Ethnobotanical, phytochemical and pharmacological review of *Arbutus unedo* L. with a bibliometric analysis

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Review

Abstract

Background: *Arbutus unedo* L. (Ericaceae) is a Mediterranean medicinal plant traditionally used to treat metabolic, inflammatory, gastrointestinal, cardiovascular, and urological disorders. This study presents the updated and quantified information on *A. unedo* with a bibliometric analysis to measure the current research trends, hot topics, and key contributors.

Methods: A mixed-methods approach was employed in this study, combining a literature review and a bibliometric analysis. The literature review was conducted using peer-reviewed publications on the ethnobotanical uses, phytochemical composition, and pharmacological activities, with 51 publications selected. The bibliometric analysis was performed using the Scopus, Web of Science, and PubMed databases. After duplicate removal and screening, 726 publications (1979–2025) were included.

Results: The literature confirms that *A. unedo* is rich in phenolic compounds, flavonoids, tannins, terpenoids, and anthocyanins, which are associated with antioxidant, antimicrobial, anti-inflammatory, antidiabetic, and other pharmacological activities that support many of its traditional medicinal uses. Bibliometric analysis revealed a continuous increase in scientific production, with research predominantly originating from Mediterranean countries, particularly Italy, Spain, Portugal, and Morocco. Thematic analyses identified phytochemistry, antioxidant activity, ethnopharmacology, and ecological adaptation as the major research areas, whereas clinical studies and industrial applications remain comparatively limited.

Conclusions: *Arbutus unedo* is a promising source of bioactive compounds with considerable pharmaceutical, nutraceutical, and cosmetic potential. Future research should emphasize standardized experimental protocols, in vivo and clinical validation, and interdisciplinary approaches to facilitate the sustainable valorization of this Mediterranean species.

Keywords: Ethnobotany; *Arbutus unedo*; Ethnopharmacology; Phytochemistry; Bibliometric analysis; Medicinal plants; Bioactive compounds

Background

Arbutus unedo, referred to as the "strawberry tree," is a species of the Ericaceae family. It is widely distributed in Mediterranean regions, where it is associated with Mediterranean forest ecosystems and has attracted scientific interest because of its ecological, nutritional, ethnobotanical, phytochemical and biological properties. Within the genus *Arbutus*, *A. unedo* is also recognized as the most widely distributed species (De Santis *et al.* 2023). Although it is globally assessed as Least Concern by the IUCN (De Santis *et al.* 2023), several regional populations, particularly in Tunisia and Morocco, are reported to be declining as a result of deforestation, over-collection, wildfires, and agricultural conversion (Faida *et al.* 2019, Mhamdi Takrouni *et al.* 2012). Moreover, the species is considered sensitive to drought, which may further increase its vulnerability under changing climatic conditions. It holds great importance in traditional medicine in Mediterranean areas where it is used as a multipurpose remedy for the management of metabolic disorders such as diabetes and hypertension, gastrointestinal disturbances, inflammatory and rheumatic conditions, urological diseases, and certain dermatological applications (Bebek Markovinović *et al.* 2022, Bouyahya *et al.* 2021, Doudach *et al.* 2023, El Haouari *et al.* 2021, El Mekkaoui *et al.* 2024, Faida *et al.* 2019, Morgado *et al.* 2018, Twilley *et al.* 2017).

This species can reach a height of 10 meters. In contrast to other species of the same genus, it has leathery, serrated, green leaves and white to pink flowers that hang in clusters during the fall (Miguel *et al.* 2014, Morales 2022). *Arbutus unedo* produces globular berries that turn bright red upon maturation. Although edible, these fruits are not widely consumed due to their granular texture and slightly astringent aftertaste. Nevertheless, they play a key ecological role, as their seeds are dispersed by animals, facilitating the natural propagation of the species (De Santis *et al.* 2023, Molina *et al.* 2016). Another distinction of this species is its notable adaptation to calcareous soils (Mhamdi Takrouni *et al.* 2012). These biological and ecological characteristics are relevant when considering both the traditional exploitation and the conservation and sustainable valorization of the species.

Since the beginning of the 21st century, numerous studies have been published highlighting the phytochemical richness of *Arbutus unedo*, particularly polyphenols, flavonoids, tannins, and terpene derivatives, which have antioxidant, anti-inflammatory, antimicrobial, and antidiabetic properties (Asmaa *et al.* 2019, Lehfa & Sahnouni 2023, Martins *et al.* 2022, Tenuta *et al.* 2019). The occurrence of these bioactive constituents provides a possible biological basis for some of the activities reported for *A. unedo* and offers an important framework for examining the relationship between its traditional uses and experimentally investigated biological effects.

In addition, the pharmaceutical, food, and cosmetic industries have seen an increase in scientific interest in the pursuit of sustainable natural resources and the reappraisal of traditional knowledge to discover and develop new bioactive molecules that can replace synthetic products.

Although several reviews and research studies have examined different aspects of *A. unedo*, the available evidence remains distributed across ethnobotanical, phytochemical, nutritional and pharmacological literature. Previous reviews have provided valuable syntheses of the traditional uses, chemical composition and biological activities of the species (El Haouari *et al.* 2021, Morgado *et al.* 2018). However, these contributions have different geographical and thematic scopes, and the broader evolution and structure of the scientific literature on *A. unedo* remain insufficiently characterized. In particular, there is a need to bring together documented traditional uses, the distribution of bioactive compounds and the available biological evidence while simultaneously identifying research trends, geographical patterns and areas that remain comparatively underexplored. Addressing this gap can provide a more comprehensive basis for interpreting the current state of knowledge on *A. unedo* and for identifying priorities for future research.

In this context, the present study aims to provide an updated and comprehensive synthesis of the available knowledge on *Arbutus unedo*, integrating documented ethnobotanical uses with phytochemical and pharmacological evidence. The study also incorporates a bibliometric analysis to characterize the evolution of scientific production, identify major research themes, examine geographical and scientific contributions, and highlight areas that remain insufficiently investigated. By combining qualitative literature synthesis with quantitative analysis of scientific literature, this work seeks to provide an integrated overview of the current state of research on *A. unedo* and to identify perspectives for future research and sustainable valorization of the species.



Figure 1. General habit of *Arbutus unedo* L.: (A) whole tree, (B) fruit at an early stage of development, (C) mature fruit.

Materials and Methods

Data source

To ensure solid and comprehensive insights into the research on *A. unedo*, the study used a dual-method approach that combined a bibliometric analysis and literature review.

The literature review was carried out using a broad and inclusive search strategy, without restricting the selection to a single database. For the bibliometric analysis, in an effort to capture as many ethnobotanical, phytochemical and pharmacological studies as possible, structured searches were run in Scopus, Web of Science and PubMed due to their broad indexing coverage and citation tracking capabilities, considering all articles published to December 2025.

Search strategies

A thorough search was carried out simultaneously without any time constraints for the bibliometric analysis and the literature review. Using the core keyword "*Arbutus unedo*", pertinent articles were retrieved from the databases for the bibliometric analysis. The "OR" operator was used to apply the search to the titles, abstracts, or keywords fields in order to capture all species naming variations.

The literature review consisted of using key terms such as "*Arbutus unedo*" or "strawberry tree" and other descriptive words ("phytochemical composition", "secondary metabolites", "polyphenols", "flavonoids", "biological activities", "pharmacological properties", "ethnobotanical" and "medicinal"). In order to expand the search to include additional materials, the keywords were further combined, as necessary, using the operators 'AND' or 'OR'. The results from these searches were then separated to identify and remove duplicate items and to provide a clean non-duplicated set of records to use for analysis purposes.

Criteria

During the screening process, precise criteria were applied to assure data quality and relevance. The bibliometric analysis used a more generalized inclusion strategy than the literature review. In bibliometric analysis, any manuscripts in English language, book chapters, conference papers, reviews and short surveys addressing any aspect of the medicinal plant were included for further analysis. This broader approach to inclusion was selected to establish a broader bibliometric landscape, to identify research projects, collaborations and emerging research topics that pertain to the area of medicinal plants. Also, including a wide spectrum of published articles will provide more context and a better overall understanding of research on these plants. The literature review would be more focused, restricting to peer-reviewed articles, book chapters, and articles specifically dealing with pharmacology, traditional uses and phytochemical composition of the plant. Excluded were articles that were not printed in English, articles lacking scientific merit, duplicate articles and abstracts of conference proceedings.

Analysis tool

Microsoft Excel was used to merge the records retrieved from PubMed, Scopus, and Web of Science and to organize the bibliographic dataset before analysis. Duplicate records were identified during the data-cleaning process by comparing DOI, title, and author information, and the results were cross-checked using Bibliometrix. After screening and duplicate removal, 726 publications were retained as the bibliometric dataset. A separate focused screening based on the relevance of the publications to the ethnobotanical uses, phytochemical composition, and pharmacological activities of A. unedo resulted in a qualitative literature-review dataset of 51 publications.

The bibliometric dataset was analyzed using the R package Bibliometrix. The analysis included annual scientific production, citation indicators, scientific production by country, affiliations, authors, and sources, as well as keyword frequency and keyword co-occurrence. Multiple Correspondence Analysis (MCA) and thematic mapping were used to further explore the conceptual structure of the research field, including the main thematic relationships and their organization within the scientific literature on A. unedo (Aria and Cuccurullo 2017). The 51 publications selected for the qualitative literature review were examined according to their relevance to ethnobotanical uses, phytochemical composition, and pharmacological activities, and their findings were synthesized thematically.

Search results

A total of 1,272 records were identified through the bibliographic searches, including 505 records from Web of Science, 497 from Scopus, and 270 from PubMed. After screening and removal of duplicate records, 726 publications were retained for the bibliometric analysis. In parallel, a more focused screening based on the relevance of the publications to the ethnobotanical uses, phytochemical composition, and pharmacological activities of *Arbutus unedo* resulted in the selection of 51 publications for the qualitative literature review.

Results and Discussion

Literature Review

Ethnomedicinal uses

The ethnomedicinal uses of *Arbutus unedo* reported in the reviewed literature indicate a relatively broad but generalized therapeutic application, primarily centered on gastrointestinal, cardiovascular, dermatological, and urological disorders. A notable feature of the available data is the predominance of leaf-based preparations, particularly in the form of herbal infusions and decoctions, suggesting that leaves are the main medicinally exploited organ of the plant. This predominance may reflect practical considerations, as leaves are available throughout the year, easy to harvest, and simple to prepare as

aqueous preparations. Roots and bark are also used, but less frequently, and are generally associated with specific indications such as renal pain, hypertension, and rheumatism. Fruits are mainly consumed raw or as infusions for gastrointestinal complaints.

