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Medicinal Plants of the Family Lamiaceae as Functional Foods – a Review

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Abstract

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Historically, species of the family Lamiaceae have enjoyed a rich tradition of use for flavouring, food preservation, and medicinal purposes, due to both their curative and their preventive properties. It is well known that each species has a special, complex mixture of bioactive compounds in which each component contributes to its overall bioactivity. Their value lays in the production of a wide range of secondary metabolites with potent antibacterial, antioxidant, anti-inflammatory, antimicrobial, antiviral, and anticancer activities. This review focuses on the Lamiaceae species and their secondary metabolites encompassing a wide array of beneficial functions and their applicability as sources of functional foods. It could help in addressing specific consumer needs as healthy diet is a part of the lifestyle that maintains or improves overall health.

Keywords: biological activity, food, herbs, nutraceuticals

Throughout the ages, humans have relied on plants as a source of food, flavours, fragrances, and medicines. Even today a large number of people use traditional medicinal plants containing mixtures of various compounds acting individually, additively or in synergy to improve health.

In the developed world food consumption not only just satisfies hunger but also it is associated with a requirement for happiness and well-being. Eating is a social and cultural act, and consequent health benefits have an important role in food consumption (Carrillo *et al*. 2013). The term "functional food" was first introduced in Japan in the mid-1980s and refers to processed foods containing ingredients that aid specific biological functions in addition to being nutritive (Arai 1996). Functional foods may improve health in general, reduce the impact of illness, and delay the onset of disease (Luthria 2006). Therefore functional foods blur the distinction between a food and a medicine and serve as a connection between them. In contribution to that, the advice of Hippocrates (an ancient Greek physician, and he is considered one of the most outstanding personalities in the history of medicine; c. 460–c. 370 BC) can be used: 'Let food be thy medicine and medicine be thy food'.

Functional foods

Concept of functional foods. Increasing interest in improving or maintaining health by intake of all-natural products in combination with lifestyle changes has created a desire for a more streamlined approach to nutrition. Growing consumer health awareness and available information about the usefulness of different diets and their impact on human health lead to the demand for functional food and beverages. The concept of functional foods includes foods or food ingredients that exert a beneficial effect on host health and/or reduce the risk of chronic disease beyond basic nutritional functions (Das *et al.* 2012). According to International Food Information Council Foundation (2011) there are several groups of

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functional components: carotenoids, phenolic acids, flavonoids, plant stanols/sterols, dietary fibres, fatty acids, isothiocyanates, minerals, polyols, prebiotics, probiotics, phytoestrogens, soy proteins, sulphides/thiols, and vitamins.

Functional foods can include foods used to improve the nutritional quality of an otherwise nutrient-deficient food (e.g. calcium in orange juice) or to resolve public health issues (e.g. iodised table salt). It can take many forms; some may be conventional food that is consumed as a part of a usual diet and has physiological benefits or can reduce the risk of chronic disease beyond basic nutritional functions. Some may be fortified or enhanced foods as well as products isolated or purified from foods that are generally sold in application forms. They are not usually associated with foods having a physiological benefit and are called nutraceuticals (Monge *et al.* 2008), such as multivitamin pills. Therefore, consumers can already select from a wide spectrum of foods that contain functional components.

Traditional functional foods. Positive effects of various plant species on well-being and human health were acknowledged centuries ago and their use in healing various diseases is as old as the practice of medicine. The basic knowledge of foods and their nutritional values was gained and developed in ancient times in the process of looking for adequate foods. The concept of food as medicine was accepted worldwide, especially in China, Japan, and other Asian countries where it was understood that foods have both preventive and curative effects and are an important part of health. Numerous functional foods and corresponding recipes for combining specific foods with culinary and non-culinary herbs to produce healing remedies have been documented in the publications of Chinese traditional medicine. Garlic (*Allium sativum* L.) is one of the earliest documented examples of plants used for disease treatment and maintenance of health (Rivlin 2001). It has been used for a wide variety of medicinal purposes and represented a staple crop in the diets of numerous cultures. The Egyptians, Babylonians, Greeks, and Romans used it for many conditions, including blood pressure disorders, snakebites, and infections (Koch *et al.* 1996). Antibacterial activity was discovered in 1858 by Pasteur and it was used as an antiseptic to prevent gangrene during World War I and II (Murray 1995). Peppermint (*Mentha piperita* L.) tea has a long history of use for digestive complaints and cranberries (*Vaccinium macrocarpon* L.) have long been known to maintain a healthy urinary tract, as their juice contains proanthocyanidins that inhibit the growth of *Escherichia coli* (Galland 2009). The health benefits of ginger (*Zingiber officinale* Roscoe) were documented 2000 years ago. It has been used in Chinese, Ayurvedic, and Unani-tibb herbal medicines all over the world, for a wide range of conditions including arthritis, rheumatism, sprains, sore throats, infections, digestion disorders, etc. (Ali *et al.* 2008). Curcumin from turmeric (*Curcuma longa* L.) has been used as spice as well as medicine in ancient traditional medicinal systems to treat gas, colic, toothaches, chest pains, stomach, and liver problems, to heal wounds and scars (Aggarwal 2007). Chinese herbal tonics prepared with ginger root, cinnamon bark (*Cinnamomum* spp.), and liquorice root (*Glycyrrhiza glabra* L.) have been widely used as a remedy for stomach ailments (Galland 2009).

During the second half of the twentieth century, new nutritional insights emerged and allowed the development of foods and beverages with a claimed health benefit, based on scientific evidence (Weststrate *et al.* 2002). So far, the functional food industry has focused mainly on ingredients that are inherent in vegetables, grains, and fruit. Examples for widespread foods that provide health benefits beyond basic nutrition are tomatoes (lycopene), green tea (catechins), cranberry juice (proanthocyanidins), and psyllium seeds (soluble fibre). Soybean grain is well-known for its functional components such as proteins, isoflavones, oligosaccharides, and phospholipids with beneficial effects on cardiovascular diseases, cancer, and diabetes (Dixit *et al.* 2011). Glucosinolates in broccoli (Fabek *et al.* 2012), amino acids in red head chicory (Herak Ćustić *et al.* 2009), phosphorus (Petek *et al.* 2008), and proteins (Petek *et al.* 2012) in beetroot can also improve human health. Phytosterols found naturally in vegetable oils, beans, and nuts have proven cholesterol lowering properties. Pomegranate juice contains antioxidants at much higher levels than other fruit juices and its consumption provides several heart-protecting benefits. Carrots, pumpkins, sweet potatoes, cantaloupe, spinach, and tomatoes are rich in beta-carotene that neutralises free radicals, stimulates cellular antioxidants, and is a precursor in vitamin A synthesis. Phenolic acids (especially caffeic and ferulic acid), determined in apples, pears, citrus fruits, whole grains, and coffee, are able to bolster cellular antioxidant defences as well as support the maintenance of eye and heart health. Plant stanols/sterols, as those from maize,

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soybean, and wheat, may reduce risks of the coronary heart disease (CHD) (International Food Information Council Foundation 2011).

Rediscovery of the connection between plants and health is responsible for launching a new generation of botanical therapeutics that include plant-derived pharmaceuticals, multicomponent botanical drugs, dietary supplements, functional foods, and plant-produced recombinant proteins (Raskin *et al.* 2002). There is an increasing number of studies that highlight the applicability of medicinal plants and herbs as sources of more potent or even innovative ingredients. They are an object of interest because many of them have been demonstrated that they possess antioxidant, antimicrobial, and cancer-protecting properties.

