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Study of the chemical composition of the plant leaves of the *Salicornia europaea L.* plant spread along the Syrian coast adjacent to the Mediterranean Sea

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ABSTRACT

Salicornia europaea L. is an annual halophyte adapted to saline coastal environments, valued as a food source and in traditional medicine for its antioxidant and anti-inflammatory properties. This study investigates the chemical composition of *Salicornia europaea L.* from the Syrian coast, focusing on samples collected from Two stations: Sports City Station and Jableh Corniche Station. GC-MS analysis of methanolic extracts revealed variations in primary metabolites between the stations (Jableh Corniche and Sports City). Palmitic acid (16.3%) was the dominant compound in the Sports City station samples, whereas oleic acid (19.1%) predominated in the Jableh Corniche station samples. HPLC analysis of ethanolic extracts identified chlorogenic acid (2.6%) in Sports City and coumaric acid (2.5%) in Jableh Corniche station samples. These findings highlight the chemical diversity of *Salicornia europaea L.* on the Syrian coast and suggest its potential for pharmaceutical, nutritional, and biofuel applications. Further research is warranted to explore these applications in depth.

Keywords: *Salicornia europaea L.*, GC-MS (Gas Chromatography-Mass Spectrometry), HPLC (High-Performance Liquid Chromatography), Syrian marine waters.

1. INTRODUCTION

The world population will probably increase from 7.7 to 9.7 billion by 2050, necessitating increased agricultural production to meet rising food demands (Salazar et al., 2024). Global climate change and prevailing environmental conditions are accelerating and further exacerbate this challenge. Traditional crop cultivation faces numerous limitations, including water scarcity, elevated temperatures, soil salinization, pollution, and the degradation of soil properties, as observed in regions

such as the Mediterranean basin (Souid et al., 2024). Consequently, there is growing interest in exploring alternative plant species and innovative agricultural practices to address food and water shortages.

Halophytes have attracted attention because they flourish in highly saline, water-deficient environments (Puccinelli et al., 2024). Halophytes are a unique type of plant capable of prospering in high-salinity environments due to their development of various adaptation mechanisms enabling them to manage challenging biotic conditions. They have adapted and evolved to endure salinity levels of up to 200 m mol/L of sodium chloride and elevated temperatures, making them more effective than synthetic antioxidants. The parts of halophyte plants contain minerals, vitamins, carotenoids, and polyphenols that are responsible for their beneficial nutritional and medicinal properties (Davy et al., 2001; Shamsutdinov et al., 2017; Pérez et al., 2021; Castagna et al., 2022).

In addition, it has a low percentage of sugar and high levels of unrefined protein, fatty acids, and antioxidant compounds such as phenolic (Lopes et al., 2021). Syria is home to a remarkable array of halophytes, encompassing 110 distinct species classified within 70 genera and 28 families. They typically exist in as "plant groups", most of which are terrestrial, with some located near the coast and others irrigated with seawater, such as the plant Salicornia (Al-Oudat and Qadir, 2011). Salicornia is commonly known as glasswort, sea beans, sea asparagus, crow's foot and samphire. It is classified as a halophyte and belongs to the Amaranthaceae family (Kumari et al., 2023).

Salicornia europaea L. is a halophyte plant from the Chenopodiaceae family, indigenous to the Mediterranean, found across Africa, America, Asia, and Europe. It features leafless, multi-branched stems up to 45cm tall and small yellowish-white hermaphrodite flowers. The plant's green stems contain a fluid elastic substance and change color from dark green to yellow-green, then pink or dark red as it ages. For centuries, various cultures have utilized cultural medicinal practices to treat a range of diseases, including asthma. These practices have been actively used and have proven effective in treating a variety of illnesses (Kadereit et al., 2007; Rahmani et al., 2022).

