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ORIGINAL PAPER

Phenolic composition and biological activities of *Ornithogalum sigmoideum* Freyn & Sint. from Black Sea Region

Mehtap Atak[1,6] · Hüseyin Avni Uydu[2] · Eda Yılmaz Kutlu[1] · Saliha Ekşi[3] · Erva Rakıcı[3] · Nebahat Ejder[3] · Adem Demir[4] · Sevgi Kolaylı[5]

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Abstract

Ornithogalum sigmoideum Freyn & Sint., locally known as Sakarca, is a wild edible plant that grows naturally in the Eastern Black Sea Region of Türkiye and is traditionally consumed as a seasonal food, typically after cooking in accordance with local preparation practices. In this study, the aerial, flower, and bulb parts of the plant were investigated to characterize their phenolic composition, antioxidant capacity, and antiproliferative properties. Total phenolic content (TPC) and total flavonoid content (TFC) were determined using standard spectrophotometric methods, while individual phenolic constituents, including protocatechuic acid and flavonoids such as chrysin, were identified by HPLC-PDA. Antioxidant activity was assessed by FRAP, CUPRAC, and DPPH assays to evaluate reducing power and radical scavenging capacity. The aerial parts exhibited the highest TPC and TFC values, whereas the flower extract, characterized by relatively higher chrysin content, demonstrated stronger reducing activity in the FRAP and CUPRAC assays together with consistent DPPH scavenging behavior. Antiproliferative activity was assessed in HepG2, DU145, and HT-29 cancer cell lines, with CRL-1790 used as the normal control. The aerial extract produced measurable but limited growth inhibition (49–59%) in cancer cells at the highest tested concentration, while exerting comparatively low effects on normal cells. The flower and bulb extracts showed weaker antiproliferative activity overall. Collectively, these findings indicate that *O. sigmoideum* possesses noteworthy antioxidant potential and limited antiproliferative effects. Although not a potent cytotoxic agent, its phenolic profile supports its potential relevance as a source of bioactive compounds for functional food and nutraceutical applications.

Keywords Antioxidant · Black Sea Region · Cytotoxic effect · Phenolic compounds · Ornithogalum sigmoideum · Wild edible plant

✉ Mehtap Atak
mehtap.atak@erdogan.edu.tr

Hüseyin Avni Uydu
huseyin.uydu@samsun.edu.tr

Eda Yılmaz Kutlu
eda.yilmazkutlu@erdogan.edu.tr

Saliha Ekşi
saliha.eksi@erdogan.edu.tr

Erva Rakıcı
erva.esmer@erdogan.edu.tr

Nebahat Ejder
nebahat.aydogan@erdogan.edu.tr

Adem Demir
adem.demir@erdogan.edu.tr

Sevgi Kolaylı
skolayli@ktu.edu.tr

[1] Department of Medical Biochemistry, Recep Tayyip Erdogan University, Rize, Türkiye

[2] Department of Medical Biochemistry, Samsun University, Samsun, Türkiye

[3] Department of Medical Microbiology, Recep Tayyip Erdogan University, Rize, Türkiye

[4] Central Research Laboratory, Application and Research Centre, Recep Tayyip Erdogan University, Rize, Türkiye

[5] Department of Chemistry, Karadeniz Technical University, Trabzon, Türkiye

[6] Department of Biochemistry, Faculty of Medicine, Recep Tayyip Erdogan University, Islampasa Mahallesi, Iki numaralı Sehitler Caddesi, No: 74, Rize 53020, Türkiye, Turkey

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Introduction

Ornithogalum sigmoideum Freyn & Sint. is one of the *Ornithogalum* species found across temperate regions of Europe, Asia and Africa. In Türkiye, it is known locally as Sakarca, Çökülçe or Salivary herb, and grows naturally during early spring, especially in the Giresun and Ordu provinces of the Eastern Black Sea Region. The plant is typically consumed as a seasonal vegetable, and all of its parts, including roots, stems and flowers, are traditionally cooked and regarded as having certain healing properties [1–3].

