



Apricot leaf: A new source of bioactive compounds – an overview

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ABSTRACT

Background: Growing awareness of the health benefits of functional foods has fueled interest in products rich in bioactive compounds. Fruits and berries are well-established sources of phytochemicals such as polyphenols, terpenes, pectin, fiber, minerals, and vitamins. More recently, plant leaves have emerged as promising alternative reservoirs of these bioactive compounds. Several berry leaves are already included in the European Commission's Novel Food Catalogue or are traditionally consumed in herbal teas. Within this context, the leaves of apricot (*Prunus armeniaca* L.) represent a valuable yet largely underexplored resource.

Objectives: This review summarizes current knowledge on the biochemical composition, phytochemical diversity, and health-promoting effects of apricot leaves, highlighting their potential applications in functional foods and natural health products.

Results: Apricot leaves contain abundant polyphenols, flavonoids, phenolic acids, tannins, essential oils, and vital macro- and microelements. Key phenolic compounds include chlorogenic acid, catechin, rutin, and naringin, while condensed tannins dominate the tannin fraction. ORAC, ABTS, FRAP, and chemiluminescent assays confirm strong free-radical-scavenging capacity. Quercetin-3-O-rutinoside, 5-O-caffeoylquinic acid, and 3-O-caffeoylquinic acid exhibit anti-obesity effects through pancreatic lipase and COX-1 inhibition. Essential oils rich in phytol show notable antioxidant and neuroprotective activity, including acetylcholinesterase inhibition. Apricot leaf extracts display hepatoprotective,

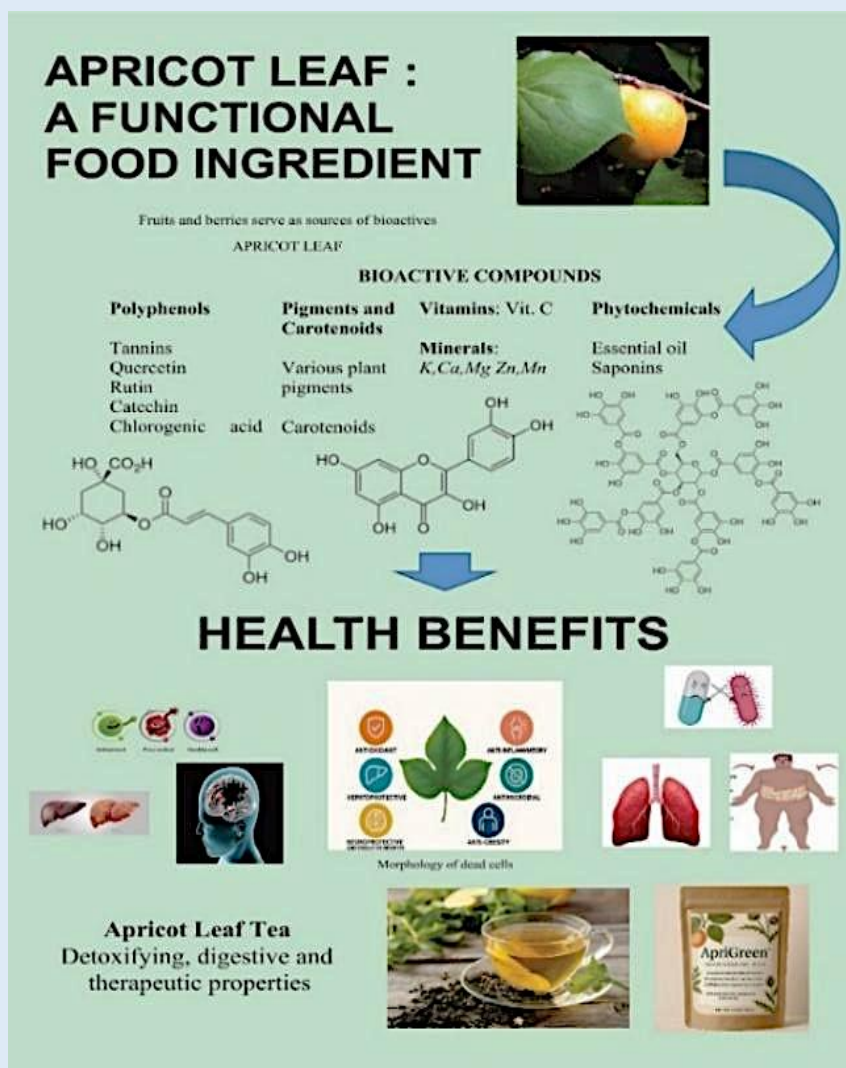
antimicrobial (notably against *Staphylococcus aureus* and *Salmonella typhimurium*), and antifungal properties without cytotoxicity. Minerals such as potassium, calcium, magnesium, iron, and zinc further enhance their nutritional value.

Conclusions: With their rich phytochemical and mineral profile, apricot leaves offer promising applications in herbal teas, oral care, skincare, and as natural flavoring agents. Their antioxidant, antimicrobial, and hepatoprotective effects support their potential as functional food ingredients and natural health-promoting products.

Novelty: This is the first comprehensive review dedicated to the phytochemistry, pharmacological potential, and food-industry applications of apricot leaves.