The *Salicornia europaea L.* plant has multiple health benefits as it contains nutritional contains nutritional fibers, minerals (Mg, Ca, P, K, Na), Microelements (Fe, Mn, Cu, Ni, Si) Evlash et al., (2021), amino acids Kim et al., (2021), Ameixa et al., (2022), vitamins Evlash et al., (2021), Kim et al., (2021), Oleanane triterpenoid saponins Kim et al., (2021), Caffeoylquinic acid derivatives Kim et al., (2021), sterols Lignans Kim et al., (2021), Fatty acids Kim et al., (2021), Ameixa et al., (2022), Phenolic acids Zengin et al., (2018), Hydroxycinnamic acids (Wang et al., 2013; Panth et al., 2016; Kim et al., 2021).

These bioactive secondary metabolites contribute to the efficacy of *Salicornia europaea L.* plant extracts against bacteria, oxidative stress, diabetes, asthma, hepatitis, cancer, gastroenteritis, and nephropathy, treating inflammation, depression, memory, cognitive deficits, cardiovascular disease, and fungi (Puccinelli et al., 2024). In addition to its cosmetic uses, this plant offers a dual benefit for skin: hydrating and refining its texture, as well as providing protection from ultraviolet radiation (Doi et al., 2020). Nevertheless, to the best of our knowledge, no research has been conducted on the pharmaceutical and cosmetic potential of *Salicornia europaea L.* Therefore, this study aims to examine the chemical composition of the tissues of this plant and identify the active substances present in it at two different locations along the Syrian coastline.

2. MATERIALS AND METHODS

Description of the study area

The study area comprised two stations: Jableh Corniche station, located 25 km south of Lattakia City, and the Sports City station, situated in the northwest of Lattakia City (Figure 1).

Study Area Description

Collection and Processing of plant

A collection of freshly harvested plant leaves was obtained, thoroughly washed, and stored in a dark place for 20-25 days to achieve the desired degree of desiccation. Thereafter, the plant was identified by means of a systematic approach that drew upon established international standards.

Screening of Phytochemicals

Identification of the Plant

The halophyte, *Salicornia europaea L.* is shown in (Figure 2).

Figure 1 *Salicornia europaea L.*

Figure 2 *Salicornia europaea L.* grows widely along the coast of the Syrian Arab Republic.

Extraction of phytochemicals by Soxhlet

Salicornia europaea L. leaves were extracted by us through a Soxhlet apparatus, and ethanol was used for HPLC analysis while methanol was used for GC-MS analysis (Figure 3). The ethanol extract from the biomass manifested as a pale-yellow hue, while the methanol extract exhibited a distinctly dark brown coloration. The ethanol extract demonstrated transparency, while the methanol extract displayed turbidity, as observed in (Figure 4).

Figure 3 Phytochemical extraction of *Salicornia europaea L.*

Figure 4 Methanol and ethanol extract of *Salicornia europaea L.*

The Chemical fingerprint of *Salicornia europaea L.* by GC-MS

The identities of the resulting compounds were ascertained through the injection of 1 µL of the sample into a gas chromatography-mass spectrometry (GC-MS) system. The system utilized a phenyl methyl silicone capillary column with a length of 30 m, an inner diameter of 0.25 mm, and a thickness of 0.25 µm. Helium was employed as the carrier gas (mobile phase) at a flow rate of 1 mL/min. The injector temperature was 250°C. The source of ions temperature was 230°C while the mass analyzer was at 130°C. Separation was accomplished by using a temperature program of 70°C, ramped at 4°C/min to 280°C (held for 10 min).

The identification of compounds was achieved through a rigorous comparative analysis of their mass spectrograms with the NIST and Wiley spectral libraries, complementing it with a thorough evaluation of their relative abundance. The implementation of this

method was meticulous in a two-sample investigation. The process involved a systematic calculation of the percentage of each compound in each sample, culminating in the determination of the mean percentage for each compound.

