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REVIEW

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A review of the bioactive properties of Mongolian plants, with a focus on their potential as natural food preservatives

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Abstract

Consumers have recently preferred food that is easy to make and of excellent quality, as well as food that is safe, natural, and minimally processed, but has a longer shelf life. Food deteriorates over time as a result of microbiological, chemical, or physical changes. Phytochemicals derived from medicinal and food plants have long been recognized for their biological activity to protect plants. These bioactivities are designed to increase the shelf life of food while inhibiting the growth of microorganisms. The use of natural plant food preservatives containing bioactive compounds as health-promoting agents is particularly intriguing. Furthermore, due to their effectiveness against food spoilage and foodborne pathogens, natural plant-origin antimicrobial compounds have been investigated as alternatives to synthetic antimicrobial compounds for preserving food quality. This review focused on the plant composition and properties that can be utilized as a natural food preservative, as well as the possibilities of using Mongolian medicinal plants.

KEYWORDS

antibacterial, antifungal plants, antioxidant, Mongolian plants, natural food preservatives

1 | INTRODUCTION

Food losses are a major concern worldwide at the moment, as the world's population continues to grow, and nearly one-third of all food produced for human consumption is either lost or wasted (FAO, 2011). As pathogenic microorganisms grow and lipid oxidation increases, the shelf life, safety, and quality of food are reduced (Campêlo et al., 2019). When considering food types, these losses correspond to 40%–50% of root crops, fruits, and vegetables; 35% of fish and seafood; 30% of cereals; and 20% of meat, oil seed, and dairy products (FAO, 2017).

The food industry is under significant strain as a result of the use of synthetic food additives such as artificial preservatives and antibacterial physical treatments that extend the shelf life of food by preventing bacterial growth. Today, consumers demand ready-to-eat, natural, microbiologically safe, and organic foods. Even short shelf life foods require special protection against bacterial contamination during their processing, storage, and transportation (Gutiérrez-del-Río et al., 2018).

Several food preservation methods are known, including traditional: drying, freezing, cooling, and pasteurization and advanced technologies, such as chemical processing, irradiation, high-pressure technology, hurdle engineering, and nanotechnology. In addition, other procedures such as planting, harvesting, packaging, storing, and transporting are performed in a way to account for food preservation requirements (Amit et al., 2017; Bajpai et al., 2018; Msagati, 2013).

Living organisms, including plants, herbs, spice plants, animals, and microorganisms, produce a wide variety of secondary metabolites, such as terpenes, saponins, phenolic compounds, flavonoids, nitrogen- and sulfur-containing compounds, thiosulfinates, and glucosinolates that exhibit antioxidative and antimicrobial activities. Because of these properties, they have been used as preservatives to replace artificial supplements and to increase the shelf life of a variety of foods or foodstuffs. In addition, these compounds have other valuable features, such as flavoring properties, etc., so they can be considered multifunctional (Amit et al., 2017; Campêlo et al., 2019; Msagati, 2013).

The present study reviews some Mongolian natural plants with antioxidant, antibacterial, and antifungal properties that can be used as food preservatives. There are 3160 flowering plant species registered, 1100 of which are medicinal plants used in Mongolian traditional medicine (Magsar et al., 2018). The herbal plants of Mongolia contain a variety of secondary metabolites, including tannins, dyes, coumarins, flavonoids, alkaloids, saponins, vitamins, essential oils, and alkaloids (Magsar et al., 2017).

Medicinal plants and spices have been used as therapeutics and food preservatives since antiquity worldwide, and there are some recognized ancient writings that record plant usage from a historical context. Traditional Asian medicines, particularly Chinese, Tibetan, and Ayurvedic medicine, are well known throughout the world and are used as alternative or complementary medicines (El-Sayed & Youssef, 2019). The Mongolian Traditional Medicine originated from Mongolian, Tibetan, and Ayurvedic medicine. Following a period of stagnation, scientific research into traditional medicine has been gradually evolving (Pitschmann et al., 2013). The field had resumed by Soviet Russian scientists. Medicinal herbs were no exception.

The country is located at the crossroads of two major floristic regions of the world, the Siberian taiga and the Central Asian steppe and desert, and its topography encompasses a wide range of vegetation zones, including alpine, taiga, steppe, wetland, and desert. Its climate is also extreme, with temperatures ranging from +45°C to −45°C. Mongolian plants had to be adaptable in order to survive in these severe conditions, which required the production of various metabolites, which are the main ingredients in traditional medicines. In recent years, phytochemical studies on traditional medicinal plants used by Mongol nomadic have been conducted in Mongolia. However, phytochemical findings are preliminary and not comprehensive. The gathering and analysis of Mongolian folk medicinal botanical knowledge have grown in importance. As of 2013, 11 traditional herbal products had been officially approved, and many unregistered medicinal plants were widely used in our healthcare system (Pitschmann et al., 2013). For example, *Achillea asiatica* Serg., *Dianthus versicolor Fisch ex Link*., *Euphorbia pallasii Turcz. ex Ledeb*, *Lilium pumilum Delile*, and *Saussurea amara* (L.) DC are all used in Traditional Mongolian Medicine to treat liver diseases. To date, medicinal and food plant research refers to the development of new products or alternative applications in the pharmaceutical and food industries (Gonchig et al., 2008).

