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Nutritional and Bioactive Properties of *Rubus ulmifolius* Schott (Blackberry): A Review

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ABSTRACT

Rubus ulmifolius Schott, commonly known as blackberry, has been widely used as a food source as well as in jams, juices, *etc.* for its purported medical benefits. It has also been extensively investigated for its nutritional and bioactive constituents, which might be responsible for these benefits. In general, the plant is rich in carbohydrates, lipids, vitamins and minerals. The primary carbohydrates are glucose and sucrose; while ascorbic acid has been reported to be the primary vitamin, contributing to the acidic nature of the fruits. The bioactive compounds identified in the various plant parts include polyphenols such as phenolic acids, flavonoids and anthocyanins and other chemicals in lesser amounts. The antioxidant and antimicrobial properties of various parts of the plant have been investigated. The antioxidant effect has been attributed both to the presence of ascorbic acid as well as the other polyphenolic compounds. An antimicrobial activity has also been reported against the common human pathogens. This review summarizes the prevailing literature on the nutritional and bioactive composition of the plant and the evidence for its antioxidant and antimicrobial properties. This review summarizes the prevailing literature on the nutritional and bioactive composition of the plant and the evidence for its antioxidant and antimicrobial properties.

Key words: Antimicrobial, Antioxidant, Blackberry, Nutritional composition, Polyphenolic content.

Rubus ulmifolius Schott (wild blackberry or elm-leaf blackberry) is one of the natural products that have been widely investigated for its beneficial properties with respect to nutrition and health. The plant is a perennial shrub of the family *Rosaceae* (Sochor *et al*., 2018). It is native to Europe, North Africa and parts of Asia. The detailed taxonomy of the plant is outlined in Table 1. The plant flowers during the months of May and June following which the fruits ripen and their colour changes from green to black; hence the term called 'blackberry' (Bandeira Riedel *et al*., 2016). Apart from direct consumption, the deliciously flavoured fruits are also used in juices, jams and marmalades (da Silva *et al*., 2019; Peano *et al*., 2017).

Rubus ulmifolius was used as a traditional medicine in Chile for its hypoglycaemic property (Lemus *et al*., 1999). It has been also used as antipyretic as well as carminative agent (Ahmad *et al*., 2013). In Italy, the plant has been served as a folk medicine for treating the diseases like haemorrhoids, intestinal inflammations, abscesses, ulcer, diarrhoea, red eyes, along with vaginal infections (Manganelli and Tomei, 1999). *Rubus ulmifolius* offers phenolic acid and flavonoids which provides antioxidant activity also (Ali *et al*., 2017).

This review describes the nutrients and the bioactive compounds identified in various parts of the *Rubus ulmifolius* Schott plant along with the antioxidant, antimicrobial and antipyretic activity of the plant.

Nutritional value

The fruits of *Rubus ulmifolius* are rich in various nutrients, as outlined in various studies (Table 2). Consumption of fresh fruits of berries such as *Rubus* is associated with a greater amount of nutritional content than that of processed or refined foods (Fuhrman, 2018; Moscato and Machin, 2018; Moubarac *et al*., 2017; Murray *et al*., 2013). These values tend to differ substantially in various studies probably due to the differences in the geographical location of the plant, the part of the plant selected for the study, as well as the extraction methods used (Faniadis *et al*., 2010). Similar variations are also reported with other berries of the *Rubus* genus (Yang *et al*., 2018; Uhler and Yang, 2018; Wajs-Bonikowska *et al*., 2017; Mazur *et al*., 2014; Krauze-Baranowska *et al*., 2014).

The dry matter content in the has been reported in various studies to vary from 12% to 28%, the ash content around 3.5 g/100 g of dry matter and the pH between 3.3 to 3.7 is acidic with the presence of citric and other acids (Schulz and Chim, 2019; Contessa *et al*., 2013).

