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REVIEW

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Ethnobotany of the genus *Taraxacum*—Phytochemicals and antimicrobial activity

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Plants belonging to the genus *Taraxacum* have been used in traditional healthcare to treat infectious diseases including food-borne infections. This review aims to summarize the available information on *Taraxacum* spp., focusing on plant cultivation, ethnomedicinal uses, bioactive phytochemicals, and antimicrobial properties. Phytochemicals present in *Taraxacum* spp. include sesquiterpene lactones, such as taraxacin, mongolicumin B, and taraxinic acid derivatives; triterpenoids, such as taraxasterol, taraxerol, and officinatrione; and phenolic derivatives, such as hydroxycinnamic acids (chlorogenic, chicoric, and caffeoyltartaric acids), coumarins (aesculin and cichoriin), lignans (mongolicumin A), and taraxacosides. Aqueous and organic extracts of different plant parts exhibit promising in vitro antimicrobial activity relevant for controlling fungi and Gram-positive and Gram-negative bacteria. Therefore, this genus represents a potential source of bioactive phytochemicals with broad-spectrum antimicrobial activity. However, so far, preclinical evidence for these activities has not been fully substantiated by clinical studies. Indeed, clinical evidence for the activity of *Taraxacum* bioactive compounds is still scant, at least for infectious diseases, and there is limited information on oral bioavailability, pharmacological activities, and safety of *Taraxacum* products in humans, though their traditional uses would suggest that these plants are safe.

KEYWORDS

antibiotic resistance, antimicrobial activity, food preservatives, functional foods, nutraceuticals, *Taraxacum*

1 | INTRODUCTION

Plants of the genus *Taraxacum* are members of the family Asteraceae and are widely distributed in the warmer temperate zones of the northern hemisphere (Schuetz, Carle, & Schieber, 2006). This genus was analysed in 1920 by Stork and was found to include more than 2,500 species (Stork, 1920). However, many new species of *Taraxacum* have been identified since then (Uhlemann, 2007), giving about 60 "sections" with a total of about 2,800 species (Kirschner, Drábková, Štěpánek, & Uhlemann, 2015).

Plants of the genus *Taraxacum* have a long history of use in traditional medicine (Martinez et al., 2015; Schuetz et al., 2006). Common dandelion (*Taraxacum officinale*) (Figure 1) is an ancient and very popular folk remedy, considered as an "elixir of life" (Hojimatov, 1989). Theophrastus, an ancient Greek scientist, recommended dandelion against freckles and liver spots on the skin. In Chinese traditional medicine, the dried roots of *T. officinale* have been used as a drug to cure oedema (Saeki et al., 2013). According to Abu Ali Sino (Avicenna), the milky juice of dandelion reduces the severity of glaucoma and the squeezed juice is very useful for liver protection and against hydrops, as well as an antidote for scorpion bites. Muhammad Husain indicated in his book "Mahzan-ul-adwiya" that dandelion arrests haemoptysis and strengthens the stomach. Its roots were used for the bite of poisonous insects and animals. In folk medicine of Central Asia, decoctions of dry grass and roots were used in the treatment of stomach diseases, abdominal pains, and kidney stones, as well as for the treatment of liver disorders due to its hepatoprotective effects (Asadi-Samani et al., 2015; Hojimatov, 1989). The leaves smoked like tobacco were used to treat cough. Leaf juice (2–3 tablespoons) was used for jaundice and bladder diseases (Hojimatov, 1989). It has been described the use of *T. officinale* to cure gout, diarrhoea, blisters, spleen, and liver complaints (Schuetz et al., 2006).

Some traditional uses of *T. officinale* have been validated by modern science. In addition to the data mentioned by the review paper cited above, Domitrovic, Jakovac, Romic, Rahelic, and Tadic (2010) investigated the efficacy of *T. officinale* root water-ethanol extract on CCl_4-induced liver fibrosis in mice, due to the inactivation of hepatic stellate cells and the enhancement of hepatic regeneration. Their results substantiated the traditional use of *T. officinale* root in hepatic disorders (Domitrovic et al., 2010). In addition, dandelion is considered safe and may improve the metabolism of androgens, recover hepatitis B infection, reverse *Helicobacter pylori*-related gastritis, and intestinal metaplasia, at least as suggested in a review by Yarnell and Abascal (2009). *T. officinale* has been investigated for its antioxidant properties (Hudec et al., 2007; Jeon et al., 2008), nutritional value (Escudero, De Arellano, Fernández,

FIGURE 1 Ligulate and bisexual florets of dandelion (*Taraxacum officinale* (L.) Weber ex F. H. Wigg) [Colour figure can be viewed at wileyonlinelibrary.com]

Albarracín, & Mucciarelli, 2003), and fatty acid composition (Liu, Howe, Zhou, Hocart, & Zhang, 2002), though its consumption may cause hypoglycaemia (Goksu, Eken, Karadeniz, & Kucukyilmaz, 2010). *T. officinale* extracts showed a powerful antiradical capacity in vitro (Kenny et al., 2014). According to a review by Asadi-Samani et al. (2015), which was focused on the hepatoprotective effects of Iranian medicinal plants, particularly against $CC1_4$ agent, *T. officinale* enhanced the levels of antioxidant enzymes (reduced glutathione content) and reduced lipid peroxidation in mice (Mahesh et al., 2010). This emphasizes again the hepatoprotective activity of extracts from this plant.

Many studies have documented the in vitro/in vivo anticancer activity of several plant phytochemicals, comprising chemopreventive and adjuvant activities (Bagheri, Mirzaei, Mehrabi, & Sharifi-Rad, 2016; Salehi, Zucca, et al., 2018). In this context, *Taraxacum* has also been used to treat breast cancer and sterility because some plant components showed an oestrogenic activity in traditional medicine. Oh, Kim, Park, Lee, and Chung (2015) hypothesized that *Taraxacum mongolicum* can act as a selective oestrogen receptor modulator and can be effective in hormone replacement therapy in postmenopausal women. *T. mongolicum* ethanol extract exerted oestrogenic activity in human breast cancer (MCF-7) cells and in immature female rats. The results on oestrogenic activity of *T. mongolicum* support its use in traditional medicine (Oh et al., 2015). In addition, Tahtamouni, Alqurna, Al-Hudhud, and Al-Hajj (2011) demonstrated that the aqueous extract of *T. officinale* decreased male rat fertility.

This review aims to summarize the available information on the cultivation, ethnomedicinal uses, bioactive phytochemicals, and antimicrobial activity of plants belonging to the genus *Taraxacum*.

