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The Antioxidant and Antibacterial Activity of Oriental Strawberry (*Arbutus andrachne* L.): A Review Article

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Abstract:

Oxidation is one of the most critical processes in food systems. It has an impact on a variety of dietary ingredient interactions, resulting in both desired and unwanted results. It was found in many studies that high concentrations of synthetic antioxidants may havesome carcinogenic effects in some animals, thus natural antioxidants would be analternative to synthetic antioxidants in food. These natural antioxidants can be present in any plant part, including grains, fruits, leaves, nuts, seeds, roots and barks. Many studies showed that there is an inverse relationship between the dietary intake of medicinal plants rich in antioxidants and the prevalence of human diseases. Oriental strawberry (*Arbutus andrachne* L.) is one of many medicinal plants for which antibacterial and antioxidant activity have been widely documented for a long time. This review intends to discuss the use of *Arbutus andrachne* L. as antibacterial and antioxidant.

Keywords: antioxidants, oriental strawberry, (*Arbutus andrachne* L.), medicinal plants, antibacterial activity.

النشاط المضاد للأكسدة والبكتيريا لنبات القيقب (*Arbutus andrachne* L.)

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تعد الأكسدة واحدة من أهم العمليات في النظم الغذائية، وهي ذات تأثير على مجموعة متنوعة من تفاعلات المكونات الغذائية، ممّا يؤدي إلى النتائج المرغوبة وغير المرغوب فيها. وقد وجد في كثير من الأبحاث أن التركيزات العالية من مضادات الأكسدة الاصطناعية قد يكون لها تأثيرات مسرطنة في بعض الحيوانات، وبالتالي فإن مضادات الأكسدة الطبيعية يمكن استعمالها كبديل لمضادات الأكسدة الاصطناعية في الطعام. ويمكن أنْ توجد مضادات الأكسدة الطبيعية هذه في أي جزء من أجزاء النبات، بما في ذلك الحبوب والفواكه والأوراق والمكسرات والبذور والجذور واللحاء. وقد أظهرت العديد من الدراسات أن هناك علاقة عكسية بين الاستهلاك الغذائي للنباتات الطبية الغنية بمضادات الأكسدة وانتشار الأمراض التي تصيب الإنسان. ويعد نبات القيقب (*Arbutus andrachne* L) واحداً من بين العديد من النباتات الطبية التي تم توثيق نشاطها باعتبراها مضاد للبكتيريا، ومضاداً للأكسدة على نطاق واسع ولفترة طويلة. تهدف هذه المراجعة إلى استعراض استخدام نبات القيقب كمضاد للبكتيريا ومضاد للأكسدة.

الكلمات المفتاحية: نشاط مضاد للتأكسد، القيقب (*Arbutus andrachn*e L.)، نباتات طبية، نشاط مضاد للبكتيريا.

Introduction

Foods are made up of proteins, saccharides, lipids, and vitamins that can be oxidized by free radicals (Škrovánková et al., 2012). Lipids are a group of molecules that have a variety of activities in the body, including functioning as an efficient source of energy, as cell membrane components and nerve tissues, as thermal and electrical insulators, and as local hormones, among others. Fats are also important nutritional elements due to the essential fatty acids and fat-soluble vitamins present in the fats of natural foods (Södergren, 2000). In addition, fats contribute to a variety of desirable food characteristics including texture, structure, color, mouth feel and flavor. However, the fundamental issue with food lipids is that they are extremely sensitive to oxidation processes that lead to food spoilage.Such spoilage may occur during the production, storage, distribution, and final preparation of foods, producing both desired and undesirable products (Wąsowicz et al., 2004). Moreover,oxidized fats are responsible for the loss of sensory quality in lipids and lipid-containing foods due to the production of offensive rancid odors flavors (Škrovánková et al., 2012).