Table 1. Ethnomedicinal uses of different parts of *Arbutus unedo*

Plant part used	Use	Preparation method and administration route	Reference
Leaves	Kidney disease	Decoction – oral	(Bencheikh *et al.* 2021)
	Diabetes	Decoction – oral	(Bnouham *et al.* 2002, Doudach *et al.* 2023, El Haouari *et al.* 2021)
	Rheumatism	Infusion – external	(González *et al.* 2010, Morgado *et al.* 2018)
	Urological disease	Infusion – oral	(Bebek Markovinović *et al.* 2022)
	Diuretic	Decoction – oral	(Benković *et al.* 2024, Faida *et al.* 2019)
	Gastrointestinal disorders	Infusion – oral	(Mrabti *et al.* 2017, Wahabi *et al.* 2025)
	Cardiac disease	N.D.	(Jouad *et al.* 2001)
	Hypertension	N.D.	(El Haouari *et al.* 2021, Jouad *et al.* 2001)
	Diarrhea	Infusion – oral	(Maleš *et al.* 2013, Oliveira *et al.* 2011)
	skin diseases	Direct application	(Aït Youssef 2006, Guendouze-Bouchefa *et al.* 2015)
Root	Renal pain / Renal colic	Decoction – oral	(Bencheikh *et al.* 2021)
	High blood pressure and liver aches	Decoction – oral	(Faida *et al.* 2019)
	High blood pressure and diabetes	Decoction – oral	(Mrabti *et al.* 2019)
	Asthma and stomach	Decoction – oral	(Faida *et al.* 2019)
	Hypertension and rheumatism	Decoction – oral	(Rhattas *et al.* 2016)
	Renal pain	Decoction – oral	(Bencheikh *et al.* 2021)
	Metabolic and digestive tract	Decoction/infusion	(Slimani *et al.* 2016)
Bark	Digestive diseases	Raw	(Faida *et al.* 2019)
	Depurative and anti-diarrheal effect	Raw	(Rhattas *et al.* 2016)
	Antiseptic, astringent, anti-inflammatory	Decoction – oral	(Elachouri & Idrissi 2023)
	Diabetes	Decoction – oral	(Mrabti *et al.* 2019)
Fruit	Diarrhea	Raw	(El Haouari *et al.* 2021)
	Digestive diseases	Infusion – oral	(Ait Lhaj *et al.* 2021, Faida *et al.* 2019, Gil *et al.* 2023)

Bioactive compounds

Arbutus unedo contains several major classes of secondary metabolites, including volatile compounds and essential oils, phenolic compounds, flavonoids, anthocyanins, and tannins. Their distribution varies according to the plant organ, with leaves and fruits being the most extensively investigated parts. The major compounds reported in the reviewed literature, together with their documented plant parts and associated biological activities, are summarized in Table 2.

Table 2. Major bioactive compounds identified in *Arbutus unedo* L., plant parts, biological properties, and reported mechanisms of action.

Compound/class	Related compounds	Plant part	Biological properties	Reported mode of action	References
Volatile compounds and essential oils	α-Fenchone, cymenene, linalool oxide, salvene, (Z,Z)-2,4-heptadienal, fenchyl acetate, α-ylangene, (E,E)-2,4-heptadienal, camphor, linalool, 1-octanol, pinocarvone, bornyl acetate, caryophyllene, terpinen-4-ol, myrtenal, (E)-2-decanal,	Leaves, fruits	Antimicrobial	Disruption of microbial cell membrane integrity, increased permeability and leakage of intracellular contents,	(Al-Mijalli *et al.* 2022, Asmaa *et al.* 2019, Belfekih *et al.* 2025, Kivcak *et al.* 2001)

	pinocarveol, myrtenyl acetate, α-terpineol, eucarvone, δ-carvone, 2-methylacetophenone, myrtenol, geraniol, palmitic acid, octanol, 2-hexadecanone, nonanoic acid, anethole, ethyl myristate, methyl palmitate, ethyl palmitate, cuminal, m-cymene-8-ol, p-cymene-8-ol, neryl acetone, β-ionone, viridiflorol			inhibition of DNA/RNA and protein synthesis.	
Polyphenols	Anisic acid, caffeic acid, ellagic acid 4-O-β-D-glucopyranoside, ellagic acid, ferulic acid, gallic acid, galloylquinic acid (3-O- or 5-O-), protocatechuic acid, quinic acid, galloyl shikimic acid (3-O- or 5-O-), syringic acid	Leaves, fruits	Antioxidant, antibacterial, anti-inflammatory, anticancer	Reduction of oxidative damage and neutralization of free radicals, inhibition of growth of some cancer cells, induction of apoptosis, reduction of vascular inflammation, inhibition of LDL oxidation	(Brčić Karačonji *et al.* 2021, El Cadi *et al.* 2020, Espíndola *et al.* 2019, Harper 2023, Izcara *et al.* 2021, Tenuta *et al.* 2020, Yoon *et al.* 2013, Ziółkiewicz *et al.* 2023)
Flavonoids	Afzelin, catechin, isovitexin 7-O-glucoside, kaempferol, kaempferol 3-O-glucoside, myricetin 3-O-xyloside, naringenin 7-O-glucoside, norbergenin, rutin, hyperoside, isoquercitrin, myricetin, myricetin 3-O-rhamnopyranoside, quercetin 3-O-arabinoside, quercetin 3-O-xyloside, quercitrin	Leaves, fruits	Antioxidant, anti-inflammatory, antimicrobial, antiviral, antiproliferative, anticancer	Inhibition of pro-inflammatory cytokine production, disruption of pathogen cell membranes and metabolism, induction of apoptosis in cancer cells	(Brčić Karačonji *et al.* 2021, Deepika & Maurya 2022, El Cadi *et al.* 2020, Izcara *et al.* 2021, Jan *et al.* 2022, Park *et al.* 2016, Shamsudin *et al.* 2022, Tenuta *et al.* 2020)
Anthocyanins	Delphinidin-3-galactoside, cyanidin-3-galactoside, cyanidin-3-glucoside, cyanidin-3-arabinoside, delphinidin, cyanidin	Fruits	Antioxidant, anti-inflammatory	Free-radical scavenging, reduction of oxidative stress, inhibition of IL-6 and TNF-α	(Guimarães *et al.* 2013, Hao *et al.* 2021, Liang *et al.* 2021, Miguel *et al.* 2014, Zitouni *et al.* 2020)
Tannins	Gallocatechin, epicatechin-(4→6)-catechin, epicatechin-(4→8)-epicatechin, ellagitannins	Leaves, roots	Antimicrobial, antioxidant, anti-inflammatory, anticancer	Inhibition of bacterial and fungal growth, free-radical scavenging	(Banc *et al.* 2023, Farha *et al.* 2020, Fortalezas *et al.* 2010, Tenuta *et al.* 2019)

Overall, the reported phytochemical profile provides a possible basis for several biological activities investigated for *A. unedo*. Phenolic compounds and flavonoids are mainly associated with antioxidant, anti-inflammatory and antimicrobial effects, while anthocyanins contribute to the antioxidant and anti-inflammatory potential of the fruits. Essential oils and their volatile constituents have also demonstrated antimicrobial activity, whereas tannins have been associated with antimicrobial,

antioxidant and anti-inflammatory effects. However, the available evidence is heterogeneous and depends on the plant organ, extraction procedure, chemical composition, experimental model, and level of investigation. Consequently, the presence of bioactive compounds and the biological activities reported in experimental studies should be considered as evidence of potential biological effects rather than as direct confirmation of clinical efficacy.

Nutritional composition of the fruit

The fruits of *Arbutus unedo* contain carbohydrates and sugars as predominant components, together with dietary fiber, proteins, lipids, vitamins, and several mineral elements, particularly potassium, calcium, phosphorus, and iron. The nutritional composition reported in different studies is summarized in Table 3.

Table 3. Nutritional composition of *Arbutus unedo* L. fruits reported in the reviewed literature. Values are presented according to the reported analytical basis, including fresh weight (FW) and dry weight (DW).

Component	Reported values	Basis / Unit	References
Moisture	46.70–74.13	% FW	(Litrenta *et al.* 2025, Vidrih *et al.* 2013)
Carbohydrates	12.68–31.55	g/100 g FW	(Litrenta *et al.* 2025, Ruiz-Rodríguez *et al.* 2011)
	78.24–84.75	g/100 g DW	(Ait Lhaj *et al.* 2021)
Total sugars	7.17–27.18	g/100 g FW	(Çakmak & Yılmaz 2024)
	52.05–67.15	g/100 g DW	(Ait Lhaj *et al.* 2021)
Glucose	2.32–8.34	g/100 g FW	(Çakmak & Yılmaz 2024, Vidrih *et al.* 2013)
Fructose	3.08–17.93	g/100 g FW	(Çakmak & Yılmaz 2024, Vidrih *et al.* 2013)
Sucrose	0.02–1.93	g/100 g FW	(Çakmak & Yılmaz 2024)
Dietary fiber	10.04–22.27	g/100 g FW	(Ruiz-Rodríguez *et al.* 2011, Vidrih *et al.* 2013)
	11.02–20.10	g/100 g DW	(Ait Lhaj *et al.* 2021)
Protein	0.58–2.50	g/100 g FW	(Litrenta *et al.* 2025, Ruiz-Rodríguez *et al.* 2011, Vidrih *et al.* 2013)
	1.69–3.97	g/100 g DW	(Ait Lhaj *et al.* 2021)
Total lipids / fat	0.43–2.43	g/100 g FW	(Litrenta *et al.* 2025, Ruiz-Rodríguez *et al.* 2011)
	1.56–5.16	g/100 g DW	(Ait Lhaj *et al.* 2021)
Ash	0.48–2.82	g/100 g FW	(Litrenta *et al.* 2025, Şeker & Toplu 2010, Vidrih *et al.* 2013)
	1.53–3.87	g/100 g DW	(Ait Lhaj *et al.* 2021)
Energy	61.48–135.93	kcal/100 g FW	(Ruiz-Rodríguez *et al.* 2011)
	346.48–384.11	kcal/100 g DW	(Ait Lhaj *et al.* 2021)
Vitamin C	13.53–280.00	mg/100 g FW	(Ben Salem *et al.* 2018, Celikel *et al.* 2008, Çakmak & Yılmaz 2024, Vidrih *et al.* 2013)
Vitamin A	0.302	mg/100 g FW	(Ben Salem *et al.* 2018)
α-Tocopherol	0.207	mg/100 g FW	(Ben Salem *et al.* 2018)
β-Tocopherol	0.117	mg/100 g FW	(Ben Salem *et al.* 2018)
Potassium (K)	79.72–394.10	mg/100 g FW	(Litrenta *et al.* 2025, Ruiz-Rodríguez *et al.* 2011, Vidrih *et al.* 2013)
Sodium (Na)	4.33–72.08	mg/100 g FW	(Ben Salem *et al.* 2018, Ruiz-Rodríguez *et al.* 2011, Vidrih *et al.* 2013)
Calcium (Ca)	36.05–128.60	mg/100 g FW	(Ben Salem *et al.* 2018, Litrenta *et al.* 2025, Vidrih *et al.* 2013)
Magnesium (Mg)	9.56–302.91	mg/100 g	(Ben Salem *et al.* 2018, Litrenta *et al.* 2025, Ruiz-Rodríguez *et al.* 2011, Vidrih *et al.* 2013)
Phosphorus (P)	19.99–95.20	mg/100 g	(Litrenta *et al.* 2025, Vidrih *et al.* 2013)
Iron (Fe)	0.354–1.856	mg/100 g FW	(Litrenta *et al.* 2025, Ruiz-Rodríguez *et al.* 2011, Vidrih *et al.* 2013)
Zinc (Zn)	0.188–0.762	mg/100 g FW	(Litrenta *et al.* 2025, Ruiz-Rodríguez *et al.* 2011, Vidrih *et al.* 2013)
Copper (Cu)	0.073–0.264	mg/100 g FW	(Litrenta *et al.* 2025, Ruiz-Rodríguez *et al.* 2011)
Manganese (Mn)	0.038–0.2	mg/100 g FW	(Litrenta *et al.* 2025, Ruiz-Rodríguez *et al.* 2011)

Integration of ethnobotanical uses and pharmacological evidence

The ethnomedicinal uses of *A. unedo* reported in the reviewed literature are mainly centered on metabolic, gastrointestinal, cardiovascular, inflammatory, and urological disorders, with leaves being the most frequently used plant part (Table 1). When these traditional uses are examined alongside the biological activities and mechanisms summarized in Table 2, several correspondences can be identified, although the level of pharmacological validation remains variable. The degree of correspondence is not uniform across therapeutic areas, with some traditional applications supported by experimental evidence, while others remain largely based on ethnobotanical reports.