Carbohydrates

The studies on multiple berries with regards to their sugar content was reviewed by Lee (2015) and reported that the

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total sugars in the *Rubus* fruits range from 2.6 - 13.9 g per 100 g of the fruit, with the major sugars being glucose, sucrose, fructose and sorbitol (Table 2). Similarly, glucose and fructose were reported to have the highest concentrations; and malic and citric acids are the major organic acids in the berries (Mikulic-Petkovsek *et al*., 2012). Schulz and co-workers (2019) revealed that the mature blackberry fruits contained around 17.38 g/100 g of glucose and 22.52 g/100 g of fructose; while the fully mature blackberry fruits contained 19.12 g/100 g of glucose and 26 g/100 g of fructose.

Lipids

Blackberries are generally low in fat. However, 74 different lipid compounds are present in the *Rubus ulmifolius* fruit volatiles by solid-phase microextraction (D'Agostino *et al.*, 2015). Ahmad *et al.* (2015) reported a total lipid content of 4.7% in the *Rubus ulmifolius* fruit. Moreover, linoleic acid is the most common lipid in the *Rubus ulmifolius* fruits (Morales *et al.*, 2013).

Vitamins

The presence of Vitamin C in *Rubus ulmifolius* fruits from two different sites in Madrid, Spain was observed by Ruiz-Rodriguez and co-workers (2014), who reported that majority of the Vitamin C (60%) was present as ascorbic acid and dehydroascorbic acid.

Minerals

The concentration of minerals such as sodium, potassium, manganese, magnesium, calcium, *etc.* have been identified by different researchers. These have also been summarized in Table 2. According to Schulz *et al.* (2019), the concentrations of sodium, potassium and calcium decreased significantly while that of magnesium increased further with the ripening of the fruit. This reduction may be attributed to the utilization of the minerals during the process of ripening.

Bioactive compounds

The fruits of *Rubus ulmifolius* have been the subject of considerable attention on account of their rich anti-inflammatory as well as antioxidant properties, which was due to the presence of polyphenols, ascorbic acid and tannins (Barros *et al*., 2010). The nature of these bioactive compounds and their concentration has been the subject of intensive study and scrutiny by various researchers.

Phenolic compounds

Compounds with a phenolic structure such as flavonoids, phenolic acids, anthocyanins, hydroxycinnamic acids, ellagic acid, cyanidin-3-*O*-glucoside derivatives along with carotenoids have been reported in the literature in various berries such as blackberry and raspberry (Staszowska-Karkut and Materska, 2020; Oszmiański *et al*., 2015; Amjad *et al*., 2013). In a recently published study by Candela *et al.* (2021), dihydroflavonol glycosides, quercetin and proanthocyanidins has been confirmed as the primary phenolic compounds.

Total phenols

The total phenolic content has been reported in the total *Rubus ulmifolius* fruits in two edible stages (Della Betta *et al*., 2018; Contessa *et al*., 2013), hydroalcoholic extract of flowers and decoction from lyophilized flowers (Martins *et al*., 2014), polar and non-polar extracts of fruits (Akkari *et al*., 2016) and leaves (Tabarki *et al*., 2017).

Phenolic acids

The average concentration of phenolic acids in wild *Rubus ulmifolius* fruits at two different sites in Madrid and was found to be 414.34 mg/100 g; gallic acid being the predominant phenolic acid with a concentration of 268.72±183.35 mg/100 g (Ruiz-Rodriguez *et al*., 2014). Gallic acid concentration 481.71±0.81 µg/100 g was reported in the fruit by Schulz *et al*., (2019). Twenty-four phenolic compounds were identified in the phenolic extracts of *Rubus ulmifolius* flowers, out of which seven were phenolic acid derivatives, eleven as flavonoids and six were tannins (Martin *et al*., 2014). Ellagic acid was identified only in the decoction and not in the extract.