The oxidation rate is proportional to the degree of unsaturation. Aldehydes, ketones, and alcohols are some of the oxidation products produced by lipid peroxidation (Ahmed et al., 2016; Böttcher et al., 2014). When oxygen combines with unsaturated lipids, their oxidation products have mutagenic, carcinogenic, and cytotoxic qualities that make them a risk factor for human health. These metabolites generate serious health problems, such as tumor cell development due to lipid peroxidation, as fatty acid hydroxides are genotoxic (Ahmed et al., 2016).

Oxidation of long-chain fatty acids causes neuromyopathy in both adults and children (Ahmed et al., 2016). Lipid oxidation decreases the nutritional value and shelf life of many complex food products by lowering the quantity of polyunsaturated fatty acids that are important to health (Ahmed et al., 2016). It is essential to increase the content of polyunsaturated fatty acids in foods to satisfy current dietary requirements; however, reduced oxidative stability is unavoidable as a result of this increase. As a result, antioxidants and lipid oxidation remains essential research subjects with great significance for both academia and business, necessitating both basic and applied studies (Jacobsen et al., 2019). Antioxidants have been shown to improve the oxidative stability of vegetable oils for both culinary and industrial use in numerous studies (Aluyor et al., 2008). Although synthetic antioxidants such as butylatedhydroxytoluene (BHT), butylatedhydroxyanisole (BHA), propyl gallate (PG), and tertbutylhydroquinone (TBHQ) are most widely used in foods, some reports have indicated that certain synthetic antioxidants such as BHA and BHT may possess weak carcinogenic effects in some animals at high levels (Shahidi and Zhong, 2010). As a result of concerns regarding the safety of synthetic antioxidants (Kumar et al., 2015), researchers have been looking for natural antioxidants in recent years. These antioxidants can be located in any plant part, including seeds, grains, leaves, roots, barks fruits and nuts. Phenolic compounds make up the majority of natural antioxidants, with phenolic acids, flavonoids (Kumar et al., 2015) and tocopherols (Shahidi and Zhong, 2010) being the most important. All of these can be found in a variety of plant sources (Kumar et al., 2015).

There is a worldwide trend of using natural substances found in medicinal plants as sources of therapeutic antioxidants. Thistrend has emerged due to rising human risk factors for numerous lethal diseases(Jamshidi-Kia et al.,2020 ;Hano and Tungmunnithum, 2020). It has been reported that the consumption of antioxidant-rich foods and medicinal plants has an inverse link with the prevalence of human diseases(Al-Aboudi and Afifi, 2011). Natural antioxidants would be a suitable alternative to synthetic antioxidants in the food, cosmetics, and pharmaceutical industries regarding their low cost and high compatibility with food intake, as well as lack of adverse effects on the human body (Lobo et al., 2010).

In addition to the antioxidant effects of many medicinal and edible plants, many authors have reported the antibacterial effects of using such plants of different families (Donmez, 2018; Baskan et al., 2019). Among the plants which have been reported to have antibacterial properties is *Arbutus andrachne* L. This plant is an edible wild plant that is dominant in many parts of Palestine and Jordan among other countries. In this review, we show that using plant sources of antioxidant compounds with a focus on *Arbutus andrachne* L. would be reflected on human health, whether through consumption of these food plants or their use in food and pharmaceutical industries.

The use of plants as antioxidants

According to numerous scientific studies, the antioxidant activity of medicinal plants from various parts of the world have been reported (Sen and Chakraborty, 2011). These plants exhibit a powerful antioxidant activity due to the existence of significantly higher levels of phenolic compounds compared to common vegetables and fruits. Flavonoids, tannins, curcuminoidscoumarins, lignans, stilbenes and quinones, are the main phenoliccompounds

identified in medicinal plants (Tlili et al., 2013). These phenolic compounds can react in different ways to delay or inhibit the oxidation reactions(Maury et al., 2020) according to one or more of the following mechanisms: (1) scavenging species that initiate peroxidation, (2) chelating metal ions so that they are unable to generate reactive species or decompose lipid peroxides, (3) quenching $O\bullet_2-$ preventing the formation of peroxides, (4) breaking the autoxidative chain reaction, and/or (5) reducing localized O2 concentrations (Maqsood et al., 2014).