2 | CULTIVATION OF PLANTS OF THE GENUS *TARAXACUM*

Various species of *Taraxacum* are cultivated for rubber production in temperate regions of the world. *T. officinale* seeds are sown under a thin layer of soil, and plants grow rapidly, producing relatively large roots (Josefsson, 1953; Van Beilen & Poirier, 2007). *T. officinale* grows well in a slightly acidic soil. Major problems for poor cultivation and yield of *Taraxacum* include difficulties in collecting the seeds due to uneven flowering, weak stems, and sensitivity to both dry and wet weather. The rubber molecules are located in the laticifers of the root (Kreuzberger, Hahn, Zibek, Schiemann, & Thiele, 2016), though difficulties in harvesting the roots efficiently make the entire cultivation process extremely laborious (Josefsson, 1953). To overcome these problems, trials were carried out by the Swedish Seed Association (Sveriges Utsädesförening) in the 1940s and 1950s to cross *T. officinale* with *Taraxacum kok-saghyz* (a species with larger roots, quicker growth rate, and better setting of seed) for improving cultivation and higher rubber production; however, the trials were unsuccessful. Conventional breeding was also conducted by the Swedish Seed Association in Svalöv, Skåne, between 1944 and 1952 (Josefsson, 1953) with the focus of increasing the rubber content of the root. In 1952, after 7 years of breeding, the average rubber content increased from 6–7% in the wild type to 15% in the bred populations. The average rubber content of the best selected lines was 23%, whereas some plants reached rubber contents as high as 30% (Josefsson, 1953).

Scientists are focusing currently on modern techniques to explore the pathways of rubber production, such as genetic engineering. However, at present, these experiments are restricted to *Hevea brasiliensis*, although it is expected that they can be applied in the future to *T. kok-saghyz* and its close relative *T. brevicorniculatum*. Currently, many of the proteins and molecular pathways involved in rubber biosynthesis are known (Hillebrand et al., 2012; Post et al., 2014; Schmidt et al., 2010; Wahler et al., 2009). It was shown that rubber from *T. kok-saghyz* contains less protein than rubber from *H. brasiliensis*, which might cause fewer allergic reactions (Van Beilen & Poirier, 2007).

There are several modern options to overcome the difficulties with cultivation of *Taraxacum* spp. plants in the field. In particular, it is easier to cultivate only the plant roots in vitro (Georgiev, Pavlov, & Bley, 2007; Pomar, Slabnik, Caso, & Díaz, 1986). It is also possible to cultivate roots in a sterile environment controlling the growth conditions without phytohormones. Another possibility is to cultivate only the rubber-producing laticifer cells in vitro; this has been tried as proof of concept but not at a larger scale (Post et al., 2014).

3 | ETHNOBOTANY RELATED TO THE ANTIBACTERIAL ACTIVITY OF THE GENUS *TARAXACUM*

Species of the genus *Taraxacum* have been used extensively by human populations in the treatment of various diseases. Martinez et al. (2015) recorded the medicinal potential of 15 different species for the treatments of inflammatory, gastrointestinal, hepatic, renal, circulatory, genitourinary, respiratory, hormonal and infectious disorders, among others. Table 1 is a selection of uses that may be related to bacterial infection. In this context, eight species are mentioned: *Taraxacum androssovii* Schischkin, *Taraxacum cyprium* H. Lindb., *Taraxacum fedtschenkoi* Hand.-Mazz., *Taraxacum macrolepium* Schischkin, *T. mongolicum* Hand.-Mazz., *Taraxacum platycarpum* Dahlst., *Taraxacum stevenii* (Spreng.) DC., and *Taraxacum oellgaardii* C. C. Haw. under the synonym *T. officinale* (L.) Weber ex F. H. Wigg. The latter is, by far, the most cited and versatile species. Ethnomedicinal uses are recorded in Latin America, Europe, and Asia. Every part of the plant is used; however, leaves are mentioned for all the species cited. The forms of use vary according to the symptoms, including infusions, decoctions, tinctures, pastes, poultices, and powders, whereas the administration route can be both oral and topical. The main therapeutic indications are against gastrointestinal, skin, and respiratory disorders.

4 | PHYTOCHEMICAL CONSTITUENTS OF THE GENUS *TARAXACUM* AND OTHER COMPONENTS

4.1 | Volatile compounds

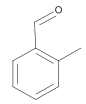
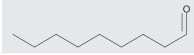
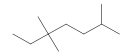
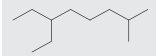
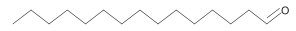
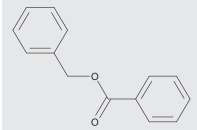
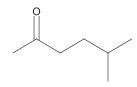
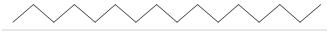
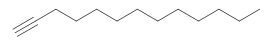
Identification and characterization of the essential oil from *T. officinale* florets have been carried out, showing 25 compounds belonging to various chemical groups: straight chain aliphatic hydrocarbons

TABLE 1 Use of *Taraxacum* spp. plants in traditional medicine against signs and symptoms related to bacterial infection

Plant species	Indications	Plant parts used	Methods of use	Preparation/administration	Countries	References
Taraxacum androssovii Schischkin	Wounds, stomach disorders	Leaves	Poultice and infusion	Poultice/external; infusion/internal	Turkey	Altundag and Ozturk (2011)
Taraxacum cyprium H. Lindb.	Anti-cough, expectorant, dyspepsia	Roots, plant core	Infusion	Orally	Cyprus	Dokos, Hadjicosta, Dokou, and Stephanou (2009)
Taraxacum fedtschenkoi Hand.-Mazz.	Wounds, stomach disorders	Leaves	Poultice and infusion	Poultice/external; infusion/internal	Turkey	Altundag and Ozturk (2011)
Taraxacum macrolepium Schischkin	Wounds, stomach disorders	Leaves	Poultice and infusion	Poultice/external; infusion/internal	Turkey	Altundag and Ozturk (2011)
Taraxacum. mongolicum Hand.-Mazz	Tuberculosis, fever, acne	Roots, aerial parts	Infusion; crushing in water	Orally; topical application	China	Chaudhary, He, Cheng, and Xiao (2006)
Taraxacum oellgaardii C. C. Haw. synonym, *Taraxacum officinale* (L.) Weber ex F. H. Wigg.	Fever, cough, dysmenorrhea, headache, constipation, stomach pain, digestive, stomachache, skin problems, toothache, wounds, swelling, digestive disorders, peptic ulcer, migraine, abdominal complaints, blisters and rash, treatment of gastrointestinal diseases, eczema	Flowers (fresh/dried), leaves (dried), roots, shoots, whole plant (fresh/dried), aerial parts, inflorescences, latex	Flower extract; powdered roots; leaf paste; leaf decoction; fresh flower or aerial part infusion; tea; inflorescence decoction; latex application; fresh whole plant (poultice, decoction); shoots, flowers and leaves (infusion and tincture)	Flower extract mixed with lemon juice to cure fever; leaves either consumed as vegetable or in the form of curry to relieve abdominal spasms; as antiseptic to cure wound; decoction (oral); infusion (oral); tea (oral); in external washes; leaf paste applied topically at the site of swelling; topical infusion of fresh flowers; infusion of aerial parts (oral); powdered (2.5 to 5 g), twice a day for 30–45 days; paste applied externally on wounds twice a day for a week as an antiseptic; decoction of inflorescence to cure blisters; latex, applied externally during skin irruption; whole fresh plant (mixed to other plants) poultice, two times per month; one cup, four times a day for 1 month (oral); shoot, flower, and leaf infusion (oral) and topical application of tincture	India, Mexico, Pakistan, Kosovo, Romania, Bulgaria, Argentina, Italy, Serbia, Bolivia, Georgia, Peru, Turkey	Trak and Giri (2017); Gheno-Heredia, Nava-Bernal, Martínez-Campos, and Sánchez-Vera (2011); Bhatia, Sharma, Manhas, and Kumar (2015); Mahmood et al. (2012); Mustafa et al. (2012); Pieroni, Nedelcheva, and Dogan (2015); Rahman et al. (2016); Kozuharova, Lebanova, Getov, Benbassat, and Napier (2013); Bhatia, Sharma, Manhas, and Kumar (2014); Ummara, Bokhari, Altaf, Younis, and Dasti (2013); Trillo, Toledo, Galetto, and Colantonio (2010); Guarrera (2005); Pieroni, Giusti, and Quave (2011); Macía, García, and Vidaurre (2005); Dangwal, Sharma, and Rana (2010); Bhatt, Kumar, Joshi, and Tewari (2013); Bussmann et al. (2016); Rana, Kumar, Singhal, and Rana, (2014); Fakir, Korkmaz, and Güller (2009)
Taraxacum platycarpum Dahlst.	Furuncles	Leaves	Not indicated	Not indicated	Korea	Kim, Song, and Potter (2006)
Taraxacum stevenii (Spreng.) DC.	Toothache, abdominal spasms	Aerial parts	Infusion	Internally	Turkey	Özdemir and Alpınar (2015)