Flavonoids

The presence of flavonoids in the aerial parts of the plant has been confirmed in *in vitro* and in animal studies (Ali *et al*., 2017). In their study, Ruiz-Rodriguez *et al.* (2014) reported the 44 mg/100 g total flavonoids in *Rubus ulmifolius* fruit. The total flavonoids content was almost equal in both the hydroalcoholic extract of flowers and decoction from lyophilized flowers of *Rubus ulmifolius* evaluated (14.45± 0.44 mg/g and 13.38 ± 0.05 mg / g) (Martins *et al*., 2014). Akkari *et al*., (2016) found that the total polyphenolic content was highest in the aqueous extracts of the *Rubus ulmifolius* fruits (28.06 mg QE/g of dry weight) and lowest in the hexanic extracts (0.71 mg QE/g of dry weight).

The studies also reported the content of flavonoids such as catechin, quercetin 3-*O*-glucoside, quercetin 3-*O*-rutinoside, kaempferol 3-*O*-glucoside and kaempferol 3-*O*-rutinoside in both the hydroalcoholic extract of the flowers as well as the decoction prepared from the lyophilized flowers (Table 3).

Schulz *et al*., (2019) identified that thirteen flavonoid compounds in *Rubus ulmifolius* fruits were present among which are quercetin, isoquercitin, kaempferol, catechin and

Table 1: Classification of *Rubus ulmifolius*.

Heading	Name
Domain	Eukaryota
Kingdom	Plantae
Phylum	Spermatophyta
Subphylum	Angiospermae
Class	Dicotyledonae
Order	Rosales
Family	Rosaceae
Genus	*Rubus*
Species	*R. ulmifolius*

Table 2: Nutritional content of *Rubus ulmifolius*.

Content	Concentration	Part of plant	References
	Carbohydrates		
Total sugars	2.6 - 13.9 g/100 g fresh weight	Fruit	(Lee, 2015)
Glucose	17.38±0.48 g/100 g dry matter	Mature fruit	(Schulz *et al.*, 2019)
	19.12±0.01 g/100 g dry matter	Fully mature fruit	(Schulz *et al.*, 2019)
Fructose	22.52±0.74 g/100 g dry matter	Mature fruit	(Schulz *et al.*, 2019)
	26.00±0.47 g/100 g dry matter	Fully mature fruit	(Schulz *et al.*, 2019)
	Lipids		
Methylbutanal	2.02-25.70%	Fruit volatile	(D'Agostino *et al.*, 2015)
Methylbutanoic acid	0.53-21.48%	Fruit volatile	(D'Agostino *et al.*, 2015)
Trans-2-hexenal	0.49-17.49%	Fruit volatile	(D'Agostino *et al.*, 2015)
1-hexanol	0.56-16.39%	Fruit volatile	(D'Agostino *et al.*, 2015)
2,3-butanedione	2.31-14.71%	Fruit volatile	(D'Agostino *et al.,* 2015)
1-octanol	0.49-10.86%	Fruit volatile	(D'Agostino *et al.,* 2015)
3-hydroxy-2-butanone	0.08-7.39%	Fruit volatile	(D'Agostino *et al.*, 2015)
	Vitamins		
Ascorbic acid	10.59 mg/100 g fresh weight	Fruit	(Ruiz-Rodríguez *et al.,* 2014)
Dehydroascorbic acid	5.32 mg/100 g fresh weight	Fruit	(Ruiz-Rodríguez *et al.,* 2014)
	Minerals		
Sodium	5.05±0.22 mg/g dry matter	Mature fruit	(Schulz *et al.*, 2019)
	1.68±0.03 mg/g dry matter	Fully mature fruit	(Schulz *et al.*, 2019)
Potassium	24.09±1.63 mg/g dry matter	Mature fruit	(Schulz *et al.*, 2019)
	15.40±0.47 mg/g dry matter	Fully mature fruit	(Schulz *et al.*, 2019)
Calcium	6.39±0.05 mg/g dry matter	Mature fruit	(Schulz *et al.*, 2019)
	4.33±0.18 mg/g dry matter	Fully mature fruit	(Schulz *et al.*, 2019)
Magnesium	3.35±0.06 mg/g dry matter	Mature fruit	(Schulz *et al.*, 2019)
	7.07±0.08 mg/g dry matter	Fully mature fruit	(Schulz *et al.*, 2019)

epicatechin (Table 3). Quercetin 3-galactoside, quercetin 3-glucoside and quercetin-3-rutinoside are the major flavonoid compounds present in the *Rubus ulmifolius* wild fruits. Kaempferol-3-*O*-rutinoside and naringenin have been previously identified by Tabarki and co-workers (2017) as the dominant phenolic compounds in the extracts of *Rubus ulmifolius* leaves.