The most effective antioxidants are those that inhibit free radical chain reactions. These antioxidants, which usually contain aromatic or phenolic rings, contribute H+ to free radicals generated during oxidation, becoming radicals themselves. The resonance delocalization of the electron within the aromatic ring and the creation of quinone structures stabilize these radical intermediates. As a result, these substances are regarded to be the most advantageous (Maqsood et al., 2014).

Oriental strawberry (*Arbutus andrachne*L.)

The Greek or "Oriental strawberry tree" (*Arbutus andrachne*L.) which belongs to the Ericaceae family and the Arbutoideae subfamily (Jafal et al., 2020) is a small tree that is evergreen (Aljabari et al., 2012), usually less than 4 m high. It is indigenous to South Western Asia and the Mediterranean region (Serçe et al., 2010). It is found in Palestine where it grows on rocky hills with high pHsoil (Aljabari et al., 2012). It is also widespread in enclaves in the Black Sea region, while it can be found naturally in Turkey's Mediterranean and Aegean regions (Saral et al., 2017). Moreover, it grows in Lebanon (Abidi et al., 2016 b) and in the Jordanian mountains at high altitudes including Jarash, Irbid and Ajloun areas (Jafal et al., 2020).

*Arbutus andrachne*L. has other names: in Turkey, the berries are known as "Davulga" or "Kocayemis" and the tree as "Sandal″ (Sıcak and Eliuz, 2019), whereas, the common name in the Arab countries is "Qaiqab or Qatlab" (Jafal et al., 2020). According to published studies, it was found that the bark and leaves of this tree contain triterpenoids, sterols, lipids, arbutin, menotropins, unedoside, and catechins (Aljabari et al., 2012). On the other hand, the fruits are rich in tannin, anthocyanin, and carotenoids which are generally sweet, although they have an unpleasant taste (Baskan et al., 2019) particularly when they are not fully ripe. They also contain triterpenoids, sterols, and lipids (Aljabari et al., 2012) and are rich in many acids and sugars including malic acid, fumaric acid, fructose, glucose and sucrose (Jafal et al., 2020)**(see Table 1).**

The smooth bark of the "Qaiqab or Qatlab" tree is exfoliating during the summer, leaving a layer with a pistachio green color, which changes to a beautiful orange-brown, while its flower blooms in spring with white or yellowish green color. Its fruits ripen in autumn (Abidi et al., 2016 b) and have a pleasant flavor. They can be eaten fresh, dried (Aljabari et al., 2012), or changed into a variety of culinary products such as jelly, beverage, jam (Donmez, 2018), alcoholic beverages (liquor and wine), and marmalade (Baskan et al., 2019). (

The biological properties of the Oriental strawberry is well known since a long time ago; traditionally the plant has been used in folk medicine (Abidi et al., 2016 a), as anti-diarrheal and depurative, as a blood tonic, for joints pain, in the treatment of wounds, as well as astringent and antiseptic for the urinary tract (Aljabari et al., 2012; Abidi et al., 2016 a).

Arbutus andrachne L. became endangered species because of the increasing demand, due to its wide medical uses. In Jordan, it is considered the highest among 51 other medicinal plant species that have antioxidant content (Aljabari et al., 2012). Moreover, its effect as anticancer, antimicrobial, and anti-inflammatory is well known (Baskan et al., 2019).

According to the literature, the plant had also hypolipidemic, and hypoglycemic protective effects in diabetic rats. Furthermore, it was reported to have immunological defensive effects related to changes in the number of white blood cells (WBCs) in rats, as well as anti-proliferative, anti-malarial, antibiotic, and anti-hypertensive properties (Jafal et al., 2020).

The use of oriental strawberry as an antioxidant

Antioxidant activity has been demonstrated in several different plant extracts and products (Çoban et al., 2003). The chemical composition of *Arbutus andrachne* fruits shows that they are rich in phenolic and antioxidant capacity **(Table 2),** are good providers of ascorbic acid and minerals, and are poor in soluble sugars (Seker and Toplu, 2010).