Keywords: apricot leaves, bioactive compounds, functional food, bioactive properties, applications in functional foods

Graphical abstract: Apricot leaf: a new source of bioactive compounds – an overview



INTRODUCTION

In recent decades, growing awareness of the health benefits of functional foods has driven strong consumer interest. These foods are valued for their biologically active compounds, which help prevent disease and support overall well-being [1, 2]. Fruits and berries are well established in this context, providing rich sources of polyphenols, triterpenes, tetraterpenes, pectin, fiber, minerals, and vitamins.

Recently, attention has turned to plant leaves as underutilized reservoirs of bioactive compounds, often with comparable or even superior potency. Leaves from rowanberry, crowberry, lingonberry, and bilberry are listed in the European Commission's Novel Food Catalogue, while others - such as sea buckthorn, wild strawberry, and blackcurrant - are frequently used in herbal teas and wellness products.

Among these, the apricot (*Prunus armeniaca* L.) stands out for its nutritional value and cultural importance, particularly in Armenia, one of its centers of origin. While the fruits and kernels of apricot have been widely studied for their phytochemical richness—including carotenoids, fatty acids, sterols, glycosides, and polyphenols such as catechins, chlorogenic acid, and quercetin derivatives—making the health benefits of these components well documented [3–6].

Despite this focus, the leaves of apricot remain largely unexplored—a noteworthy gap given the rising interest in alternative plant parts with functional potential. Initial evidence suggests that apricot leaves contain diverse bioactive compounds suitable for nutraceutical and therapeutic applications.

Historical sources support this view. In 15th-century Armenian medicine, Amirdovlat Amasiatsi recommended apricot leaves for diphtheria, and traditional Chinese medicine used them to treat gastrointestinal, respiratory, and skin ailments [7, 8]. Modern studies have begun to

confirm these traditional applications, noting bronchodilatory and anti-inflammatory properties in apricot leaf extracts [9, 10].

The biochemical similarities between apricot fruits and leaves suggest they may share valuable functional compounds. However, comprehensive profiling of apricot leaves remains limited. Investigating their phytochemical composition could uncover promising applications in supplements, teas, skincare products, oral health formulations, and as natural flavor or aroma enhancers.

This review aims to synthesize existing knowledge on the composition of apricot leaves - focusing on phenolics, pigments, carotenoids, and minerals—and to evaluate their antioxidant and antimicrobial potential in the context of future health-related applications.

The Apricot: History And Cultivation: The apricot is a fruit-bearing species of considerable economic, agronomic, and cultural significance, predominantly cultivated in temperate regions, particularly across the Mediterranean basin. A member of the Rosaceae family, *P. armeniaca* is closely related to other economically important species such as peaches (*P. persica*), almonds (*P. dulcis*), plums (*P. domestica*), and cherries (*P. avium*, *P. cerasus*).

Current global apricot production is estimated at approximately 2.6 million metric tons. Turkey and Uzbekistan are the leading producers, with Turkey producing around 803,000 tons in 2022, primarily from the Malatya region, internationally recognized for its high-quality dried apricots. Uzbekistan follows with approximately 541,263 tons. In Europe, Italy ranks first and fifth globally, with a production volume of about 230,080 tons, concentrated mainly in the Campania and Emilia-Romagna regions. France and Greece are also notable contributors to European apricot output (Fig. 1).

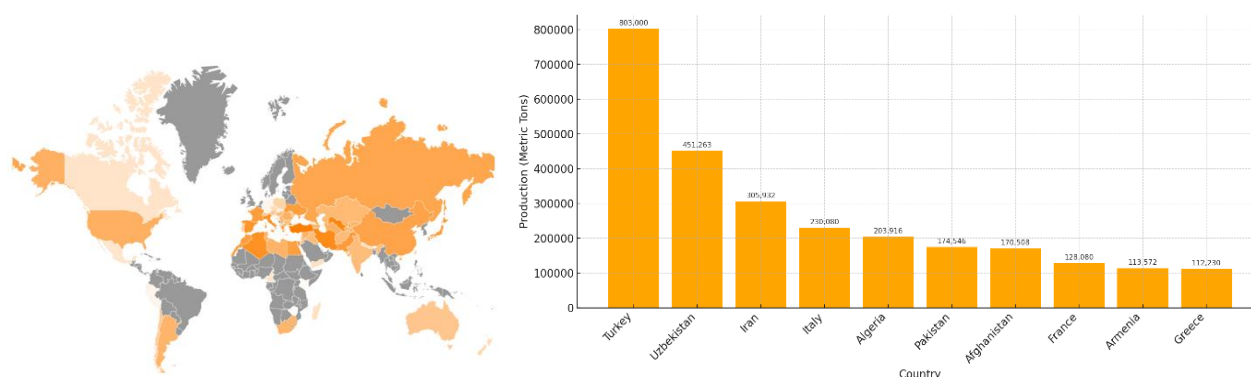


Figure 1. Production of apricots for the top 10 countries in the year 2022.

Armenia, with a 2022 yield of approximately 113,572 tons, holds particular historical and genetic significance in apricot cultivation. Archaeobotanical and historical evidence supports Armenia as one of the centers of apricot domestication, with traces of cultivation dating back more than 6,000 years near the Temple of Garni and the Neolithic site of Shengavit. This ancient association is reflected in the species' Latin name, *Prunus armeniaca*, and in the historical Roman reference to apricots as “Armenian apples.”