Anthocyanins

Anthocyanins are pigments responsible for imparting colours such as red, blue and purple to the fruits. The total anthocyanins in *Rubus ulmifolius* wild fruits was 141.89 mg /100 g with pelargonidin-3-rutinoside, cyanidin-3-glycoside and cyanidin-3-glucoside being the major compounds (Ruiz-Rodriguez *et al*., 2014).

More recently, six anthocyanins have been identified by Candela *et al.* (2021) in the *Rubus ulmifolius* fruit extract, the major constituents being cyanidin dihexoside and cyanidin dioxalylglucoside and others being pelargolidin and delphinidin. Anthocyanidins and proanthocyanidins have also been similarly reported in varying concentrations in other fruits of the *Rubus* genus as well.

Other compounds

Apart from the phenolic acids and flavonoids, lignin-derived aldehydes (sinapaldehyde, coniferaldehyde and syringaldehyde) have also been reported in *Rubus ulmifolius* fruits in concentrations between 0.15 to 0.75 µg/g of the fruit (Schulz *et al*., 2019) along with hydrolysable tannins (203.39 mg/g) (Martins *et al*., 2014).

Bioactive effects

The major benefits of the *Rubus ulmifolius* plants that have been primarily explored include the antioxidant and antimicrobial activities.

Antioxidant activity

Antioxidant activities have been reported with various *Rubus* plants (Samaniego *et al*., 2020; Caidan *et al*., 2015; Skrovankova *et al*., 2015).

Ruiz-Rodriguez *et al*., (2014) measured the mean antioxidant activity of the *Rubus ulmifolius* wild fruits by using four different methods as mentioned in Table 4. The antioxidant activity of the hydroalcoholic extract of *Rubus ulmifolius* flowers was much greater than the decoction from lyophilized flowers (Martins *et al*., 2014).

The antioxidant activity of the *Rubus ulmifolius* leaves extracts obtained from four different sites in Tunisia was dependent upon the phenol content of the leaves (Tabarki *et al*., 2017) (Table 4).

Schulz *et al*., (2019) reported the antioxidant activity of the mature and fully mature fruits of *Rubus ulmifolius* and

Table 3: Concentration of phenolic compounds in *Rubus ulmifolius*.