Table 1: Nutrition Composition of *Arbutus andrachne* L. According to its studied part and location.

Author and year	Location	Cultivars	Studied part	Nutrient Contents
Seker and Toplu, 2010	Turkey	*A.andrachne* L.	Fruits	Protein 3.77%, moisture 38.21%, ash 4.35%, pH 4.3, soluble solids 14%, acidity 0.6, ascorbic acid 140 mg/100g, fructose 4.12% DW, glucose 2.73% DW, sucrose 0.16% DW, aluminum 17.35 mg/kg, arsenic 0.36 mg/kg, boron 23.53 mg/kg, beryllium 0.01 mg/kg, calcium 7.2 mg/kg, cadmium 0.01 mg/kg, chromium 11.47 mg/kg, gallium 0.01 mg/kg, iron 61.46 mg/kg, copper 17.91 mg/kg, potassium 9.85 mg/kg, magnesium 872.6 mg/kg, lithium

				0.37 mg/kg, manganese 27.68 mg/kg, sodium 1.12 mg/kg, nickel 0.05mg/kg, phosphorus 3.25 mg/kg, vanadium12.37 mg/kg, zinc 33.78 mg/kg.
Serce et al., 2010	Turkey	*A.andrachne* L.	Fruits	Malic acid 0.34g/100g, ascorbic acid 0.10 g/100g, citric acids 0.03 g/100 g, total sugars 16.38 g/100 g, fructose 9.75 g/ 100 g, glucose 5.33 g/100 g, sucrose 1.19 g/100 g.
Karabulut et al., 2006	Turkey	*A.andrachne* L.	Leaves	Protein 10.5%, ash 4.4%, NDF 49.2%, ADF 37%.
Kamalak et al., 2010	Turkey	*A.andrachne* L.	Leaves	DM 93.28%, protein 1.13- 4.9%, NDF 29.43-35.58 %, ADF 24.99- 30.22%, ash 4.86-7.65%, CT 11.63-20.71 mg.

CT: condensed tannin, DW: dry weight, NDF: neutral detergent fiber, ADF: acid detergent fiber.

Table 2: Bioactive compound content, antioxidant and antibacterial activity of *Arbutus andrachne L.* according to its parts, Location and Cultivar.

Author and year	Location	Cultivars	Studied part	Bioactive compounds and activities	Main Outcome
Tawaha et al., 2007	Jordan	*A.andrachne* L.	Not mentioned	Phenolic compounds Antioxidant activity	57.6-58.6 mg GAE/g DW 720 - 731 µmol TE/g DW
Saral et al., 2017	Turkey	*A.andrachne* L.	Flowers	Phenolic compounds Flavonoids Antioxidant activity	43.57 mg GAE/g DW 114.28 mg QE/g DW 104.81 µmol FeSO4.7H2O /g DW
			Fruits	Phenolic compounds Flavonoids Antioxidant activity	7.29 mg GA/g DW 6.17 mg QE/g DW 3.41 µmol FeSO4.7H2O /g DW
Bilto et al., 2015	Jordan	*A.andrachne* L.	Leaves	Phenolic compounds Flavonoids Antioxidant activity	105 mg CE/g Ext 112 mg Ruta E/g Ext IC50 19 µg/ml
Seker and Toplu, 2010	Turkey	*A. andrachne* L.	Fruits	Phenolic compounds Antioxidant activity	64.8mg GAE/g DW 47.52 µMTE/g DW
		A. unedo L.	Fruits	Phenolic compounds Antioxidant activity	26.75 mg GAE/g DW 18.51 µMTE/g DW
Hmaidosh , et al., 2020	Syria	*A. andrachne* L.	Leaves	Phenolic compound Antioxidant activity	37.25 mg GAE/g FW 16.81µMFe2 +/g
			Fruits	Phenolic compounds Antioxidant	3.62 mg GAE/g FW 1.02