Medicinal plants of the family Lamiaceae

Plants have been the source for medicinal treatments for thousands of years. Traditional medicine uses plants for both their curative and their preventive properties. When used for preventive purposes, i.e. for the maintenance of overall good health, medicinal plants can be classified as functional foods and/or nutraceuticals. A good example is the use of spices that besides adding the flavour to foods can improve digestion or help in prevention of diseases.

The mint family (Lamiaceae) is an important medicinal plant family. It contains about 236 genera and more than 6000 species, and the largest genera are *Salvia*, *Scutellaria*, *Stachys*, *Plectranthus*, *Hyptis*, *Teucrium*, *Vitex*, *Thymus*, and *Nepeta*. It is a family of great diversity and variety with a cosmopolitan distribution. Species from the family inhabit different natural ecosystems and many members of the family are cultivated. The species of this family are easily recognisable by square stems and opposite leaves. The flowers are zygomorphic with five united petals and five united sepals, usually bisexual and verticillaster. Most of the species belonging to the family are aromatic and possess essential oils (Lawrence 1992). The aromatic essential oils are mostly present in leaves, however, they can be found in all aboveground parts of the plants. They are valuable in cosmetic, flavouring, fragrance, perfumery, pesticide, and pharmaceutical industries (Ozkan 2008). Some of the Lamiaceae species are used as culinary herbs and grown for edible leaves, e.g. basil (*Ocimum* spp.), mint (*Mentha* × *piperita* L.), rosemary (*Rosmarinus officinalis* L.), sage (*Salvia officinalis* L.), savory (*Satureja hortensis* L.), marjoram (*Origanum majorana* L.), oregano (*Origanum vulgare* L.), thyme (*Thymus vulgaris* L.), lavender (*Lavandula angustifolia* Mill.) and perilla (*Perilla frutescens* (L.) Britton) (Licina *et al.* 2013). The members of the family Lamiaceae also include plants that are widely used in traditional medicine as a cure for various disorders.

Secondary metabolites. The metabolic performance of living organisms can be distinguished into primary and secondary metabolism. Secondary metabolites represent features that can be expressed in terms of ecological, taxonomic, and biochemical differentiation and diversity. The presence of these compounds in the biochemistry of the plant is often difficult to explain as they are synthesised by the plants mainly as a part of their defence system against diseases and herbivores (Mazid *et al.* 2011). They can be found in roots, rhizomes, tubers, leaves, aerial parts, flowers, fruits, and seeds. Different classes of secondary metabolites constitute the bioactive compounds in various plants which can be used as functional foods. They have attracted particular interest as many of them have demonstrated to be antiallergenics, antidiabetics, antioxidants, antimutagenics, anticarcinogenics, antimicrobial, and anti-inflammatory agents, enhancers of the gastrointestinal function, immune-modulators and stimulators as well as blood pressure and cholesterol reducing agents (Vaishali Rai *et al.* 2013). The therapeutic application of medicinal plants is attributed to the presence of a wide range of secondary metabolites or phytochemicals such as alkaloids, saponins, flavonoids, glycosides, and phenols which all have various pharmacological activities classifying them as functional foods.

Phenols belong to the largest group of secondary metabolites in plants, foremost of the family Lamiaceae, and they exhibit multidirectional biological activity. Phenolic classes of pharmaceutical interests are: simple phenolic compounds (e.g. eugenol), tannins, quinones, flavonoids, lignans, and some terpenoids. Flavonoids are attracting interest due to the discovery of their anti-inflammatory, analgesic, anti-tumour, antimicrobial, antioxidant, and immunostimulant activities. Monoterpenes are the metabolites usually found in essential oils with anti-inflammatory properties. Saponins show various pharmacological activities e.g. anti-inflammatory, antitussive, expectorant, analgesic, and cytotoxic. Cardiotonic glycosides are used as drugs for the treatment of cardiac insufficiency (Vaishali Rai *et al.* 2013). Besides being natural

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colouring agents for food substances and cosmetics, carotenoids are also used for the treatment of retinal disease and glaucoma.

Many authors have reported antioxidant, antimicrobial, and anti-inflammatory properties of Lamiaceae species. It is well known that each species has a special, complex mixture of bioactive compounds in which each component contributes to its overall bioactivity. Moreover, in cases of some species a direct food-related application has been established.

Lamiaceae as antioxidants. In hope to find natural antioxidants for the food industry and consequently efficient therapy for numerous present-day human problems the screening studies for antioxidant properties of plants have been very common in the last few decades. Plant antioxidants are very significant as their presence in the human diet can help the body to neutralise free radicals and reduce the oxidative stress damage. On the contrary, synthetic antioxidants have possible activity as promoters of carcinogenesis (Suhaj 2006). The antioxidant activity of phenolic compounds depends on the structure and the natures of substitutions on the aromatic rings (Balasundram *et al.* 2005) while their health benefits depend on their absorption and metabolism (Parr & Bolwell 2000). Edible antioxidants commonly found in plants are ascorbic acid, tocopherols, carotenoids, and several phenolic compounds (Arash *et al.* 2006) such as phenolic acids, flavonoids, and tannins (King and Young 1999). Phenolic acids, for example caffeic, ferulic, and vanillic acids have been known as natural antioxidants widely distributed in the plant kingdom. Besides, naturally occurring polyphenols whose oxidation inhibiting activities have been known for a long time are tannins. Additionally, some studies have revealed that low amounts of tannins (0.15–0.2%) in the diet can be beneficial to human health and will create a more astringent feel to the taste, while at higher concentration, they inhibit the digestive enzymes and reduce the bioavailability of iron and vitamin B12 (King-Thom *et al.* 1998). Most of the Lamiaceae sources of antioxidants belong to the subfamily Nepetoideae, including basil, lemon balm, marjoram, mint, oregano, rosemary, sage, etc. They contain rosmarinic acid and are frequently abundant in fragrant volatile terpenes (Wink 2003). Moreover, the extracts of rosemary were the first marketed natural antioxidants. In the study of Kaefer and Milner (2008) thyme, sage, rosemary, and marjoram showed the greatest antioxidant capacity among the investigated herbs. Albayrak *et al.* (2013) have shown that besides thyme, rosemary, and sage, peppermint, lemon balm, and basil also contain a considerable amount of phenolic compounds with strong total antioxidant and DPPH radical scavenging activities. The aforementioned species are among the most frequently investigated species of the family Lamiaceae and their antioxidant activity has been demonstrated in numerous studies (Gonçalves *et al.* 2009; Ahmad *et al.* 2012; Sodré *et al.* 2012; Trakoontivakorn *et al.* 2012; Lagouri *et al.* 2013; Licina *et al.* 2013).

Lamiaceae as antimicrobial agents. Due to the overall usage of commercial antimicrobial drugs, multidrug resistance in both human and plant pathogenic microorganisms has developed (Eldeen *et al.* 2005). Therefore, scientists are trying to find new antimicrobial sources from plants which can be used in food industry, pharmacy, and medicine.