Compound	Concentration	Part of plant	References
	Phenolic acids		
Total phenolic acid	607.67 mg/100 g	Fruit	(Ruiz-Rodriguez *et al.*, 2014)
	21.28±0.59 mg/g	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
	23.21±0.96 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
	64.5 mg GAE/g dry weight	Aqueous extract of fruit	(Akkari *et al.*, 2016)
	1.57 mg GAE/g dry weight	Hexanic extract of fruit	(Akkari *et al.*, 2016)
	53.32 mg GAE/g dry weight	Leaves extract	(Tabarki *et al.*, 2017)
3, 4-Dihydroxybenzoic acid	481.71±0.81 µg/100 g	Fruit	(Schulz *et al.*, 2019)
Gallic acid	1510.97±80.36 µg/100 g	Fruit	(Schulz *et al.*, 2019)
	268.72±183.35 mg/g	Fruit	(Ruiz-Rodríguez *et al*, 2014)
Ellagic acid	5.69±0.28 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
3-*p*-Coumaroylquinic acid	1.45±0.00 mg/g	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
	1.18±0.12 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
3-O-Caffeoylquinic acid	17.83±0.55 mg/g	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
	13.69±0.63 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
	Flavonoids		
Total flavonoids	51.44 mg/100 g	Fruit	(Ruiz-Rodríguez *et al.*, 2014)
	14.45±0.44 mg/g	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
	13.38±0.05 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
	28.06 mg QE/g of dry weight	Aqueous extract of fruit	(Akkari *et al.*, 2016)
	0.71 mg QE/g of dry weight	Hexanic extract of fruit	(Akkari *et al.*, 2016)
Isoquercetin	15.27±0.6 µg/100 g	Fruit	(Schulz *et al.*, 2019)
Quercetin	91.50±1.5 µg/100 g	Fruit	(Schulz *et al.*, 2019)
Quercetin-3-*O*-rutinoside	0.48±0.03 mg/g	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
	0.48±0.05 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
Quercetin-3-*O*-glucoside	2.54±0.03 mg/g	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
	2.05±0.27 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
Catechin	2.83±0.10 mg/g	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
	2.29±0.37 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
Kaempferol-3-*O*-glucoside	0.71±0.01 mg/g	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
	0.74±0.06 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
Kaempferol-3-*O*-rutinoside	0.62±0.11 mg/g	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
	0.76±0.03 mg/g	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
	Anthocyanins		
Total anthocyanins	141.89 mg/100 g	Fruit	(Ruiz-Rodríguez *et al.*, 2014)

Table 4: Antioxidant activity of *Rubus ulmifolius.*

Antioxidant activity	Test	Part of plant	References
34.23±2.75 µg/mL (EC_{50} value)	DPPH scavenging activity	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
184.21±21.40 µg/mL (EC_{50} value)	DPPH scavenging activity	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
29.27±0.80 µg/mL (EC_{50} value)	Reducing power	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
191.23±0.58 µg/mL (EC_{50} value)	Reducing power	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
3.90±0.46 µg/mL (EC_{50} value)	β-carotene bleaching inhibition	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
197.04±4.81 µg/mL (EC_{50} value)	β-carotene bleaching inhibition	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
1.58±0.07 µg/mL (EC_{50} value)	TBARS inhibition	Hydroalcoholic extract of flowers	(Martins *et al.*, 2014)
201.72±3.67 µg/mL (EC_{50} value)	TBARS inhibition	Decoction from lyophilized flowers	(Martins *et al.*, 2014)
89.99% (100 µg/mL)	*In vitro* ROS scavenging activity	Methanolic extract	(Hajaji *et al.*, 2017)
79.55% (100 µg/mL)	Inhibition of superoxide generation	Methanolic extract	(Hajaji *et al.*, 2017)
99.95% (100 µg/mL)	*In vitro* hydrogen peroxide scavenging activity	Methanolic extract	(Hajaji *et al.*, 2017)
241.06/ µM Fe^{+2}/per g of dry matter	Ferric reducing antioxidant power (FRAP) assay	Fully mature fruit	(Schulz *et al.*, 2019)
7.62±3.61 mmol Trolox equivalent per 100 g of fresh weight of fruit	Ferric reducing antioxidant power (FRAP) assay	Wild fruit	(Ruiz-Rodríguez *et al.*, 2014)
28.22/mg gallic acid equivalent (GAE)/per g of dry matter	Folin-Ciocalteu assay	Fully mature fruit	(Schulz *et al.*, 2019)
39.40 mg/L (IC_{50} value)	Reducing power	Leaves extract	(Tabarki *et al.*, 2017)

observed that the antioxidant capacity was higher in the fully mature fruit, indicated by the values of 241.06/ µM Fe^{+2}/ per g of dry matter by the FRAP assay and 28.22/ mg GAE/ per g of dry matter by the Folin-Ciocalteu assay (Table 4). The antioxidant activity of the crude methanolic extract was equivalent to that of ascorbic acid (Ali *et al.*, 2017). Contrarily, the antioxidant activity of the methanolic extract of *Rubus ulmifolius* has been reported to be more than ascorbic acid (Hajaji *et al.*, 2017).