(nonadecane, hexadecane, heneicosane, pentadecane, tricosane, eicosane, and 1-tridecyne), branched aliphatic hydrocarbons (2,5,5-trimethylheptane and 6-ethyl-2-methyloctane), esters (benzyl benzoate), alkylated benzenes (1,3-dimethylbenzene, 1,2-dimethylbenzene, 1-ethyl-3-methylbenzene, and 1-hydroxymethyl-4-methylbenzene), alcohols (2-nonen-1-ol, 1,9-nonanediol, and 1-tridecanol), aldehydes (octanal, phenylacetaldehyde, 2-methylbenzaldehyde, nonanal, pentadecanal, and 10-undecenal), and ketones (5-methyl-2-hexanone and hexadecanoic acid) as reported in Table 2 (Bylka et al., 2010). To the best of our knowledge, other species of the genus *Taraxacum* have not been analysed yet for their essential oil content.

TABLE 2 Chemical composition of essential oil from *Taraxacum officinale* florets (Bylka, Matlawska, & Frański, 2010)

	1,3-Dimethylbenzene
	1,2-Dimethylbenzene
	Octanal
	Phenylacetaldehyde
	2-Methylbenzaldehyde
	Nonanal
	2,5,5-Trimethylheptane
	6-Ethyl-2-methyloctane
	2-Nonen-1-ol
	1,9-Nonanediol
	Pentadecanal
	Benzyl benzoate
	5-Methyl-2-hexanone
	1-Tridecanol
	Nonadecane
	Hexadecanoic acid
	Hexadecane
	Heneicosane
	1-Tridecyne
	10-Undecenal
	Pentadecane
	Tricosane
	Eicosane

4.2 | Phytochemicals: Terpenoids and phenolic compounds

Plants of the genus *Taraxacum* represent a valuable source of bioactive compounds and have attracted the attention of many researchers around the world due to their unique biological properties (Sánchez-Mata et al., 2012). Phytochemicals present in *Taraxacum* spp. include taraxasterol and other phytosterols (Akashi, Furuno, Takahashi, & Ayabe, 1994), taraxacin, taraxol, taraxerol (Zhu, 1998), taraxinic acid derivatives (eudesmanolide, guaianolide, and germacranolide derivatives; Kisiel and Barszcz, 2000), taraxacoside (Rudenskaya et al., 1998), mongolicumin A and B (in *T. mongolicum*; Shi et al., 2007), and officinatrione (in *T. officinale*; Asadi-Samani et al., 2015; Figure 2).

As previously introduced, plants of the genus *Taraxacum* represent a source of taraxinic acid derivatives. Kisiel and Michalska (2005) studied the chemistry of these sesquiterpene lactones in roots of nine *Taraxacum* species: *Taraxacum laevigatum*, *Taraxacum disseminatum*, *Taraxacum rubicundum*, *Taraxacum erythrospermum*, *Taraxacum hondoense*, *Taraxacum obovatum*, *Taraxacum udum*, *Taraxacum bicorne*, and *Taraxacum serotinum*. The most abundant components isolated were germacrane-, eudesmane-, and guaiane-type sesquiterpene lactones and phenolic compounds (Kisiel & Michalska, 2005; Michalska & Kisiel, 2008, 2009; Michalska, Marciniuk, & Kisiel, 2010; Zielinska & Kisiel, 2000). Furthermore, taraxinic acid β-D-glucopyranosyl ester (Figure 2), two eudesmane-type sesquiterpene lactones, 2β-hydroxysantamarine-1β-D-glucopyranoside and 3β-hydroxy-4αH-3-dihydrosantamarine-β-D-glucopyranoside, and two inositol derivatives, (1*S*,2*S*,4*R*,5*S*)-2,3,4,6-tetrahydroxy-5-[2-(4-hydroxyphenyl)acetyl]oxycyclohexyl-2-(4-hydroxyphenyl) acetate and (2*S*,3*R*,5*R*,6*S*)-2,3,5,6-tetrahydroxy-4-[2-(4-hydroxyphenyl) acetyl]oxycyclohexyl-2-(4-hydroxyphenyl) acetate, were isolated from the methanol extract of subaerial parts of *Taraxacum linearisquameum* (Zidorn, Ellmerer-Mueller, & Stuppner, 1999).

Phenolic compounds in flowers and leaves include hydroxycinnamic acid derivatives, notably chlorogenic, dicaffeoyltartaric (chicoric), and monocaffeoyltartaric acids (Schuetz et al., 2006). Coumarins (aesculin and cichoriin) (Figure 2) and numerous flavonoids are also present (Hu & Kitts, 2005; Williams, Goldstone, & Greenham, 1996). Moreover, 10 phenylpropanoids (*p*-coumaric acid, ferulic acid, caffeic acid, chlorogenic acid, three isomers of di-*O*-caffeoylquinic acid, esculetin, rufescidride, and mongolicumin A; Shi, Huang, et al., 2008; Figure 2) and 16 aglycones and flavonoid glycosides were isolated from whole *T. mongolicum* plants growing in China (Shi, Zhang, et al., 2008).