Plants have long played essential roles in daily life, serving not only as sources of food but also as materials for shelter and medicine. A major reason for this is their ability to synthesize a wide variety of secondary metabolites that support adaptation and defense. Among these compounds, polyphenols stand out because of their well-known antioxidant, antimicrobial, anti-inflammatory and antiviral activities [3–5]. They are broadly classified into phenolic acids and flavonoids, both of which contribute to antioxidant defense by scavenging reactive radicals or interrupting radical chain reactions [6, 7].

In recent years, increasing attention has been directed toward regional wild edible plants (WEPs) as important reservoirs of biodiversity and cultural heritage, in parallel with advances in food chemistry and functional ingredient research. The scientific characterization of traditionally gathered plant species is now recognized not only as a phytochemical endeavor, but also as a means of promoting agro-biodiversity conservation, sustainable foraging practices, and diversification of local food systems. In this context, ethnobotanical knowledge associated with WEPs is increasingly viewed as a key component of resilient agricultural transitions and sustainable food systems [8].

At a broader scale, recent studies in agricultural economics and agri-food systems analysis emphasize that diversification strategies involving underutilized plant resources can strengthen rural livelihoods, enhance farm resilience, and contribute to sustainable agricultural business models. Research focusing on agricultural productivity, value chain integration, and decision making processes highlights the growing importance of integrating locally available bioresources into food systems to improve economic efficiency and long term sustainability [9–11].

Complementary to this economic perspective, recent literature on agricultural value chains and resource governance further underlines that the sustainable utilization and valorization of plant based bio resources can reduce waste, improve resource efficiency, and generate socio-economic benefits, particularly in rural regions [12, 13]. Within this framework, the scientific evaluation of underutilized or locally consumed plant species provides an evidence base for the development of functional foods and nutraceutical value chains, linking traditional dietary practices with contemporary goals of sustainability, food security, and rural economic resilience [14, 15].

Research on *Ornithogalum* species has expanded in recent years and includes studies related to taxonomy, morphology, genetic variation and various phytochemical or pharmacological properties [4, 16]. These investigations have documented the presence of secondary metabolites such as alkaloids, flavonoids and saponins, which may underlie the traditional medicinal value attributed to this genus. However, despite increasing interest, information on *O. sigmoideum* is still limited. In particular, there is a noticeable gap regarding the biological potential of different anatomical parts especially the aerial tissues, flowers and bulbs which have not been comprehensively compared in terms of their phenolic composition and associated bioactivities.

With this background, the present study aimed to examine the phenolic profile, antioxidant characteristics and antiproliferative effects of methanolic extracts prepared from the aerial, flower and bulb parts of *O. sigmoideum*. By integrating chemical analyses with in vitro biological evaluation, the study seeks to provide scientific support for the traditional use of this plant and to better assess its potential as a natural source of bioactive phytochemicals.

Materials and methods

Plants and extractions

Experimental research and field studies on plants, including the collection and handling of plant material, complied with all relevant institutional, national, and international guidelines and legislation. *Ornithogalum sigmoideum* specimens collected from Giresun (Türkiye) in February 2018 were separated into aerial parts, flowers, and bulbs. After washing, the samples were oven-dried at 37 °C until constant weight. The dried materials were mechanically ground using an Anton Paar Ball Mill BM500 operated at 30 Hz for 5 min to obtain a homogeneous powder suitable for extraction.

Three grams of the ground plant material were placed in 50 mL Falcon tubes and extracted with 30 mL of 98% methanol. The extraction was performed by combining ultrasonic bath treatment for 2 h with subsequent maceration on a shaker for 24 h [17], a hybrid approach applied to enhance solvent penetration and extraction efficiency [18, 19]. Following extraction, the methanolic solutions were divided into two portions. One portion was used directly for phenolic composition and antioxidant activity analyses. The solvent from the second portion was removed under

reduced pressure using a rotary evaporator, and the resulting dry extracts were dissolved in 10% dimethyl sulfoxide (DMSO) for use in cell culture experiments. All extract aliquots were stored at − 20 °C until further analysis.