It is well documented that the majority of the investigated species belonging to the family Lamiaceae, e.g. lemon balm (Sarac & Ugur 2007), mint (Toroglu 2009), basil (Carović-Stanko *et al.* 2010; Rao *et al.* 2011), oregano (Dorman & Deans 2004), and rosemary (Toroglu 2009), possess antimicrobial properties. Thymol and carvacrol are the main components responsible for these actions (properties) as they interfere with cellular metabolism after penetrating into the cell (Marino *et al.* 2001). Plants have such important biological and pharmacological activities also due to the triterpene acids that also exhibit anti-inflammatory, antiviral, cytotoxic, and cardiovascular effects (e Silva *et al.* 2012). For example *Eriope blanchetii* produces considerable amounts of betulinic acid, as well as oleanolic and ursolic acids which are triterpenoid compounds that widely occur in nature in free acid form or as an aglycone precursor for triterpenoid saponins (Jesus *et al.* 2015). One of the most famous Lamiaceae species rich in ursolic acid is rosemary which was the subject of numerous studies. The Sharma and Bhadange (2013) study showed that basil (*Ocimum gratissimum* L. and *Ocimum kilimandscharicum* Baker ex Gürke) and *Pogostemon benghalensis* Kuntze possess antimicrobial activity against bacterial (*E. coli*, *S. aureus*, *S. typhimurium*) and fungal (*C. albicans* and *A. niger*) strains. Lemon balm, mint, basil, Brazilian boldo (*Plectranthus barbatus* Andrews), and rosemary were the subject of the Araújo *et al.* (2014) study and they have shown antibacterial activity to Gram-positive and Gram-negative bacterial strains (*E. faecalis*, *S. aureus*, *S. mutans*, *E. coli*, *K. pneumoniae*, and *P. aeruginosa*).

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Table 1. List of most used Lamiaceae species which can be used as a functional food

No.	Species	Medicinal properties due to biological activity	Edible part
1	*Acinos arvensis* (Lam.) Dandy	antimicrobial (Jovanovic *et al.* 2005)	leaves
2	*Ajuga reptans* L.	antibacterial and antitumour (Yildirim *et al.* 2013)	leaves and young shoots
3	*Agastache mexicana* (Kunth.) Link. & Epling	anti-nociceptive and anti-inflammatory (Gonzalez-Ramirez *et al.* 2012); vasoactive and antioxidant (Ibarra-Alvarado *et al.* 2010)	leaves and flowers
4	*Betonica officinalis* (L.) Trevis. syn. *Stachys officinalis* L.	antioxidant (Sliumpaite *et al.* 2013); anti-inflammatory effect of *Stachys* species (Háznagy-Radnai *et al.* 2012); antimicrobial, antioxidant, and antifungal (Háznagy-Radnai *et al.* 2012)	leaves and flowering tops
5	*Calamintha officinalis* Moench.	antidiabetic and antioxidant (Singh *et al.* 2012)	leaves
6	*Clinopodium vulgare* L.	antibacterial (Stefanovic *et al.* 2011); antitumour (Dzhambazov *et al.* 2002)	leaves
7	*Coleus forskohlii* Briq. syn. *Plectranthus barbatus* Andrews	activator of adenylyl cyclase (weight-loss) (Mohamed 2013); antioxidant (Khatun *et al.* 2011); antibacterial (Araújo *et al.* 2014)	leaves, tubers
8	*Dracocephalum heterophyllum* Benth.	antimicrobial and antioxidant (Zhang *et al.* 2008)	roots
9	*Elsholtzia splendens*	antioxidant (Lee *et al.* 2013); antibacterial, anti-inflammatory, antioxidant (Guo *et al.* 2012)	flowers and leaves
10	*Hyptis suaveolens* (L.) Poit.	carminative, stomachic, and stimulant (Arijit & Arpita 2013); antimicrobial, toxicity (Xu *et al.* 2013)	whole plant
11	*Hyssopus officinalis* L.	antioxidant and antihemolytic (Alinezhad *et al.* 2013); antimicrobial (Rota *et al.* 2004)	flowers and leaves
12	*Isodon japonicas* (Burm.) Hara.	anti-bacterial and anti-cancer, for gastrointestinal disorders (Sun *et al.* 2006)	leaves
13	*Lamium album* L.	antimicrobial (Chipeva *et al.* 2013); antioxidant (Pereira *et al.* 2012); free radical scavenging (Yalçin *et al.* 2007)	young shoots, leaves, and flowers
14	*Lamium purpureum* L.	antimicrobial and free radical scavenging (Yalçin *et al.* 2007)	leaves
15	*Lavandula angustifolia* Mill.	anti-inflammatory and analgesic (Hajhashemi *et al.* 2003); antimicrobial (Rota *et al.* 2004); antioxidant (Blazekovic *et al.* 2010)	leaves, petals, and flowering tips
16	*Leucas aspera* Willd.	antimicrobial (Antony *et al.* 2013); antinociceptive, antioxidant, and cytotoxic (Rahman *et al.* 2007); hepatoprotective, antioxidant (Banu *et al.* 2012)	shoots and leaves
17	*Lycopus europaeus* L.	antimicrobial (Radulovic *et al.* 2010)	roots
18.	*Marrubium vulgare* L.	antibacterial, antifungal, and cytotoxic (Zarai *et al.* 2011); anti-diabetic (Boudjelal *et al.* 2011); gastroprotective (Paula de Oliveira *et al.* 2011); vermifuge-respiratory-purgative (Joudi *et al.* 2011); anti-inflamatory (El Abbouyi *et al.* 2013)	leaves
19	*Melissa officinalis* L.	digestive, tranquiliser, antimicrobial, antioxidant (Sodré *et al.* 2012); antibacterial (Sarac & Ugur 2007)	aerial part
20	*Mentha arvensis* L.	analgesic, antiseptic, antispasmodic, carminative, antimicrobial (Akram *et al.* 2011); antioxidant (Ahmad *et al.* 2012)	leaves
21	*Mentha* x *piperita* L.	antimicrobial, sedative, analgesic, carminative (Saller 2004); antioxidant (Ahmad *et al.* 2012; Gonçalves *et al.* 2009); antimicrobial (Toroglu 2011)	leaves
22	*Micromeria fruticosa* (L.) Druce	anti-inflammatory and gastroprotective (Abu-Gharbieh *et al.* 2013); antimicrobial (Toroglu 2011)	aerial part