2 | ANTIOXIDANTS

The diversity of plant metabolites and their chemical structures, especially flavonoids, is associated with a wide variety of their biological activities. Their hydroxyl groups are efficient at scavenging free radicals, thus interrupting oxidative chain reaction. This makes these compounds powerful antioxidants (Gharras, 2009). Antioxidants support cellular defense mechanisms by reducing the risk of oxidative stress (Nimse & Pal, 2015). Aside from their enzymatic vs. nonenzymatic activity, antioxidants can be classified into several groups based on their activity, solubility in water/organic solvents, and size (low and high molecular; Nimse & Pal, 2015). There are five kinds of natural antioxidants: free radical terminators, metal chelators, singlet oxygen quenchers, oxygen scavengers, and antioxidant regulators (Carocho et al., 2015; Mathew & Abraham, 2006). The wide range of antioxidants is derived from a range of spice sources such as phenolic acids (gallic acid and caffeic acid), flavonoids (quercetin and kaempferol), phenolic diterpenes (carnosic acid and carnosol), and volatile essential oils (thymol and menthol; Shan et al., 2005). Some studies indicate that antioxidative activity of polyphenols is greater than that of synthetic antioxidants, such as BHA (butylated hydroxyanisole) and BHT (butylated hydroxytoluene). Even though natural antioxidants inhibit oxidation stress, their antioxidant potential depends on many other factors, such as food composition, matrix type (emulsion, foam, aqueous, and protein), the presence of other constituents, and environmental properties (ionic strength and pH; Brewer, 2011).

In Mongolia, *Carum carvi* L. is a wildly grown as a medicinal herb and vegetable. The previous studies revealed its antioxidant characteristics based on chemical compositions including monoterpene alcohols, linalool, carvacrol, carvone, limonene, anethole, estragole, flavonoids, and other polyphenolic compounds in caraway oil and aqueous extracts from roots (Agrahari & Singh, 2014). The major compounds in Mongolian caraway were found to be (S)-(+)-carvone (up to 65%) and (R)-(+)-limonene (up to 50%), with minor compounds also detected. It is an ingredient of the various traditional prescriptions and is used to treat nervous diseases, tumors, eye diseases, bronchial phlegm, inflammation, and stomach disorders. In addition, the antioxidant activity was found in some local medicinal plants, including *Chiazospermum erectum* Bennh (total alkaloid content, not less than 0.6%), which is used to treat typhoid fever, poisoning, and blood fever, as well as to relieve pain, reduce temperature, and expel bile. *Dianthus superbus* L. (total flavonoid content, not less than 1.2%), *Gentiana barbata* Froel (total alkaloid content 0.2%), *Hippophae rhamnoides* (Wild.) L., *Inula Britannica* L., *Odontites ruber* Gilib (total polyphenolic compound content, not less than 5.0%), *Oxytropis strobilacea* Bunge (rutin content, not less than 2.0%), *Polygonum hydropiper* Lour, *Vaccinium vitis-idaea* L. (tannins, not less than 5.0%), and *Zygophyllum potanini* Maxim (total flavonoid content based on kaempferol, 1.4%; WHO, 2013).

Allium mongolicum Regel is also well distributed in the country as a medicinal herb, which has some biological activities such as antioxidant, antitumor, antihypertensive, antimicrobial, anti-inflammatory, and improver gastrointestinal motility, hypolipidemic, appetite stimulating, kidney replenishing, and aphrodisiac (Dong et al., 2020; Wang et al., 2019). Wang et al. (2019) have studied the bioactivities of *A. mongolicum* in aqueous and methanol extracts. As reported by Wang et al. (2019), *A. mongolicum* has shown strong antioxidant activity.

Moreover, the strong antioxidant activities of *Fragaria orientalis* Losinsk, *Vaccinium vitis-idaea*, *Hippophae rhamnoides*, and *Paeonia anomala* L. were discovered that ranged from 797, 923, 1300 to 1544 mol TE/g dry leaf, respectively. The highest total phenolic compounds and flavonoid contents were observed in the dry leaf of the *Vaccinium vitis-idaea* (175 and 9 mg QE/g) (Enkhtuya et al., 2014). Birasuren et al. (2012) documented the antioxidant activity of *Ribes diacanthum* Pall. in its various extracts, which have traditionally been used in Mongolian medicine to treat kidney illnesses such as cystitis, bladder infections, retention, and edema. The ethyl acetate extract of *R. diacanthum* Pall. has potential antioxidant activities (Birasuren et al., 2012).