The Chemical fingerprint of *Salicornia europaea L.* by HPLC

Our research team identified the organic extracts using High-Performance Liquid Chromatography (HPLC). Samples were analyzed with a JASCO UV-970 detectorUsing an RP (Licrosorb) C18 column measuring (250x4mm i.d.). The separation relied on reversed-phase chromatography, characterized by a stationary phase with lower polarity than the mobile phase (a specific ratio of acetonitrile to water). We eluted the components using 40% acetonitrile at a flow rate of 3ml/min, with detection at a wavelength of 280 nm and a column temperature maintained at 35°C during analysis.

3. RESULTS AND DISCUSSION

The chemical fingerprint of *Salicornia europaea L.* by GC-MS

The researchers screened the list of phytochemicals present in both extracts using GC-MS, and they tabulated the results in (Tables 1 & 2; Figures 5 & 6). Analysis has confirmed the prolific nature of Compounds in selected halophytic plants.

Table 1 The bioactive compounds identified from the methanol extract of *Salicornia europaea L.* at the Sports City Station.

S.NO	Name of the Compounds	Area%	Molecular formula
1	5,6-Dimethoxy-2-methyl- 1-indanone	1.88	C12H14
2	Butanal, 3-methyl	0.12	C5H10O
3	3,3-Dimethylbutan-2-yl Methyl phosphonofluoridate	0.55	C7H16FO2P
4	2,6-dimethoxy-4-vinyl phenol	1.7	C10 H12 O3
5	Heptafluorobutanoic acid	3.17	C3F7COOH
6	Phenol, 2,4-bis(1,1-dimethylethyl)	13.69	C17H30OSi
7	Hexadecane	0.88	C16H34
8	Tetradecane	0.98	C11H22O
9	2-5-cyclohexadien -1-one	1.13	C6H8ClN
10	6-6-(Dimethyl-5-oxohept-2-enyl)-cycloheptanone	0.06	C15H24O2
11	Oxirane	0.53	C2H4O
12	Octadecene	0.10	C18H36
13	2,4-Diphenyl-4-methyl-1-pentene	0.98	C18H20
14	Palmitinic acid	16.3	C16H32O2
15	Pyrrolo[1,2-a]pyrazine-1,4-dione	12.33	C7H10N2O2
16	Stearic acid	2.77	C6H8O7
17	Oleicacid	9.03	C18H36O2
18	Tridecanoic acid methyl ester	0.42	C14H28O2
19	3,3-Dimethylbutan-2-yl (Pinacolyl alcohol)	1.25	C6H14O
20	Acetyl tri-n-butyl citrate	0.03	C20H34O8
21	1-Heptacosanol	1.23	$C_{27}H_{56}O$
22	1,2-Benzenedicarboxylic acid	0.64	C16H22O4
23	1-Chloroeicosane	0.22	C20H39Cl

Table 2 Bioactive compounds detected from the methanol extract of plant leaves *Salicornia europaea L.* for Jableh Corniche station.

S.NO	Name of the Compounds	Area%	Molecular formula
1	2-Dodecenal	0.11	C12H22O
2	Tetracosame	0.02	C24H50
3	Hexadecane	0.68	C16H34
4	Undecanal	0.27	C11H22O
5	Phenol, 2,4-bis(1,1-dimethylethyl)	15.62	C17H30OSi
6	Tetradecane	0.49	C11H22O
7	6-6-(Dimethyl-5-oxohept-2-enyl)-cycloheptanone	5.44	C15H24O2
8	Ionol -2	3.33	CH3(CH2)14COOH
9	Oxirane	0.43	C2H4O
10	2-5-cyclohexadien -1-one	1.23	C6H8ClN
11	Octadecene	0.24	C18H36
12	1H-Indene	0.96	C9H10
13	2,4-Diphenyl-4-methyl-1-pentene	1.08	C18H20
14	Palmitinic acid	19.1	C16H32O2
15	1-Docosene	1.19	C22H44
16	Stearic acid	2.77	C6H8O7
17	Pyrrolo[1,2-a]pyrazine-1,4-dione	7.00	C7H10N2O2
18	Oleicacid	7.05	C18H36O2
19	2-H-Pyran-2-one	0.58	C5H4O2
20	Acetyl tri-n-butyl citrate	0.18	C20H34O8
21	1-Chloroeicosane	0.33	C20H39Cl
22	1-Heptacosanol	1.53	$C_{27}H_{56}O$
23	Heptafluorobutanoic acid	2.37	C3F7COOH