Diabetes is one of the most frequently reported traditional uses of *A. unedo*, involving mainly decoctions of leaves, roots, and bark. An aqueous extract of the root bark has been shown to inhibit intestinal glucose absorption and improve glucose tolerance in rodent models (Mrabti *et al.* 2019), while catechin isolated from the roots displayed α-glucosidase inhibitory activity (Mrabti *et al.* 2018). Additional studies have reported hypoglycemic and antioxidant effects of leaf extracts (Bouyahya *et al.* 2021, Doudach *et al.* 2023, Tenuta *et al.* 2020), and fruit extracts have been associated with effects on gut motility and glucose regulation (Wahabi *et al.* 2025). These findings show a degree of correspondence with the traditional use of the species in the management of diabetes, although the available evidence remains predominantly preclinical. Taken together, these findings provide experimental support for the traditional antidiabetic use of *A. unedo*, but they do not yet establish therapeutic efficacy in humans.

Cardiovascular uses, particularly hypertension, are also frequently reported in ethnobotanical literature. The traditional use of the species against hypertension has been documented in ethnopharmacological surveys (Jouad *et al.* 2001, Ziyyat *et al.* 1997). However, direct experimental evidence supporting antihypertensive activity remains limited. A similar gap is observed for urological and renal applications, including the treatment of kidney disease and renal colic, which are reported in ethnobotanical literature but remain poorly investigated experimentally. The contrast between the frequency of these traditional indications and the limited pharmacological evidence suggests that they represent comparatively under-investigated areas of *A. unedo* research.

Gastrointestinal and anti-diarrheal uses are widely reported for leaves, bark, and fruits. These uses may be related, at least in part, to the tannin content of the species, particularly ellagitannins, which have demonstrated antimicrobial activity against bacterial and fungal strains and are known to scavenge free radicals (Banc *et al.* 2023, Farha *et al.* 2020). Antimicrobial properties have also been reported for essential oils of *A. unedo* (Al-Mijalli *et al.* 2022). These antimicrobial properties, together with the antioxidant activities reported for several phytochemical classes, provide a possible biological basis for some gastrointestinal applications and may also be relevant to the traditional use of the plant in skin diseases and antiseptic preparations (Al-Mijalli *et al.* 2022, Farha *et al.* 2020, Shamsudin *et al.* 2022). Nevertheless, these associations remain mechanistic or preclinical and should not be interpreted as evidence of clinical efficacy.

Anti-inflammatory and rheumatic uses are also documented for leaf, root, and bark preparations. Flavonoids and anthocyanins reported in *A. unedo* include compounds associated with antioxidant and anti-inflammatory activities. Quercetin has been associated with inhibition of pro-inflammatory cytokine production (Deepika & Maurya 2022). Anti-inflammatory activity has also been reported for cyanidin-3-O-glucoside, one of the anthocyanins identified in *A. unedo*, through inhibition of inflammatory mediators such as IL-6 and TNF-α (Hao *et al.* 2021). Ellagic acid and caffeic acid, as isolated compounds, have additionally been reported in relation to anticancer, antioxidant, and anti-inflammatory activities (Espíndola *et al.* 2019, Harper 2023). These findings provide a possible experimental basis for some of the traditional uses, although most studies remain in vitro or preclinical. The biological activities reported for isolated compounds should therefore not be directly extrapolated to *A. unedo* extracts, and specific studies on *A. unedo* are needed to confirm these effects.

Overall, the comparison between ethnobotanical uses and pharmacological evidence shows that the relationship between traditional knowledge and experimental findings is strongest for some metabolic and gastrointestinal applications, while inflammatory uses are also supported by relevant biological activities. In contrast, cardiovascular and urological applications remain comparatively poorly investigated. The available evidence is predominantly derived from in vitro assays and animal models, and the correspondence between traditional use and pharmacological mechanisms therefore remains partial. These findings highlight the value of integrating ethnobotanical knowledge with phytochemical and pharmacological data, while also emphasizing the need for further in vivo and clinical studies to determine whether the reported biological activities translate into therapeutic effects in humans.

Toxicity

Toxicological studies on *Arbutus unedo* generally indicate a favorable safety profile, particularly for extracts prepared from its fruits and leaves. Acute and subacute toxicity evaluations in experimental animal models have shown no significant adverse effects or mortality at commonly tested doses, suggesting a relatively high margin of safety. In vitro cytotoxicity assays have also demonstrated low toxicity toward normal cell lines at concentrations exhibiting biological activity. Nevertheless, the toxicological properties of *A. unedo* may vary depending on the plant organ, extraction solvent, phytochemical composition, and administered dose (Benković *et al.* 2024, Bouyahya *et al.* 2021, Jurica *et al.* 2020, Mrabti *et al.* 2018). Although fruits have long been consumed as food in Mediterranean regions, excessive intake of overripe or naturally fermented fruits may lead to mild gastrointestinal discomfort or transient symptoms associated with their alcohol content (Bebek Markovinović *et al.* 2024). Despite the encouraging findings reported to date, comprehensive chronic toxicity, reproductive toxicity, genotoxicity, and clinical safety studies remain limited. Therefore, additional standardized toxicological investigations are warranted to establish the long-term safety profile of *A. unedo* preparations intended for medicinal or nutraceutical applications.

Bibliometric analysis

Description of data

The bibliometric dataset comprised 726 documents published in 343 sources between 1979 and 2025. These publications involved 2,857 authors, of whom only 12 contributed to single-authored documents, with an average of 7.07 co-authors per document. The dataset contains 2,351 author keywords and 5,650 Keywords Plus (i.e., algorithmically generated keywords based on cited references), reflecting the thematic diversity of research on *Arbutus unedo*. International co-authorship accounted for 18.46% of the publications. The average document age was 14 years, the annual growth rate was 7.67%, and the average number of citations per document was 36.41. The dataset comprised 672 articles, 39 reviews, 8 conference papers, 5 book chapters, and 2 comparative studies (Table 4).

Table 4. Main bibliometric characteristics of the *Arbutus unedo* L. publication dataset for the period 1979–2025.

Description	Results
Timespan	1979-2025
Sources (Journals, Books, etc)	343
Documents	726
Annual Growth Rate %	7.67
Document Average Age	14
Average citations per doc	36.41
Keywords Plus (ID)	5650
Authors Keywords (DE)	2351
Authors	2857
Single-authored docs	12
Co-Authors per Doc	7.07
Article	672
Book chapter	5
Comparative study	2
Conference paper	8
Review	39

Annual Scientific Publications

A clear upward trend in scientific production was observed from 1979 to 2025. The evolution of research output during this period can be broadly categorized into three phases: an initial exploratory phase, an intermediate period of progressive development, and a phase of rapid expansion. The first phase, from 1979 to the early 1990s, was characterized by few publications, sporadic contributions, and limited research activity. This initial phase reflects the relatively limited volume of scientific activity on the species during this period. During the second phase, from 1990 to 2009, the number of publications increased gradually, although some fluctuations were observed. This continuous expansion has been associated with advances in taxonomy, improved international collaboration, and growing interest in plant diversity, ethnopharmacology, and phytochemistry. Nonetheless, the limited availability of molecular methods on a wide scale and the lack of digital databases during this period may have slowed scientific progress. From 2010 to 2025, a visible expansion in scientific production occurred, with a considerable increase in the yearly number of publications and a peak after 2019. This faster growth is probably related to improvements in analytical technologies, increased interest in medicinal plants worldwide, a growing focus on natural product research, and easier access to digital journals and scientific databases. Furthermore, research activity may have been further encouraged by growing concerns about biodiversity conservation and the

sustainable use of plant resources. Despite some year-to-year variation, the overall linear trend observed over the study period (Fig. 2) confirms a steady increase in scientific output. The publication trend reflects a progressive diversification of research on *A. unedo*, from early descriptive and taxonomic studies to a more diversified and internationally integrated research field. The sustained growth observed after 2010 indicates increasing scientific attention to *A. unedo*, particularly in ethnopharmacological, phytochemical, ecological, and physiological research.

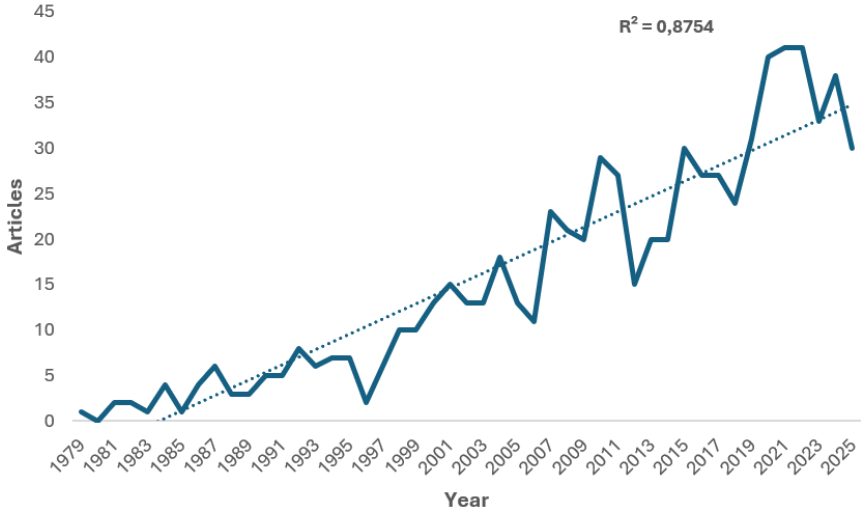


Figure 2. Annual Publication Trend on *Arbutus unedo* Research (1979–2025)

Geographic and Institutional Analysis

Scientific production by country

The analysis of scientific production reveals a strong geographical concentration of research activity in Mediterranean and European countries. Italy recorded the highest number of publications, with 295, followed by Spain with 281 and Portugal with 194. Morocco contributed 87 publications, followed by Croatia (79), Greece (69), France (67), Turkey (64), and Germany (61). Outside this main concentration, Algeria accounted for 42 publications, while the United States and the United Kingdom contributed 32 and 29, respectively. Many other countries across Europe, Asia, Africa, and the Americas contributed at lower frequencies. Overall, the distribution of publications demonstrates a strong Mediterranean concentration of scientific production, while the participation of countries outside this region indicates a broader geographical distribution of research activity on *A. unedo*.