The lowest value with a radical scavenging capacity of 50% expresses the powerful antioxidant characteristics of the medicinal plants. Based on this value, *Rhodiola rosea* L., *Saxifraga Spinulosa* Adams, *Bupleurum* L., *Artemisia dolosa* Krasch. and *Cicuta virosa* L. were indicated to have strong antioxidant properties (5.84, 28.7, 67.93, 103.96, and 165.14 μg/mL, respectively; Badral et al., 2017).

3 | ANTIBACTERIALS

The second group of natural food preservatives is antibacterial plants, which contain terpenes, peptides, polysaccharides, and phenolic compounds. These bioactive compounds have medicinal characteristics including antioxidant, antimicrobial, and anti-inflammatory effects that reduce or inhibit the risk of chronic and acute diseases. The primary function of antimicrobial activity is to control the growth of microorganisms that cause bacterial and fungal contamination in food products. The main goal of their use in food industry is to prevent food spoilage in processed and ready-to-eat food.

Microorganisms can have an impact on food in both positive and negative ways. *Saccharomyces cerevisiae*, lactic acid bacteria, and *Acetobacterium* species are the main microorganisms for food fermentation (Xu, 2017). Several phenolic compounds as well as ferulic acid, coumaric acid, and catechins were found to inhibit the growth of microbes, for example, *Staphylococcus aureus*, *Salmonella enteritidis*, and *Listeria monocytogenes* (El-Sayed & Youssef, 2019). Saprophytic microorganisms also influence the spoilage of food and the growth of pathogenic microorganisms that cause food-borne illnesses (Xu, 2017). Many natural ingredients have antimicrobial properties that range from mild to potent. An ideal model compound for the natural antimicrobial activity should have broad bactericidal and fungicidal activities, be active at low concentrations, heat stable, unaffected by pH, nontoxic, easily assayable, nonpharmaceutical, nonsusceptible to resistance from contaminants, label-friendly, and cost-effective (Carocho et al., 2015).

The primary function of secondary metabolites with antimicrobial activity is to protect against pests and stress while also acting as signaling molecules between the cell and the environment. The mixture of plant polyphenols and essential oils with antimicrobial properties is used for the preservation of raw and processed products, for example, meat, fish, dairy products, fruit, and vegetables. Furthermore, essential oils such as thymol and carvacrol have been used in the packaging of food (Carocho et al., 2015).

The research on the antibacterial activity of Mongolian herbs is summarized in Table 1. Antibacterial activity of bacteria such as *S. aureus*, *E. faecalis*, and *M. luteus* was determined in most plants.

From the table, *Sedum hybridum* L. (Crassulaceae), a local medicinal plant, demonstrated strong antioxidant (31.93 ± 0.65 μg/mL at IC_{50}) and antibacterial activities in ethanol extract against gram-positive strains *M. luteus* and *S. aureus*. Herbs for food preservation can be utilized as whole plants, in parts, and in various forms such as extracts, solutions, and dried forms. As a result, it is appropriate to utilize the plant parts containing the most biologically active chemicals. Eighteen known compounds were extracted and identified using serial column chromatography of the ethyl acetate fraction of the plant extract using several packing materials and the researchers also investigated the antibacterial properties of isolated compounds found in medicinal plants against bacterial strains *P. aeruginosa*, *E. coli*, *E. faecalis*, *M. luteus*, and *S. aureus* by the disk diffusion method. The ethyl gallate inhibited the growth of *M. luteus*. (10.3–15.8 mm), *E. faecalis* (9.2–13.2 mm), *E. coli*, (9.2–13.5 mm), and *S. aureus* (9.8 mm) at 200–1000 μg/disk using the disk diffusion method (Gendaram et al., 2011). In 2015, Saruul et al. (2015) conducted the similar study. Aromatic abietane diterpenoids (demethylcryptojaponol, 6α-hydroxydemethyl cryptojaponol, and 6-hydroxysalvinolone) isolated from *Caryopteris mongolica* suppressed the growth of the *S. aureus*, *S. epidermidis*, *E. faecalis*, *and M. luteus*.

Moreover, natural antimicrobial – essential oil of the *Pyrethrum pulchrum* Ledeb. was investigated by Erdenetsogt et al. (2019). The essential oil, which was mostly composed of camphor (33.9%), linalool (21.1%), and α-pinene (9.0%), indicated a medium antibacterial activity against bacteria *P. aeruginosa*, *M. vaccae*, *and E. faecalis*. As previously reported, the essential oil extracted from the aerial part of the plant produced the same results (Erdenetsogt et al., 2019).

