P.; Niamnont, N.; Tamtin, M.; Sobhon, P. and Meemon, K. (2022**)**. Ethyl acetate extract of marine algae, Halymenia durvillei, provides photoprotection against UV-exposure in L929 and HaCaT cells. Mar. Drugs, 20**(**11**)**: 707.

Leong, Y.K. and Chang, J.S. (2024**)**. Proteins and bioactive peptides from algae: Insights into antioxidant, anti-hypertensive, anti-diabetic and anti-cancer activities. Trends Food Sci. Technol.: 104352.

Marjanović, B.; Benković, M.; Jurina, T.; Sokač Cvetnić, T.; Valinger, D.; Gajdoš Kljusurić, J. and Jurinjak Tušek, A. (2024**)**. Bioactive compounds from Spirulina platensis spp. - nutritional value, extraction, and application in food industry. Separations, 11**(**9**)**: 257.

Martinez-Morales, F.; Alonso-Castro, A.J.; Zapata-Morales, J.R.; Carranza-Álvarez, C. and Aragon-Martinez, O.H. (2020**)**. Use of standardized units for a correct interpretation of IC50 values obtained from the inhibition of the DPPH radical by natural antioxidants. Chem. Pap., 74: 3325-3334.

Matin, M.; Koszarska, M.; Atanasov, A.G.; Król-Szmajda, K.; Jóźwik, A.; Stelmasiak, A. and Hejna, M. (2024**)**. Bioactive potential of algae and algae-derived compounds: Focus on anti-inflammatory, antimicrobial, and antioxidant effects. Molecules, 29**(**19**)**: 4695.

Nurkolis, F.; Subali, D.; Taslim, N.A.; Mayulu, N.; Hardinsyah, H.; Tjandrawinata, R.R. and Kim, B. (2024**)**. Unleashing the potential of marine algae in cancer prevention and treatment through combination of tradition and innovation.

Ogidi, O.I. and Akpan, U.M. (2022**)**. Aquatic biodiversity loss: impacts of pollution and anthropogenic activities and strategies for conservation. In Biodiversity in Africa: Potentials, Threats and Conservation **(**pp. 421-448**)**. Singapore: Springer.

Ouahabi, S.; Loukili, E.H.; Daoudi, N.E.; Chebaibi, M.; Ramdani, M.; Rahhou, I.; Bnouham, M.; Fauconnier, M.L.; Hammouti, B.; Rhazi, L. and Ayerdi Gotor, A. (2023**)**. Study of the phytochemical composition, antioxidant properties, and in vitro anti-diabetic efficacy of Gracilaria bursa-pastoris extracts. Mar. Drugs, 21**(**7**)**: 372.

Panya, A.; Wathikthinnakon, M.; Thepmalee, C.; Chiawpanit, C.; Panwong, S.; Wutti-In, Y.; Vongchan, P.; Klangsinsirikul, P.; Sattayawat, P. and Pekkoh, J. (2024**)**. Polysaccharide extract of Spirulina platensis sp. increases effector immune-cell killing activities against cholangiocarcinoma. PLoS ONE, 19**(**10**)**: e0312414.

Pereira, L.; Cotas, J. and Valado, A. (2024**)**. Antioxidants from microalgae and their potential impact on human well-being. C.D.E.R., 2: 292-321

Quitério, E.; Grosso, C.; Ferraz, R.; Delerue-Matos, C. and Soares, C. (2022). A critical comparison of the advanced extraction techniques applied to obtain health-promoting compounds from seaweeds. Mar. Drugs, 20(11): 677.

Rahman, M.M.; Islam, M.R.; Rahman, F.; Rahaman, M.S.; Khan, M.S.; Abrar, S.; Ray, T.K.; Uddin, M.B.; Kali, M.S.K.; Dua, K. and Kamal, M.A. (2022**)**. Emerging promise of computational techniques in anti-cancer research: at a glance. Bioengineering, 9**(**8**)**: 335.

Rashad, S. and El-Chaghaby, G.A. (2020**)**. Marine algae in Egypt: distribution, phytochemical composition and biological uses as bioactive resources **(**a review**)**. EJABF, 24**(**5**)**: 147-160.

Ren, J.; Yan, G.; Yang, L.; Kong, L.; Guan, Y.; Sun, H.; Liu, C.; Liu, L.; Han, Y. and Wang, X. (2025**)**. Cancer chemoprevention: signaling pathways and strategic approaches. Signal Transduct. Target. Ther., 10**(**1**)**: 113.

Rout, S.; Rath, B.; Bhattamisra, S.K.; Rath, I. and Kumar, A. (2021**)**. Antioxidant and anti-inflammatory activities of methanol and aqueous extracts of Sargassum wightii. J. Herbmed Pharmacol., 11**(**1**)**: 75-82.

Roy, A.; Gogoi, N.; Yasmin, F. and Farooq, M. (2022**)**. The use of algae for environmental sustainability: trends and future prospects. ESPR, 29**(**27**)**: 40373-40383.

Scesa, P.D.; Lin, Z. and Schmidt, E.W. (2022**)**. Ancient defensive terpene biosynthetic gene clusters in the soft corals. Nat. Chem. Biol., 18**(**6**)**: 659-663.