Several cultivars indigenous to Armenia, including Yerevani (Shalakh), Khosrovshay, and Tabarza, exhibit high adaptability to local agro-ecological conditions and have been maintained through centuries of traditional selection and propagation. In addition to their horticultural and nutritional value, apricot trees are valued for their ornamental appeal, traditional medicinal uses, and apicultural importance, owing to their early flowering, which provides vital forage for early-season pollinators.

Bioactive Compounds Of Apricot Leaf: Polyphenolic composition: Biochemical analyses confirm that both fresh and dried apricot leaves are rich in polyphenolic compounds. Qualitative studies on the leaves of the Yerevani (Shalakh) cultivar have identified condensed tannins (proanthocyanidins) as the predominant phenolic constituents, with hydrolysable tannins

occurring at much lower levels. Additional classes of polyphenols detected include flavones, flavanols, 5-hydroxyflavonols, chalcones, aurones, catechins, and coumarins. Notably, younger apricot trees exhibit higher concentrations of tannins, flavanols, and catechins than older trees, indicating that polyphenol accumulation is influenced by plant age.

Quantitative analyses show that tannins are the dominant phenolic group in apricot leaves, regardless of the extraction solvent. When extracted with ethanol, tannin levels reached as high as 23.6 %, while aqueous extractions yielded up to 19.5 %. Spectrophotometric analysis (UV-1700, Shimadzu, Japan) confirmed the presence of flavanols, particularly quercetin, with maximum absorbance (optical density 0.465) at 437–438 nm [11, 12].

Building on these findings, Yilmaz Ugur et al. investigated seasonal variation in phenolic content across five apricot cultivars from Malatya Province, Turkey [13]. Using high-performance liquid chromatography (HPLC), they analyzed leaf samples collected in spring (April), summer (June), and autumn (November). The most abundant phenolic compounds identified were chlorogenic acid (59.85–167.75 mg/kg) and rutin (24.79–129.42 mg/kg), alongside catechin, naringin, and caffeic acid. Their study highlighted not

only the diversity of phenolic compounds but also their pronounced seasonal and varietal variability, indicating a complex interplay between plant development and environmental factors.

Complementary insights were provided by Alam Zeb, who performed a detailed characterization of the polyphenolic profile in apricot leaves, identifying ten major compounds [14]. These included several caffeoylquinic acid isomers—namely 3-O-, 4-O-, and 5-O-caffeoylquinic acids—as well as quercetin-3-O-glucosides, with lesser amounts of caffeic acid, *p*-coumaric acid derivatives, and kaempferol derivatives. Notably, Zeb documented substantial compositional

shifts during leaf maturation, underscoring the dynamic biosynthetic processes governing phenolic accumulation.

Taken together, these studies demonstrate that apricot leaves are a potent reservoir of polyphenolic compounds, prominently including tannins, chlorogenic acid, rutin, and various quercetin derivatives. The concentration and composition of these bioactive compounds are shaped by multiple factors, including tree age, cultivar, extraction method, seasonality, and environmental conditions.

Table 1 summarizes the pharmacological activities of selected phenolic compounds commonly identified in apricot leaves.

Table 1. Specific phenolic compounds found in apricot leaves, their healing properties, and corresponding references.

Phenolic Compound	Healing Properties	Reference
Tannins	Anti-inflammatory, antioxidant, and gut-modulating effects	[15]
Quercetin	Anti-inflammatory and antioxidant properties; supports cardiovascular health, wound healing, and antimicrobial activity	[16-18]
Rutin	Antioxidant and anti-inflammatory effects; organ protection; supports diabetes and metabolic health; cardiovascular and vascular health; skin aging and wound healing; cancer and senescence modulation; gut microbiota modulation	[19-22]
Catechin	Antioxidant activity; supports lipid regulation and obesity management in overweight adults; modulates the gut–metabolic axis	[23, 24]
Chlorogenic Acid & Derivatives	Antioxidant and anti-inflammatory effects; hepatoprotective properties; cognitive benefits; anti-skin aging effects	[25-29]
<i>p</i> -Coumaric Acid Derivatives	Supports diabetic wound healing	[30]
Kaempferol Derivatives	May aid in the management of neurodegenerative disease	[31]
Naringin	Anti-inflammatory and antioxidant properties; neuroprotective and anticancer potential; hepatoprotective effects	[32]

Chlorophyll, Carotenoids and Pectin: Chlorophylls and carotenoids are lipid-soluble pigments responsible for the green, yellow, orange, and red hues of plants. Beyond their visual roles, these pigments influence the sensory qualities of foods and are considered key indicators of quality in food technology. Their combined interactions contribute to the vibrant appearance of fruits,

vegetables, and leaves, enhancing both aesthetic and nutritional appeal.

Among dietary sources, fruits and vegetables are the primary providers of carotenoids, which are well known for their protective effects on human health (Table 2).

Table 2. Chlorophylls, pigments, and carotenoids identified in apricot leaves and their reported biological (healing) properties.