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Table 1 to be continued

No.	Species	Medicinal properties due to biological activity	Edible part
23	*Monarda fistulosa* L.	antibacterial, antimycotic, and anti-inflammatory (Zhilyakova *et al.* 2009)	leaves and flowers
24	*Nepeta cataria* L.	antioxidant (Naguib *et al.* 2012); antibacterial, antifungal, antioxidant (Formisano *et al.* 2011)	leaves
25	*Ocimum americanum* L.	antibacterial (Carović-Stanko *et al.* 2010); antioxidant (Trakoontivakorn *et al.* 2012); antiviral (Yucharoen *et al.* 2011)	leaves
26	*Ocimum basilicum* L.	antibacterial (Alzoreky & Nakahara 2003; Carović-Stanko *et al.* 2010); antioxidant (Trakoontivakorn *et al.* 2012); antiviral (Carović-Stanko *et al.* 2010); antibacterial and antifungal (Rao *et al.* 2011)	leaves, flowers, and seeds
27	*Ocimum tenuiflorum* syn. *O. sanctum* L.	antioxidant (Trakoontivakorn *et al.* 2012); antiviral (Yucharoen *et al.* 2011); antimicrobial and antioxidant (Joshi 2013); antibacterial and antifungal (Rao *et al.* 2011)	leaves and flowers
28	*Origanum majorana* L.	antioxidant, antibacterial, expectorant, sedative, carminative, and stimulant (Chih-Chien *et al.* 2011)	leaves
29	*Origanum vulgare* L.	antioxidant and antimicrobial, against cold, for digestive, and respiratory problems (Licina *et al.* 2012); antimicrobial antioxidant (Dorman & Deans 2004); antibacterial (Alexopoulos *et al.* 2011)	leaves
30	*Perilla frutescens* (L.) Britton	antioxidant, induction of perspiration and dispelchills, regulation of stomach function (Hong *et al.* 2011); antidepressant (Yi *et al.* 2013)	leaves, inflorescence
31	*Phlomis lychnitis* L.	anti-inflammatory (Algieri *et al.* 2013); antioxidant (Lopez *et al.* 2010)	flowered aerial part
32	*Phlomis pungens* Willd.	antibacterial and antitumour (Yildirim *et al.* 2013); antibacterial, antifungal, and antiviral (Ozcelik *et al.* 2010); antioxidant (Keser *et al.* 2012)	aerial part
33	*Prunella vulgaris* L.	antibacterial (Sarac and Ugur 2007); antioxidant and anticancer (Hwang *et al.* 2013)	leaves
34	*Rosmarinus officinalis* L.	antiseptic, anti-inflammatory, antispasmodic, hepatoprotective, anti-diabetic, anti-ulcerogenic, antidepressant, and antioxidant (Yosr *et al.* 2013); antimicrobial (Rota *et al.* 2004; Toroglu 2011); antioxidant (Lagouri and Alexandri 2013)	aerial part
35	*Salvia fruticosa* Mill.	antioxidant and anticholinesterase (Topcu *et al.* 2013); antimicrobial and antioxidant (Giweli *et al.* 2013); antioxidant (Erdogan *et al.* 2011); antimicrobial (Askun *et al.* 2009)	leaves
36	*Salvia hispanica* L.	antioxidant (Reyes-Caudillo *et al.* 2008); prevent cardiovascular diseases, inflammatory and nervous system disorders, and diabetes (Munoz *et al.* 2013)	seeds
37	*Salvia officinalis* L.	antimicrobial (Rota *et al.* 2004); antibacterial, allelopathic, and antioxidant (Bouajaj *et al.* 2013); gastroprotective, antidiabetic, anti-obesity, anti-inflammatory, antispasmatic, virucidal, fungicidal, and bactericidal (Jug-Dujaković *et al.* 2003)	leaves and flowers
38	*Salvia sclarea* L.	antimicrobial (Rota *et al.* 2004); antioxidant and antiviral (Ogutcu *et al.* 2008)	leaves and flowers
39	*Salvia tomentosa* Mill.	antioxidant (Erdogan *et al.* 2011; Dincer *et al.* 2013) antimicrobial (Askun *et al.* 2009)	leaves
40	*Satureja hortensis* L.	antinociceptive and anti-inflammatory (Hajhashemi *et al.* 2002); antibacterial (Dincer *et al.* 2013); antioxidant (Yesiloglu *et al.* 2013)	leaves

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Table 1 to be continued

No.	Species	Medicinal properties due to biological activity	Edible part
41	*Satureja montana* L.	antimicrobial (Rota *et al.* 2004); antibacterial (Nedorostova *et al.* 2011; Sfeir *et al.* 2013); cytotoxic, antioxidant, and antimicrobial (Miladi *et al.* 2013); antioxidant and antimicrobial (Cavar *et al.* 2008)	leaves and flowered aerial part
42	*Scutellaria baicalensis*	antioxidant and antiinflamatory (Seok *et al.* 2016); cardiovascular, kidney, and liver diseases (Lai *et al.* 2016)	leaves
43	*Scutellaria indica* L.	antitumour (Min *et al.* 1997); antioxidant (Kim *et al.* 2009)	leaves
44	*Sideritis scardica* Griseb.	expectorant, pulmonary emphysema, urogenital diseases, immunostimulant (Ivanova *et al.* 2005); anti-inflammatory, gastroprotective, and cytotoxic (Tadic *et al.* 2012); antioxidant (Koleva *et al.* 2003)	leaves, flowers
45	*Stachys byzantina* C. Koch.	antimicrobial, antioxidant, and antifungal (Conforti *et al.* 2009)	leaves and flowering tops
46	*Stachys chrisantha* Boiss. & Heldr.	antimicrobial, antioxidant, and antifungal (Conforti *et al.* 2009)	leaves and flowering tops
47	*Stachys cretica* L.	antibacterial (Sarac & Ugur 2007); antimicrobial, antioxidant, antifungal, antiradical, and cytotoxic (Conforti *et al.* 2009)	leaves and flowering tops
48	*Stachys inflata* Benth.	antiinflammatory (Joudi *et al.* 2011); antimicrobial, antioxidant, and antifungal (Conforti *et al.* 2009)	leaves and flowering tops
49	*Stachys laxa* Boiss. and Buhse.	antimicrobial, antioxidant, and antifungal (Conforti *et al.* 2009); citotoxic (Khanavi *et al.* 2012)	leaves and flowering tops
50	*Teucrium chamaedrys* L.	antibacterial (Eldeen *et al.* 2005; Djabou *et al.* 2013); antioxidant (Stankovic *et al.* 2010)	flowered aerial part
51	*Teucrium polium* L.	antibacterial (Eldeen *et al.* 2005; Djabou *et al.* 2013); antibacterial (Zerroug *et al.* 2011); antioxidant (D'abrosca *et al.* 2013)	leaves and flowered aerial part
52	*Thymbra spicata* L.	antioxidant (Yilmaz & Yilmaz 2012); antimicrobial (Markovic *et al.* 2011)	flowered aerial part
53	*Thymus serpyllum* L.	antibacterial (Nedorostova *et al.* 2011; Joshi 2013) antibacterial, antioxidant, antimalarial, and antiproliferative (Hussain *et al.* 2013); antioxidant and antihypertensive (Mihailovic-Stanojevic *et al.* 2013)	leaves
54	*Thymus vulgaris* L.	antioxidant (Cerda *et al.* 2013); antifungal (Sellamuthu *et al.* 2013); antimicrobial (Alinezhad *et al.* 2013); antibacterial (Nedorostova *et al.* 2011; Ballester-Costa *et al.* 2013; Sfeir *et al.* 2013); antioxidant and antibacterial (Aliakbarlu & Shameli 2013)	flowered aerial part
55	*Ziziphora clinopodioides* Lam.	antioxidant and antibacterial (Aliakbarlu & Shameli 2013); antibacterial (Aghajani *et al.* 2008)	aerial parts
56	*Ziziphora tenuior* L.	anti-diarrhea, febrifuge, and pectoral effects (Joudi *et al.* 2011); antioxidant and antibacterial (Aliakbarlu & Shameli 2013)	aerial parts

Within the aforementioned properties, a common need is the availability of natural extracts with preservative action, aimed to avoid oxidation and spoilage by microorganisms combined with pleasant taste or odour. Moreover, the scientific verification of the biological activity of plants with potential antimicrobial activities is needed, but unfortunately most of the medicinal and aromatic plants have not yet been exploited for their bioactivities.