A number of novel compounds have been characterized in *Taraxacum* species, including terpenoids and phenolic compounds. Concerning terpenoids, two new sesquiterpene lactones (11β,13-dihydrotaraxinic acid and taraxinic acid 6-*O*-acetyl-β-glucopyranosyl ester) were isolated from roots of *T. udum* (Michalska et al., 2010)

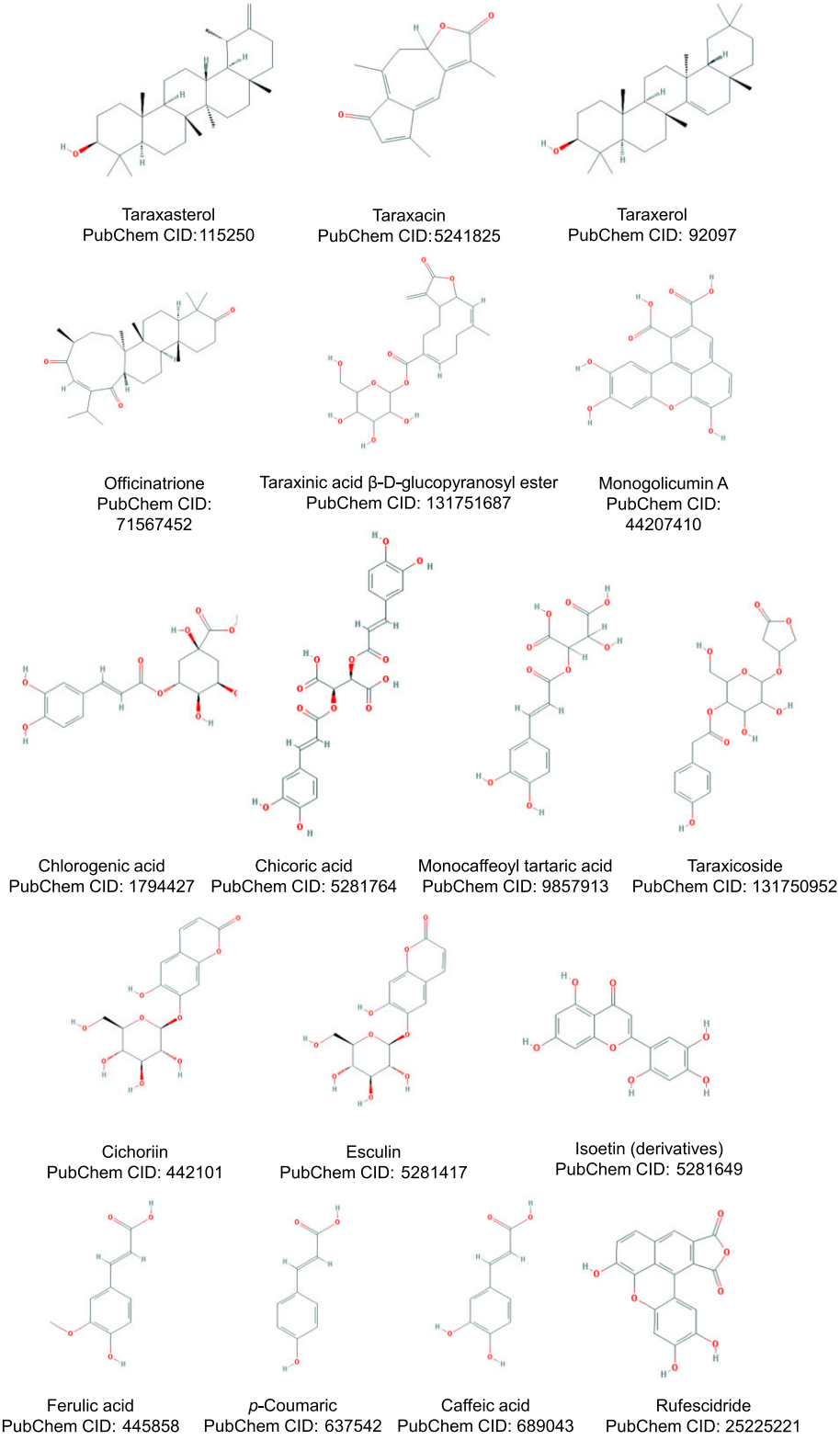


FIGURE 2 Example of chemical structures (terpenoids and phenolic compounds) found in *Taraxacum* spp. and retrieved from PubChem database [Colour figure can be viewed at wileyonlinelibrary.com]

and a new guaianolide (mongolicumin B) from the aerial parts of *T. mongolicum* (Shi et al., 2007). Five novel lupane-type triterpenoids and officinatrione were isolated from the roots of *T. officinale*, which exhibited a moderate cytotoxic activity against L1210 cell line (IC_{50} in the range 10.1–10.5 mM; Saeki et al., 2013). In the case of phenolic compounds, the lignans mongolicumin A and rufescidride were isolated from *T. mongolicum* by preparative high-speed counter-current chromatography (Shi, Zhang, et al., 2008). Mongolicumin A was a new compound, and rufescidride was obtained from this genus for the first time. Moreover, two new flavone glycosides (isoetin-7-*O*-β-

D-glucopyranosyl-2′-*O*-α-L-arabinopyranoside and isoetin-7-*O*-β-D-glucopyranosyl-2′-*O*-α-D-glucopyranoside) and mongolicumin A were identified in the aerial parts of *T. mongolicum* (Shi et al., 2007).

4.3 | Latex

Considerable efforts have been made to discover the chemistry of the secondary metabolites secreted by highly specialized laticifer cells, using a combination of analytical techniques such as liquid and gas chromatography, mass spectrometry, and nuclear magnetic resonance spectrometry (Huber et al., 2015). *T. officinale* latex consists of three main classes of secondary metabolites: phenolic inositol esters, triterpene acetates, and the sesquiterpene lactone taraxinic acid β-D-glucopyranosyl ester. The latex constituents were biologically active and strongly repelled cucumber beetle (*Diabrotica balteata*) larvae (Huber et al., 2015).

4.4 | Polysaccharides

The novel heteropolysaccharide DPSW-A (80 kDa) was extracted and purified from *T. mongolicum* in 2016 by Chen et al. (2016). It was composed of three types of monosaccharide, rhamnose, arabinose, and galactose, at a molar ratio of 1.0:10.7:11.9. The anti-complement effects in a dose-dependent manner were investigated for the sulfated derivative Sul-DPSW-A through the classical (CH50: Sul-DPSW-A, 3.9 μg/ml; heparin, 104.4 μg/ml) and alternative (AP50: Sul-DPSW-A, 42.7 μg/ml; heparin, 43.4 μg/ml) pathways. The Sul-DPSW-A inhibited complement activation by blocking C1q, C1r, C1s, and C9 but not C2, C3, C4, and C5, as well as showing slight anticoagulant effects. The results indicated that Sul-DPSW-A might be valuable for treating diseases caused by excessive complement system activation (Chen et al., 2016).

4.5 | Others

Taraxalisin is a serine proteinase found in the latex of dandelion roots with a molecular mass of 67 kDa (Rudenskaya et al., 1998).

5 | THE GENUS *TARAXACUM* AS A FOOD PRESERVATIVE

The World Health Organization reports that unsafe food results in the illnesses of at least 2 billion people annually worldwide. Food safety impacts people in both developing and developed countries. For example, in the United States, the Centers for Disease Control and Prevention estimate that each year, about one in six Americans becomes ill and 3,000 die of food-borne diseases (www.cdc.gov/foodborneburden/2011-foodborne-estimates.html).