In 2008, Gonchig et al. conducted a large study on the antibacterial effects of the plants' extracts collected from 67 different plant species. The whole herb extracts of *Hedysarum alpinum*, *Comarum salesovianum*, and *Sedum hybridum* exhibited significant antibacterial activity against *P. aeruginosa* (10.5 mm), *S. aureus* (24.2 mm), and *E. faecalis* (17.1 mm), respectively. Furthermore, the root extract of *Paeonia anomala* exposed the highest antibacterial properties against *E. coli* (10 mm) and *M. luteus* (25.7 mm). Besides, the antibacterial activities of the plant extracts were evaluated in the different solvent fractions (dichloromethane, ethyl acetate, n-butanol, n-hexane, and water) and concentrations (0.5–4 mg/disc). The strong antibacterial activities were observed for ethyl acetate and n-butanol fractions obtained from the whole herb of *Sedum hybridum* and *Sedum aizoon* as well as the ethyl acetate fraction of the leaf extract of *Dasiphora fruticosa* and root extract of *Paeonia anomala* against *S. aureus* and *M. luteus*, respectively. Moreover, the ethyl acetate and n-butanol fractions of flower extracts of the *Dasiphora fruticosa* and *Sedum aizoon* were found to have a clear antibacterial effect against *E. faecalis*, while the whole herb

TABLE 1 The antibacterial activity of some Mongolian plants (inhibited growth in mm).

Plant names	*S. aureus*	*E. coli*	*P. aeruginosa*	*N. Gonorrhoeae*	*C. albicans*	*S. epidermidis*	*E. faecalis*	*M. luteus*	*B. subtilis*	*B. cereus*	*C. violaceum*	References
Abies sibirica L.	13.1							22				Gonchig et al. (2008)
Agrimonia pilosa L.	20.2							21.3				
Aquilegia sibirica Lam.	11.2											
Artemisia pectinata Pall.	14.7							18				
Astragalus junafovii Sancz.											19–25	(Zolboo et al., 2015)
Caryopteris mongolica Bunge.	10.2–12.9					10.2–15.9	9.6–23.2	9.0–16.3				(Saruul et al., 2015)
Comarum salesovianum Steph.	24.2						15.3	24.7				Gonchig et al. (2008)
Dasiphora fruticosa (L.) Rydb.	11.5–13.0						10.2	12.6–13.0				
Goniolimon speciosum (L.) Boiss.	18							10.9			23.5–27.5	Gonchig et al. (2008)
Hedysarum alpinum L.											24.5	Zolboo et al. (2015)
Lagotis integrifolia (Willd.) Schischk.	11.9							11.4				Gonchig et al. (2008)
Ledum palustre L.											19–28	Zolboo et al. (2015)
Lophanthus chinensis (Raf.) Benth.											22	
Lophanthus krylovii Lipsky.											20.5	
Malva mohileviensis Down.								11.6				Gonchig et al. (2008)
Myricaria alopecuroides Schrenk.	11.7						12.2	13.7				
Paeonia anomala L.	16.5	10					12	25.7				
Pinus sylvestris. var mongolica Litv.	4								5	5		Namshir et al. (2020)
Potentilla viscosa G. Donn	14						14.3	15				Gonchig et al. (2008)
Pyrola incarnata (D.C.) Freyn	17.5						13.6	18.4				
Pyrethrum pulchrum L	11		17		12		14		11			Erdenetsogt et al. (2019)
Rhinanthus songaricus (Skerneck) B.Fedtsch.								9.8				Gonchig et al. (2008)
Rosa acicularis Lindl.	13.2						12.4	15.8				

TABLE 1 (Continued)

Plant names	S.aureus	E.coli	P.aeruginosa	N.Gonorrhoeae	C.albicans	S.epidermidis	E.faecalis	M.luteus	B.subtilis	B.cereus	C.violaceum	References
Scutellaria baicalensis Georgi	15.9											Gonchig et al. (2008)
Sedum aizoon L.	13.6						9.7	11.9				Gendaram et al. (2011); Gonchig et al. (2008)
Sedum hybridum L.	10.5; 8.6–13.9	9.2–13.5					17.1; 9.2–13.2	14.6; 9.1–15.8	15.8			Gonchig et al. (2008)
Serratula centauroides L.								10				
Spiraea media F. Schmidt											18	Zolboo et al. (2015)
Spongiocarpella grubovii Ulzii											36.5	

extract of *Sedum aizoon* at 2 and 4 mg/disc demonstrated effective antibacterial activity against *S. aureus* (Gonchig et al., 2008). Antibacterial properties were also found in *Chelidonium majus* L. *and Plantago major* L. (WHO, 2013). Plants with the highest antibacterial activity, such as *Sedum hybridum*, *Pyrethrum pulchrum L*, and *Caryopteris mongolica Bunge*, have the potential to be used as natural food preservatives in the future.

4 | ANTIFUNGALS

Fungi, among spoilage microorganisms, are a major issue at any stage of the food chain because of their ability to grow in a variety of, even harsh environments. As a result, food spoiling by mold can result in significant economic losses for the food industry, as well as a health risk for consumers due to mycotoxin-producing mold species (Pitt & Hocking, 2013).