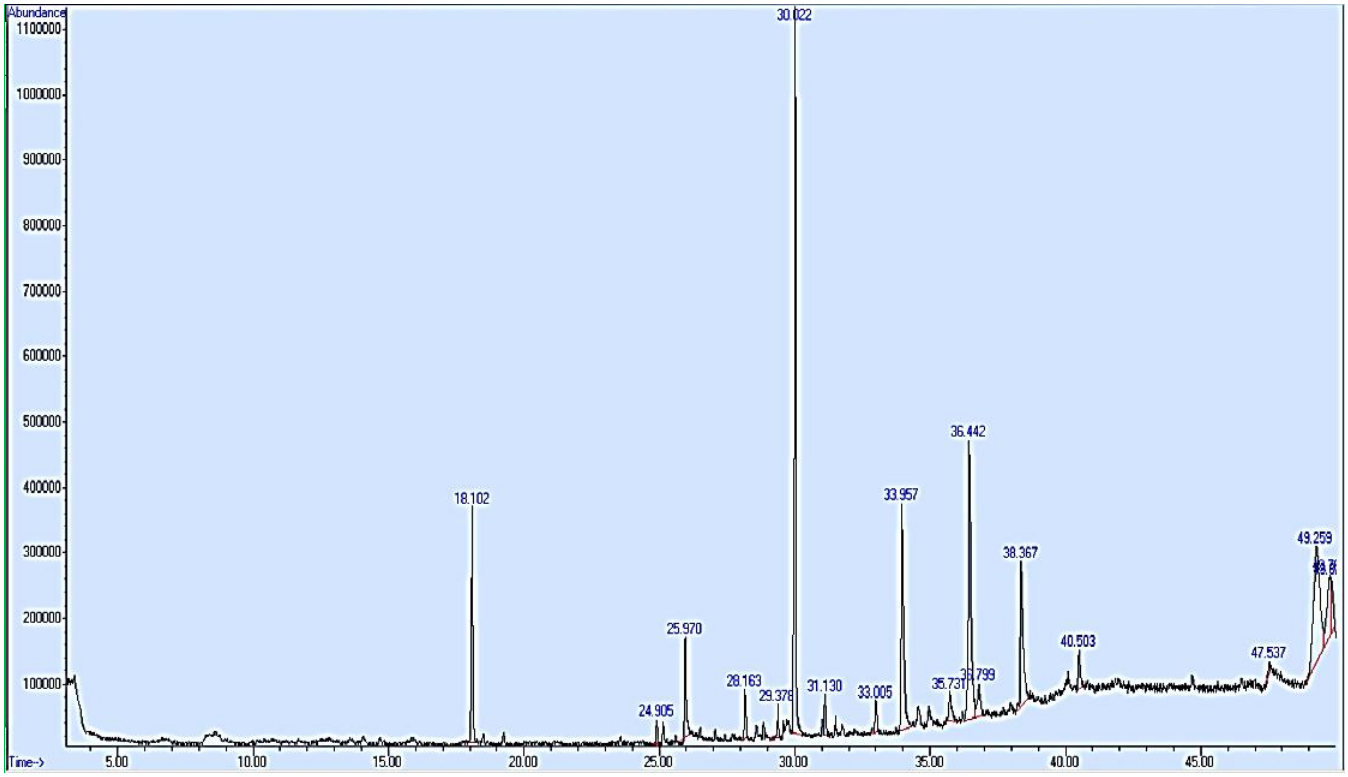

Figure 5 GC-MS chromatogram of methanol extract of plant leaves *Salicornia europaea L.* for Sports City station.