Food is often processed to prolong shelf life and enhance safety, and there are many physical processes involved, including thermal processing, high-pressure processing, and dehydration. Preservatives are commonly used to reduce the risk of food-borne illnesses. Conventional food preservatives include sodium benzoate, benzoic acid, sodium nitrite, and sulphur dioxide. Consumers' negative responses to chemical compounds used in food have prompted the development of suitable alternatives.

Antimicrobials derived from botanicals have been studied extensively, but only few natural products have been exploited as food preservatives on a commercial scale (Sharifi-Rad, Salehi, Schnitzler, et al., 2017; Sharifi-Rad, Salehi, Varoni, et al., 2017). Many challenges in achieving regulatory approval for the use of natural food preservatives and the production costs are often higher than those of conventional food antimicrobials (Raeisi, Ojagh, Sharifi-Rad, Sharifi-Rad, & Quek, 2017). Technological advances in high-level production of such compounds will likely lower their production costs and thus make their use more attractive.

Antimicrobial agents have been predominantly isolated from bacteria and fungi and are produced either through fermentation or chemical synthesis. New sources of novel antimicrobial compounds, including plants, need to be thoroughly investigated (Sharifi-Rad et al., 2016; Sharifi-Rad, Ayatollahi, et al., 2017; Sharifi-Rad, Varoni, et al., 2017; Salehi et al., 2017; Sharifi-Rad, Salehi, Stojanović-Radić, et al., 2017; Sharifi-Rad, Salehi, Varoni et al., 2017; Sahraie-Rad, Izadyari, Rakizadeh, & Sharifi-Rad, 2015; Snow Setzer, Sharifi-Rad, & Setzer, 2016). Some spices and herbs possess antimicrobial activity, although there are conflicting reports in the literature about the efficacy of several of them. The spices cinnamon, mustard, vanillin, and clove, as well as some herbs, specifically oregano, rosemary, thyme, sage, and basil, all exhibit powerful antimicrobial activity (Holley & Patel, 2005; Salehi, Mishra, et al., 2018).

Alternatives to conventional antimicrobial compounds include plant antimicrobial peptides (pAMPs). Some studies demonstrated that pAMPs are part of plant defence mechanisms against pathogens. pAMPs have been shown to have a broad-spectrum antimicrobial activity against fungi and bacteria (Barbosa Pelegrini, del Sarto, Silva, Franco, & Grossi-de-Sa, 2011). Given the consumer demand for natural preservatives, it is imperative that more research is focused on the application of plant antimicrobials in food safety (Sharifi-Rad et al., 2016; Sharifi-Rad, Sureda, et al., 2017; Sharifi-Rad, Hoseini-Alfatemi, Sharifi-Rad, & Miri, 2014; Stojanović-Radić, Pejčić, Stojanović, Sharifi-Rad, & Stanković, 2016).

As previously introduced, *Taraxacum* is a common weed that is often consumed as a green vegetable in salads and in prepared foods around the world. Concern has been raised due to the consumption of *Taraxacum* and associated intake of nitrate. It has been suggested that consumption of 100 g of *Taraxacum* would result in a maximal nitrate intake corresponding to 22% of the acceptable daily intake (Gorenjak, Koležnik, & Cencič, 2012). However, the focus of this review article is not on the actual consumption of *Taraxacum* but rather on the antimicrobial properties ascribed to the plant and application in food preservation (Martinez et al., 2015).

As mentioned, *Taraxacum* produces antimicrobial peptides (AMPs) active against human pathogens (Astafieva et al., 2012). Three novel AMPs were isolated from *T. officinale* and named ToAMP1, ToAMP2, and ToAMP3 (Astafieva et al., 2012). Peptides ranged in size from 38 to 42 amino acid residues. ToAMP1 and ToAMP3 exhibited selectivity with respect to pathogens: ToAMP1 inhibited growth of *Botrytis cinerea* and *Aspergillus niger*, whereas ToAMP3 was active against *Fusarium oxysporum*. The authors noted that, despite considerable

sequence identity between ToAMP1 and ToAMP2, their inhibitory activity against pathogens varied significantly. Therefore, a combination of these peptides may be more effective than a single peptide in inactivating food-borne pathogens.

Researchers have attempted to isolate compounds from *Taraxacum* that have activity against food-borne pathogens and thus possible applications in food systems. Oligosaccharides isolated from *Taraxacum* referred to as dandelion-derived oligosaccharides (DOs) were evaluated for activity against *Bacillus subtilis*, *Staphylococcus aureus*, and *Escherichia coli* (Qian, Zhou, Teng, Du, & Tian, 2014). The diameter of the zone of inhibition by DOs ranged from 12.04 to 16.15 mm for the latter bacteria (100 mg/ml), indicating that DOs had high antibacterial activity. Unfortunately, in this study, there was no comparison with a broad-spectrum antibiotic or conventional food preservative. Ethyl acetate extract of *Taraxacum* was evaluated against *Pseudomonas aeruginosa* and *B. subtilis*, determining minimum inhibitory concentration (MIC) values of 125 and 62.5 μg/ml, respectively (Qiao & Sun, 2014). Water extract exhibited no activity against *E. coli*, *P. aeruginosa*, *Klebsiella pneumoniae*, *S. aureus*, and *B. subtilis*. Using cellulose-assisted extraction, water-soluble polysaccharides (PDs) from *T. officinale* were evaluated against *S. aureus*, *E. coli*, and *B. subtilis*. The diameters of the inhibition zone were between 11.02 and 15.26 mm at 100 mg/ml, indicating a high antibacterial activity of PDs. The authors indicated a potential application of PDs as food preservative, although such a high concentration may be limiting (Wang, 2014).

In summary, potential application of antimicrobial compounds derived from *Taraxacum* in food preservation has not been fully investigated. The research, to date, suggests that *Taraxacum* peptides (AMPs) and PDs are effective in inhibiting a range of bacteria and fungi associated with food-borne diseases. The major limitation is that no study has evaluated the ability of *Taraxacum* compounds to inhibit food-borne pathogens in a food matrix. Such studies are pivotal because many compounds that are effective in vitro fail to show activity in situ.

6 | ANTIBACTERIAL ACTIVITY OF THE GENUS *TARAXACUM*

Taraxacum spp. have been tested against a high number of bacteria related to respiratory, intestinal and oral disorders, meningitis, and other ailments (Table 3), exhibiting a broad-spectrum antibacterial activity, especially for those bacteria depicted in Table 4.

6.1 | *Taraxacum vulgare*

Bonjar (2004) evaluated the antibacterial activity of 45 plant species used in Iranian medicine including *Taraxacum vulgare* (Lam.) against *Bacillus cereus*, *Bacillus pumilus*, *Bordetella bronchiseptica*, *E. coli*, *K. pneumoniae*, *Micrococcus luteus*, *P. aeruginosa*, *Pseudomonas fluorescens*, *Serratia marcescens*, *S. aureus*, and *Staphylococcus epidermidis*. Methanol extracts from different parts of these plants and *T. vulgare* roots were tested at 20 mg/ml (2 mg/well) using the agar diffusion assay. The latter extract resulted in inhibition zone diameters of 7 and 9 mm for *K. pneumoniae* and *B. bronchiseptica*, respectively, whereas no activity was observed for the other bacterial species. In another work, Bonjar, Aghighi, and Karimi Nik (2004) also determined the antimicrobial activity of methanol extract of flowers (20 mg/ml) by disc diffusion assay. In this study, the tested strains were *B. bronchiseptica*, *B. pumilus*, *E. coli*, *K. pneumoniae*, *M. luteus*, *P. aeruginosa*, *Pseudomonas fluorescens*, *S. aureus*, and *S. epidermidis*, and the extract did not show significant inhibitory activity. In both studies, negative control were pure solvents, whereas no conventional antimicrobial was used as a reference.