Beyond their negative impact on food quality, some fungal genera such as *Aspergillus*, *Penicillium*, *Alternaria*, and *Fusarium* have the ability to produce mycotoxins that can have a toxic effect on humans and animals. Furthermore, mycotoxins are able to withstand many food processing steps, raising concerns about food safety (Sanzani et al., 2016). *A. ochraceus* and *P. verrucosum*, *A. westerdijkiae* are considered the most important ochratoxin A (OTA) producers in foods (Frisvad et al., 2019; Mantle, 2002). OTA is nephrotoxic, neurotoxic, hepatoxic, teratogenic, genotoxic, immunotoxic, embryotoxic, and carcinogenic and is classified as a possible human carcinogen (group 2B; Mantle et al., 2015; WHO, 2008). OTA is not destroyed during standard food production processes due to its high stability and can be found both in raw materials and in processed foods such as cereals and cereal products, coffee, grapes, wine, beer, cocoa, nuts, dried fruits, and spices (Jeršek et al., 2014; Malir et al., 2016).

A conventional way to prevent decomposition by microorganism growth is the use of preservatives. Despite the desire for safe food, there is an increasing consumer demand to avoid or diminish chemical food additives, resulting in a growing interest in new safe and biodegradable preservatives. The possible adverse health and ecological effects of convinced fungicides and preservatives have led to more natural methods. Until now, many plant extracts with antibacterial and antifungal activity have already been known, including essential oils (EOs) and their active components (Bakkali et al., 2008; Calo et al., 2015).

Giordani et al. (2020) investigated the antifungal activity of extracts obtained from some Mongolian medicinal plants by measuring their minimal inhibitory concentration (MIC) against fungi cause of cutaneous diseases such as *Candida* species, dermatophytes *Microsporum gypseum*, *Trichophyton mentagrophytes*, and *Malassezia furfur*. Only *Stellaria dichotoma* L., *Scutellaria scordifolia* L., *Aquilegia sibirica* Fisch. Et Schrenk, and *Hyoscyamus niger* L. showed antifungal activity. Their geometric mean (GM) MIC_{50} values against *Candida* spp were 84, 22, 181, and 169 mg/mL, respectively. The GM MIC_{50} values for dermatophytes of *Scutellaria scordifolia* L., *Aquilegia sibirica* Fisch. Et Schrenk were 32 and 256 mg/mL, correspondingly. For

Malassezia furfur, *Scutellaria scordifolia* L. showed the best activity with MIC_{50} value of 64 mg/mL. In particular, *S. scordifolia* L. methanol extract exhibited the best activity against *Candida* spp., dermatophytes, and *Malassezia furfur* with GM MIC_{50} values of 22, 32, and 64 mg/mL, respectively (Olennikov & Chirikova, 2013; Shang et al., 2010).

Several studies have shown that *Scutellaria barbata*'s essential oil inhibits the growth of *Candida albicans*, *Candida tropicalis*, and *S. aureus* (Yu et al., 2004) and *Scutellaria baicalensis* L. plant extracts prevent the growth of *C. albicans*, *Cryptococcus neoformans*, *Pityrosporum ovale*, and *S. aureus* (Gonchig et al., 2008). *Scutellaria barbata* has 51 flavonoids (Каримов et al., 2016. *Scutellaria barbata* is most noted for its potent anticancer properties and is frequently combined with other herbs for anticancer traditional Chinese medicine formulations to treat cancers of the lung, liver, breast, and gastrointestinal tract (Dharmananda, 2004; Gao et al., 2019). To date, multiple classes of phytochemicals, including flavonoids, essential oils, polysaccharides, and terpenoid alkaloids, have been identified from *S. barbata* herb (Gao et al., 2019). The most widespread and therefore studied in detail is *S. baicalensis*. So far, 131 flavonoids, 96 flavone derivatives, 21 flavanones, 6 flavonols, 4 isoflavones, 3 flavanonols and 1 chalcone have been found in various organs of *S. baicalensis* (Каримов et al., 2016)

Currently, 57 natural compounds isolated from 16 plant species of *Aquilegia* genus. These include labdane diterpene −2 (3.5%), cycloartane −13 (22.8%), flavonoids −22 (38.5%), alkaloids and nitrogen-containing compounds −10 (17.5%) and phenolic acids, and fatty acids. From these 19 new natural compounds belonging to cycloartane glycosides, labdane diterpene, flavoalkaloids, and nitrile nitrogen compound have been identified. The presence of flavoalkaloid can consider a specific characterization of *Aquilegia* species (Odontuya & Nomin, 2018).

The flavones luteolin and apigenin identified in *S. scordifolia* Fisch. ex Schrank extracts, as well as rutin found in *Stellaria dichotoma* L. and *Hyoscyamus niger* L. extracts, could be responsible for the observed antifungal activity (Giordani et al., 2020). Dulger et al. (2010) studied the antifungal properties of the methanolic extract obtained from *H. niger* against some clinically relevant fungi such as *Candida* and *Cryptococcus* species. Greater activity was observed for the extracts of *H. niger* against both *Cryptococcus* species, with values of 15 μg/mL. The extracts have a strong effect against *Candida albicans* and *C. guilliermondii* as the same MIC values (60 μg/mL), followed by yeast cultures such as *C. tropicalis*, *C. krusei*, and *C. parapsilosis* have susceptible to the extract at a MIC of 12.5 μg/mL. The highest MICs of the extract were 250 μg/mL against *C. glabrata* (Dulger et al., 2010).