Compound	Healing Properties	Ref.
Chlorophyll and its derivatives	Anti-obesity effects; supports wound healing	[34]
Neoxanthin	Renal Protection	[35]
Lutein	Cognitive performance in children	[36]
β-Carotene	Antioxidant properties; provitamin A activity; supports diabetes and metabolic health; anti-osteoarthritis effects; cardiovascular and vascular protection; skin aging and wound healing; cancer and senescence modulation	[37, 38]
Pectin	Supports digestive and gut health; aids in cholesterol management, blood sugar control, weight management; exhibits anti-cancer properties; balances gut microbiota	[39]

Pigment analysis of apricot leaves from the Yerevani (Shalakh) cultivar confirmed the presence of chlorophyll in all samples (Fig. 2). Notably, leaves from older trees exhibited the highest concentrations of total chlorophyll (3.7 mg/g) and carotenoids (0.8 mg/g), while younger leaves contained higher levels of chlorophyll a (2.75 mg/g).

Pectin biosynthesis also showed seasonal variation. Soluble pectin synthesis peaked during the vegetative growth phase but began to decline approximately three weeks before the fruit reached technological maturity.

This decline coincided with an increase in protopectin content, and the highest total pectin accumulation was recorded in leaves collected about three weeks prior to full fruit ripening. Supporting these findings, Wojdyło et al. reported that apricot leaves contained the highest chlorophyll concentrations among several fruit tree species, although their carotenoid levels were comparatively lower than those found in the leaves of apple, quince, pear, peach, plum, and both sour and sweet cherry trees [33].

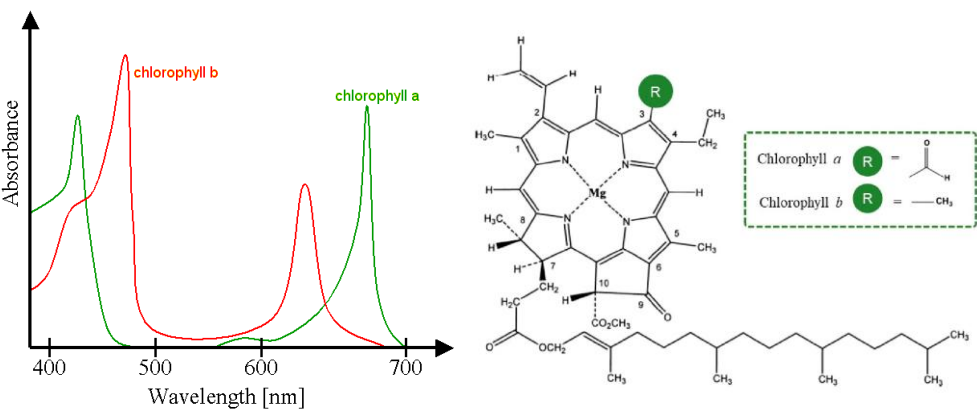


Figure 2. UV spectrum of the acetone extract of common apricot leaves (horizontal axis: wavelength [nm]; vertical axis: optical density) and structures of chlorophyll *a* and chlorophyll *b*.

Similarly, Turkish studies observed significant changes in pigment content during leaf maturation [14]. The major carotenoids identified included lutein (56.7–65.7 µg/g), neoxanthin (0.66–4.79 µg/g), 5,6-epoxy-α-carotene (5.89–7.9 µg/g), and β-carotene (12.3–26.9

µg/g). Throughout maturation, chlorophyll *a* levels consistently exceeded chlorophyll *b* levels.

Chlorophyll *a* content decreased significantly ($p < 0.01$) from 23.37 mg/mL at 15 days to 5.40 mg/mL at 45 days, then rose again to 19.90 mg/mL at 60 days. A similar

trend was observed for chlorophyll *b*, which declined from 13.18 to 6.22 mg/mL over the same period before increasing again at 60 days. Total chlorophyll content mirrored these fluctuations, reflecting dynamic pigment regulation during leaf development.

K > Ca > Mg > P >> Fe > Na > Al > B > Zn > Mn > Ba > Cu >> Ti > Ni >> Mo > I > Cr > Li > Pb > Co >> As > Sb > V > Ag > Sr > Sn > Cd > Bi.

Figure 3. Quantitative ranking of elements in apricot leaves.

Among these, potassium is notably abundant, averaging approximately 35380 mg/kg (dry weight), and exceeding 50000 mg/kg in young foliage. Potassium plays a vital role in fluid balance, muscle contraction, heart rhythm, and blood pressure regulation. It is associated with a reduced risk of hypertension and ischemic stroke and contributes to bone health by minimizing urinary calcium excretion. For perspective, the adult recommended daily intake of potassium is around 3,400 mg (men) and 2,600 mg (women), so just 100 g of dried young leaves could theoretically supply well over the daily requirement—underscoring their nutritional significance.

Calcium, the second most abundant element, also appears in high concentrations in both mature and young leaves (old trees - 15216, 3mg/kg, young trees - 14301,6 mg/kg).

The health benefits of these major minerals are well-documented. For example, a large cohort study found that high-normal serum levels of potassium, calcium, and magnesium significantly reduce mortality and disability following ischemic stroke [40]. Meta-analyses further support that optimal intake of these elements aids cardiovascular function, maintains healthy blood pressure, and enhances bone mineral density. Supplementation with potassium citrate, particularly in postmenopausal individuals, has been shown to reduce

Mineral Composition: Using inductively coupled plasma mass spectrometry (ICP-MS), up to 30 macro- and microelements have been identified in apricot leaves.

The quantitative ranking of these elements in apricot leaves, from highest to lowest concentration, is shown in figure 3.

urinary calcium loss and improve bone outcomes when combined with calcium and vitamin D [41].