6.2 | *Taraxacum mongolicum*

Another study using the agar diffusion method was performed with *T. mongolicum*, in which Demin (2010) assessed the nutritional components and their antibacterial activity against *E. coli*, *S. aureus*, and *S. aureus* isolates, as well as *Shigella fiexneri*, *Proteus vulgaris*, and *P. aeruginosa* strains. Aqueous and ethanol extracts were assayed at concentrations from 10 and 500 μg/ml, although the plant part used was not mentioned. According to inhibition zone diameter, only the ethanol extract was active on four bacterial strains; that is, *S. aureus* (12.67 mm), *S. aureus* (isolate) (17.34 mm), *E. coli* (13.33 mm), and *P. aeruginosa* (10.05 mm). The MIC for *S. aureus*, *S. aureus* (isolate), and *E. coli* was 50 μg/ml, and for *P. aeruginosa*, it was 100 μg/ml. Erythromycin was the reference drug (positive control), but the MIC value was not clarified.

Antimicrobial activity of *T. mongolicum* aqueous and ethanol extracts (0.125–0.5 g/ml) has also been determined by disc diffusion against the major cow mastitis pathogenic bacteria (*E. coli*, *S. aureus*, *Streptococcus agalactiae*, and *Streptococcus dysgalactiae*); the plant was purchased in a pharmacy as dried herb. The aqueous extract presented the lowest inhibition haloes for *S. aureus* (0–12.2 mm) and the highest inhibition values for *E. coli* (14.5–22.7 mm). Similarly, for the ethanol extract, the lowest values were for *S. aureus* (12.3–18.3 mm), and the most effective inhibition was recorded for *E. coli* (16.6–22.5 mm). At the highest concentration (0.5 g/ml), both aqueous and ethanol extracts were effective against *S. dysgalactiae* (18.2 and 19.6 mm, respectively; Peng et al., 2012).

The antibacterial activity of *T. mongolicum* floret ethanol extract and its fractions (petroleum ether, ethyl acetate, and aqueous fractions; 10 mg/ml) was determined by agar disc diffusion and microdilution methods (Qiao & Sun, 2014). The tested strains were Gram-negative (*E. coli*, *P. vulgaris*, *P. aeruginosa*, *K. pneumoniae*) and Gram-positive (*S. aureus* and *B. subtilis*) bacteria, with gentamicin or tetracycline as for Gram-negative or Gram-positive strains, respectively. The highest activity for the ethanol extract was against *P. aeruginosa* (16.25 mm) and *S. aureus* (11.22 mm). The petroleum ether fraction was not active on all strains. The ethyl acetate fraction showed the highest inhibition against *P. aeruginosa* and *B. subtilis* with (19 mm for both strains), whereas the aqueous extract showed no significant inhibitory activity. The MIC was determined only for the active products. The MIC of the ethyl acetate fraction ranged from 125 to 250 μg/ml and from 62.5 to 250 μg/ml for Gram-negative and Gram-positive bacterial strains, respectively. In particular, the ethyl acetate fraction was more effective against *B. subtilis* (62.5 μg/

TABLE 3 Bacterial species used in antibacterial tests of *Taraxacum* spp. plants and related infections in humans

Bacterium	Infections/symptoms	References
Aeromonas hydrophila	Gastroenteritis, colitis, peritonitis and cholangitis, infections, septicemia, wound and respiratory infections	Parker and Shaw (2011)
Bacillus subtilis	Vomiting, diarrhoea	Logan (2012)
Bordetella bronchiseptica	Respiratory infections	García-de-la-Fuente et al. (2015)
Enterococcus faecalis	Wound and urinary tract infections, bacteremia, infective endocarditis	Hammerum (2012)
Escherichia coli	Intestinal and extra-intestinal infections, such as diarrhoea, urinary tract infections, meningitis, peritonitis, septicemia, gram-negative bacterial pneumonia	Hammerum and Heuer (2009)
Klebsiella pneumoniae	Pneumonia, wound, soft tissue or urinary tract infections, pyogenic liver abscess, and meningitis	Holt et al. (2015)
Micrococcus kristinae	Peritonitis, endocarditis, cholecystitis, bacteremia	Lakshmikantha, Devki, and Yogesh (2015)
Micrococcus luteus	Infective endocarditis, meningitis, intracranial abscess, arthritis, pneumonia	Miltiadous and Elisaf (2011); Tsai et al. (2010)
Proteus vulgaris	Wound and respiratory infections	Pandey and Mishra (2010)
Pseudomonas aeruginosa	Pneumonia, diabetic foot, nosocomial, urinary tract, bloodstream, and skin infections	Driscoll, Brody, and Kollef (2007)
Salmonella abony	Septicaemia and meningitis	Van Meervenne et al. (2009)
Salmonella typhi	Typhoid fever, intestinal perforation, septicemia and meningitis, chronic and acute infections of the gallbladder	Gonzalez-Escobedo, Marshall, and Gunn (2011)
Salmonella typhimurium	Gastroenteritis, bloodstream infection	Feasey et al. (2014); Broz, Ohlson, and Monack (2012)
Serratia marcescens	Opportunistic and nosocomial infections, respiratory and urinary tract infections, surgical wounds, meningitis, endocarditis and osteomyelitis	Khanna, Khanna, and Aggarwal (2013)
Staphylococcus aureus	Bacteremia, infective endocarditis, osteoarticular, skin, soft tissue and pleuropulmonary infections	Tong, Davis, Eichenberger, Holland, and Fowler (2015)
Streptococcus dysgalactiae	Superficial and invasive infections, septic arthritis of native and prosthetic joints, skin and soft tissue infections	Parks, Barrett, and Jones (2015)
Vibrio cholerae	Diarrheal disease, cholera	Fazil and Singh (2011)