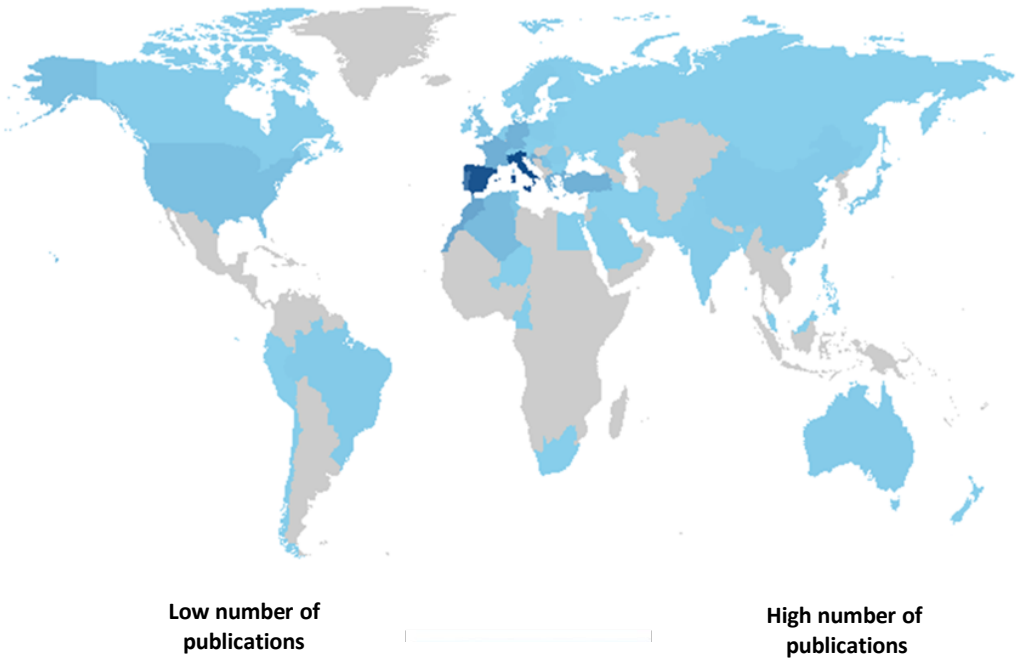


Figure 3. Geographic distribution of scientific publications on *Arbutus unedo* L. by country.

Temporal Trends in Scientific Production by Country

The data show a clear evolution in the scientific production of the five leading countries Italy, Portugal, Spain, Morocco, and Croatia from 1979 to 2025 (Fig. 4). Italy began publishing on *Arbutus unedo* in the early 1980s and exhibited gradual growth during the first two decades, followed by a marked acceleration in scientific output after 2000. By 2025, Italy had accumulated 295 publications, representing the highest cumulative production among the five countries. Spain followed a similar but later trajectory, with no publications recorded until the early 1990s and a pronounced increase in output after 2000. Its cumulative production reached 281 publications by 2025, approaching that of Italy. Portugal showed an earlier but more moderate and steady development, with a gradual increase in cumulative publications over the study period, reaching 194 publications by 2025. Morocco had a later start, with no recorded publications until the late 1990s, followed by a marked increase after 2010 and a cumulative total of 87 publications by 2025. Croatia displayed a similarly delayed but comparatively rapid increase, with no publications recorded before 2006 and a notable rise after 2015, reaching 79 cumulative publications by 2025. Overall, the temporal distribution indicates a gradual expansion of research activity, with Italy and Spain showing the strongest cumulative growth, while Portugal, Morocco, and Croatia followed more delayed or moderate trajectories. This pattern reflects the progressive development and internationalization of research on *A. unedo*, particularly from the beginning of the 21st century onward.

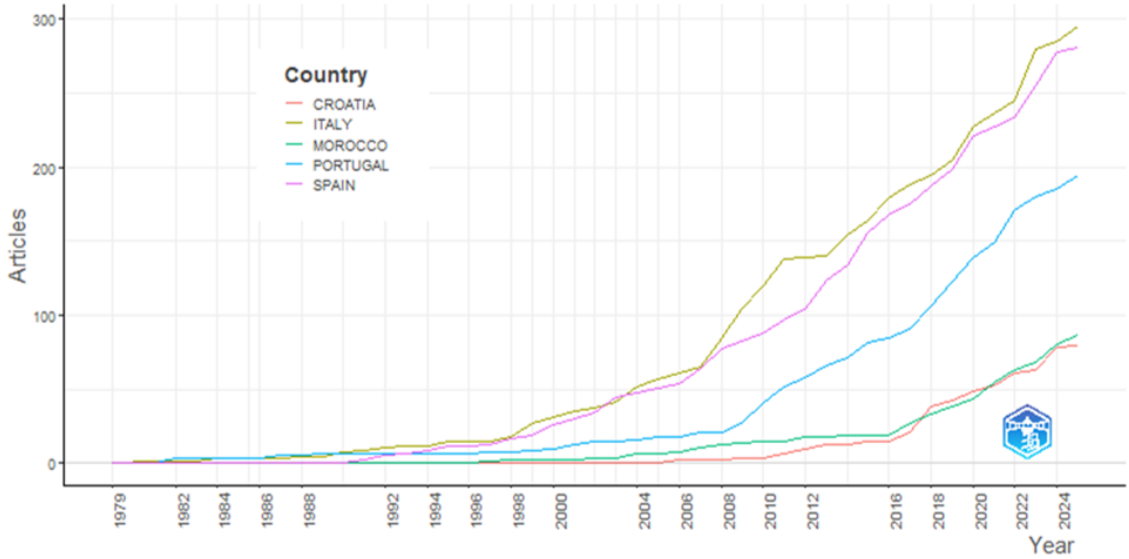


Figure 4. Cumulative scientific production on *Arbutus unedo* L. for the five countries with the highest publication output during 1979–2025.

Affiliations and most productive sources

The most active affiliates

The distribution of leading affiliations reveals a structured and regionalized research landscape. The high number of publications by the Consejo Superior de Investigaciones Científicas (CSIC) shows that research on *A. unedo* has remained very active. The high level of production from CSIC highlights the prominent contribution of Spanish research institutions to the field. Similarly, the notable contributions of Université Mohammed V and Université Sidi Mohamed Ben Abdellah suggest that Moroccan research institutions play an important role, possibly reflecting the species ecological presence and local importance in the ecosystems of North Africa. Furthermore, the significant presence of the Autonomous University of Barcelona and the Centro de Investigación Ecológica y Aplicaciones Forestales demonstrates the prominence of Spain in this area of research, especially concerning studies of an ecological and environmental nature. The University of Zagreb and the Aristotle University of Thessaloniki extend this pattern toward Eastern and southeastern Europe, where the climate bears resemblance to the Mediterranean or sub-Mediterranean climate category. The contribution of CNRS also highlights the participation of major research institutions in the study of *A. unedo*. This distribution reveals a Mediterranean centered research network, where the most influential institutions are geographically aligned with the natural distribution of *A. unedo*. This spatial coherence supports the interpretation that scientific output is closely linked to regional biodiversity availability and research accessibility to the species.

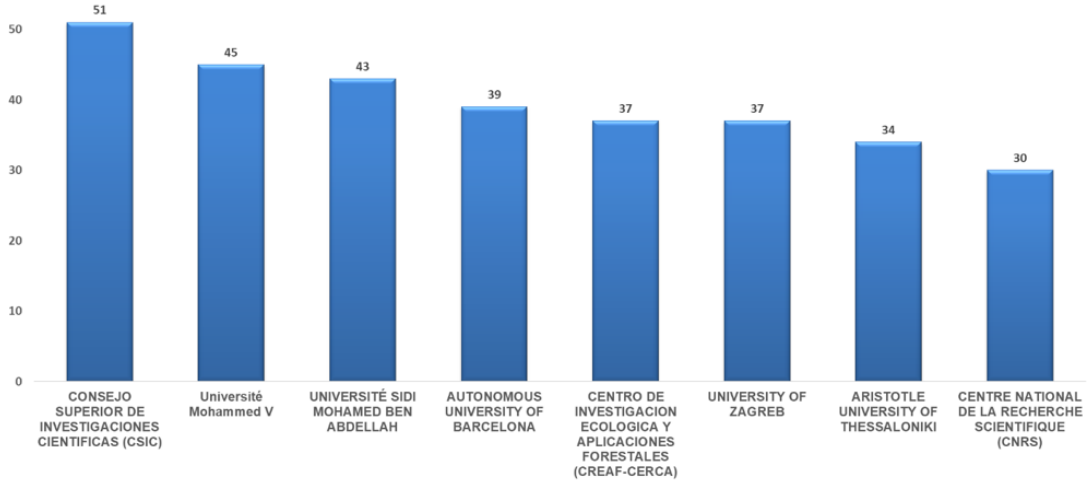


Figure 5. Most productive affiliations contributing to research on *Arbutus unedo* L.

The most productive sources

Food Chemistry is the most prolific journal (19 papers), indicating the high degree of interest in the phytochemical composition, antioxidant potential and nutritional value of *A. unedo.* A similarly important contribution is observed in Foods (15 papers), indicating increasing interest in the species as a potential source of functional foods and nutraceuticals.

Research on *A. unedo* is not, however, limited to food-related applications. Over the years, Forest Ecology and Management has published 15 articles, Environmental and Experimental Botany has published 12 articles, while Oecologia has also published 12 articles. The research carried out by these journals mostly focuses on how plants adapt and respond to environmental stress, and how ecosystem function.

The presence of 14 articles in the Journal of Ethnopharmacology further highlights the ongoing scientific interest in the traditional drug uses of the species and evaluation of its biological activities. This trend is reinforced by publications in Molecules (10 articles), where studies mainly focus on the identification and characterization of bioactive constituents, thereby expanding current knowledge of the phytochemical profile of *A. unedo*.

In addition, journals such as New Phytologist (10 articles), Photosynthetica (11 articles), and Plants (10 articles) demonstrate sustained interest in the physiological and molecular aspects of the species, including photosynthesis, plant metabolism, and other fundamental biological processes.

Overall, the distribution of publications across these journals reflects the multidisciplinary nature of *A. unedo* research. The species has attracted considerable attention from researchers working in food science, phytochemistry, ethnopharmacology, plant physiology, and ecology, underscoring its broad scientific relevance.

Most frequently cited countries

The citation analysis shows differences in both cumulative citation counts and average citations per article among countries contributing to A. unedo research. Spain recorded the highest total number of citations, with 7,364 citations and an average of 58.9 citations per article. Italy and Portugal recorded 4,061 and 2,729 total citations, with average values of 34.7 and 34.5 citations per article, respectively, while Morocco recorded 1,914 citations with an average of 32.4 citations per article. Greece recorded 1,090 citations. France and the United States recorded 817 and 717 citations, respectively, with average citations per article of 54.51 and 55.2. These values indicate that, although their total number of publications is lower, their contributions have had a relatively high citation impact. Switzerland recorded 582 citations but had the highest average citation value, at 194 citations per article. This suggests that a small number of highly cited publications from Switzerland have had a disproportionate impact on the field. These results indicate that cumulative citation counts are influenced by the volume of scientific production, whereas average citations per article provide a different perspective on citation distribution among countries.

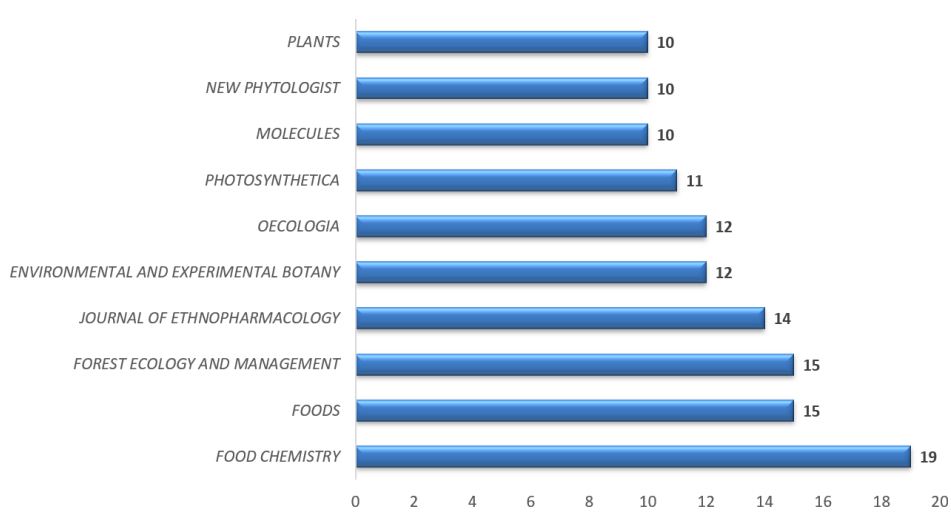


Figure 6. Most productive Sources publishing research on *Arbutus unedo* L., expressed as the number of publications.