Beyond potassium and calcium, apricot leaves offer a diverse range of micronutrients with metabolic, antioxidant, and immunological benefits. These include zinc (old trees 35.6 mg/kg, young trees 17.6 mg/kg), copper (old trees 12.4 mg/kg, young trees 17.6 mg/kg), iron (old trees 138.3 mg/kg, young trees 118.3 mg/kg), and trace elements such as iodine, cobalt, molybdenum, and lithium. For comparison, the recommended daily intakes are about 8–11 mg for zinc, 0.9 mg for copper, and 8–18 mg for iron. Thus, even modest consumption of dried apricot leaves could make a meaningful contribution to daily micronutrient requirements.

Notably, apricot leaves - especially those from older trees - contain significant levels of iodine (old trees 0.62 mg/kg; young trees 0.51 mg/kg), suggesting potential as a dietary source in iodine-deficient regions. For context, the adult RDI for iodine is about 150 µg/day.

Each trace element contributes uniquely to human health. Copper supports protein synthesis, angiogenesis, and bone repair, and exhibits antimicrobial activity via its role in enzymatic processes [42–44]. Zinc, manganese, iron, and magnesium are essential for immune function, growth, metabolism, and neurocognitive health. Zinc, for instance, regulates over 300 enzymes and is critical for DNA synthesis and immune defense [45]. Manganese supports antioxidant systems and collagen production

[46], while iron ensures effective oxygen transport and helps prevent anemia [47]. Magnesium stabilizes nerve, muscle, and cardiovascular functions [48]. A balanced intake is crucial, as both deficiencies and excesses may have harmful effects.

The elemental profile of apricot leaves varies depending on biological and environmental factors, such as plant age, developmental stage, soil composition, climate, and cultivation practices [49-51].

In conclusion, apricot leaves are a valuable source of essential macro- and micronutrients. The dominance of potassium and calcium, alongside the presence of antioxidant and immune-supportive elements such as zinc, copper, and iron, underscores their potential to support cardiovascular, skeletal, and metabolic health.

The main volatiles of apricot leaf essential: Essential oils are complex mixtures of volatile compounds extracted from various aromatic plants, representing between 0.1% and 1% of their dry weight. The extraction of these hydrophobic compounds is primarily performed through hydrodistillation and steam distillation techniques, which

allow the isolation of bioactive components.

In this context, Bonesi et al. investigated the volatile profile of apricot leaves collected in Italy [52]. The leaves were subjected to hydrodistillation for three hours, and the extracted essential oils were stored at +4 °C in brown bottles under nitrogen to preserve their integrity. To identify the active constituents of the oils, gas chromatography systems were employed, resulting in the identification of 23 major volatile compounds.

The essential oils from apricot leaves were found to be rich in manoyl oxide (5.21–6.53%), linalool (4.44–4.81%), limonene (2.44–2.87%), and (E)-2-hexenal (3.54–4.87%). Additionally, the alkanes nonacosane (21.11–23.76%) and heptacosane (10.14–11.61%) were present in substantial quantities. Notably, oils obtained from leaves harvested in June exhibited particularly high levels of γ -cadinene (4.76%), β -cadinene (4.73 %), and pentacosane (7.39%).

Essential oil volatiles have broad bioactive potential, spanning antimicrobial, anti-inflammatory, neuropsychological, respiratory, and metabolic effects (Table 3).

Table 3. The main volatiles of apricot leaf essential oils and their reported health benefits.

Compound	Health Benefits		Reference
Manoyl oxide	Anticancer potential (e.g., in <i>Cyperaceae species</i> essential oil)		[53]
Linalool	Anti-inflammatory and anti-arthritic effects; neuroprotective and anxiolytic properties		[54]
Limonene	Antioxidant, anti-inflammatory, analgesic, wound-healing, antidiabetic, anticancer, and immunomodulatory activities		[55]
(E)-2-Hexenal	Antifungal activity (in wampee <i>Clausena lansium</i> essential oil)		[56]
Nonacosane	Antioxidant and DNA-protective effects (observed in <i>Potentilla argentea</i>)		[57]
Heptacosane	Antibacterial and antifungal activity (commonly found in essential oils of <i>Sesamum</i> and <i>Moringa</i>)		[58]
Pentacosane	Antimicrobial effects (e.g., in <i>Centaurea triumfeti</i> essential oil)		[59]
γ -Cadinene, β -Cadinene	Tyrosinase inhibition		[60, 61]

Bioactive Properties Of Apricot Leaves: Antioxidant activity: The antioxidant potential of apricot leaves has been extensively investigated using various in vitro systems, where their ability to neutralize free radicals has been compared with standard reference compounds. These studies provide growing evidence supporting the health-promoting properties of apricot leaves.

For instance, a study by Aneta Wojdyło et al. evaluated the antioxidant activity of apricot leaves from three cultivars of *Prunus armeniaca* (Somo, Harcot, and Early Orange) using ORAC, ABTS, and FRAP assays [62]. The results demonstrated cultivar-dependent variation in antioxidant capacity. The ABTS⁺ and ORAC values (mmol Trolox/100 g dry weight, $p < 0.05$) ranged from 167.8 to 72.7 and from 411.8 to 297.5, respectively, in the order: Somo > Early Orange > Harcot. Similarly, FRAP assay results confirmed the superior antioxidant performance of the Somo cultivar (71.4 mmol Trolox/100 g DW), followed by Harcot (50.4) and Early Orange (17.1). These findings indicate that the antioxidant activity of apricot leaves is strongly influenced by genetic factors. Notably, quercetin-3-O-rutinoside and caffeoylquinic acids were identified as the major contributors to this activity.