The extraction yield (% w/w) was calculated for each plant part to assess the practical feasibility of obtaining bioactive fractions. After solvent evaporation, the dry extract yields obtained from 3 g of dried material were 0.839 g for aerial parts, 0.901 g for flowers, and 0.330 g for bulbs, corresponding to extraction yields of 27.97% (w/w), 30.03% (w/w), and 11.00% (w/w), respectively. These results indicate that the aerial and flower parts provide higher extractable yields than bulbs, suggesting their greater suitability for the recovery of bioactive constituents.

Total phenolic content (TPC)

Total phenolic content was determined spectrophotometrically at 760 nm using the Folin–Ciocalteu method [20]. A gallic acid calibration curve was used for quantification, and results were expressed as mg gallic acid equivalents (GAE) per g dry weight (DW).

Total flavonoid content (TFC)

Total flavonoid content was measured spectrophotometrically according to Fukumoto and Mazza [21]. Reaction mixtures containing 50 µL of 10% $Al(NO_3)_3$, 50 µL of 1.0 M NH_4CH_3COO, and 250 µL of extract were diluted to 2.5 mL with methanol and incubated at 25 °C for 40 min. Absorbance was measured at 415 nm, and TFC values were expressed as mg quercetin equivalents (QE)/g DW using the calibration curve.

Determination of phenolic profile with HPLC-PDA

Phenolic compounds were analyzed by reversed-phase HPLC coupled with a photodiode array detector (HPLC–PDA) using a Shimadzu LC-20AT system (Shimadzu, Japan), following the method described by Kara et al. [22]. A total of 25 phenolic standards were used for compound identification and quantification. Chromatographic separation was achieved using a gradient mobile phase consisting of acetonitrile–water (70:30, v/v) and water containing 2% acetic acid, at a flow rate of 1.0 mL/min. The column temperature was maintained at 30 °C. Quantitative results were expressed as µg/g dry weight (DW).

The HPLC–PDA method was fully validated as reported by Kara et al. [22] for the determination of the 25 phenolic compounds. Method validation parameters included limits of detection (LOD), limits of quantification (LOQ), recovery percentages, precision expressed as relative standard deviation (%RSD), and relative error values.

DPPH radical scavenging activity

DPPH radical scavenging activity was determined according to Molyneux [23]. Equal volumes (750 µL) of extract and 0.1 mM DPPH solution were mixed and incubated in the dark at 25 °C for 40 min. Absorbance was measured at 517 nm, and results were reported as SC_{50} values, indicating the concentration required to reduce DPPH radicals by 50%.

Ferric reducing/antioxidant power (FRAP)

The ferric reducing ability was assessed by the Benzie and Strain method [24]. The Fe (III)–TPTZ complex was reduced to Fe (II)–TPTZ in the presence of antioxidants, and absorbance was measured at 593 nm. Results were expressed as mg Trolox equivalents (TE)/g DW.

Copper reducing/antioxidant power (CUPRAC)

The cupric reducing antioxidant capacity was determined according to Apak et al. [25]. The Cu(II)–neocuproine complex was reduced to Cu(I)–neocuproine in the presence of antioxidants, and absorbance was recorded at 450 nm. Trolox was used as the reference standard, and results were expressed as mg TE/g DW.

Cell viability assay

Cell viability was assessed by the MTT assay [26]. HepG2, DU145, and HT-29 cancer cell lines and CRL-1790 (CCD 841 CoN, ATCC CRL-1790; normal human colonic epithelial cells) were seeded in 96-well plates at 1,000–2,000 cells/well and incubated 48 h. Extracts (12.5–800 µg/mL) were applied for 48 h, followed by MTT (5 mg/mL) incubation for 4 h at 37 °C. The formazan crystals were solubilized in 100 µL DMSO, and absorbance was read at 570 nm. Cell viability was expressed as a percentage of the vehicle control (0.8% DMSO). All experiments were performed in triplicate and repeated independently at least three times. Growth inhibition was calculated using the following formula:

$$\text{Growth inhibition } (\%) = \left[\left(OD_{\text{Negative control}} - OD_{\text{Sample}}\right)/OD_{\text{Negative control}}\right] \times 100$$

Statistical analysis

All experiments were performed as three independent biological replicates, each measured in technical triplicates. Accordingly, the "n = 3" reported in tables and figures refers to independent biological experiments. Data are presented as mean ± standard deviation (SD). The normality of data distribution was assessed using the Shapiro–Wilk test. Since all variables met the assumptions of normality, statistical