Lamiaceae as anti-inflammatory agents. Even today many people, foremost in rural areas, depend on herbal medicines to treat inflammation-related conditions such as rheumatism, muscle swelling, cut wounds, accidental bone fractures, insect bites,

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etc. Discovery of natural inflammatory agents and further development of novel dietary supplements with anti-inflammatory activities is of considerable public health relevance, since malnutrition (modern dietary habit) is linked to inflammation, aging, and other degenerative processes (Charami *et al.* 2008). The species of the family Lamiaceae are a great source of phenolic compounds of multidirectional biological activity, including anti-inflammatory one. The main classes of phenolic compounds reported to be present in the family Lamiaceae are phenolic acids, mainly caffeic and rosmarinic acid and flavonoids. The species of the family Lamiaceae known to possess anti-inflammatory activity are Mexican giant hyssop (*Agastache mexicana* (Kunth.) Link. & Epling.) (Gonzalez-Ramirez *et al.* 2012), lavender (Hajhashemi *et al.* 2003), rosemary (Yosr *et al.* 2013), sage (Jug-Dujaković *et al.* 2012), savory (Hajhashemi *et al.* 2002), and horehound (*Marrubium vulgare* L.) (El Abbouyi *et al.* 2013).

Lamiaceae and other activity of contained substances. In addition, the Lamiaceae species are an important source of preventive agents for the treatment of global health problems. For diabetes *Gmelina arborea* Roxb. (Nayak *et al.* 2013), *Marrubium vulgare* L. (Boudjelal *et al.* 2011), *Salvia hispanica* L. (Munoz *et al.* 2013) have proven to be effective, while *Salvia elegans* Vahl. (Jimenez *et al.* 1988), *Thymus capitatus* (L.) Hoffmanns & Link (Yvon *et al.* 2012), *Salvia hispanica* L. (Mihailovic-Stanojevic *et al.* 2013), and *Thymus serpyllum* L. (Jovanovic *et al.* 2005) can be used for hypertension.

Due to their chemical composition, species of the family Lamiceae indicate a great potential as functional foods. Numerous studies have shown their properties that can be relevant to the promotion of health and the prevention or treatment of some diseases. Therefore, the most commonly used species with a sound scientific basis for the relationship between foods and health benefits are summarised in Table 1, while the more detailed list of species and their health claims is given in the Suplemmentary material.

Consumer well-being

The Lamiaceae as natural antioxidants, antimicrobial, and anti-inflammatory agents are assumed to be safe. However, the consumption of functional foods or food ingredients with health claims should be based on sound scientific evidence. Even if there is evidence that certain functional foods or food ingredients can play a role in the prevention or treatment of illnesses, safety considerations should be in the first place. As it is permitted to make statements on food labels related to the health benefits of functional foods, interest in developing such products for the health and wellness market is growing. However, we cannot be certain that all the foods in the market which are labelled as functional truly are. Claims about the health benefits from functional foods must be communicated effectively to consumers and should be based on scientific criteria including safety studies. Herbs and spices are normally accepted as safe, at least at concentrations normally present in foods. Still, many of such species and their bioactive components are studied for potential disease prevention at concentrations which exceed those usually present in food. It is therefore important to identify any potential safety concerns associated with the use of various dosages which range from doses commonly used for culinary purposes to those used for medicinal purposes (Kaefer & Milner 2008).

CONCLUSION

The intention of this review is to present the reported beneficial effects of Lamiaceae species from scientific literature. General inspection of the literature suggests that these species possess antioxidant, antimicrobial, and anti-inflammatory properties. In addition, most of them have been reported to possess several beneficial properties suggesting that this type of knowledge could affect overall interest in Lamiaceae as functional foods and encourage the production and consumption of these species. It could help in addressing specific consumer needs as healthy diet is a part of the lifestyle that maintains or improves overall health. Since the availability of this type of food in the market is relatively new, its popularity depends on publications directed at consumer education and development and widespread use of new and improved functional properties by the food industry.

References

Abu-Gharbieh E., Shehab N.G., Khan S.A. (2013): Anti-inflammatory and gastroprotective activities of the aqueous extract of *Micromeria fruticosa* (L.) Druce ssp.

doi: 10.17221/504/2015-CJFS

serpyllifolia in mice. Pakistan Journal of Pharmaceutical Sciences, 26: 799–803.

Aggarwal B.B., Sundaram C., Nikita M., Ichikawa H. (2007): Curcumin, the Indian solid gold. Advances in Experimental Medicine and Biology, 595: 1–75.

Aghajani Z., Assadian F., Masoudi S., Chalabian F., Esmaeili A., Tabatabaei-Anaraki M., Rustaiyan A. (2008): Chemical composition and in vitro antibacterial activities of the oil of *Ziziphora clinopodioides* and *Z. capitata* subsp. *capitata* from Iran. Chemistry of Natural Compounds, 44: 387–389.

Ahmad N., Fazal H., Ahmad I., Abbasi B.H. (2012): Free radical scavenging (DPPH) potential in nine *Mentha* species. Toxicology and Industrial Health, 28: 83–89.

Akram M., Uzair M., Malik N.S., Mahmood A., Sarwer N., Madni A., Asif H.M. (2011): *Mentha arvensis* Linn. a review article. Journal of Medicinal Plants Research, 5: 4499–4503.

Albayrak S., Aksoy A., Albayrak S., Sağdıç O. (2013): *In vitro* antioxidant and antimicrobial activity of some Lamiaceae species. Iranian Journal of Science and Technology Transaction A-Science, 1: 1–9.

Alexopoulos A., Kimbaris A.C., Plessas S., Mantzourani I., Theodoridou I., Stavropoulou E., Polissiou M.G., Bezirtzoglou E. (2011): Antibacterial activities of essential oils from eight Greek aromatic plants against clinical isolates of *Staphylococcus aureus*. Anaerobe, 17: 399–402.

Algieri F., Zorrilla P., Rodriguez-Nogales A., Garrido-Mesa N., Banuelos O., Gonzalez-Tejero M.R., Casares-Porcel M., Molero-Mesa J., Zarzuelo A., Utrilla M.P. (2013): Intestinal anti-inflammatory activity of hydroalcoholic extracts of *Phlomis purpurea* L. and *Phlomis lychnitis* L. in the trinitrobenzenesulphonic acid model of rat colitis. Journal of Ethnopharmacology, 146: 750–759.

Ali H.B., Blunden G., Tanira O.M., Nemmar A. (2008): Some phytochemical, pharmacological and toxicological properties of ginger (*Zingiber officinale* Roscoe): a review of recent research. Food and Chemical Toxicology, 46: 409–442.

Aliakbarlu J., Shameli F. (2013): *In vitro* antioxidant and antibacterial properties and total phenolic contents of essential oils from *Thymus vulgaris, T. kotschyanus*, *Ziziphora tenuior* and *Z. clinopodioides*. Turkish Journal of Biochemistry, 38: 425–431.

Alinezhad H., Azimi R., Zare M., Ebrahimzadeh M.A., Eslami S., Nabavi S.F., Nabavi S.M. (2013): Antioxidant and antihemolytic activities of ethanolic extract of flowers, leaves, and stems of *Hyssopus officinalis* L. var. *angustifolius*. International Journal of Food Properties, 16: 1169–1178.

Alzoreky N.S., Nakahara K. (2003): Antibacterial activity of extracts from some edible plants commonly consumed in Asia. International Journal of Food Microbiology, 80: 223–230.

Antony J.J., Nivedheetha M., Siva D., Pradeepha G., Kokilavani P., Kalaiselvi S., Sankarganesh A., Balasundaram A., Masilamani V., Achiraman S. (2013): Antimicrobial activity of *Leucas aspera* engineered silver nanoparticles against *Aeromonas hydrophila* in infected *Catla catla*. Colloids and Surfaces B: Biointerfaces, 109: 20–24.

Arai S. (1996): Studies on functional foods in Japan: state of art. Bioscience, Biotechnology, and Agrochemistry, 60: 9–15.