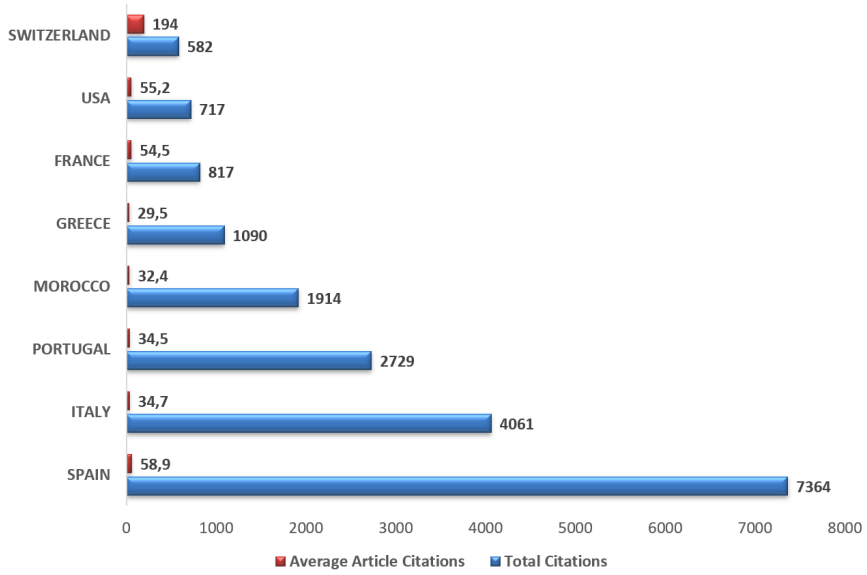


Figure 7. Total number of citations and average citations per article by country for publications on *Arbutus unedo* L.

The most cited articles

The publication by (Ziyyat *et al.* 1997) in Journal of Ethnopharmacology records the highest total citation count (356), indicating the greatest cumulative citation impact within the dataset. (Larcher 2000) and (Cherubini *et al.* 2003) received a comparable number of total citations, with 350 and 349 citations, respectively, reflecting their long-term influence within the field. Another pattern is observed for more recent articles. (Jamila & Mostafa 2014) and (Barbeta *et al.* 2015) had significantly higher annual citation rates, 25.15 and 24.25, respectively, but a lower overall citation of 327 and 291, respectively. This trend suggests that these results have gained academic interest faster than past reports. A similar observation can be made for (Ganhão *et al.* 2010) whose article combines a substantial total citation count (308) with a relatively high average of 18.12 citations per year. By comparison, (Martínez-Vilalta *et al.* 2002) has accumulated 313 citations overall but shows a lower annual average (12.52), reflecting its publication at an intermediate point within the study period.

Taken together, these findings illustrate two complementary dimensions of citation performance. Older publications generally achieve higher cumulative citation counts because they have remained available for a longer period, whereas more recent studies often exhibit stronger annual citation rates, indicating a faster pace of citation accumulation. This distinction emphasizes the importance of considering both total citations and citations per year when evaluating the scientific influence of highly cited publications.

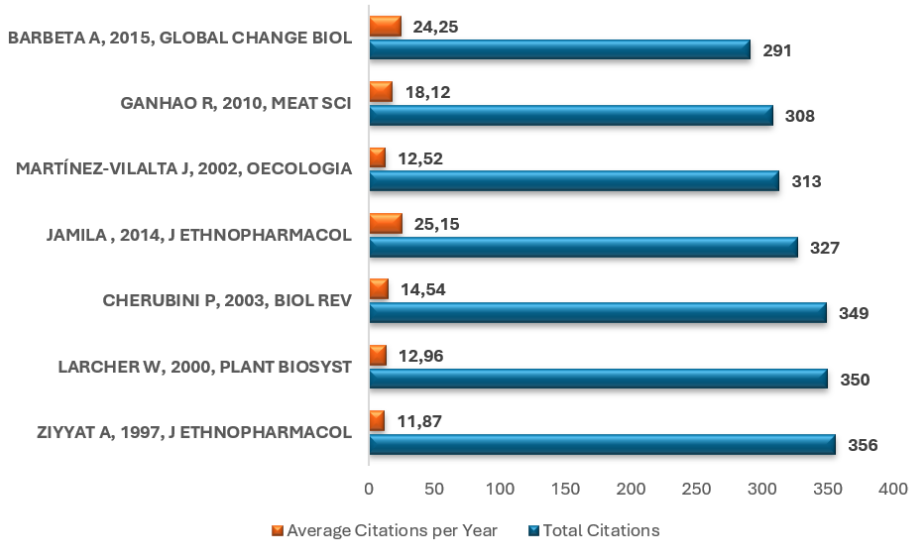


Figure 8. Total Citations and Average Citations per Year of the Most Highly Cited *Arbutus unedo* L. Publications

Thematic analysis

Co-occurrence word network and keyword frequency

The co-occurrence network illustrates the main thematic structure of scientific production on *Arbutus unedo* (fig. 10), which is divided into five clusters.

The major cluster concentrates on the phytochemical and pharmacological studies which contain the terms related to bioactive compounds and antioxidant activity. The topics covered in the other clusters are about ecology and forestry, plant development, ecophysiology response to stress and physiological measurements. This distribution shows a clear discipline-based division, with interconnection between research areas. Additionally, the keyword frequency analysis (fig. 9), indicates that aside from the anticipated prevalence of *Arbutus unedo*, the most frequently appearing terms (antioxidant activity, plant extract, unclassified drug, plant leaf) affirm the substantial focus on bioactivity and phytochemical investigations. Terms used to index papers, such as article, nonhuman, and human, refer more to the type of studies than any specific themes.

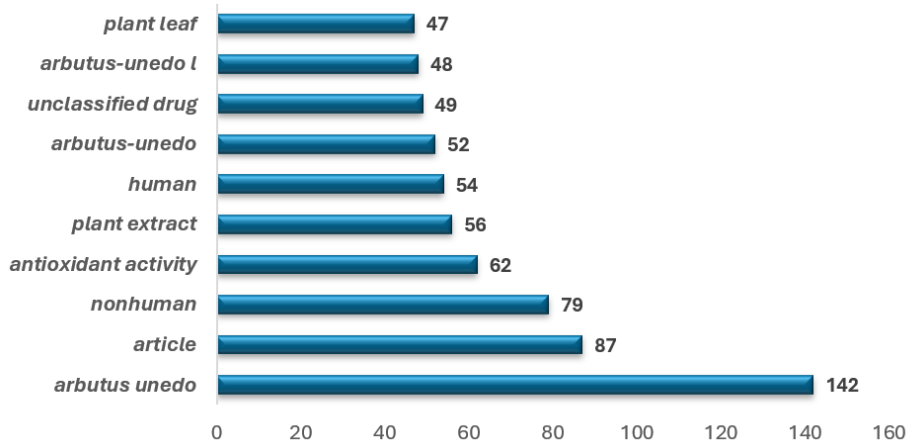


Figure 9. Frequency of the most frequently occurring keywords in publications on *Arbutus unedo* L.

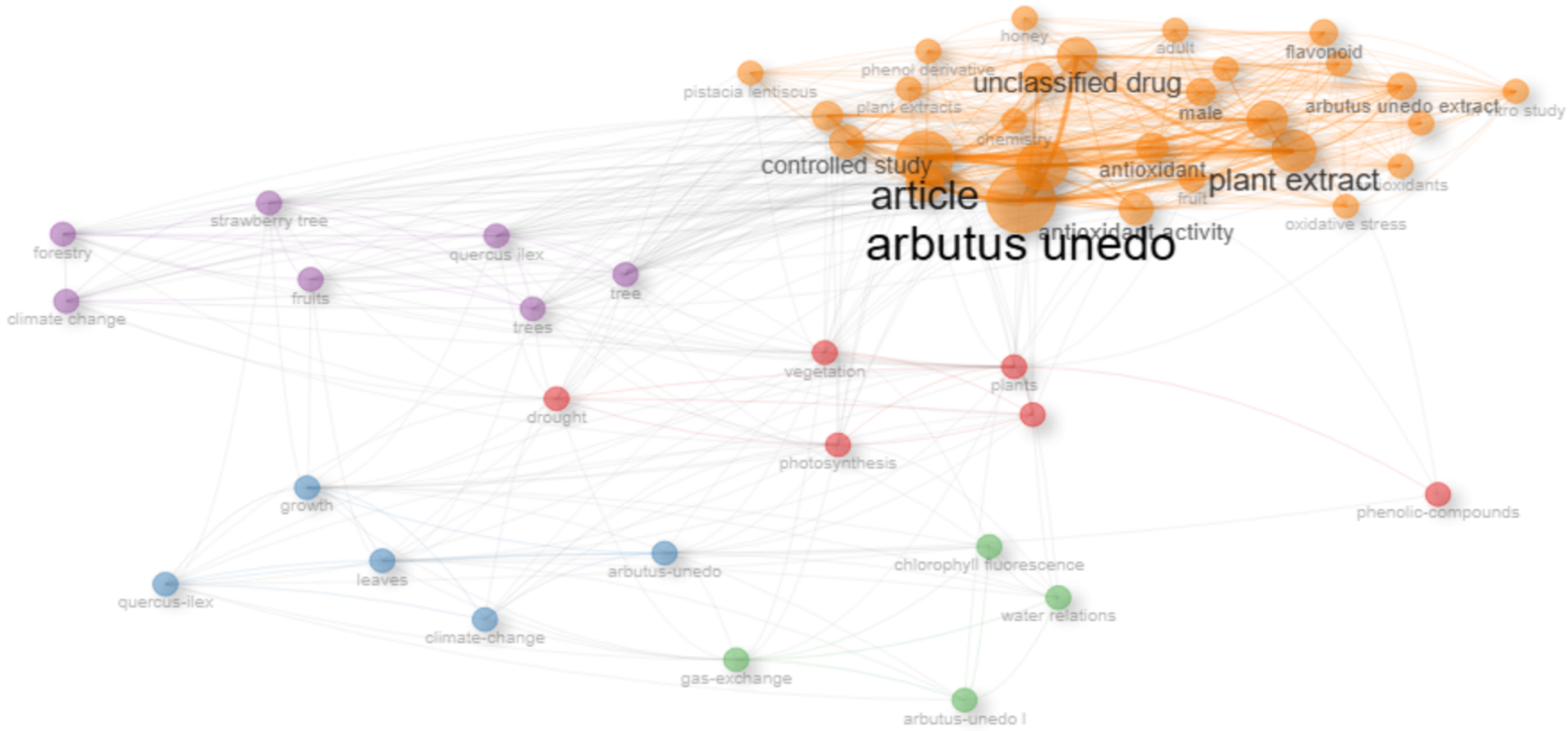


Figure 10. Co-occurrence network of keywords in *Arbutus unedo* L. publications, showing the main thematic clusters within the research field.

Factorial analysis

The Multiple Correspondence Analysis (MCA) structure revealed a highly structured organization of the *Arbutus unedo* knowledge domain, with the first two factorial dimensions accounting for 90.62% of the total inertia (Dim1 = 83.68%, Dim2 = 6.94%). The predominance of Dimension 1 indicates that the horizontal distribution represents the principal conceptual cleavage within the literature.