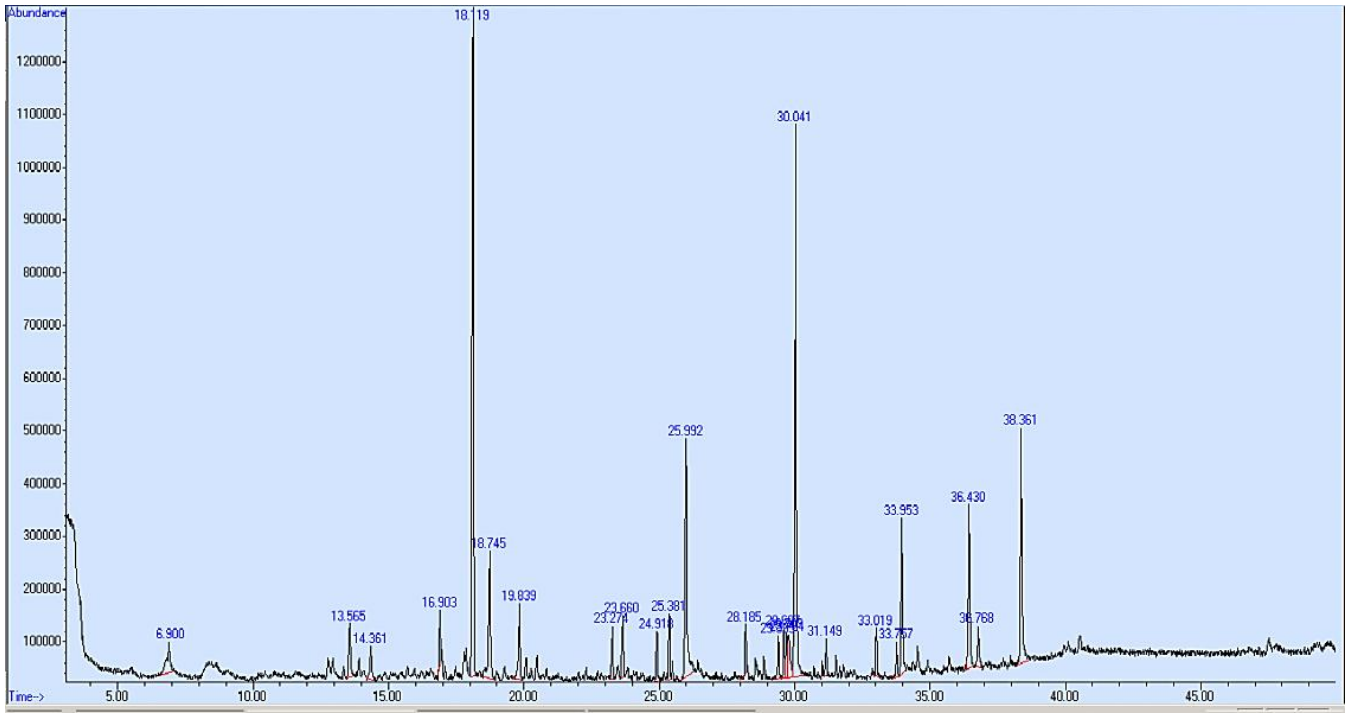

Figure 6 GC-MS chromatogram of methanol extract of plant leaves *Salicornia europaea L.* for Jableh Corniche station.

The analysis revealed that palmitic acid is the predominant compound in the organic extract samples of *Salicornia europaea L.* Studies provide evidence that this compound, derived from *Salicornia europaea L.*, is taken as a dietary supplement to improve muscle and joint

strength, as well as to help treat diabetes. It is also classified among compounds with anticancer and antibiotic properties. According to extant literature, oleic acid, a monounsaturated fatty acid, exhibits promising medicinal properties (Ravi and Krishnan, 2017; Alamzadeh et al., 2021).