Table 1 Total phenolic and flavonoid contents of *O. sigmoideum*

Parts	Total Phenolic Content (TPC) mg GAE/g DW	Total Flavonoid Content (TFC) mg QUE/g DW
Aerial ($n=3$)	21.50 ± 0.60^{a}	13.10 ± 0.80^{a}
Flower ($n=3$)	7.10 ± 0.50^{b}	5.40 ± 0.30^{b}
Bulb ($n=3$)	1.20 ± 0.20^{c}	0.80 ± 0.20^{c}
Whole plant	29.70 ± 0.40	19.30 ± 0.60

Values are expressed as mean ± SD ($n=3$ independent biological experiments). Different superscript letters (a–c) within the same column indicate statistically significant differences among plant parts, as determined by one-way ANOVA followed by post hoc multiple comparison tests. Statistical significance was accepted at $p<0.001$. The "whole plant" values represent calculated totals derived from the individual plant parts and do not correspond to separately prepared whole plant extracts

comparisons among groups were performed using one-way analysis of variance (ANOVA), followed by the least significant difference (LSD) post hoc test. A p value < 0.05 was considered statistically significant. Statistical analyses were carried out using SPSS software (version 18.0, IBM Corp., Chicago, IL, USA).

Results and discussion

Antioxidant activity and capacity

In this study, firstly, total phenolic content (TPC), total flavonoid content (TFC) and individual phenolic substances amounts of the methanolic extracts obtained from three different parts of the plant were determined. The results were summarized in Table 1. It was determined that the aerial parts of the plant are richer in total phenolic and total flavonoid content compared to other parts of the plant. The total phenolic content in all parts of the plant was determined to be 29.70 ± 0.40 mg GAE/g, while the total flavonoid content was measured at 19.30 ± 0.60 mg QUE/g.

In this study, the phenolic compositions of the methanolic extracts from three different parts of the plant were determined by high-performance liquid chromatography with photodiode array detection (HPLC-PDA). The values obtained in this study, in which 25 phenolic compounds were used, are given in Table 2. It was detected only seven components among the phenolic standards in the different parts of the samples. In the flower parts of the plant, *p*-OH benzoic acid and ferulic acid are the most abundant phenolic acids, while pinocembrin is the most prevalent flavonoid. Protocatechuic acid and chrysin have been identified as the predominant phenolic compounds in the aerial parts of the plant, whereas in the bulb, chrysin, pinocembrin, *p*-coumaric acid, and ferulic acid were detected in lower concentrations. *t*-cinnamic acid was detected in low concentrations in both the flower and bulb parts. The flavonoid chrysin was found to be the most abundant phenolic compound in the plant.

Table 2 Phenolic components of *O. sigmoideum* extract

	Phenolic component	Flower	Aerial	Bulb
Phenolic acids (µg/g DW)	Gallic acid	-	-	-
	Protocatechuic acid	-	40.00	-
	Chlorogenic acid	-	-	-
	p-OH benzoic acid	29.54	-	-
	Caffeic acid	-	-	-
	Syringic acid	-	-	-
	m-OH benzoic acid	-	-	-
	Ellagic acid	-	-	-
	p-coumaric acid	-	-	5.44
	Ferulic acid	12.89	-	4.91
	t-cinnamic acid	1.66	-	4.28
Flavanoids (µg/g DW)	Epicatechin	-	-	-
	Rutin	-	-	-
	Myricetin	-	-	-
	Daidzein	-	-	-
	Luteolin	-	-	-
	Quercetin	-	-	-
	Apigenin	-	-	-
	Hesperetin	-	-	-
	Rhamnetin	-	-	-
	Chrysin	7.28	583.10	13.40
	Pinocembrin	8.35	-	15.80
	CAPE	-	-	-
	Curcumin	-	-	-
	Resveratrol	-	-	-

(-): not detected (< LOD values)