The negative side of Dimension 1 is characterized by the concentration of phytochemical and pharmacological descriptors, including arbutus.*unedo*.extract, phenol.derivative, in.vitro.study, plant.extract, unclassified.drug, flavonoid, and controlled.study. This factorial positioning is consistent with the high recurrence and network relevance of associated biomedical terms such as antioxidant activity, plant extract, antioxidant, and plant leaf, confirming the strong representation of extract-based bioactivity screening, antioxidant assessment, and medicinal compound characterization.

In contrast, the positive side of Dimension 1 groups descriptors related to ecophysiological functioning and environmental adaptation, notably gas.exchange, water.relations, chlorophyll.fluorescence, climate.change, growth, leaves, photosynthesis, and plants. These terms coincide with highly central ecological keywords such as plants, photosynthesis, temperature, and tree, indicating that physiological adaptation to drought, carbon assimilation, and Mediterranean forest performance constitutes the second major thematic pole.

The second factorial dimension explains a smaller proportion of the total inertia (6.94%) but provides additional insight into the internal organization of the dataset. The positive side of this axis is mainly associated with ethnomedicinal descriptors, including adult, female, male, and medicinal.plant. In contrast, the negative side is characterized by phytochemical and bioactivity-related terms such as phenol.derivative, antioxidants, antioxidant, and flavonoid.

Rather than representing unrelated themes, this contrast reflects two complementary approaches within medicinal research. One is centered on ethnomedicinal knowledge and human-related descriptors, whereas the other emphasizes the chemical characterization of bioactive compounds and their antioxidant potential through experimental analyses.

Overall, this analysis demonstrates that the *A. unedo* literature is primarily organized around a dominant opposition between phytochemical–pharmacological valorization and ecological–physiological performance, with a secondary subdivision reflecting ethnomedicinal contrasting with analytical experimental orientations.

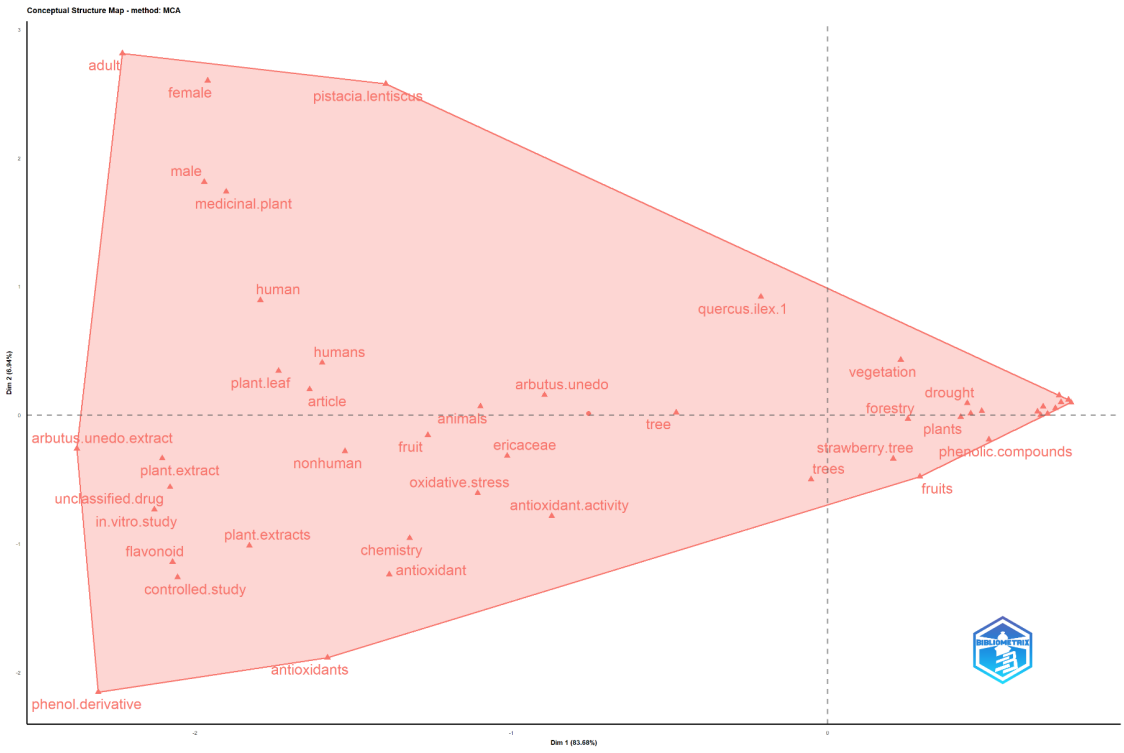


Figure 11. Multiple Correspondence Analysis (MCA) of the Conceptual Structure of *Arbutus unedo* L. Research

Thematic map

The map indicates that two main themes maintain the scientific development of *Arbutus unedo* research. The first is oriented towards pharmacological and experimental studies, with recurrent descriptors, such as antioxidant activity, plant extract, and nonhuman, indicating that characterization of extracts and evaluation of biological activities constitute important areas of investigation.

The second thematic relates to ethnomedicinal and traditional-use studies, as seen by the close prominence of male, female, medicinal plant, and human, showing ongoing scholarly interest in the documenting of folk therapeutic applications and human-related medicinal value. Keywords pertaining to plants, photosynthesis, temperature and vegetation reveal an ecological interest alongside these predominant medicinal themes, indicating that physiological adaptation and integration within Mediterranean forest ecosystems constitute a crucial supporting element of literature. Themes impacted by growth, leaves, fruits, and phenolic chemicals, on the other hand, appear less structured, occupying comparatively smaller position within the overall thematic structure. Gas exchange, water relations, and chlorophyll fluorescence further reflect a more specialized physiological line, showcasing a concentrated but rather isolated body of work devoted to the plant functional responses to environmental stress. Overall, the thematic map indicates that medicinal research and ecological adaptation constitute major areas of investigation, whereas developmental and fruit-quality themes occupy a comparatively smaller position within the overall research landscape.

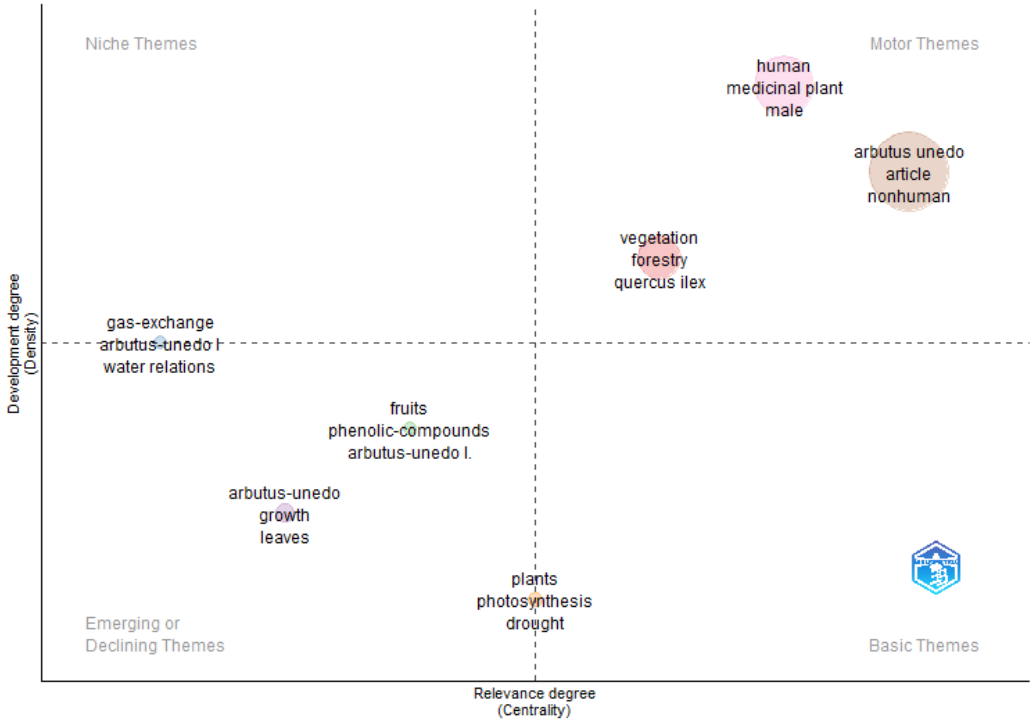


Figure 12. Thematic map of research on *Arbutus unedo* L., showing the principal thematic areas identified from keyword relationships.

Synthesis of bibliometric findings

Taken together, the bibliometric analyses indicate a sustained expansion and diversification of research on *A. unedo* between 1979 and 2025. The temporal analysis shows that scientific production increased progressively, particularly after 2010, while the country and affiliation analyses demonstrate a strong concentration of research activity in Mediterranean and European countries. The citation analysis further indicates that scientific visibility is influenced by both the volume of research output and the time available for publications to accumulate citations. At the thematic level, keyword co-occurrence, MCA, and thematic mapping consistently identify phytochemical and pharmacological research as major components of the field, alongside a distinct ecological and physiological research domain and a smaller but identifiable ethnomedicinal component. The coexistence of these thematic orientations reflects the multidisciplinary nature of current *A. unedo* research. At the same time, the comparatively limited representation of clinical research, industrial applications, and some aspects of cultivation and fruit-quality research points to areas that could benefit from further investigation. These findings support

the need for research strategies that connect traditional knowledge, phytochemical characterization, biological validation, and practical applications while maintaining attention to the ecological context and sustainable use of the species.

Conclusion and perspective

Arbutus unedo contains a diverse range of bioactive compounds, particularly phenolics, flavonoids, and tannins, which have been associated with antioxidant, antimicrobial, anti-inflammatory, and antidiabetic activities. Several of these biological activities show a degree of correspondence with traditional uses of the species, although the available evidence remains predominantly in vitro or preclinical and varies among therapeutic areas. A. unedo therefore represents a promising source of compounds with potential pharmaceutical, nutraceutical, and cosmetic applications. However, further standardized in vivo studies and well-designed clinical investigations are required to clarify their therapeutic relevance, safety, and bioavailability.

Complementing these pharmacological insights, the bibliometric analysis conducted in this study shows a progressive increase in scientific publications on *A. unedo*, reflecting growing global interest in this species. The analysis also highlights the predominance of research outputs originating from Mediterranean and European countries, where the plant is naturally distributed, along with increasing international collaboration networks. Moreover, leading journals in the fields of ethnopharmacology, phytochemistry, and natural products have played a key role in disseminating research findings related to this species.

The keyword analysis indicates a dominant occurrence of terms such as “antioxidant activity,” “phenolic compounds,” and “ethnopharmacology,” reflecting a strong research focus on the phytochemical characterization and biological evaluation of *A. unedo*. This pattern demonstrates a clear trend toward the scientific validation of traditional knowledge through modern experimental approaches. Nevertheless, the relative underrepresentation of keywords related to clinical studies, industrial applications, and agronomic practices highlights existing gaps in the current research landscape.

Despite these advances, the present study also has certain limitations. First, the bibliometric analysis is dependent on the selected databases and may not capture all relevant publications. Second, the inclusion criteria, particularly the restriction to English-language articles, may limit the comprehensiveness of the dataset. Third, citation-based indicators used in bibliometric analysis may not fully reflect the scientific impact of individual studies, as they can be influenced by factors such as journal visibility and accessibility.

Future research should prioritize the standardization of experimental methodologies and the establishment of stronger links between phytochemical composition and biological activity. Greater emphasis should be placed on in vivo studies and clinical validation to facilitate the translation of laboratory findings into practical applications. In addition, interdisciplinary approaches integrating phytochemistry, pharmacology, agronomy, and biotechnology could enhance the sustainable exploitation of *A. unedo*. Strategies such as metabolic profiling, biotechnological production, and improved cultivation practices may further support the development of high-value products. Finally, strengthening collaboration between researchers, industry stakeholders, and policymakers will be crucial to promote the effective valorization of this Mediterranean species.