In addition to its potential to treat cardiovascular disease and certain types of cancer, such as bladder, breast, and pancreatic cancer, research has increasingly highlighted its role in modulating inflammatory pathways and lipid metabolism. As a result, oleic acid has become an innovative approach to addressing complex health issues (El-Masry et al., 2024). Furthermore, our results indicated a substantial amount of 2,4-bis(1,1-Dimethylethyl) in the phenolic compound. Many studies have shown the value of this compound because of its antioxidant and anticancer properties, as well as its high capacity to reduce inflammation in humans (Ren et al., 2019; Gupta et al., 2023).

The analysis revealed the presence of the Pyrrolo[1,2-a]pyrazine-1,4-dione, as studies have demonstrated that this compound induces apoptosis in cancer cells by activating enzymes that lead to DNA division and the formation of programmed bodies for cellular death. Research has been shown that its combination with chemical drugs such as gemcitabine enhances anticancer efficacy, indicating its potential application in cancer treatment (Nam et al., 2022). Marine plants are the source of Pyrrolo[1,2-a] pyrazine-1,4-dione, which is an antibacterial agent, exhibiting strong effectiveness against drug-resistant strains of Staphylococcus aureus, making it a candidate for the treatment of bacterial infections (Kiran et al., 2018).

The Chemical fingerprint of *Salicornia europaea L.* by HPLC

The extracts of *Salicornia europaea L.* showed a high concentration of phenolic compounds through HPLC analysis (Tables 3 & 4). This finding was supported by a comparison of the retention times and DAD spectra of the standard compounds analyzed under identical conditions. Furthermore, the results were corroborated by comparing them with existing phenolic literature. It was accomplished to identify and quantify eleven phenolic compounds in the ethanol extract from the two study areas. Notably, all identified compounds were found to be consistent across both regions, thereby confirming their presence.

Table 3 Bioactive compounds detected from the ethanol extract of plant leaves *Salicornia europaea L.* for Sports City station.

S.NO	Name of the Compounds	Area%	Molecular formula
1	Salicylic acid	0.01	C7H6O3
2	Chlorogenic acid	2.6	C16H18O9
3	Rutin	0.04	C27H30O16
4	p-cresol	0.1	CH3C6H4(OH)
5	Eugenol	0.1	C10H12O2
6	Caffeic acid	0.02	C9H80O
7	Cummaric acid	0.01	C9H8O3
8	Ferulic acid	0.03	C10H10O4
9	Vaillin	0.09	C5H11NO2
10	2-6-Dimethyl pheno	0.1	C8H10O

Table 4 Bioactive compounds detected from the ethanol extract of plant leaves Salicornia europaea L. for Jableh Corniche station.

S.NO	Name of the Compounds	Area%	Molecular formula
1	Chlorogenic acid	1.3	C16H18O9
2	2-6-Dimethyl phenol	1.4	C8H10O
3	Cummaric acid	2.5	C9H8O3
4	Vaillin	0.02	C5H11NO2
5	Salicylic acid	0.2	C7H6O3
6	p-cresol	0.1	CH3C6H4(OH)
7	Eugenol	0.1	C10H12O2
8	Ferulic acid	2	C10H10O4