Complementing this, a 2024 study by Kece further examined the relationship between biochemical composition and antioxidant activity across 31 apricot cultivars in Central Anatolia, Türkiye. Using multivariate analysis and a modified DPPH method (0.26 mM DPPH), the study confirmed significant variability among cultivars. The highest total phenolic content, flavonoid content, and antioxidant activity were recorded in “Cebas Red” (59.4 ± 3.05 mg GAE/100 g), “Sakit 2” (17.07 ± 4.15 mg QE/100 g), and “Ordubat” ($84.36 \pm 6.26\%$), respectively. These results reinforce the influence of cultivar on antioxidant potency and underline the importance of biochemical diversity in leaf extracts [46].

Our own investigations employed chemiluminescent, permanganatometric, and

voltammetric techniques to assess the antioxidant activity of apricot leaf (Yerevani (Shalakh) variety) extracts. Consistently, extracts from young trees (less than 8 years old) exhibited stronger antioxidant capacity than those from older trees. These outcomes not only align with previous studies but also emphasize the role of tree age in determining antioxidant effectiveness.

Building upon these findings, the following conclusions were drawn: in various model systems, apricot leaf extract exhibits a direct, concentration-dependent antioxidant effect that varies by extraction method. Ethanolic extracts displayed significantly higher activity than aqueous ones, underscoring the importance of solvent choice. Across all systems tested, antioxidant activity increased with extract concentration. The primary contributors to this activity appear to be polyphenolic compounds—particularly flavonols—which showed the strongest antioxidant response.

Hepatoprotective properties: Several studies have explored the hepatoprotective properties of apricot leaf extracts, highlighting their potential as natural therapeutic agents for liver health.

One such investigation by Strobilia et al. evaluated the pharmacological effects of PrALe in animal models [63]. The extract was deemed “relatively harmless,” showing no signs of ulcerogenic, irritant, or allergenic effects. Notably, in a tetrachloromethane-induced liver injury model, the extract demonstrated significant antioxidant and hepatoprotective activity. It reduced oxidative stress, restored the endogenous antioxidant defense system, and enhanced detoxification, as evidenced by a shortened hexenal-induced sleep duration. Key liver function markers such as ALT and alkaline phosphatase were favorably modulated, and bile secretion parameters significantly improved. These effects collectively indicated the extract’s ability to stabilize hepatocyte membranes and promote bile production. The hepatoprotective effect was further

supported by favorable changes in serum and bile cholesterol levels and reduced protein oxidation, with efficacy comparable to the established hepatoprotective agent Silibor. Although Allochol was also used as a reference compound, the apricot extract showed superior improvement in bile flow rate.

Complementing these findings, a study by Raj investigated the effects of PrALe in a paracetamol-induced liver injury model in rats [64]. This study provided additional evidence of the extract's protective capabilities. Following the induction of liver toxicity, various biochemical parameters were assessed, including serum glutamic pyruvic transaminase (sGPT), serum glutamic oxaloacetic transaminase (sGOT), serum alkaline phosphatase (sALP), serum bilirubin (SB), thiobarbituric acid reactive substances (TBARS), γ -glutamyl transferase (GGT), lactate dehydrogenase (LDH), total protein (TP), and albumin. Physical parameters, such as liver weight, body weight, and histopathological changes in the liver, were also examined. Ursodeoxycholic acid served as the standard hepatoprotective agent. Pre-treatment with methanol and aqueous apricot leaf extracts significantly reduced sGOT, sGPT, sALP, TBARS, GGT, LDH, TP, albumin, and SB levels ($p < 0.01$), with effects nearly comparable to those of ursodeoxycholic acid. The hepatoprotective activity was further confirmed through histopathological examination of liver tissues from both control and treated animals.

Together, these studies provide compelling evidence for the hepatoprotective effects of apricot leaf extracts, likely attributable to their rich polyphenolic and flavonoid content. Their ability to modulate liver function markers, protect against oxidative damage, and improve bile secretion suggests promising applications in liver health management and the development of natural therapeutics.

Anti-obesity effect: According to the World Health Organization (2023), obesity is a global public health concern and a well-established risk factor for numerous serious conditions, including type II diabetes, hypertension, cardiovascular disease, and certain types of cancer. Given the urgency to identify effective prevention and treatment strategies, increasing attention has been directed toward natural bioactive compounds with anti-obesity potential.

In this context, Wojdyło et al. analyzed the inhibitory effects of PrALe on three key digestive enzymes: α -amylase, pancreatic lipase, and α -glucosidase [62]. The extent of α -glucosidase inhibition was positively correlated with the content of *p*-coumaroylquinic acid and quercetin-3-O-rutinoside. In contrast, pancreatic lipase inhibition was strongly associated with all caffeoylquinic acid derivatives and several flavonols, including quercetin-3-O-rutinoside, quercetin-3-O-galactoside, and kaempferol-3-O-rutinoside. Notably, the most effective PrALe fraction for inhibiting α -amylase contained substantial levels of polymeric procyanidins ($r = 0.918$) and certain phenolic acids ($r > 0.755$).