Antimicrobial activity

The extracts of various parts of *Rubus ulmifolius* plants identified to have activity against microbes pathogenic to humans.

Biofilm formation by *Staphylococcus aureus* was inhibited by the butanolic extract of *Rubus ulmifolius* roots at concentrations from 50-200 µg/mL; that has been attributed to the presence of ellagic acid and its derivatives (Quave *et al.*, 2012). It has also been identified that ellagic acid xyloside and ellagic acid rhamnoside in the leaf extracts of *Rubus ulmifolius* inhibit biofilm formation by *Staphylococcus aureus* (Fontaine *et al.*, 2017). In another study, the structure of Rubanthrone A, an anthrone derived from the aerial parts of *Rubus ulmifolius* was shown to have an *in vitro* activity against *Staphylococcus aureus* at 4.5 mg/mL concentration (Flamini *et al.*, 2012). The planktonic cultures of *Streptococcus pneumoniae* were completely eradicated at an *in vitro* concentration of 80 µg/mL of the butanolic extract on overnight incubation (Talekar *et al.*, 2014).

In another study, the methanolic extract of *Rubus ulmifolius* was detected to have an activity against *Entamoeba histolytica in vitro* with IC_{50} value of 61.785 ± 1.322 µg/mL; as also against *Staphylococcus aureus, Streptococcus agalectiae, Salmonella typhimurium, Escherichia coli and Candida albicans* with MIC values between 2.29-4.76 mg/mL for these organisms (Hajaji *et al.*, 2017).

Antimicrobial activity of the *Rubus ulmifolius* leaves extracts with MIC values between 6.25-25 mg/mL and inhibition zones between 8-16 mm in diameter against six different bacteria was observed and was higher in Gram-positive bacteria (Tabarki *et al.*, 2017).

Antipyretic activity

In rats, pyrexia was induced by injecting 20% Brewer's yeast at a dose of 1 ml/100 g body weight (Ali *et al.*, 2011). The study comprised rats with a temperature rise of at least 0.5°C to 1°C. Ali *et al.* (2017) conducted an experiment in which they divided the albino rats into 6 groups (GI - GVI) involving six rats in every group. The GI (control group) was given 2 percent gum acacia orally. The GII group functioned as the control group, receiving paracetamol orally (33 mg/kg of body weight in 2% gum acacia). GIII and GIV were given 150 mg/kg and 300 mg/kg body weight of *Rubus ulmifolius* crude methanolic extract, respectively (per oral). GV and GVI, on the other hand, got 150 mg/kg

and 300 mg/kg body weight of *Rubus ulmifolius* crude flavonoids extract, respectively.

Antipyretic activity was observed in GIII, GIV, GV and GVI. The extract of crude flavonoids caused an 85.83 percent drop in body temperature in a test dose of 300 mg. On the fourth hour after administration, crude methanolic extract of *Rubus ulmifolius* in a test dose of 300 mg lowered rectal temperature by 74%. Overall findings showed that *Rubus ulmifolius* crude methanolic extract and crude flavonoids rich extract had significant antipyretic effect. Moreover, the presence of phytochemicals like flavonoids, which have been shown to inhibit cyclooxygenases, is responsible for *Rubus ulmifolius* considerable antipyretic activity (Rust *et al.*, 2008).

CONCLUSION

Rubus ulmifolius fruit offers good amount of nutrients like carbohydrates (mainly glucose and fructose), lipids, vitamin C and minerals (K and Ca). The different parts of the *Rubus ulmifolius* plant such as the fruits, leaves and flowers also contain various phenolic acids, flavonoids and anthocyanins. These compounds can be further explored for various health benefits such as antioxidant, antimicrobial and antipyretic activity. This plant can therefore, be incorporated as food supplements or further explored as phytopharmaceuticals for human ailments. However, further studies are warranted to explore this highly potential plant source, which has so far been relatively untapped.

Conflict of interest: None.

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