TABLE 4 Antibacterial effect of some *Taraxacum* species

Species	Extract	In vitro effect	Reference
Taraxacum vulgare	Methanol extracts of roots	Halo zones: *Klebsiella pneumoniae* (7 mm) and *Bordetella bronchiseptica* (9 mm)	Bonjar (2004)
Taraxacum mongolicum	Ethanol extracts	*Halo zones: Staphylococcus aureus* (12.67 mm), *S. aureus* (isolate; 17.34 mm), *Escherichia coli* (13.33 mm), and *Pseudomonas aeruginosa* (10.05 mm). MIC values: 50 μg/ml (*S. aureus*, *S. aureus* [isolate], and *E. coli*) and 100 μg/ml (*P. aeruginosa*)	Demin (2010)
	Aqueous and ethanol extracts of commercial dry spice	Halo zones (0.125–0.5 g/ml): Aqueous (14.5–22.7 mm) and ethanol (16.6–22.5 mm) extracts against *E. coli*.	Peng, Yu, Wang, Wang, and Sun (2012)
	Floret ethanol extract and its fractions (petroleum ether, ethyl acetate, and aqueous fractions)	Halo zones (10 mg/ml): Ethanol extract against *P. aeruginosa* (16.25 mm) and *S. aureus* (11.22 mm); ethyl acetate fraction against *P. aeruginosa* and *Bacillus subtilis* with (19 mm for both strains). MIC values: 62.5 μg/ml (*B. subtilis*) and 125 μg/ml (*P. aeruginosa*)	Qiao and Sun (2014)
Taraxacum officinale	Methanol extract of roots	MIC value (500 μg/ml): *S. aureus* (standard), clinical isolate of methicillin resistant *S. aureus*, and *Bacillus cereus*	Kenny et al. (2015)
	Methanol and chloroform leaf extracts	Halo zones (0.30 mg/ml): *E. coli* (14 mm) and *S. aureus* (13 mm)	Iqbal et al. (2014)
Taraxacum ohwianum	Ethanol extract	Halo zone: *S. aureus* (10.4 mm)	Sun et al. (2014)
Taraxacum laevigatum	Green-synthesized platinum nanoparticles with the aqueous extract of the plant	Halo zone (1 mg/ml): *B. subtilis* (18 mm) and *P. aeruginosa* (15 mm) with nanoparticles; 8 mm for both bacteria with the extract MIC values: *B. subtilis* (53.2 μg) and *P. aeruginosa* (62.5 μg)	Tahir et al. (2017)

Note. MIC: minimum inhibitory concentration.

ml) compared with Gram-negative bacteria *P. aeruginosa* and *K. pneumoniae* (125 μg/ml).

Co-medication with herbs can result in changes in pharmacological effects of many drugs (Bo et al., 2016). *T. mongolicum* decoction was able to synergize with trimethoprim (TMP); the most active combination was 2.5 g dandelion and 10 mg TMP (Zhu, 1998). On the contrary, *T. mongolicum* extracts can represent a potential problem for the absorption of quinolone antibiotics (ciprofloxacin), as reported by Zhu, Wong, and Li in 1999. Indeed, an in vivo study on Sprague Dawley rats investigated the possible interactions between *T. mongolicum* and ciprofloxacin (Zhu et al., 1999). A group of animals received a single oral dose of ciprofloxacin (20 mg/kg) followed by oral administration of *T. mongolicum* aqueous extract (2 g of crude extract/kg), and the control group received oral ciprofloxacin (20 mg/kg) alone. The results indicated that, compared with the control, the maximum plasma concentration of ciprofloxacin was significantly reduced by 73% in rats receiving simultaneously *T. mongolicum* aqueous extract. Oral administration of *T. mongolicum* also increased the apparent volume of drug delivery of (92 vs. 30.8 L/kg in control) and terminal elimination half-life (5.71 vs. 1.96 hr in control), suggesting a possible multifactorial drug–drug interaction between *T. mongolicum* extract and ciprofloxacin.

6.3 | *Taraxacum officinale*

Taraxacum officinale root extract was tested against Gram-positive and Gram-negative bacterial strains, *S. aureus* (standard), clinical isolate of methicillin resistant *S. aureus* (MRSA), *B. cereus*, *E. coli*, and *Salmonella typhimurium*. Eleven extracts (2 mg/ml) were prepared with different solvents: hexane, dichloromethane, methanol, and water. The MIC was determined by microdilution, with two controls, gentamicin (negative) and dimethyl sulfoxide (positive). The most relevant results were obtained from the crude methanol extract, which showed the highest inhibitory activity against all Gram-positive strains, *S. aureus*, MRSA, and *B. cereus* (MIC 500 μg/ml); however, it was not active against *E. coli* and *S. typhimurium*. The hexane extract demonstrated antimicrobial properties against *B. cereus* (MIC 1,000 μg/ml), whereas the dichloromethane extract was active against *S. aureus* and MRSA (MIC 1,000 μg/ml; Kenny et al., 2015). Another study showed that the methanol extract from *T. officinale* flowers (512 μg/ml) exhibited an antimicrobial effect (12.8 mm) on chloramphenicol *E. coli* resistant strains, though no effect was determined on the strains susceptible to the antibiotics (Hleba et al., 2013). *T. officinale* leaf extracts in methanolic, chloroformic, and water aqueous leaf extracts were assayed against *P. aeruginosa*, *E. coli*, *S. aureus*, *B. subtilis*, and *M. luteus* strains (Iqbal et al., 2014). Again, the methanol extract together with the chloroform extract were active against *E. coli* (14 mm) and *S. aureus* (13 mm) at 0.30 mg/ml, whereas the aqueous extract did not demonstrate significant inhibition against any strain.

Methanol seems to be one of the most effective extraction agents as shown in several comparative studies. As an example, the in vitro antibacterial effects of methanol, chloroform, hexane, and water extracts from *T. officinale* leaves (20 μl) were assessed against different pathogenic bacterial strains (*P. aeruginosa*, *E. coli*, *S. aureus*, *B. subtilis*, and *M. luteus*). The highest activity was observed with methanol extract against *S. aureus* followed by hexane extract on *E. coli*. The water extract showed no activity (Sohail Iqbal, Afzal, Afzal, Ur Rahman, & Shad, 2014). Recently, dichloromethane, ethyl acetate, methanol, and water extracts of stem, root, and flower of *T. officinale* were assayed against five microbial strains (*Streptococcus mutans*, *Streptococcus pyogenes*, *Streptococcus pneumonia*, *S. aureus*, and *P. aeruginosa*). The root methanol extract (0.5 mg/50 μl and 1 mg/50 μl) showed the highest antimicrobial potential against all bacterial strains, followed by the ethyl acetate extracts (Amin, Sawhney, & Manmohan, 2016).

Conversely, in a study conducted by Jaca and Kambizi (2011), a survey of plant species used for medicinal purposes, the antimicrobial activities of aqueous and acetone extracts of *T. officinale* (the plant part was not specified) were investigated. The aqueous extract was more active than the acetone extract, but with MICs between 1 and 7 mg/ml against Gram-positive (*E. coli*, *P. vulgaris*, and *S. marcescens*) and Gram-negative (*B. subtilis*, *Micrococcus kristinae*, and *S. aureus*). In another study, the efficiency of *T. officinale* leaf aqueous and ethanol extracts (0.5 and 1 mg/ml) was investigated against Gram-negative (*Proteus mirabilis* and *E. coli*) as well as Gram-positive (*S. aureus*) bacteria by agar diffusion assay (Jassim, Safanah, & Omar, 2012). Both extracts inhibited bacterial growth at the assayed concentrations, especially on *S. aureus* (4–10 mm), though with a lower efficacy on *P. mirabilis* (1–4 mm). The ethanol extract at 0.5 mg/ml exhibited the highest potential against *E. coli* (1–4 mm), when compared with the aqueous extract. The poorer activity of the aqueous extract of this plant compared with that of ethanol was also shown by Oseni and Yussif (2012) on *E. coli*, *K. pneumoniae*, *P. aeruginosa*, and *S. aureus* using agar diffusion test at 50 to 200 mg/ml and chloramphenicol (10 mg/ml) as a positive control. The ethanol extract at the highest concentration was effective against *E. coli* and *S. aureus* (23.50 and 10.75 mm, respectively), whereas at the lowest concentration, it inhibited only *E. coli* (10.5 mm). In contrast, the aqueous extract showed inhibition only against *E. coli* at 200 (7.5 mm) and 100 mg/ml (5.25 mm), thus revealing that the bactericidal activity of aqueous and ethanol extracts is dose dependent.