Seershika, A. and Seedevi, P. (2024**)**. Antioxidant activity of methanolic extract from the seaweed of Gracilaria edulis. AIP Conf. Proc., 3193**(**1**)**.

Sene, M.; Barboza, F.S.; Sarr, A.; Dione, F.K.; Diatta, C.; Ndiaye, M.; Ndiaye-Sy, A. and Sy, G.Y. (2023**)**. Anti-inflammatory and analgesic activities of methanolic extract of Elaeis guineensis Jacq. leaves **(**Arecaceae**)** and its fractions. Afr. J. Pharm. Pharmacol., 17**(**2**)**: 43-51.

Sharma, D.; Sharma, S.; Hasan, F. and Dhobi, M. (2024**)**. The role of nutrition in the management of health and diseases.

Sharma, P.; Rani, L.; Grewal, A.S. and Srivastav, A.L. (2022**)**. Impact of pharmaceuticals and antibiotics waste on the river ecosystem: a growing threat. In Ecological Significance of River Ecosystems **(**pp. 15-36**)**. Elsevier.

Sharma, R.; Mondal, A.S. and Trivedi, N. (2023**)**. Anticancer potential of algae-derived metabolites: recent updates and breakthroughs. F.J.P.S., 9**(**1**)**: 44.

Shi, L.; Zhao, W.; Yang, Z.; Subbiah, V. and Suleria, H.A.R. (2022**)**. Extraction and characterization of phenolic compounds and their potential antioxidant activities. ESPR, 29**(**54**)**: 81112-81129.

Singh, A.V.; Chandrasekar, V.; Prabhu, V.M.; Bhadra, J.; Laux, P.; Bhardwaj, P.; Al-Ansari, A.A.; Aboumarzouk, O.M.; Luch, A. and Dakua, S.P. (2024**)**. Sustainable bioinspired materials for regenerative medicine: Balancing toxicology, environmental impact, and ethical considerations. Biomed. Mater., 19**(**6**)**: 060501.

Spínola, M.P.; Mendes, A.R. and Prates, J.A. (2024**)**. Chemical composition, bioactivities, and applications of Spirulina platensis **(**Limnospira platensis**)** in food, feed, and medicine. Foods, 13**(**22**)**: 3656.

Sundaramoorthy, S.; Dakshinamoorthi, A. and Chithra, K. (2022**)**. Evaluation of anti-oxidant and anticancer effect of marine algae Cladophora glomerata in HT29 colon cancer cell lines - an in-vitro study. I.J.P.P.P., 14**(**6**)**: 332.

Suresh, C.; Roy, A.; Sivaperumal, P. and Thangavelu, L. (2021**)**. Preparation of methanolic crude extract of Padina gymnospora seaweed and their anticancer activities against cancer cell line. J. Pharm. Res. Int., 33**(**63A**)**: 312-321.

Thanigaivel, S.; Thomas, J.; Chandrasekaran, N. and Mukherjee, A. (2023**)**. Preparation of marine algal **(**seaweed**)** extracts and quantification of phytocompounds. *In* Aquaculture Microbiology **(**pp. 135-140**)**. New York, NY: Springer US.

Torić, J.; Brozovic, A.; Baus Lončar, M.; Jakobušić Brala, C.; Karković Marković, A.; Benčić, Đ. and Barbarić, M. (2020**)**. Biological activity of phenolic compounds in extra virgin olive oils through their phenolic profile and their combination with anticancer drugs observed in human cervical carcinoma and colon adenocarcinoma cells. *Antioxidants*, **9(**5**)**: 453.

van Hove, M.; John, J.B.; Ojelade, E.; Ayyaz, F.; Koris, J.; Frame, J.; Swart, M.; Snowden, C.; Briggs, T.W.R. and Gray, W.K. (2024**)**. Unwarranted variation and the goal of net zero for the NHS in England: exploring the link between efficiency working, patient outcomes and carbon footprint. Anaesthesia, **79(**3**)**: 284-292.

Xin, Z.; Zhang, M.; Cui, H.; Ding, X.; Zhang, T.; Wu, L.; Cui, H.; Xue, Q.; Chen, C. and Gao, J. (2023**)**. Algae: A robust living material against cancer. Int. J. Nanomedicine: 5243-5264.

Yang, N.; Zhang, Q.; Chen, J.; Wu, S.; Chen, R.; Yao, L.; Li, B.; Liu, X.; Zhang, R. and Zhang, Z. (2023**)**. Study on bioactive compounds of microalgae as antioxidants in a bibliometric analysis and visualization perspective. Front. Plant Sci., 14*:* 1144326.

Zhang, H.; Mareeh, H.; Belhaj, F.A.; Hazaea, S.A.; Liu, N.; Raid, M. and Hael, M. (2025**)**. Trends in research on the carbon footprint of economic growth: A bibliometric analysis. *J. Knowl. Econ.*: 1-46.

Zheng, X.; Zhang, X. and Zeng, F. (2025**)**. Biological functions and health benefits of flavonoids in fruits and vegetables: A contemporary review. Foods, 14**(**2**)**: 155