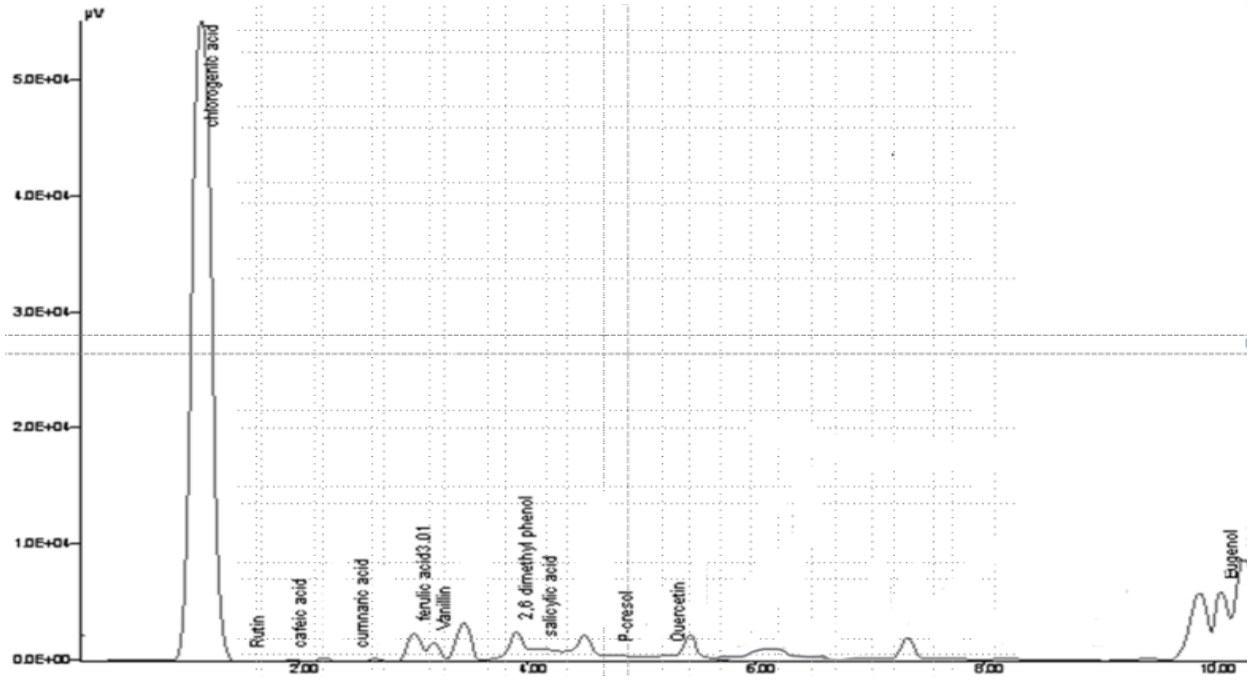

Figure 7 HPLC chromatogram of ethanol extract of plant leaves *Salicornia europaea L* for Sports City.

The chemical fingerprint of *Salicornia Europaea L*. was determined using the HPLC technique (Figures 7 & 8). Our study identified phenolic compounds in two different samples of the ethanolic extract of *Salicornia Europaea L*. Ten phenolic compounds were found: Salicylic acid, Chlorogenic acid, p-cresol, Eugenol, Caffeic acid, Cummaric acid, Ferulic acid, Vaillin, and 2-6-Dimethyl phenol in the Sports City station (Rahmani et al., 2022). The compound that had the most abundant quantity was chlorogenic acid (2.6%). The pharmaceutical industry uses this compound because it has antioxidant and anti-inflammatory properties. It plays an essential role in regulating glucose and lipid metabolism, improving insulin resistance.