Arash R., Koshy P., Muniandy S. (2010): Antioxidant potential and phenolic content of ethanolic extract of selected Malaysian plants. Research Journal of Biotechnology, 5: 16–19.

Araújo S.G., Alves L.F., Pinto M.E.A., Oliveira G.T., Siqueira E.P., Ribeiro R.I.M.A., Ferreira J.M.S., Lima L.A.R.S. (2014): Volatile compounds of Lamiaceae exhibit a synergistic antibacterial activity with streptomycin. Brazilian Journal of Microbiology, 45: 1341–1347.

Arijit S., Arpita B. (2013): Documentation of some ethnomedicinal plants of family Lamiaceae in Bankura district West Bengal India. International Research Journal of Biological Sciences, 2: 63–65.

Askun T., Tumen G., Satil F., Ates M. (2009): Characterization of the phenolic composition and antimicrobial activities of Turkish medicinal plants. Pharmaceutical Biology, 47: 563–571.

Balasundram N., Sundram K., Samman S. (2006): Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. Food Chemistry, 99: 191–203.

Ballester-Costa C., Sendra E., Fernandez-Lopez J., Perez-Alvarez J.A., Viuda-Martos M. (2013): Chemical composition and in vitro antibacterial properties of essential oils of four *Thymus* species from organic growth. Industrial Crops and Products, 50: 304–311.

Banu S., Bhaskar B., Balasekar P. (2012): Hepatoprotective and antioxidant activity of *Leucas aspera* against D-galactosamine induced liver damage in rats. Pharmaceutical Biology, 50: 1592–1595.

Blazekovic B., Vladimir-Knezevic S., Brantner A., Stefan M.B. (2010): Evaluation of antioxidant potential of *Lavandula × intermedia* Emeric ex Loisel. 'Budrovka': a comparative study with *L. angustifolia* Mill. Molecules, 15: 5971–5987.

Bouajaj S., Benyamna A., Bouamama H., Romane A., Falconieri D., Piras A., Marongiu B. (2013): Antibacterial allelopathic and antioxidant activities of essential oil of *Salvia officinalis* L. growing wild in the Atlas Mountains of Morocco. Natural Product Research, 27: 1673–1676.

Boudjelal A., Henchiri C., Siracusa L., Sari M., Ruberto G. (2011): Compositional analysis and *in vivo* anti-diabetic activity of wild Algerian *Marrubium vulgare* L. infusion. Fitoterapia, 83: 286–292.

doi: 10.17221/504/2015-CJFS

Carović-Stanko K., Orlić S., Politeo O., Strikić F., Kolak I., Miloš M., Šatović Z. (2010): Composition and antibacterial activities of essential oils of seven *Ocimum* taxa. Food Chemistry, 119: 196–201.

Carrillo E., Prado-Gascó V., Fiszman S., Varela P. (2013): Why buying functional foods? Understanding spending behaviour through structural equation modelling. Food Research International, 50: 361–368.

Cavar S., Maksimovic M., Solic M.E., Jerkovic-Mujkic A., Besta R. (2008): Chemical composition and antioxidant and antimicrobial activity of two *Satureja* essential oils. Food Chemistry, 111: 648–653.

Cerda A., Martínez M.E., Soto C., Poirrier P., Perez-Correa J.R., Vergara-Salinas J.R., Zúñiga M.E. (2013): The enhancement of antioxidant compounds extracted from *Thymus vulgaris* using enzymes and the effect of extracting solvent. Food Chemistry, 139: 138–143.

Charami M., Lazari D., Karioti A., Skaltsa H., Hadjipavlou-Litina D., Souleles C. (2008): Antioxidant and antiinflammatory activities of *Sideritis perfoliata* subsp. *perfoliata* (Lamiaceae). Phytotherapy Research, 22: 450–454.

Chih-Chien L., Chao-Hsun Y., Pey-Shiuan W., Chang-Chin K., Yi-Shyan C. (2011): Antimicrobial anti-tyrosinase and antioxidant activities of aqueous aromatic extracts from forty-eight selected herbs. Journal of Medicinal Plants Research, 5: 6203–6209.

Chipeva V.A., Petrova D.C., Geneva M.E., Dimitrova M.A., Moncheva P.A., Kapchina-Toteva V.M. (2013): Antimicrobial activity of extracts from *in vivo* and *in vitro* propagated *Lamium album* L. plants. African Journal of Traditional Complementary and Alternative Medicines, 10: 559–562.

Conforti F., Menichini F., Formisano C., Rigano D., Senatore F., Arnold N.A., Piozzi F. (2009): Comparative chemical composition free radical-scavenging and cyto-toxic properties of essential oils of six *Stachys* species from different regions of the Mediterranean area. Food Chemistry, 116: 898–905.

D'Abrosca B., Pacifico S., Scognamiglio M., D'Angelo G., Galasso S., Monaco P., Fiorentino A. (2013): A new acylated flavone glycoside with antioxidant and radical scavenging activities from *Teucrium polium* leaves. Natural Product Research, 27: 356–363.

Das A., Raychaudhuri U., Chakraborty R. (2012): Cereal based functional food of Indian subcontinent: a review. Journal of Food Science and Technology, 49: 665–672.

Dincer C., Tontul I., Cam I.B., Ozdemir K.S., Topuz A., Nadeem H.S., Tugrulay S., Gokturk R.S. (2013): Phenolic composition and antioxidant activity of *Salvia tomentosa* Miller: effects of cultivation, harvesting year, and storage. Turkish Journal of Agriculture and Forestry, 37: 561–567.

Dixit A.K., Antony J.I.X., Sharma N.K., Tiwari R.K. (2011): Soybean constituents and their functional benefits. In: Opportunity Challenge and Scope of Natural Products in Medicinal Chemistry. India, Research Signpost: 367–383.

Djabou N., Lorenzi V., Guinoiseau E., Andreani S., Giuliani M.C., Desjobert J.M., Bolla J.M., Costa J., Berti L., Luciani A. (2013): Phytochemical composition of Corsican *Teucrium* essential oils and antibacterial activity against foodborne or toxi-infectious pathogens. Food Control, 30: 354–363.

Dorman H.J.D., Deans S.G. (2004): Chemical composition, antimicrobial and in vitro antioxidant properties of *Monarda citriodora* var. *citriodora*, *Myristica fragrans*, *Origanum vulgare* ssp. *hirtum*, *Pelargonium* sp. and *Thymus zygis* oils. Journal of Essential Oil Research, 16: 145–150.

Dzhambazov B., Daskalova S., Monteva A., Popov N. (2002): In vitro screening for antitumour activity of *Clinopodium vulgare* L (Lamiaceae) extracts. Biological and Pharmaceutical Bulletin, 25: 499–504.

e Silva M. de L., David J.P., Silva L.C.R.C., Santos R.A.F., David J.M., Lima L.S., Reis P.S., Fontana R. (2012): Bioactive oleanane, lupane and ursane triterpene acid derivatives. Molecules, 17: 12197–12205.

El Abbouyi A., El Khyari S., Eddoha R., Filali-Ansari N. (2013): Anti-inflammatory effect of hydromethanolic extract from *Marrubium vulgare* Lamiaceae on leukocytes oxidative metabolism: an *in vitro* and *in vivo* studies. International Journal of Green Pharmacy, 7: 224–229.

Eldeen I.M.S., Elgorashi E.E., Staden J.V. (2005): Antibacterial, anti-inflammatory, anti-cholinesterase and mutagenic effects of extracts obtained from some trees used in South African traditional medicine. Journal of Ethnopharmacology, 102: 457–464.