Table 3 Antioxidant activities of *O. sigmoideum*

Parts of the Plant	DPPH (SC_{50}, mg/mL)	FRAP (mg TE/ g DW)	CUPRAC (mg TE/ g DW)
Aerial ($n=3$)	0.80 ± 0.01^{a}	19.80 ± 0.80^{a}	25.60 ± 2.60^{b}
Flower ($n=3$)	0.64 ± 0.01^{b}	23.90 ± 1.10^{b}	39.50 ± 3.50^{a}
Bulb ($n=3$)	2.21 ± 0.08^{c}	8.30 ± 0.50^{c}	17.80 ± 0.30^{c}
Whole plant	3.65 ± 0.05	52.00 ± 1.20	82.30 ± 2.10

Values are expressed as mean ± SD ($n=3$ independent biological experiments). Different superscript letters (a–c) within the same column indicate statistically significant differences among plant parts, as determined by one-way ANOVA followed by post hoc multiple comparison tests. Statistical significance was accepted at $p<0.001$. The "whole plant" values represent calculated totals derived from the individual plant parts and do not correspond to separately prepared whole plant extracts

In this study, the antioxidant capacities of the methanolic extracts were examined using classical antioxidant tests (FRAP, CUPRAC and DPPH). The results are given in Table 3. According to all measurements, it was found that all three parts of the *O. sigmoideum* plant possess significant antioxidant capacity, with the flowering part exhibiting a higher antioxidant value. In the study, it was determined that the methanolic extracts of all three parts of the plant showed consistent DPPH radical scavenging activity, FRAP and CUPRAC antioxidant values. However, it was found that there is no complete correlation between the total phenolic and flavonoid content in Table 1 and the antioxidant values.

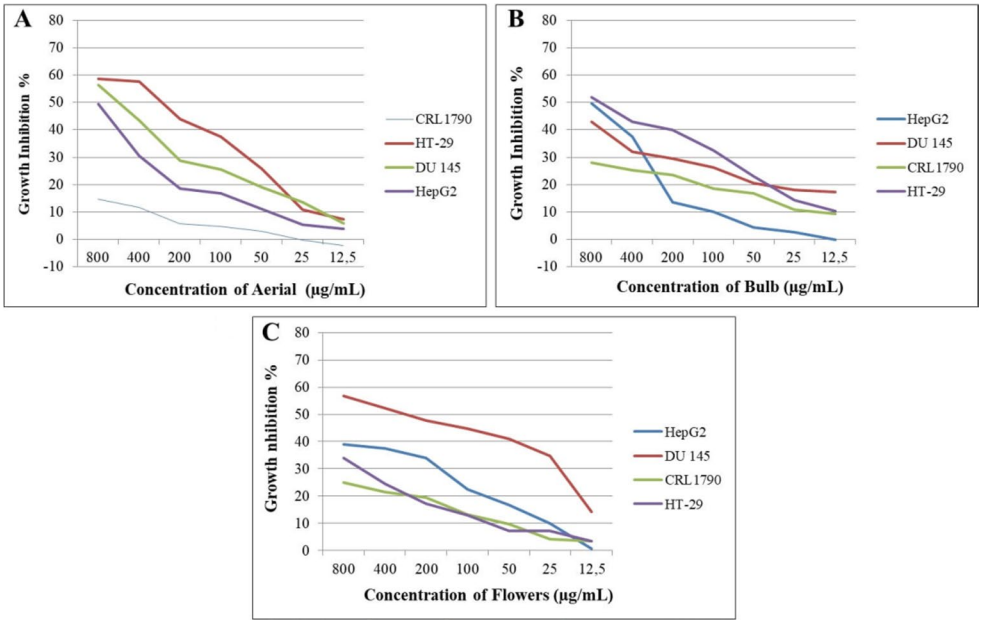

Fig. 1 The antiproliferative effect of *O. sigmoideum* on the proliferation of HepG2, DU145, HT-29 and CRL 1790 cells as examined by MTT assay