				activity	µMFe2+/g
			Flowers	Phenolic compounds Antioxidant activity	38.32 mg GAE/g FW 19.35 µMFe2+/g
			Bark	Phenolic compounds Antioxidant activity	36.93 mg GAE/g FW 14.33 µMFe2+/gFW
Bouyahya et al., 2016	Morocco	A .unedo L.	Leaves	Phenolic compounds	133.61 mg GAE/g Ext
				Antibacterial activity	Against *S. aureus* , *L. monocytogenes*, *P. aeruginosa* and *Escherichia coli*
Serce et al., 2010	Turkey	*A. andrachne* L.	Fruits	Phenolic compounds Antioxidant activity	2422 - 4102 µg GAE /g FW, 36.1 µmol TE g/FW
Baskan et al., 2019		*A. andrachne* L.	Leaves	Phenolic compounds Flavonoids Antioxidant activity	11.6-151.87 mg GAE/g Ext 65.2-71 mg QTE/g EXT IC50 146.6-333.3 ml/ml
				Antibacterial activity	against *Bacillus subtilis, Bacillus cereus and Staphylococcus aureus*
Ergun et al., 2014	Turkey	*A. andrachne* L.	Leaves + flowers	Antibacterial activity	against *S. aureus* -17, *S. aureus*- 18, CNS-33, CNS-36, CNS-37 at inhibition zones between 8-17mm.

			Leaves	Antioxidant activity	2.10 µMTE/g dry biomass, IC50=81%, CAT; 0.35 µM/min/g fw APX; 7.61 µM/min/g fw
			Flowers	Antioxidant activity	2.11 µMTE/g dry biomass, IC50=81%, CAT; 0.25 µM/min/g fw APX; 8.8 µM/min/g fw
Sıcak and Eliuz 2019	Turkey	*A. andrachne* L.	Essential oil from wood	Antioxidant activity	IC50 = 3.22 µg/mL: β-carotene/ linoleic acid assay. IC50=3.47 µg/mL: ABTS assay. IC50=48.31µ g/mL DPPH˙ assay IC50=27.55 µg/Ml: CUPRAC assay
				Antibacterial activity	against *B. subtilis*, *C. albicans*, *C. parapsilosis*, *E. coli*, *P. aureginosa* and *S. aureu*
Abidi et *al*., 2016 (a)	Lebanon	A. andrachne L.	Bark roots	Phenolic compounds Flavonoids Tannins Total anthocyanins	298.65-547.15mg GAE/g DM 17.25-48.81mg QE/g DM 48.14-207.83mg CA/g DM 65.38-338.41mg/g DM
Abidi et al., 2016	Lebanon	*A. andrachne*L.	Roots	Antioxidant activity	IC50= 0.63-1.8 µg/mL

(b)					2 mg /ml
Okman , 2015	Turkey	*A. andrachne*L.	Flowers	Antioxidant activity	2.25 mg TE/100g ml
			Leaves	Antioxidant activity	1.88mg TE/100g/ ml
Isbilir et al.,2012	Turkey	*Arbutus unedo*L.	Flowers	Phenolic compounds Antioxidant activity	232.38 mg GAE/g EXT IC50= 81.3 ug/ml
Malheiro et al., 2012,	Portugal	*Arbutus unedo*	Leaves	Antibacterial activity	Against: *B. cereus, B. subtilis, S. aureus*and *S. epidermis, E. coli, P. aeruginosa, C. albicans, C. krusei*, *C. parapsilosis*and *C.glabrata.*

TE: Trolox equiv, FW: Fresh weight, DW: Dry weight, CNS: Coagulase negative Staphylococci, CAT: Catalase activity, APX: Ascorbate peroxidase.

The antioxidant properties of methanol extracts of *Arbutus andrachne*L.fruits, roots, and leaves against electrolysis, as well as their effect on the cardiac dynamics of isolated perfused rabbit hearts, were tested by Abidi et al. (2016 b). Their findings demonstrated that the roots have the highest in vitro antioxidant activity of all of the methanol extracts, especially at 2 mg, which fully blocked free radical formation after 4 minutes.