Table 2 lists the Mongolian herbs that have been examined and determined for their biological activity useful in food preservation, as well as their chemical components.

In addition, Table 3 contains the most prevalent local herbal spices that can be used as natural food preservatives. The antioxidant, antibacterial, and antifungal activities of commonly used herbal spices in Mongolia are listed in Table 3 on the basis of some applications including raw and processed food preservation, alternative medicines, and natural therapies. The relationship between antioxidant properties of spices and food spoilage has been well documented. Starting from the food preparation, spices can affect both food spoilage microorganisms (food preservation) and human pathogens (food safety) due to the antibacterial and antifungal activity of their natural constituents. These species can be used as sources of natural food preservatives with remarkable health benefits. Several studies have documented these effects and, in some cases, confirmed the mechanisms of action, though more research is needed in this area (Carocho et al., 2014).

TABLE 2 Mongolian herbs with antioxidant, antimicrobial, and antifungal properties.

Herbs	Compounds	Antioxidant	Antibacterial	Antifungal	Authors
Calligonum mongolicum Turcz.	22 compounds	+	+		Buyankhishig et al. (2021)
Caryopteris mongolica Bunge	7 compounds		+		Saruul et al. (2015)
Leaves of *Paeonia anomala L.*	Methyl gallate, pentagalloylglucose, tellimoside	+			Enkhtuya et al. (2017)
Mongolian medicinal plant extracts	-		+	+	Enkhtuya et al. (2017)
Mongolian medicinal plants	-		+		Gonchig et al. (2008)
Oxytropis pseudoglandulosa Gontsch. ex Grubov	26 components in volatile oil and 21 compounds in lipid extract	+	+		Narangerel, Bonikowski, et al. (2021)
Pinus sylvestris. var mongolica Litv.	101 compounds in the essential oil.	+	+		Namshir et al. (2020)
Pyrethrum pulchrum Ledeb.	55 chemical compounds in essential oil.		+	+	Erdenetsogt et al. (2019)
Ribes diacanthum Pall	-	+			Birasuren et al. (2012)
Saxifraga spinulosa Adams	25 compounds in aerial parts.	+	+		Birasuren et al. (2012)
Sedum hybridum L. (*Crassulaceae*),	18 compounds	+	+		Gendaram et al. (2011)
Thymus baicalensis Serg.	37 chemical compounds in volatile oil, 10 polyphenolic compounds, and 32 lipid components		+		Narangerel, Sójka, et al. (2021)

TABLE 3 Herbal spices with antioxidant, antibacterial, and antifungal activities as natural food preservatives.