MTT cell viability assay

The methanolic extracts of the flower, bulbs, and aerial parts of *O. sigmoideum* were examined for potential antiproliferative effects using MTT cell viability on HepG2, DU145, and HT-29 human cancer cell lines, and CRL 1790 as the normal cell line. These cells were selected because prostate and colon cancers are two of the five main causes of both patient and death rates [27, 28]. As seen in Fig. 1, the investigated extracts were tested on the human cell lines at 800 –12.5 µg/mL concentrations. High concentrations of the aerial extract had less effect (15%) on non-transformed CRL 1790 cells, while causing growth inhibition rates of 49%, 56%, and 59% in the HepG2, Du145 and HT-29 cancer cell lines, respectively. The IC_{50} concentration of the aerial extract was 285 µg/mL at 48 h in the HT-29 cells. For clarity and comparative evaluation, the IC_{50} values obtained for all tested extracts and cell lines, including the non-cancerous CRL-1790 cells, are summarized in Table 4. The antiproliferative effects of the flower extract (800 µg/mL) on HepG2, Du145, and HT-29 human cancer cells demonstrated growth inhibition rates of 39.0%, 56.8%, and 33.9%, respectively. A cell death rate of 25% was detected in normal cells. The extract produced dose-dependent inhibition of cell growth on the HepG2 cell lines. The IC_{50} value of the flower extract was calculated as 300 µg/mL in DU145 cells. As presented in Fig. 1, the effects of the bulb against the human cancer cells and non-transformed cells exhibited a moderate, concentration-dependent antiproliferative effect in a concentration-dependent manner. The results indicated that HT-29 was the most affected cell line in terms of growth inhibition. The IC_{50} of the bulb against the HT-29 cells was 710 µg/mL.

Table 4 IC_{50} values of *O. sigmoideum* extracts against cancer and normal cell lines

Extract	Cell Line	IC_{50} (µg/mL)
Aerial	HT-29	285
Flower	DU145	300
Bulb	HT-29	710
Aerial	CRL1790 (non-cancerous)	ND
Flower	CRL1790 (non-cancerous)	ND

ND: Not determined, as cell growth inhibition did not reach 50% at the highest tested concentration (800 µg/mL)

Dose–response effects of methanolic extracts of *O. sigmoideum* aerial (A), bulb (B), and flower (C) parts on the viability of HepG2, DU145, and HT-29 cancer cell lines and the non-cancerous CRL-1790 cells, as assessed by the MTT assay after 48 h of treatment. Cells were exposed to extract concentrations ranging from 12.5 to 800 µg/mL. Data shown represent the mean values obtained from three independent biological experiments performed in triplicate. Corresponding IC_{50} values are summarized in Table 4.

Discussion

Phenolic composition of different parts of *O. sigmoideum*

Polyphenols and other plant-derived secondary metabolites are widely recognized for their contribution to antioxidants and other biological activities, and higher phenolic content is often associated with stronger bioactivity [6, 17, 29]. In our study, the aerial parts of *O. sigmoideum* showed the

highest total phenolic and flavonoid content, which aligns with earlier findings reported for other *Ornithogalum* species collected from the Eastern Black Sea Region [16]. This suggests that, similar to related species, the aerial tissues of *O. sigmoideum* may serve as the primary reservoir of phenolic constituents.

The HPLC-PDA results further revealed a distinct phenolic composition among plant parts. Particularly, the flower extract contained notable amounts of p-hydroxybenzoic acid, ferulic acid and the flavonoid pinocembrin, whereas chrysin and protocatechuic acid predominated in the aerial parts, and the bulb extract contained these compounds at comparatively lower levels. Previous work on *O. narbonense* identified caffeic acid, rutin, p-hydroxybenzoic acid and ferulic acid as major components [30]; however, caffeic acid and rutin were not detectable in *O. sigmoideum* in our study. These interspecies differences, also supported by earlier reports showing variation in p-hydroxybenzoic and protocatechuic acid distribution among *Ornithogalum* taxa [3], highlight the chemical diversity within the genus.

Antioxidant activity in relation to phenolic composition

Despite the aerial extracts exhibiting higher TPC and TFC, the flower extract demonstrated superior FRAP and CUPRAC responses. This apparent discrepancy may be explained by the differing antioxidant capacities of individual phenolic compounds rather than their total concentration. In particular, the relatively high levels of chrysin in the flower extract appear to contribute substantially to its reducing power, consistent with the well-documented antioxidant potential of chrysin, a flavone abundant in various plant species [31]. Similar observations have been reported for other *Ornithogalum* species, where different plant parts display distinct antioxidant profiles depending on their phenolic composition [30]. The present findings support this pattern and suggest that the antioxidant performance of *O. sigmoideum* flowers is driven more by qualitative composition than by total phenolic load.