These strong correlations between specific phenolic compounds and enzyme inhibition emphasize the therapeutic potential of PrALe as a natural agent for obesity management.

Antimicrobial activity: The antimicrobial activity of apricot, particularly from its fruits, kernels, and oil, has been well documented in earlier studies. These investigations primarily targeted bacterial and fungal pathogens using various apricot-derived substances. For example, Rashid et al. demonstrated that butanoic apricot extracts inhibited a broad spectrum of microorganisms, including 20 Gram-positive and 13 Gram-negative bacterial strains [65]. Complementing these findings, Saeed and Tariq reported the antibacterial effects of apricot oil against *Escherichia coli* O157:H7 and

Salmonella typhimurium, two significant Gram-negative pathogens [66].

Beyond antibacterial effects, apricot also exhibits antifungal properties. Yiğit et al. [67] found that methanolic extracts from apricot kernels were notably effective against *Candida albicans*.

Building on this body of research, a study conducted in Turkey investigated the antifungal effect of apricot leaf extracts against *Aspergillus niger* in cherry juice [68]. Both ethanol and methanol extracts were evaluated, with the methanol extract from microwave-dried leaves reducing fungal counts by 2.94 log CFU/mL. However, the ethanol extract from air-dried leaves exhibited even stronger activity, likely due to greater phenolic solubility in ethanol and reduced thermal degradation of bioactive compounds during air-drying.

Similarly, Alan et al. [69] confirmed the antimicrobial potential of ethanolic apricot extracts against a variety of bacterial strains, including *Klebsiella pneumoniae*, *Escherichia coli*, *Streptococcus faecalis*, *Staphylococcus aureus*, *Bacillus megaterium*, and *Enterococcus faecalis*. More recently, Gültekin [70] showed that apricot oil exerts inhibitory effects on *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*, reinforcing the relevance of apricot-derived products in combating microbial threats.

Expanding the scope to include apricot leaves—an underexplored part of the plant—further research examined their antimicrobial properties in more detail [12]. Water extracts prepared from both fresh and dried leaves were tested against a panel of microorganisms, including nine Gram-positive and two Gram-negative bacterial strains, as well as two fungal species. The bacterial strains included *Staphylococcus aureus* 205, *Staphylococcus citreus*, *Bacillus megaterium*, *Bacillus mesentericus*, *Brevibacterium flavum* 14067, *Bacillus mycoides*, *Bacillus subtilis* 1759, *Bacillus subtilis* 205, *Escherichia coli* M17, and *Salmonella typhimurium*.

Antifungal testing targeted *Candida guilliermondii* and *Candida albicans*.

The aqueous leaf extracts exhibited notable antimicrobial effects, particularly against *Staphylococcus citreus*, *Salmonella typhimurium*, and *Bacillus subtilis* 1759. Antifungal activity was also observed against both *Candida* species. These results may be attributed to the leaf's high content of tannins, total phenolics, and especially flavonols—compounds known to contribute significantly to antimicrobial defense.

Collectively, findings from these diverse studies highlight the broad-spectrum antimicrobial efficacy of apricot-derived substances—including oils, kernel extracts, and notably, leaf extracts. The consistent inhibition of both bacterial and fungal pathogens underscores their potential as candidates for antimicrobial herbal formulations, natural preservatives, or adjunct therapies in combating infectious diseases.

Neuroprotective and cognitive benefits: Identifying natural-origin inhibitors of acetylcholinesterase (AChE) and butyrylcholinesterase (BChE) is of great therapeutic interest, as these enzymes are promising targets for the treatment of neurological disorders such as Alzheimer's and Parkinson's diseases, myasthenia gravis, senile dementia, and ataxia. Bonesi (2018) reported on the antioxidant and neuroprotective effects of essential oils obtained via hydro distillation from the apricot leaves. The results demonstrated notable radical scavenging activity in the ABTS, DPPH, and β -carotene bleaching assays. Additionally, the essential oil from apricot leaves was found to inhibit AChE and partially inhibit BChE [52].

When considering PrALe more broadly, the overall inhibitory activity was low—less than 10%—but a significant positive correlation was observed with the polyphenol content of the evaluated cultivar. Although the total polyphenol and flavonol content exhibited only weak correlations with AChE and BChE inhibition, a strong correlation was found between AChE inhibition

and the presence of polymeric procyanidins ($r = 0.941$), suggesting that these compounds may play a key role in the observed enzyme inhibition.

Anti-inflammatory effects: Inflammation is a complex physiological process that can lead to a variety of disorders. During this process, numerous inflammatory mediators are produced, contributing to chronic conditions such as osteoarthritis, rheumatoid arthritis, asthma, cancer, and neurological diseases.

The anti-inflammatory activity of PrALe is attributed to its ability to inhibit cyclooxygenase (COX) enzymes. The inhibition of COX-1 by PrALe demonstrated relatively consistent IC_{50} values, ranging from 0.9 to 2.2 $\mu\text{g/mL}$, whereas COX-2 inhibition exhibited greater variability, with IC_{50} values ranging from 1.8 to 9.7 $\mu\text{g/mL}$. These findings suggest that COX-2 is generally less susceptible to inhibition by PrALe [62].