Erdogan S.S., Karik U., Baser K.H.C. (2011): The determination of total phenolics and flavonoid contents and antioxidant activity of some sage populations of *Salvia fruticosa* Mill., *Salvia pomifera* Mill. and *Salvia tomentosa* Mill. in the Marmara region of Turkey. Planta Medica, 77: 1319–1319.

Fabek S., Toth N., Radojčić Redovniković I., Herak Ćustić M., Benko B., Žutić I. (2012): The effect of nitrogen fertilization on nitrate accumulation and the content of minerals and glucosinolates in broccoli cultivars. Food Technology and Biotechnology, 50: 183–191.

Formisano C., Rigano D., Senatore F. (2011): Chemical constituents and biological activities of *Nepeta* species. Chemistry and Biodiversity, 8: 1783–1818.

Galland L. (2009): Functional foods: Health effects and clinical applications. In: Caballero B. (ed.): Guide to Nutritional Supplements. 1st Ed. Oxford, Elsevier Ltd.: 219–220.

Giweli A.A., Dzamic A.M., Sokovic M., Ristic M.S., Janackovic P., Marin P.D. (2013): The chemical composition, antimicrobial and antioxidant activities of the essential oil of *Salvia fruticosa* growing wild in Libya. Archives of Biological Sciences, 65: 321–329.

doi: 10.17221/504/2015-CJFS

Gonçalves R.S., Battistin A., Pauletti G., Rota L., Serafini L.A. (2009): Antioxidant properties of essential oils from *Mentha* species evidenced by electrochemical methods. Revista Brasileira de Plantas Medicinais, 11: 372–382.

Gonzalez-Ramirez A., Gonzalez-Trujano M.E., Pellicer F., Lopez-Munoz F.J. (2012): Anti-nociceptive and anti-inflammatory activities of the *Agastache mexicana* extracts by using several experimental models in rodents. Journal of Ethnopharmacology, 142: 700–705.

Guo Z., Liu Z., Wang X., Liu W., Jiang R., Cheng R., She G. (2012): *Elsholtzia*: phytochemistry and biological activities. Chemistry Central Journal, 6: 147.

Hajhashemi V., Ghannadi A., Pezeshkian S.K. (2002): Antinociceptive and anti-inflammatory effects of *Satureja hortensis* L. extracts and essential oil. Journal of Ethnopharmacology, 82: 83–87.

Hajhashemi V., Ghannadi A., Sharif B. (2003): Anti-inflammatory and analgesic properties of the leaf extracts and essential oil of *Lavandula angustifolia* Mill. Journal of Ethnopharmacology, 89: 67–71.

Háznagy-Radnai E., Balogh Á., Czigle S., Máthé I., Hohmann J., Blazsó G. (2012): Antiinflammatory activities of Hungarian *Stachys* species and their iridoids. Phytotherapy Research, 26: 505–509.

Herak Ćustić M., Horvatić M., Pecina M. (2009): Nitrogen fertilization influences protein nutritional quality in red head chicory. Journal of Plant Nutrition, 32: 598–609.

Hong E., Hwan Park K., Kim G.-H. (2011): Phenolic-enriched fractions from *Perilla frutescens* var. *acuta*: Determinating rosmarinic acid and antioxidant activity. Journal of Food Biochemistry, 35: 1637–1645.

Hussain A.I., Anwar F., Chatha S.A.S., Latif S., Sherazi S.T.H., Ahmad A., Worthington J., Sarker S.D. (2013): Chemical composition and bioactivity studies of the essential oils from two *Thymus* species from the Pakistani flora. LWT-Food Science and Technology, 50: 185–192.

Hwang Y.J., Lee E.J., Kim H.R., Hwang K.A. (2013): *In vitro* antioxidant and anticancer effects of solvent fractions from *Prunella vulgaris* var. *lilacina*. BMC Complementary and Alternative Medicine, 13: Article ID 310. doi 101186/1472-6882-13-310

Ibarra-Alvarado C., Rojas A., Mendoza S., Bah M., Gutierrez DM., Hernandez-Sandoval L., Martinez M. (2010): Vasoactive and antioxidant activities of plants used in Mexican traditional medicine for the treatment of cardiovascular diseases. Pharmaceutical Biology, 48: 732–739.

International Food Information Council Foundation (2011). Available at http://foodinsightorg (accessed Jun, 2014).

Ivanova D., Gerova D., Chervenkov T., Yankova T. (2005): Polyphenols and antioxidant capacity of Bulgarian medicinal plants. Journal of Ethnopharmacology, 96: 145–150.

Jesus J.A., Lago J.H.G., Laurenti M.D., Yamamoto E.S., Passero L.F.D. (2015): Antimicrobial activity of oleanolic and ursolic acids: an update. Evidence-Based Complementary and Alternative Medicine, Article ID 620472. doi.org/10.1155/2015/620472

Jimenez J., Zarzuelo A., Crespo M.E. (1988): Hypotensive activity of *Thymus orospedanus* alcoholic extract. Phytotherapy Research, 2: 152–153.

Joshi R.K. (2013): Chemical composition, *in vitro* antimicrobial and antioxidant activities of the essential oils of *Ocimum gratissimum*, *O. sanctum* and their major constituents. Indian Journal of Pharmaceutical Sciences, 75: 457–462.

Joudi L., Bibalani G.H., Shadkami H. (2011): Exploration of medicinal species of Lamiaceae family in Ilkhji and Sharafaldin Regions of Esat Azarbaijan in Iran. Current Research Journal of Biological Sciences, 3: 385–387.

Jovanovic T., Kitic D., Palic R., Stojanovic G., Ristic M. (2005): Chemical composition and antimicrobial activity of the essential oil of *Acinos arvensis* (Lam.) Dandy from Serbia. Flavour and Fragrance Journal, 20: 288–290.

Jug-Dujaković M., Ristić M., Pljevljakušić D., Dajić-Stevanović Z., Liber Z., Hančević K., Radić T., Šatović. Z. (2012): High diversity of indigenous populations of Dalmatian sage (*Salvia officinalis* L.) in essential-oil composition. Chemistry and Biodiversity, 9: 2309–2323.

Kaefer C.M., Milner J.A. (2008): The role of herbs and spices in cancer prevention. Journal of Nutritional Biochemistry, 19: 347–361.

Keser S., Turkoglu S., Celik S., Turkoglu. I. (2012): Determination of antioxidant capacities of *Phlomis pungens* Wild var. *hispida* Hub-Mor. Asian Journal of Chemistry, 24: 2780–2784.

Khanavi M., Manayi A., Lotfi M., Abbasi R., Majdzadeh M., Ostad S.N. (2012): Investigation of citotoxic activity in four *Stachys* species from Iran. Iranian Journal of Pharmaceutical Research, 11: 589–593.

Khatun S., Chatterjee N.C., Cakilcioglu U. (2011): Antioxidant activity of the medicinal plant *Coleus forskohlii* Briq. African Journal of Biotechnology, 10: 2530–2535.

Kim D.S., Kwon H.J., Jang H.D., Kwon Y.I. (2009): *In vitro* alpha-glucosidase inhibitory potential and antioxidant activity of selected Lamiaceae species inhabited in Korean penninsula. Food Science and Biotechnology, 18: 239–244.

King A., Young G. (1999): Characteristics and occurrence of phenolic phytochemicals. Journal of the American Dietetic Association, 99: 213–218.