In line with this interpretation, increasing evidence indicates that antioxidant activity is often more strongly influenced by phenolic composition and molecular structure than by total phenolic quantity alone. In single-electron transfer based assays such as FRAP and CUPRAC, electron-donating capacity is closely related to structural features (e.g., hydroxylation patterns, conjugation, and planarity) that determine redox behavior. Comparative profiling studies have likewise reported extracts with relatively lower global phenolic indices but higher antioxidant performance due to the presence of structurally potent phenolics and/or favorable compositional patterns [32, 33]. Moreover, antioxidant outcomes in complex extracts may also reflect synergistic or antagonistic interactions among co-occurring phenolics, meaning that activity can shift depending on compound ratios and assay mechanism [32]. Taken together, our results reinforce that comprehensive profiling offers a more mechanistically informative explanation for antioxidant performance than TPC/TFC values alone.

Antiproliferative effects

The antiproliferative results also demonstrated variation among plant parts. Earlier work on *O. sigmoideum* reported that aerial and bulb extracts exhibited cytotoxic effects in colon and prostate cancer cell lines [34]. While our study confirms that the aerial extract induced measurable growth inhibition (49–59%) depending on the cell line, the IC_{50} values obtained were higher than those previously reported for HCT-116 and PC3 cells indicating a relatively moderate antiproliferative potency under the tested conditions [34]. Several factors may account for these differences, including variations in extraction procedures, phenolic composition, or, importantly, the separation of flower tissues in the present study, which may have altered the distribution of bioactive compounds within the tested extracts. In line with this, previous work on *O. balansae* reported remarkably potent cytotoxic activity with IC_{50} values as low as 4–6 µg/mL [27], highlighting that antiproliferative potency can vary substantially across *Ornithogalum* species. Some *Ornithogalum* species have also been traditionally used for cancer-related purposes and have demonstrated cytotoxic potential in earlier reports [28].

Although the present study was limited to an MTT-based screening approach, the observed moderate and selective antiproliferative profile of the aerial extract (lower impact on normal CRL-1790 cells) can be discussed within mechanisms frequently reported for phenolic-rich plant extracts. Phenolic compounds have been widely associated with growth-inhibitory effects through induction of programmed cell death, cell-cycle arrest, and modulation of oxidative stress and inflammatory signaling pathways [35]. In particular, phenolics and flavonoids have been reported to influence apoptosis-related cascades (e.g., caspase-related signaling), interfere with cell-cycle regulatory proteins, and modulate redox balance and pro-survival pathways, including PI3K/Akt, MAPK/ERK, and NF-κB networks [35]. While mechanistic assays were beyond the scope of this work, these established pathways provide a biologically plausible framework to explain the differential response observed between cancer and normal cells and justify future studies focusing on apoptosis markers, cell-cycle distribution, and redox signaling in the context of the dominant phenolics identified here.

Comparison with other *Ornithogalum* species

Comparative investigations within the *Ornithogalum* genus show that phenolic fingerprints and bioactivities vary in a systematic yet species- and tissue-dependent manner. A comparative analysis of *O. orthophyllum*, *O. sigmoideum*, and *O. oligophyllum* reported that aerial methanolic extracts are consistently richer in key phenolic acids (including protocatechuic and p-hydroxybenzoic acids) than bulb tissues and that this enrichment is reflected in stronger antioxidant performance [3, 36]. In addition, the "phytochemical fingerprint and biological activity" study on *O. umbellatum* demonstrated that phenolic profiles and associated bioactivities are sensitive not only to tissue type but also to processing conditions (e.g., raw vs. heat-treated), underscoring that qualitative composition and matrix effects can substantially shift functional outputs [36].

Species-level composition can also translate into major differences in biological potency. For example, *O. narbonense* has been reported to contain a broader phenolic spectrum including compounds such as caffeic acid and rutin [30], whereas *O. balansae* aerial extracts exhibit pronounced antiproliferative effects that have been linked to distinct compositional dominance patterns [37]. Within this comparative framework, the present results indicate that *O. sigmoideum* conforms to the general genus level trend of richer phenolic composition in aerial/flower tissues than bulbs [3], while exhibiting a species-specific activity profile characterized by strong antioxidant performance and modest antiproliferative activity.