Mongolian herbal spices	Bioactive properties: Antioxidant	Antibacterial	Antifungal	Main biological compounds
Allium sativum L.-Garlic	+	+	+	Organosulfur such as allicin, phenolic, and polysaccharides compounds (Avato et al., 2000; Bag & Chattopadhyay, 2015; Batiha et al., 2020; Lanzotti, Barile, et al., 2012; Leontiev et al., 2018; Martins et al., 2016; Medina et al., 2019; Pârvu et al., 2019; Prados et al., 2005; Shams-Ghahfarokhi et al., 2006; Szychowski et al., 2018)
Allium cepa L.-Onion	+	+	+	Thiosulfinate compounds, phenolic compounds, especially flavonoids, and several organosulfur compounds, polysaccharides, quercetin, quercetin-4′-monoglucoside, quercetin-3,4′-diglucoside, anthocyanins, and essential oils (Bag & Chattopadhyay, 2015; Fredotovíc et al., 2017; Kocić-Tanackov et al., 2017; Lanzotti, Romano, et al., 2012; Ma et al., 2018; Marefati et al., 2021; Prakash et al., 2007; Sharma et al., 2014)
Allium mongolicum Regel-Mongolian onion	+	+	+	Polysaccharides, flavonoids polyphenols, and phenols (Chen et al., 2020; Ding et al., 2021; Li, Guo, et al., 2019; Li, Zhu, et al., 2019; Wang et al., 2019)
Allium senescens L.- Aging chive	+	+	+	Organosulfur compounds, saponins, and phenolics (Kyung, 2012; Pârvu et al., 2011; Qin et al., 2021
Allium victorialis L.- Alpine leek	+	+	+	Allicin, kaempferol, ferulic acid, astragalin, methyl allyl disulfide, quercetin, diallyl disulfide, and furostanol glycosides (Khan et al., 2015; Kyung, 2012; Nishimura et al., 2006; Woo et al., 2012
Artemisia dracunculus L.-Tarragon	+	+	+	L-ascorbic acids, chlorophylls, carotenoids, tannins and flavonoids, essential oils, coumarins (>1%), flavonoids, and phenol carbonic acid (Kordali et al., 2005; Nurzynska-Wierdak & Zawislak, 2014; Obolskiy et al., 2011; Parham et al., 2020; Sandulachi et al., 2021; Souri et al., 2004; Zare et al., 2021)
Brassica juncea L Czern.-Mustard	+	+	+	Phenolics, sinapic acid and sinapoyl esters, glucosinolate (Engels et al., 2012; Kurt et al., 2011; Miceli et al., 2014; Oguro et al., 2014; Park et al., 2017; Sturm & Wagner, 2017; Sun et al., 2018; Thiyam, Stöckmann, & Schwarz, 2006; Thiyam, Stöckmann, Zum Felde, et al., 2006; Tian & Deng, 2020
Carum carvi L.-Caraway	+	+	+	Essential oils—carvone, limonene, germacrene D, and trans-dihydrocarvone, (Assami et al., 2012; Hajlaoui et al., 2021; Hromiš et al., 2015; Kocić-Tanackov et al., 2020; Obolskiy et al., 2011; Rasooli & Allameh, 2016; Samojlik et al., 2010; Seidler-Łozykowska et al., 2013; Tomović et al., 2021)
Coriandrum sativum L.-Coriander	+	+	+	Essential oils—(+)-Linalool (S)-(+)-linalool, α-Pinene β-Pinene, γ-Terpinene, α-Cedrene (Alves-Silva et al., 2013; Bogavac et al., 2015; Delaquis et al., 2002; Diana et al., 2016; Dua et al., 2014; Freires et al., 2014; Kačániová et al., 2020; Laribi et al., 2015; Mandal & Mandal, 2015; Marangoni & De Moura, 2011; Sriti et al., 2011)
Foeniculum vulgare Mill.-Fennel	+	+	+	Phenolic compounds, essential oils such as (E)-anethole, methyl-chavicol, fenchone, and limonene, phenylpropanoid derivatives, monoterpenoids, and sesquiterpene hydrocarbons (Anwar et al., 2009; Badgujar et al., 2014; Belabdelli et al., 2020; Ben Abdesslem et al., 2021; Choi & Hwang, 2004; Conforti et al., 2006; Diao et al., 2014; Farid et al., 2020; Goswami & Chatterjee, 2014; He & Huang, 2011; Kaur & Arora, 2009; Mohamad et al., 2011; Morales et al., 2012; Roby et al., 2013; Sayed-Ahmad et al., 2017; Shahat et al., 2011)
Glycyrrhiza glabra L.-Licorice	+	+	+	Triterpenes, saponins (responsible for the sweet taste), flavonoids, glycyrrhizin, 18β-glycyrrhetinic acid, glabridin A and B, and isoflavones, dihydrostilbene derivatives, and isoflavans (Ajagannanavar et al., 2014; Alagawany et al., 2019; Ali, 2013; Cheema et al., 2014; Chouitah et al., 2011; Gupta et al., 2008; Hosseinzadeh & Nassiri-Asl, 2015; Irani et al., 2010; Jang et al., 2008; Karahan et al., 2016; Karkanis et al., 2018; Kim et al., 2013; Messier & Grenier, 2011; Pastorino et al., 2018; Simmler et al., 2013; Singh et al., 2015; Siracusa et al., 2011)

TABLE 1 (Continued)