A strong positive correlation was observed between COX-1 inhibition and the content of *p*-coumaroyl-glucoside acids ($r = 0.997$). In contrast, COX-2 inhibition correlated positively with several other compounds, including caffeoyl-glucoside, 4-O-caffeoylquinic acid, 3-*p*-coumaroylquinic acid, 5-O-caffeoylquinic acid, and feruloyl-glucoside ($r > 0.912$).

Cytotoxicity: According to the toxicity classification by K.K. Sidorov, PrALe is considered “relatively harmless,” with a single intravenous administration resulting in an LD_{50} value greater than 15,000 mg/kg.

To assess the cytotoxicity of the extracts *in vitro*, the Trypan Blue Exclusion Test for cell viability was employed [71]. The K-526 suspension cell line was maintained in RPMI-1640 (Sigma-Aldrich) nutrient medium, supplemented with 10% fetal bovine serum (FBS) and a standard antibiotic mixture (penicillin, streptomycin, gentamicin).

At initial extract concentrations ranging from 0 to 20 $\mu\text{L/mL}$, a slight decrease in the number of viable cells

was observed (up to 13%, $p = 0.17$). However, with further increases in extract concentration (40–100 $\mu\text{L/mL}$), the number of viable cells remained nearly unchanged compared to the control ($p = 0.29$ – 0.46).

Therefore, at concentrations of 20, 40, 60, 80, and 100 $\mu\text{L/mL}$, the tested solution is considered non-toxic. These results indicate that the aqueous extract obtained from apricot leaves does not exhibit significant dose-dependent cytotoxicity.

Potential applications of apricot leaves in the food industry: Apricot leaves, often overlooked in favor of the fruit, are gaining increasing attention due to their phytochemical richness and bioactive potential. This emerging interest highlights their relevance not only in health-related research but also in practical applications within the food industry.

Their unique composition makes apricot leaves suitable for several value-added uses. These include their incorporation into functional beverages such as herbal infusions, detox teas, and fortified drinks. Additionally, their tannin and polyphenol content positions them as natural preservatives and flavoring agents, while their antioxidant properties support their use in nutraceuticals, dietary supplements, and food preservation systems.

Importantly, the utilization of apricot leaves aligns with broader sustainability goals. As agricultural by-products, they represent a renewable and low-cost resource that supports zero-waste initiatives in food processing. This makes their valorization not only environmentally sound but also economically advantageous.

One particularly promising application lies in the development of apricot leaf tea (Fig. 4), a natural, caffeine-free alternative to traditional teas such as *Camellia sinensis* (green tea). With proper processing, this herbal tea can offer a beverage with high antioxidant activity, distinctive flavor, and potential therapeutic effects.



Figure 4. Apricot leaf tea.

Several attributes contribute to the viability of apricot leaves as a tea source. First, their high polyphenol and tannin content—up to 20% in aqueous extracts—includes compounds such as quercetin, flavonoids, phenolic acids, and catechins [11-13]. These compounds, while chemically distinct from those in green tea, offer comparable functional benefits [72].

Second, experimental studies indicate that apricot leaf extracts exhibit strong antioxidant and hepatoprotective properties, making them suitable for liver-supportive or detoxifying formulations [63, 64].

Third, apricot leaf tea possesses a favorable sensory profile. When processed properly, it yields a mild, fruity, and earthy flavor with subtle astringency—an appealing alternative for those who find green tea too sharp or grassy.

Finally, incorporating apricot leaves into tea products exemplifies a sustainable approach to by-product utilization. What is often discarded post-harvest can be transformed into a high-value functional beverage, contributing to both environmental conservation and agricultural innovation.

CONCLUSION

Apricot leaves, long overshadowed by the fruit and kernels, are emerging as a valuable botanical resource rich in bioactive compounds. They are abundant in polyphenols, carotenoids, chlorophylls, essential minerals, and volatile constituents, each contributing to

antioxidant, antimicrobial, hepatoprotective, anti-inflammatory, and neuroprotective effects. Demonstrated enzyme-inhibitory activities further support their potential in managing metabolic disorders such as obesity and diabetes.

As sustainable, low-cost by-products of apricot cultivation, these leaves present significant opportunities for the development of functional foods, herbal teas, nutraceuticals, and cosmetic formulations.

Nevertheless, further clinical and toxicological studies are essential to fully validate their safety and efficacy. Unlocking the full potential of apricot leaves could transform them from agricultural waste into a novel, health-enhancing ingredient with broad commercial and therapeutic appeal.

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Authors contribution: All authors contributed to this study.

Abbreviations: *Prunus armeniaca* L.leaf extract (PrALe), recommended daily intake (RDI), Oxygen Radical Absorbance Capacity (ORAC), 2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic) acid assay (ABTS), Fluorescence Recovery After Photobleaching assays (FRAP), alanine transaminase (ALT), serum glutamic pyruvic transaminase (SGPT), serum glutamic oxaloacetic transaminase (SGOT), serum alkaline phosphatase (SALP),

serum bilirubin (SB), thiobarbituric acid reactive substances (TBARS), γ -glutamyl transferase (GGT), lactate dehydrogenase (LDH), total protein (TP), acetylcholinesterase (AChE), butyrylcholinesterase (BChE), cyclooxygenase-1 (COX-1), Cyclooxygenase-2 (COX-2), fetal bovine serum (FBS), deoxyribonucleic acid (DNA)

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