Technological and sustainability implications

Beyond phytochemical profiling, the present findings can be interpreted within emerging discussions on sustainable food systems, circular bioeconomy, and resource governance. Recent work emphasizes that evidence-based characterization of underutilized, traditionally consumed plant resources can support diversification of local food systems and contribute to broader socio-economic outcomes through value-chain development and improved resource efficiency [12, 13]. In this context, the stronger antioxidant performance observed particularly in aerial and flower tissues suggests that these renewable fractions may have greater potential for valorization as functional ingredients, which aligns with circular-economy approaches that convert plant biomass into value-added products rather than waste streams [14]. Moreover, links between agrobiodiversity, health-oriented foods, and rural development outcomes have been increasingly discussed, providing a broader justification for investigating wild edible plants with measurable bioactivity [15].

From a technological perspective, recent literature highlights the transformative potential of sustainable and "green" processing technologies such as ultrasound-assisted and solvent-reduced extraction to enhance bioresource efficiency, improve recovery of bioactive, and reduce environmental footprint, while supporting economic feasibility at scale [38]. Given that our extraction already incorporated ultrasound-assisted steps, future optimization using greener solvent systems and process intensification could further improve recovery and functional performance of target phenolics in *O. sigmoideum*, facilitating translation toward practical food/nutraceutical applications.

Overall, the combined chemical and biological data indicate that *O. sigmoideum* possesses measurable antioxidant capacity and modest antiproliferative potential, with notable differences among plant parts. The distinct phytochemical signatures of the aerial, flower and bulb tissues help clarify the functional roles of these metabolites and provide a basis for understanding the plant's traditional use. Although further mechanistic studies are needed particularly to delineate apoptosis/cell-cycle and redox-related pathways suggested for phenolic-rich extracts [35] the present findings contribute valuable information toward evaluating *O. sigmoideum* as a potential source of bioactive compounds for functional food or nutraceutical applications.

Conclusion

Ornithogalum sigmoideum is a wild edible plant traditionally consumed in the Eastern Black Sea Region of Türkiye, and the present study provides a detailed characterization of its phenolic composition and associated biological properties. Among the plant parts investigated, the aerial tissues emerged as the most promising fraction due to their higher total phenolic and flavonoid contents and their moderate yet selective antiproliferative activity against cancer cell lines, while exerting limited effects on normal cells. In contrast, the flower extract exhibited pronounced antioxidant capacity, particularly in reducing power–based assays, likely reflecting its distinct qualitative phenolic profile.

Overall, these findings indicate that *O. sigmoideum* represents a valuable natural source of antioxidant phytochemicals, with the aerial and flower parts showing complementary functional properties relevant to functional food and nutraceutical research. Although the antiproliferative effects observed in this study were modest, the differential biological responses among plant parts support further investigation.

Future studies should focus on the isolation and characterization of bioactive phenolic fractions particularly chrysin-rich extracts from the aerial and flower tissues, as well as on in vivo antioxidants and antiproliferative evaluations to confirm biological relevance. Additional research addressing bioavailability, safety, and stability of these extracts, including their incorporation into food or nutraceutical models, would further clarify the potential of *O. sigmoideum* as a functional plant resource.

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Author contributions Mehtap ATAK: Conceptualization, methodology, validation, writing-original draft preparation, writing—review and editing, project administration. Hüseyin Avni UYDU: Conceptualization, formal analysis, resources, writing—original draft preparation, writing—review and editing. Eda YILMAZ KUTLU: Investigation, writing—original draft preparation, writing—review and editing. Saliha EKŞİ: Investigation. Erva RAKICI: Investigation, writing—original draft preparation. Nebahat EJDER: Methodology, investigation. Adem DEMİR: Investigation, resources. Sevgi KOLAYLI: Methodology, investigation, resources, writing—review and editing.
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Data availability The original contributions presented in the study are included in the manuscript, further inquiries can be directed to the corresponding author.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

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