Mongolian herbal spices	Bioactive properties			Main biological compounds
	Antioxidant	Antibacterial	Antifungal	
Malva sylvestris. L -Mallows	+	+		Polyphenols, anthocyanins, coumarins, tannins, flavonoids, flavones, flavonols, anthocyanidines, leucoanthocyanidines, mucilage, and terpenoids such as sesquiterpenes, diterpenes, monoterpenes (Barros et al., 2010; Cecotti et al., 2016; Cheng & Wang, 2006; Feizi et al., 2018; Mohammed et al., 2014; Mousavi et al., 2021; Razavi et al., 2011; Sharifi-Rad et al., 2020; Zhen-yu, 2005)
Matricaria recutita L.- Chamomile	+	+	+	Flavonoids, terpenoids, and phenolic compounds primarily the flavonoids apigenin, quercetin, patuletin, luteolin and their glucosides, apigenin, and matricin (Al-Dabbagh et al., 2019; Höferl et al., 2020; Jang et al., 2008; Kazemi, 2015; Miraj & Alesaeidi, 2016; Sánchez et al., 2020; Sharifi-Rad et al., 2018; Singh et al., 2011; Stanojevic et al., 2016; Tsivelika et al., 2021)
Mentha arvensis L.-Pennyroyal	+	+		Menthol, somenthone/neoisomenthol, neomenthol, menthone, phenolic acids (e.g., rosmarinic and caffeic acids), flavones (e.g., luteolin derivatives), and flavanones (e.g., eriocitrin derivatives; Anwar et al., 2019; Benabdallah et al., 2016; Biswas et al., 2014; Bokhari et al., 2016; Dorman et al., 2003; Heydari et al., 2018; Hussain et al., 2010; Kalemba & Synowiec, 2020; Khan et al., 2019; Kurilov et al., 2009; Pandey et al., 2003; Salehi et al., 2018; Singh & Pandey, 2018; Varma & Dubey, 2001)
Mentha L.-Mint	+	+	+	Phenolic compounds, flavonoids (specific lipophilic flavonoids), terpenes/ essential oils [(Iseppi et al., 2020; Jianu et al., 2021; Ludwiczuk et al., 2016; Mimica-Dukic et al., 2003; Mimica-Dukic & Bozin, 2008; Tafrihi et al., 2021; Zeljković et al., 2021)]
Origanum vulgare L.-Oregano	+	+	+	Essential oil (with carvacrol and/or thymol, linalool, γ-terpinene, and p-cymene), polyphenols (flavonoids and phenolic acids), triterpenoids, and sterols (Bhargava et al., 2015; Chishti et al., 2013; De Falco et al., 2013; El Babili et al., 2011; Fliou et al., 2020; Gutiérrez-del-Río et al., 2018; Hernández-Hernández et al., 2014; Koldaş et al., 2015; Lombrea et al., 2020; Lukas et al., 2015; Moghrovyan et al., 2019; Oniga et al., 2018; Parra et al., 2021; Pezzani et al., 2017; Pitaro et al., 2013; Potente et al., 2020; Prakash et al., 2021; Scalas et al., 2018; Soltani et al., 2021; Teixeira et al., 2013; Węglarz et al., 2020; Zhang et al., 2014)
Portulaca oleracea L.-Portulaca	+	+		Ascorbic acid, a-tocopherols, omega-3 fatty acids, apigenin, gallotannins, quercetin, and kaempferol, alkaloids, terpenoids, flavonoids, and organic acids (Alam et al., 2014; Banerjee & Mukherjee, 2002; Fernández-Poyatos et al., 2021; Gatea et al., 2017; Iranshahy et al., 2017; Rahimi et al., 2019; Sicari et al., 2018; Siriamornpun & Suttajit, 2010; Zhou et al., 2015)
Thymus L.-Thyme	+	+	+	Phenolic acids and flavonoids, caffeic, rosmarinic, p-coumaric acids, luteolin 7-O-glucoside, naringenin, and (−)-epicatechin, carvacrol, thymol, γ-terpinene, p-cymene, linalool, and phenols (Ateeq-Ur-Rehman et al., 2009; Bogavac et al., 2015; Dauqan & Abdullah, 2017; De Martino et al., 2009; Fliou et al., 2020; Galovičová et al., 2021; Iseppi et al., 2019; Mandal & DebMandal, 2016; Marques et al., 2015; Mathlouthi, 2003; Neidhart, 2016; Nzeako et al., 2006; Paaver et al., 2008; Purcell et al., 2016; Scalas et al., 2018; Sefidkon et al., 2004)
Tribulus terrestris L.-Tribulus	+	+		Tannin and phenolic acids, flavonoids, flavonol glycosides, steroidal saponins, and alkaloids (Al-Bayati & Al-Mola, 2008; Chhatre et al., 2014; Parham et al., 2020; Sivapalan, 2016; Wang et al., 2016; Zeeshan Amanullah et al., 2021)
Urtica dioica L.-Nettle	+	+	+	Carotenoids, flavonoids, quercetin, and polyphenolics (Dar et al., 2013; Grauso et al., 2020; Majedi et al., 2021; Modarresi-Chahardehi et al., 2012; Parham et al., 2020; Salehzadeh et al., 2014)

5 | CONCLUSION

Plant phytochemicals have long been known to protect plants from bacteria, fungi, viruses, and herbivores, but it was lately revealed that they are also important in protecting humans from disease. It is well known that a diverse array of herbs, vegetables, fruits, and grains, besides having nutrients, vitamins, and minerals, also possess a large variety of biologically active compounds. Significant part of medicinal plants is consumed by humans, and as a food, it additionally improves human health and well-being in general. The application of natural plant food preservatives with additional potential as health-promoting agents is especially interesting.

Furthermore, because a number of the studies use data from species collected in the wild under uncontrolled conditions, more research is needed to understand the effects of preserving food of bioactive compounds and to enhance the use of this valuable genetic material.

AUTHOR CONTRIBUTIONS

Munkhjargal Burenjargal: Data curation (equal); investigation (equal); resources (equal); software (equal); writing – original draft (equal). **Saruul Idesh:** Formal analysis (equal); methodology (equal); project administration (equal); supervision (equal); writing – original draft (equal); writing – review and editing (equal). **Tuya Narangerel:** Data curation (equal); investigation (equal); methodology (equal); validation (equal); writing – original draft (equal). **Tuyagerel Batmunkh:** Funding acquisition (equal); validation (equal); visualization (equal). **Alideertu Dong:** Methodology (equal).

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CONFLICT OF INTEREST STATEMENT

The authors declare that they do not have any conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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