Declarations

List of abbreviations: DW – Dry weight; FW – Fresh weight; IUCN – International Union for Conservation of Nature; MCA – Multiple Correspondence Analysis; N.D. – Not reported; DNA – Deoxyribonucleic acid; RNA – Ribonucleic acid; IL-6 – Interleukin-6; TNF-α – Tumor necrosis factor-alpha

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Literature Cited

Ait Lhaj Z, Bchitou R, Gaboun F, Abdelwahd R, Benabdelouahab T, Kabbour MR, Pare P, Diria G, Bakhy K. 2021. Moroccan strawberry tree (*Arbutus unedo* L.) fruits: nutritional value and mineral composition. Foods 10(10):2263. doi: 10.3390/foods10102263

Aït Youssef M. 2006. Plantes médicinales de Kabylie. Ibis Press, Paris, France.

Al-Mijalli SH, Mrabti HN, Ouassou H, Flouchi R, Abdallah EM, Sheikh RA, Alshahrani MM, Al Awadh AAA, Harhar H, El Omari N, Qasem A, Assaggaf H, Moursi NH, Bouyahya A, Gallo M, Faouzi MEA. 2022. Chemical composition, antioxidant, anti-diabetic, anti-acetylcholinesterase, anti-inflammatory, and antimicrobial properties of *Arbutus unedo* L. and *Laurus nobilis* L. essential oils. Life 12(11):1876. doi: 10.3390/life12111876

Aria M, Cuccurullo C. 2017. Bibliometrix: an R-tool for comprehensive science mapping analysis. Journal of Informetrics 11(4):959-975. doi: 10.1016/j.joi.2017.08.007

Asmaa N, Abdelaziz G, Boulanouar B, Carbonell-Barrachina AA, Cano-Lamadrid M, Noguera-Artiaga L. 2019. Chemical composition, antioxidant activity and mineral content of *Arbutus unedo* (leaves and fruits). Journal of Microbiology, Biotechnology and Food Sciences 8(6):1335-1339. doi: 10.15414/jmbfs.2019.8.6.1335-1339

Banc R, Rusu ME, Filip L, Popa DS. 2023. The impact of ellagitannins and their metabolites through gut microbiome on the gut health and brain wellness within the gut-brain axis. Foods 12(2):270. doi: 10.3390/foods12020270

Barbeta A, Mejía-Chang M, Ogaya R, Voltas J, Dawson TE, Peñuelas J. 2015. The combined effects of a long-term experimental drought and an extreme drought on the use of plant-water sources in a Mediterranean forest. Global Change Biology 21(3):1213-1225. doi: 10.1111/gcb.12785

Bebek Markovinović A, Brčić Karačonji I, Jurica K, Lasić D, Skendrović Babojelić M, Duralija B, Šic Žlabur J, Putnik P, Bursać Kovačević D. 2022. Strawberry tree fruits and leaves (*Arbutus unedo* L.) as raw material for sustainable functional food processing: a review. Horticulturae 8(10):881. doi: 10.3390/horticulturae8100881

Bebek Markovinović A, Brdar D, Putnik P, Bosiljkov T, Durgo K, Huđek Turković A, Brčić Karačonji I, Jurica K, Pavlić B, Granato D, Bursać Kovačević D. 2024. Strawberry tree fruits (*Arbutus unedo* L.): bioactive composition, cellular antioxidant activity, and 3D printing of functional foods. Food Chemistry 433:137287. doi: 10.1016/j.foodchem.2023.137287

Belfekih F, Moussaif A, Bnouham M, Elrherabi A, Abdnim R, El Hassouni M, Guerrab W, El Moutaouakil Ala Allah A, Benbacer L, Iddar A, Bengueddour R, El Mzibri M. 2025. Chemical profiling and pharmacological properties of *Arbutus unedo* L. collected from Morocco. Tropical Journal of Natural Product Research 9(9):4629-4640. doi: 10.26538/tjnpr/v9i9.66

Bencheikh N, Elbouzidi A, Kharchoufa L, Ouassou H, Alami Merrouni I, Mechchate H, Es-Safi I, Hano C, Addi M, Bouhrim M, Eto B, Elachouri M. 2021. Inventory of medicinal plants used traditionally to manage kidney diseases in North-Eastern Morocco: ethnobotanical fieldwork and pharmacological evidence. Plants 10(9):1966. doi: 10.3390/plants10091966

Ben Salem I, Ouesleti S, Mabrouk Y, Landolsi A, Saidi M, Boulilla A. 2018. Exploring the nutraceutical potential and biological activities of *Arbutus unedo* L. (Ericaceae) fruits. Industrial Crops and Products 122:726-731. doi: 10.1016/j.indcrop.2018.06.024

Benković V, Tkalčec I, Knežević A, Jurica K, Knežević F, Brčić Karačonji I, Kopjar N. 2024. Effects of strawberry tree (*Arbutus unedo* L.) aqueous leaf extract and arbutin on PK-15 and HepG2 cells. Toxics 12(9):628. doi: 10.3390/toxics12090628

Bnouham M, Legssyer A, Mekhfi H, Ziyyat A. 2002. Medicinal plants used in the treatment of diabetes in Morocco. International Journal of Diabetes and Metabolism 10(1):33-50. doi: 10.1159/000497550

Bouyahya A, El Omari N, Elmenyiy N, Guaouguaou FE, Balahbib A, Belmehdi O, Salhi N, Imtara H, Mrabti HN, El-Shazly M, Bakri Y. 2021. Moroccan antidiabetic medicinal plants: ethnobotanical studies, phytochemical bioactive compounds, preclinical investigations, toxicological validations and clinical evidences; challenges, guidance and perspectives for future management of diabetes worldwide. Trends in Food Science & Technology 115:147-254. doi: 10.1016/j.tifs.2021.03.032

Brčić Karačonji I, Jurica K, Gašić U, Dramićanin A, Tešić Ž, Milojković Opsenica D. 2021. Comparative study on the phenolic fingerprint and antioxidant activity of strawberry tree (*Arbutus unedo* L.) leaves and fruits. Plants 11(1):25. doi: 10.3390/plants11010025

Çakmak S, Yılmaz M. 2024. Fruit quality and biochemical characteristics of different strawberry tree (*Arbutus unedo* L.) genotypes grown in Giresun. Black Sea Journal of Agriculture 7(3):240-248. doi: 10.47115/bsagriculture.1434268

Celikel G, Demirsoy L, Demirsoy H. 2008. The strawberry tree (*Arbutus unedo* L.) selection in Turkey. Scientia Horticulturae 118(2):115-119. doi: 10.1016/j.scienta.2008.05.028

Cherubini P, Gartner BL, Tognetti R, Braker OU, Schoch W, Innes JL. 2003. Identification, measurement and interpretation of tree rings in woody species from Mediterranean climates. Biological Reviews 78(1):119-148. doi: 10.1017/S1464793102006000

De Santis S, Spada F, Magri D. 2023. Geographic range vs. occurrence records in plant distribution mapping: the case of *Arbutus* in the Old World. Forests 14(5):1010. doi: 10.3390/f14051010

Deepika, Maurya PK. 2022. Health benefits of quercetin in age-related diseases. Molecules 27(8):2498. doi: 10.3390/molecules27082498

Doudach L, Mrabti HN, Al-Mijalli SH, Kachmar MR, Benrahou K, Assaggaf H, Qasem A, Abdallah EM, Rajab BS, Harraqui K, Mekkaoui M, Bouyahya A, Faouzi MEA. 2023. Phytochemical, antidiabetic, antioxidant, antibacterial, acute and sub-chronic toxicity of Moroccan *Arbutus unedo* leaves. Journal of Pharmacopuncture 26(1):27-37. doi: 10.3831/KPI.2023.26.1.27

El Cadi H, El Cadi A, Kounnoun A, Oulad El Majdoub Y, Palma Lovillo M, Brigui J, Dugo P, Mondello L, Cacciola F. 2020. Wild strawberry (*Arbutus unedo*): phytochemical screening and antioxidant properties of fruits collected in northern Morocco. Arabian Journal of Chemistry 13(8):6299-6311. doi: 10.1016/j.arabjc.2020.05.022

Elachouri M, Idrissi A. 2023. *Arbutus unedo* L., *Arbutus andrachne* L. Ericaceae. In: Bussmann RW, Elachouri M, Kikvidze Z. (eds). Ethnobotany of Northern Africa and Levant. Springer, Cham, Switzerland, Pp. 1-10. doi: 10.1007/978-3-031-13933-8_36-1

El Haouari M, Assem N, Changan S, Kumar M, Daştan SD, Rajkovic J, Taheri Y, Sharifi-Rad J. 2021. An insight into phytochemical, pharmacological, and nutritional properties of *Arbutus unedo* L. from Morocco. Evidence-Based Complementary and Alternative Medicine 2021:1794621. doi: 10.1155/2021/1794621

El Mekkaoui A, Khamar M, Benlakhdar S, Ngadi M, Slimani C, Louafi B, Nounah A, Cherkaoui E, Balafrej T, Rais C. 2024. Traditional knowledge and biodiversity of medicinal plants in the Taounate region for treating human diseases: an ethnobotanical perspective. Ethnobotany Research and Applications 29:1-22. doi: 10.32859/era.29.30.1-22

Espíndola KMM, Ferreira RG, Narvaez LEM, Silva Rosario ACR, da Silva AHM, Silva AGB, Vieira APO, Monteiro MC. 2019. Chemical and pharmacological aspects of caffeic acid and its activity in hepatocarcinoma. Frontiers in Oncology 9:541. doi: 10.3389/fonc.2019.00541

Faida R, Aabdousse J, Boulli A, Bouda S, Wahid N. 2019. Ethnobotanical uses and distribution status of *Arbutus unedo* in Morocco. Ethnobotany Research and Applications 18:1-12. doi: 10.32859/era.18.30.1-12

Farha AK, Yang QQ, Kim G, Li HB, Zhu F, Liu HY, Gan RY, Corke H. 2020. Tannins as an alternative to antibiotics. Food Bioscience 38:100751. doi: 10.1016/j.fbio.2020.100751

Fortalezas S, Tavares L, Pimpão R, Tyagi M, Pontes V, Alves PM, McDougall G, Stewart D, Ferreira RB, Santos CN. 2010. Antioxidant properties and neuroprotective capacity of strawberry tree fruit (*Arbutus unedo*). Nutrients 2(2):214-229. doi: 10.3390/nu2020214

Ganhão R, Morcuende D, Estévez M. 2010. Protein oxidation in emulsified cooked burger patties with added fruit extracts: influence on colour and texture deterioration during chill storage. Meat Science 85(3):402-409. doi: 10.1016/j.meatsci.2010.02.008

Gil KA, Nowicka P, Wojdyło A, Serreli G, Deiana M, Tuberoso CIG. 2023. Antioxidant activity and inhibition of digestive enzymes of new strawberry tree fruit/apple smoothies. Antioxidants 12(4):805. doi: 10.3390/antiox12040805

González JA, García-Barriuso M, Amich F. 2010. Ethnobotanical study of medicinal plants traditionally used in the Arribes del Duero, western Spain. Journal of Ethnopharmacology 131(2):343-355. doi: 10.1016/j.jep.2010.07.022

Guendouze-Bouchefa N, Madani K, Chibane M, Boulekbache-Makhlouf L, Hauchard D, Kiendrebeogo M, Stévigny C, Okusa PN, Duez P. 2015. Phenolic compounds, antioxidant and antibacterial activities of three Ericaceae from Algeria. Industrial Crops and Products 70:459-466. doi: 10.1016/j.indcrop.2015.03.053