On the other hand, Başkan et al. (2019) confirmed that the ethanol extract of *A. andrachne*showed the best antioxidant activity. Furthermore, in the presence of H2O2, chloroform, hexane and ethanol extracts of *A. andrachne*L. displayed repair effects on plasmid DNA. According to another study, the flowers of *A. andrachne*had higher antioxidant activity, phenolic and flavonoid content than the fruits (Saral et al., 2017). This was supported by the findings of Okman, (2015) who discovered that the flowers of the plant were superior to their leaves in terms of phenolic content and antioxidant efficiency, while the study of Isbilir et al., (2012) found that flowers of *Arbutus unedo*L. (a variety close to *Arbutus andrachne*L.) were superior in their antioxidant effectiveness compared to fruits.

Catalase, superoxide dismutase, and glutathione peroxidases are examples of antioxidant enzymes that can be found in both humans and plants (André et al., 2010). When plants are stressed, antioxidant enzymes such as catalase and peroxidase increase. According to Ergun et al., (2014), the enzyme activity of ascorbate peroxidase (APX) and catalase (CAT) were shown to be greater in the flowers of *Arbutus andrachne*L. than in the leaves.

The highest content of phenolic compounds (38.32 mg/g) was found in the flowers, which were followed by the leaves (37.25 mg/g), the bark (36.93 mg/g), and finally the fruit. (3.62mg/g) (Hmaidosh et al., 2020). These findings are similar to those of Serce et al., (2010) who found that the phenolic component concentration of *Arbutus andrachne*fruits was 2.4 mg/g in fresh weight (FW), while Saral et al., (2017) found that the phenolic content of *Arbutus andrachne*fruits was 7.29 mg/g of fresh weight.

Effect of oriental strawberry as an antibacterial

The antibacterial activity of Arbutus andrachne L. leaves extracts is identified in chloroform, ethanol and hexane extracts. The results approved that hexane extracts had the strongest antibacterial action against Bacillus subtilis and Bacillus cereus. Moreover, ethanolic extracts were the most effective on S. aureus and B. cereus (Baskan et al., 2019). Similarly, in another research conducted in Turkey by Ergun et al., (2014), it was demonstrated that A. andrachne L. extracts inhibited the growth of five bacterial species and the inhibition zones ranged between 8- 17 mm. The most potent antibacterial effect was observed on S. aureus (17 mm .(According to the study that was conducted by Sıcak and Eliuz, (2019) about the determination of the antioxidant and antimicrobial effects of essential oil from *A. andrachne* L. wood that grows in Turkey, the findings revealed that the essential oil can be utilized in food as a potential antibacterial agent.

Although there is little information in the literature about *A. andrachne's*antibacterial potency, Tenuta et al., (2019) mentioned that *Arbutusspp.*leaves had the most promising action against Gram-positive bacteria. They also showed strong antibacterial action against Bacillus subtilis, Pseudomonas aeruginosa and *Staphylococcus aureus*, as well as a moderate antimicrobial effect against *Escherichia coli* and *Salmonella typhimurium*. In a similar investigation conducted by Malheiro et al., (2012), it was found that concentrations ranging from 0.1 to 20 mg/mL of *Arbutus unedo*leave extracts showed antimicrobial efficiency against a variety of microorganisms, including *B. cereus, B. subtilis, S. aureus and S. epidermis, E. coli, P. aeruginosa, C. albicans, C. krusei, C. parapsilosis and C.glabrata.* On the other hand, it was shown that methanolic, ethanolic, ethyl acetate and n-hexane extracts from *Arbutus unedo*leaves had an antibacterial effect against *E. coli, Staphylococcus aureus, Pseudomonas aeruginosa*and *Listeria monocytogenes*, with the minimal inhibitory concentrations of 0.2 mg/mL to 8 mg/mL (Bouyahya et al., 2016).

Conclusion

Arbutus andrachne L. is a wild edible plant which was known to have many biological properties and has been traditionally used in folk medicine. In this review, we focused on its antioxidant and antibacterial activities that may clarify some of its medicinal importance.

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