Ionescu et al. (2013), using the broth microdilution method, evaluated the antimicrobial activity of the hydroethanolic extract obtained from *T. officinale* leaves against *S. aureus*, *E. coli*, and *Salmonella abony* strains. MIC and minimum bactericidal concentration were determined, though the authors only reported minimum bactericidal concentration values. They concluded that dandelion extract, both undiluted (100%) and diluted (50%), exhibited bactericidal activity against *E. coli* and *S. abony* strains, though it was ineffective against *S. aureus*.

A slight antibacterial activity was shown for the ethyl acetate extract from *T. officinale* leaves, which was evaluated on *Aeromonas hydrophila*, *Salmonella typhi*, *S. aureus*, *B. cereus*, and *E. coli* clinical isolates compared with the drug control (cephalothin at 30 μg/ml, 12 mm of inhibition halo; Ghaima, Hashim, & Ali, 2013). A concentration of 20 mg/ml was used with inhibition haloes between 14 mm (*S. typhi*) and 18 mm (*B. cereus*).

A comparative study was carried out to investigate the antimicrobial potential of *T. officinale* root and leaf extracts (7 mg/ml) as possible irrigating solutions used during endodontic treatments, in comparison with sodium hypochlorite (2.5%), propolis (12%), and ethyl alcohol (55%). The authors selected 47 human dental roots, five roots without bacterial inoculation (negative control), the remaining roots

were inoculated with *Enterococcus faecalis* and divided into groups, which were treated with the products for 5, 10, and 15 min; five roots were randomly selected as positive controls. All irrigation solutions, including the *T. officinale* extracts, decreased the number of *E. faecalis* colonies, though hypochlorite was the most effective product (Shafiq & Al-Hashimi, 2014). More recently, *T. officinale* showed inhibitory activity against oral cavity microbes *E. faecalis* and *Streptococcus salivarius*, thus suggesting a potential role of the herb in control of dental caries and endodontic infections (Sangeetha & Devaraj, 2016).

In a study by Qian et al. (2014), *T. officinale* oligosaccharides (100 mg/ml) were prepared by hydrolysis with hydrogen peroxide, and their antibacterial activity against *B. subtilis*, *S. aureus*, and *E. coli* strains was investigated by the agar diffusion methods, as commented before. The inhibition zone diameter values were measured for *S. aureus* (16.15 mm), *E. coli* (13.21 mm), and *B. subtilis* (12.04 mm), indicating that the *T. officinale* oligosaccharides exert antibacterial activity. A sterile water inoculated disc was used as the control.

Using *T. officinale* floret extract, Arokiyaraj, Saravanan, and Badathala (2015) carried out the green synthesis of silver nanoparticles and tested their efficacy against *E. faecalis* and *P. aeruginosa* strains, using the disc diffusion assay and streptomycin as reference antimicrobial. Growth inhibition was recorded against *E. faecalis* (10 mm) and *P. aeruginosa* (11 mm), thus suggesting that nanoparticles showed a limited bactericidal activity against selected microorganisms.

Another study by Skariyachan, Jayaprakash, Bharadwaj, and Narayanappa (2014) investigated the effects of luteolin and taraxacin, among other natural compounds, on multidrug resistant bacteria and the products of genes responsible for *S. typhi*, *S. aureus*, and *Vibrio cholerae* drug resistance by molecular docking. The expressed proteins that characterize the resistance of pathogens to kanamycin (aph), TMP (dfrA1), methicillin (mecI), and vancomycin (VanH) were selected as possible drug target sites. These compounds present in *T. officinale* showed high binding for the *mecI* protein (methicillin resistance gene code) from *S. aureus*; luteolin was also identified as a potential inhibitor against aph (kanamycin resistance gene code) from *S. typhi*. Therefore, active compounds from *T. officinale* showed promising inhibitory potential against multidrug resistant microorganisms.

6.4 | *Taraxacum ohwianum*

The antibacterial activity of traditional Chinese herbs, including *T. ohwianum* Kitam, was investigated by Sun et al. (2014). Ethanol extract was assessed by agar diffusion method, and MIC was determined against *E. coli* and *S. aureus*. The extract did not inhibit bacterial growth, even at the highest concentration (MIC 320 mg/ml), as well as the extract did not show a significant inhibition halo at any concentration tested for *E. coli* (6.5 mm). Nevertheless, for *S. aureus*, it exhibited an inhibition halo of 10.4 mm, thus indicating a very slight antibacterial activity.

6.5 | *Taraxacum laevigatum*

Using the disc diffusion and microdilution methods, Tahir et al. (2017) investigated *T. laevigatum* extract for the green synthesis of platinum nanoparticles, to improve their antibacterial potential in vitro. The authors did not indicate the part of the plant from which the aqueous extract was obtained. Green-synthesized platinum nanoparticles (1 mg/ml) were tested against *B. subtilis* and *P. aeruginosa*. Nanoparticles were active on *B. subtilis* and *P. aeruginosa* (18 and 15 mm, respectively), compared with the controls (22 and 21 mm, respectively). Moreover, the MIC values were 53.2 μg for *B. subtilis* and 62.5 μg for *P. aeruginosa*, being in the order of streptomycin (38.3 and 36.3 μg, respectively).

7 | CONCLUSIONS AND FUTURE PERSPECTIVES

As a result of this literature survey, it is evident that *Taraxacum* spp. plants exhibit well-documented in vitro antimicrobial activities against pathogenic bacteria as well as food-borne pathogens. Both aqueous and organic extracts from different plant parts have shown promising in vitro antibacterial activity, thus supporting the uses of *Taraxacum* spp. plants as antimicrobial agents in many traditional healing systems. Nevertheless, it seems to depend on the species studied. Further research is needed to investigate the oral bioavailability, pharmacological activities, and safety of active *Taraxacum* extracts in humans, although using these plants as therapeutic medicines is an ancient tradition. Moreover, the mechanism of action and the particular active molecules also require to be better understood. We hope that, in the near future, more well-designed, placebo-controlled, randomized clinical trials can improve our current knowledge on the efficacy of *Taraxacum* spp. plants in humans. Not least, innovative *Taraxacum* nanoformulations would certainly improve the delivery and controlled release of bioactive *Taraxacum* phytochemicals at microbial target sites.

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CONFLICT OF INTEREST

There is no conflict interest.

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