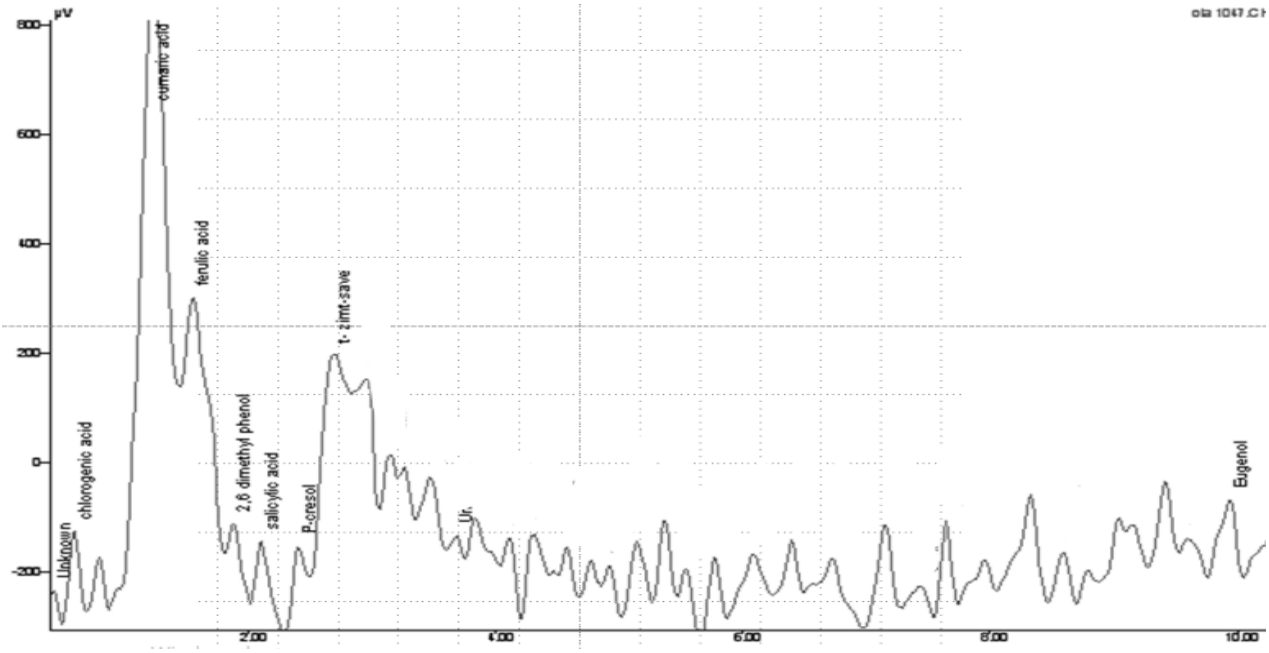

Figure 8 HPLC chromatogram of ethanol extract of plant leaves *Salicornia europaea L* for Jableh Corniche.

The approach not only aims to prevent weight gain and improve blood pressure for hypertensive patients, but also uses cutting-edge behavioral assessment tools to tailor strategies that enhance dietary decisions and physical activity levels (Yu et al., 2022). Rutin, a flavonoid, exhibits pharmacological activities such as anti-inflammatory and antioxidant effects (Dong et al., 2025). In the Corniche Jableh station, the compounds found were Chlorogenic acid, 2-6-dimethyl phenol, Cummaric acid, Vaillin, Salicylic acid, p-cresol, Eugenol, and Ferulic acid, with Cummaric acid being the most abundant at 2.5%. Cummaric acid is an antioxidant and anti-inflammatory agent (Won et al., 2017; Pateiro et al., 2023).

4. CONCLUSIONS

This study has found that *Salicornia europaea L.*, sampled from the coast of Lattakia city, contains twenty-three compounds in the Sports City station and twenty-three compounds in the Cornish Jableh station, with varying ratios as determined by GC-MS phytochemical screening. Furthermore, HPLC analysis revealed the presence of ten phenolic compounds in the sports city station and eight phenolic compounds in the Cornish Jableh station within the plant's ethanol extracts. The compounds found in *Salicornia europaea L.* exhibit significant medicinal value in pharmaceutical chemistry because of the unique phytochemical components that have proven antimicrobial and anti-inflammatory activities.

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Ethical approval & declaration

In this article, as per the plant regulations followed in the High Institute of Marine Research University, Lattakia, Syria; the authors observed the chemical composition of the plant leaves of the *Salicornia europaea* L. plant spread along the Syrian coast adjacent to the Mediterranean Sea. The ethical guidelines for plants & plant materials are followed in the study for plant collection, identification & experimentation.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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