Guimarães R, Barros L, Dueñas M, Carvalho AM, Queiroz MJRP, Santos-Buelga C, Ferreira ICFR. 2013. Characterisation of phenolic compounds in wild fruits from Northeastern Portugal. Food Chemistry 141(4):3721-3730. doi: 10.1016/j.foodchem.2013.06.071

Hao X, Guan R, Huang H, Yang K, Wang L, Wu Y. 2021. Anti-inflammatory activity of cyanidin-3-O-glucoside and cyanidin-3-O-glucoside liposomes in THP-1 macrophages. Food Science & Nutrition 9(12):6480-6491. doi: 10.1002/fsn3.2554

Harper P. 2023. A review of the dietary intake, bioavailability and health benefits of ellagic acid (EA) with a primary focus on its anti-cancer properties. Cureus 15(8):e43156. doi: 10.7759/cureus.43156

Izcara S, Morante-Zarcero S, Casado N, Sierra I. 2021. Study of the phenolic compound profile of *Arbutus unedo* L. fruits at different ripening stages by HPLC-TQ-MS/MS. Applied Sciences 11(24):11616. doi: 10.3390/app112411616

Jamila F, Mostafa E. 2014. Ethnobotanical survey of medicinal plants used by people in Oriental Morocco to manage various ailments. Journal of Ethnopharmacology 154(1):76-87. doi: 10.1016/j.jep.2014.03.016

Jan R, Khan M, Asaf S, Lubna, Asif S, Kim K-M. 2022. Bioactivity and therapeutic potential of kaempferol and quercetin: new insights for plant and human health. Plants 11(19):2623. doi: 10.3390/plants11192623

Jouad H, Haloui M, Rhiouani H, El Hilaly J, Eddouks M. 2001. Ethnobotanical survey of medicinal plants used for the treatment of diabetes, cardiac and renal diseases in the North centre region of Morocco (Fez-Boulemane). Journal of Ethnopharmacology 77(2-3):175-182. doi: 10.1016/S0378-8741(01)00289-6

Jurica K, Benković V, Sikirić S, Brčić Karačonji I, Kopjar N. 2020. The effects of strawberry tree (*Arbutus unedo* L.) water leaf extract and arbutin upon kidney function and primary DNA damage in renal cells of rats. Natural Product Research 34(16):2354-2357. doi: 10.1080/14786419.2018.1534106

Kivcak B, Mert T, Demirci B, Baser KHC. 2001. Composition of the essential oil of *Arbutus unedo*. Chemistry of Natural Compounds 37(5):445-446. doi: 10.1023/A:1014419309885

Larcher W. 2000. Temperature stress and survival ability of Mediterranean sclerophyllous plants. Plant Biosystems 134(3):279-295. doi: 10.1080/11263500012331350455

Lehfa F, Sahnouni F. 2023. Phytochemical study and biological activities of *Arbutus unedo* L. Phytothérapie 21(6):329-334. doi: 10.3166/phyto-2022-0375

Liang Z, Liang H, Guo Y, Yang D. 2021. Cyanidin 3-O-galactoside: a natural compound with multiple health benefits. International Journal of Molecular Sciences 22(5):2261. doi: 10.3390/ijms22052261

Litrenta F, Nava V, Albergamo A, Potortì AG, Sturniolo R, Lo Turco V, Di Bella G. 2025. Unveiling the nutritional quality of the Sicilian strawberry tree (*Arbutus unedo* L.), a neglected fruit species. Foods 14(15):2734. doi: 10.3390/foods14152734

Maleš Ž, Šarić D, Bojić M. 2013. Quantitative determination of flavonoids and chlorogenic acid in the leaves of *Arbutus unedo* L. using thin layer chromatography. Journal of Analytical Methods in Chemistry 2013:385473. doi: 10.1155/2013/385473

Martínez-Vilalta J, Prat E, Oliveras I, Piñol J. 2002. Xylem hydraulic properties of roots and stems of nine Mediterranean woody species. Oecologia 133(1):19-29. doi: 10.1007/s00442-002-1009-2

Martins J, Pinto G, Canhoto J. 2022. Biotechnology of the multipurpose tree species *Arbutus unedo*: a review. Journal of Forestry Research 33(2):377-390. doi: 10.1007/s11676-021-01369-x

Mhamdi Takrouni M, Ben El Haj AI, Messaoued C, Boussaid M. 2012. Genetic variability of Tunisian wild strawberry tree (*Arbutus unedo* L.) populations interfered from isozyme markers. Scientia Horticulturae 146:92-98. doi: 10.1016/j.scienta.2012.08.005

Miguel M, Faleiro M, Guerreiro A, Antunes M. 2014. *Arbutus unedo* L.: chemical and biological properties. Molecules 19(10):15799-15823. doi: 10.3390/molecules191015799

Molina M, Pardo-de-Santayana M, Tardío J. 2016. Natural production and cultivation of Mediterranean wild edibles. In: Sánchez-Mata MC, Tardío J. (eds). Mediterranean Wild Edible Plants. Springer, New York, U.S.A., Pp. 81-107. doi: 10.1007/978-1-4939-3329-7_5

Morales D. 2022. Use of strawberry tree (*Arbutus unedo*) as a source of functional fractions with biological activities. Foods 11(23):3838. doi: 10.3390/foods11233838

Morgado S, Morgado M, Plácido AI, Roque F, Duarte AP. 2018. *Arbutus unedo* L.: from traditional medicine to potential uses in modern pharmacotherapy. Journal of Ethnopharmacology 225:90-102. doi: 10.1016/j.jep.2018.07.004

Mrabti HN, Marmouzi I, Sayah K, El Ouadi Y, Chemlal L, Elmsellem H, Cherrah Y, Faouzi MA. 2017. *Arbutus unedo* L. aqueous extract is associated with in vitro and in vivo antioxidant activity. Journal of Materials and Environmental Science 8(1):217-224.

Mrabti HN, Jaradat N, Fichtali I, Ouedrhiri W, Jodeh S, Ayesh S, Cherrah Y, Faouzi M. 2018. Separation, identification, and antidiabetic activity of catechin isolated from *Arbutus unedo* L. plant roots. Plants 7(2):31. doi: 10.3390/plants7020031

Mrabti HN, El Abbes Faouzi M, Mayuk FM, Makrane H, Limas-Nzouzi N, Dibong SD, Cherrah Y, Elombo FK, Gressier B, Desjeux JF, Eto B. 2019. *Arbutus unedo* L., (Ericaceae) inhibits intestinal glucose absorption and improves glucose tolerance in rodents. Journal of Ethnopharmacology 235:385-391. doi: 10.1016/j.jep.2019.02.013

Oliveira I, Baptista P, Bento A, Pereira JA. 2011. *Arbutus unedo* L. and its benefits on human health. Journal of Food and Nutrition Research 50(2):73-85.

Park K-S, Chong Y, Kim MK. 2016. Myricetin: biological activity related to human health. Applied Biological Chemistry 59(2):259-269. doi: 10.1007/s13765-016-0150-2

Rhattas M, Douira A, Zidane L. 2016. Étude ethnobotanique des plantes médicinales dans le Parc National de Talassemtane (Rif occidental du Maroc). Journal of Applied Biosciences 97:9187-9211. doi: 10.4314/jab.v97i1.5

Ruiz-Rodríguez BM, Morales P, Fernández-Ruiz V, Sánchez-Mata MC, Cámara M, Díez-Marqués C, Pardo-de-Santayana M, Molina M, Tardío J. 2011. Valorization of wild strawberry-tree fruits (*Arbutus unedo* L.) through nutritional assessment and natural production data. Food Research International 44(5):1244-1253. doi: 10.1016/j.foodres.2010.11.015

Shamsudin NF, Ahmed QU, Mahmood S, Ali Shah SA, Khatib A, Mukhtar S, Alsharif MA, Parveen H, Zakaria ZA. 2022. Antibacterial effects of flavonoids and their structure-activity relationship study: a comparative interpretation. Molecules 27(4):1149. doi: 10.3390/molecules27041149

Şeker M, Toplu C. 2010. Determination and comparison of chemical characteristics of *Arbutus unedo* L. and *Arbutus andrachne* L. (family Ericaceae) fruits. Journal of Medicinal Food 13(4):1013-1018. doi: 10.1089/jmf.2009.0167

Slimani I, Najem M, Belaidi R, Bachiri L, Bouiamrine EH, Nassiri L, Ibijbijen J. 2016. Étude ethnobotanique des plantes médicinales utilisées dans la région de Zerhoun (Maroc). International Journal of Innovation and Applied Studies 15(4):846-863.

Tenuta MC, Tundis R, Xiao J, Loizzo MR, Dugay A, Deguin B. 2019. *Arbutus* species (Ericaceae) as source of valuable bioactive products. Critical Reviews in Food Science and Nutrition 59(6):864-881. doi: 10.1080/10408398.2018.1551777

Tenuta MC, Deguin B, Loizzo MR, Dugay A, Acquaviva R, Malfa GA, Bonesi M, Bouzidi C, Tundis R. 2020. Contribution of flavonoids and iridoids to the hypoglycaemic, antioxidant, and nitric oxide (NO) inhibitory activities of *Arbutus unedo* L. Antioxidants 9(2):184. doi: 10.3390/antiox9020184

Twilley D, Langhansová L, Palaniswamy D, Lall N. 2017. Evaluation of traditionally used medicinal plants for anticancer, antioxidant, anti-inflammatory and anti-viral (HPV-1) activity. South African Journal of Botany 112:494-500. doi: 10.1016/j.sajb.2017.05.021

Vidrih R, Hribar J, Prgomet Ž, Poklar Ulrih N. 2013. The physico-chemical properties of strawberry tree (*Arbutus unedo* L.) fruits. Croatian Journal of Food Science and Technology 5(1):29-33.

Wahabi S, Rtibi K, Abidi C, Jridi M, Gressier B, Sebai H, Eto B. 2025. Impact of wild edible fruits of *Arbutus unedo* and *Crataegus monogyna* on gut motility, contraction, secretion, and glucose regulation. Neurogastroenterology & Motility 37(12):e70189. doi: 10.1111/nmo.70189

Yoon CH, Chung SJ, Lee SW, Park YB, Lee SK, Park MC. 2013. L'acide gallique, acide polyphénolique naturel, induit l'apoptose et inhibe l'expression des gènes pro-inflammatoires dans les synoviocytes fibroblastiques de polyarthrite rhumatoïde. Revue du rhumatisme 80(3):271-278. doi: 10.1016/j.rhum.2012.10.001

Ziółkiewicz A, Kasprzak-Drozd K, Rusinek R, Markut-Miotła E, Oniszczuk A. 2023. The influence of polyphenols on atherosclerosis development. International Journal of Molecular Sciences 24(8):7146. doi: 10.3390/ijms24087146

Zitouni H, Hssaini L, Ouaabou R, Viuda-Martos M, Hernández F, Ercisli S, Ennahli S, Messaoudi Z, Hanine H. 2020. Exploring antioxidant activity, organic acid, and phenolic composition in strawberry tree fruits (*Arbutus unedo* L.) growing in Morocco. Plants 9(12):1677. doi: 10.3390/plants9121677

Ziyyat A, Legssyer A, Mekhfi H, Dassouli A, Serhrouchni M, Benjelloun W. 1997. Phytotherapy of hypertension and diabetes in oriental Morocco. Journal of Ethnopharmacology 58(1):45-54. doi: 10.1016/S0378-8741(97)00077-9