King-Thom C., Wong T.Y., Cheng I.W., Yao-Wen H., Yuan L. (1998): Tannins and human health: a review. Critical Reviews in Food Science and Nutrition, 38: 421–468.

doi: 10.17221/504/2015-CJFS

Koch H.P., Lawson L.D. (1996): Garlic: the science and therapeutic application of *Allium sativum* L. and related species. 2nd Ed. Baltimore, Williams & Wilkins.

Koleva I.I., Linssen J.P.H., van Beek T.A., Evstatieva L.N., Kortenska V., Handjieva N. (2003): Antioxidant activity screening of extracts from *Sideritis* species (Labiatae) grown in Bulgaria. Journal of the Science of Food and Agriculture, 83: 809–819.

Lagouri V., Alexandri G. (2013): Antioxidant properties of greek *O. dictamnus* and *R. officinalis* methanol and aqueous extracts – HPLC determination of phenolic acids. International Journal of Food Properties, 16: 549–562.

Lai C.C., Huang P.H., Yang A.H., Chiang S.C., Tang C.Y., Tseng K.W., Huang C.H. (2016): Baicalein, a component of *Scutellaria baicalensis*, attenuates kidney injury induced by myocardial ischemia and reperfusion. Planta Medica, 82: 181–189.

Lawrence B.M. (1992): Chemical components of Labiatae oils and their exploitation. In: Harley R.M., Reynolds T. (eds): Advances in Labiate Science. Richmond, Royal Botanic Gardens Kew: 399–436.

Lee J.S., Kim G.H., Lee H.G. (2013): Optimization of extraction conditions for *Elsholtzia splendens* and its antioxidant activity. Journal of Food Biochemistry, 37: 669–676.

Licina B.Z., Stefanovic O.D., Vasic S.M., Radojevic I.D., Dekic M.S., Comic L.R. (2013): Biological activities of the extracts from wild growing *Origanum vulgare* L. Food Control, 33: 498–504.

Lopez V., Jager A.K., Akerreta S., Cavero R.Y., Calvo M.I. (2010): Antioxidant activity and phenylpropanoids of *Phlomis lychnitis* L.: a traditional herbal tea. Plant Foods for Human Nutrition, 65: 179–185.

Luthria D.L. (2006): Significance of sample preparation in developing analytical methodologies for accurate estimation of bioactive compounds in functional foods. Journal of the Science of Food and Agriculture, 86: 2266–2272.

Marino M., Bersani C., Comi G. (2001): Impedance measurements to study the antimicrobial activity of essential oils from Lamiaceae and Compositae. International Journal of Food Microbiology, 67: 187–195.

Markovic T., Chatzopoulou P., Siljegovic J., Nikolic M., Glamoclija J., Ciric A., Sokovic M. (2011): Chemical analysis and antimicrobial activities of the essential oils of *Satureja thymbra* L. and *Thymbra spicata* L. and their main components. Archives of Biological Sciences, 63: 457–464.

Mazid M., Khan T.A., Mohammad F. (2011): Role of secondary metabolites in defense mechanisms of plants. Biology and Medicine, 3: 232–249.

Mihailovic-Stanojevic N., Belscak-Cvitanovic A., Grujic-Milanovic J., Ivanov M., Jovovic D., Bugarski D., Miloradovic Z. (2013): Antioxidant and antihypertensive activity of extract from *Thymus serpyllum* L. in experimental hypertension. Plant Foods for Human Nutrition, 68: 235–240.

Miladi H., Ben Slama R., Mili D., Zouari S., Bakhrouf A., Ammar E. (2013): Chemical composition and cytotoxic and antioxidant activities of *Satureja montana* L. essential oil and its antibacterial potential against *Salmonella* spp. strains. Journal of Chemistry, Article ID 275698. doi: 101155/2013/275698

Min B.S., Chung K.S., Bae K.H. (1997): Antitumor activity of 2(*S*)-5,2',5'-trihydroxy-7,8-dimethoxyflavanone and its analogues. Archives of Pharmacal Research, 20: 368–371.

Mohamed S. (2013): Methods of isolation and analysis of forskolin from *Coleus forskohlii*. In: Ramawat K.G., Mérillon J.M. (eds): Natural Products: Phytochemistry, Botany and Metabolism of Alkaloids, Phenolics and Terpenes. Berlin-Heidelberg, Springer-Verlag: 3325–3343.

Monge A., Cardozo T., Barreiro E.J., Pinzón R., Mora G., Núñez A., Chiriboga X., Cáceres A., Rivera G., Bocanegra-García V., Gupta M., Ferro E.A. (2008): Functional foods reflexions of a scientist regarding a market in expansion. Revista de la Sociedad Química del Perú, 74: 138–147.

Munoz L.A., Cobos A., Diaz O., Aguilera J.M. (2013): Chia seed (*Salvia hispanica*): an ancient grain and a new functional food. Food Reviews International, 29: 394–408.

Murray M.T. (1995): The healing power of herbs: the enlightened person's guide to the wonders of medicinal plants. 2nd Ed. Rocklin, Prima Publishing.

Naguib A.M.M., Ebrahim M.E., Aly H.F., Metawaa H.M., Mahmoud A.H., Mahmoud E.A., Ebrahim F.M. (2012): Phytochemical screening of *Nepeta cataria* extracts and their *in vitro* inhibitory effects on free radicals and carbohydrate-metabolising enzymes. Natural Product Research, 26: 2196–2198.

Nayak B.S., Dinda S.C., Ellaiah P. (2013): Evaluation of diuretic activity of *Gmelina arborea* Roxb. fruit extracts. Asian Journal of Pharmaceutical and Clinical Research, 6 (Suppl. 1): 111–113.

Nedorostova L., Kloucek P., Urbanova K., Kokoska L., Smid J., Urban J., Valterova I., Stolcova M. (2011): Antibacterial effect of essential oil vapours against different strains of *Staphylococcus aureus*, including MRSA. Flavour and Fragrance Journal, 26: 403–407.

Ogutcu H., Sokmen A., Sokmen M., Polissiou M., Serkedjieva J., Daferera D., Sahin F., Baris O., Gulluce M. (2008): Bioactivities of the various extracts and essential oils of *Salvia limbata* CAMey. and *Salvia sclarea* L. Turkish Journal of Biology, 32: 181–192.

Ozcelik B., Orhan I., Kartal M., Konuklugil B. (2010): In vitro testing of antiviral, antibacterial, antifungal effects and cytotoxicity of selected Turkish *Phlomis* species. Acta Alimentaria, 39: 119–125.

doi: 10.17221/504/2015-CJFS

Ozkan M. (2008): Glandular and eglandular hairs of *Salvia recognita* Fisch. & Mey. (Lamiaceae) in Turkey. Bangladesh Journal of Botany, 37: 93–95.

Parr A.J., Bolwell G.P. (2000): Phenols in the plant and in man. The potential for possible nutritional enhancement of the diet by modifying the phenols content or profile. Journal of the Science of Food and Agriculture, 80: 985–1012.

Paula de Oliveira A., Santin J.R., Lemos M., Klein Júnior L.C., Garcia Couto A., Meyre da Silva Bittencourt C., Cechinel Filho V., Faloni de Andrade S. (2011): Gastroprotective activity of methanol extract and marrubiin obtained from leaves of *Marrubium vulgare* L. (Lamiaceae). Journal of Pharmacy and Pharmacology, 63: 1230–1237.

Pereira O.R., Domingues M.R.M., Silva A.M.S., Cardoso S.M. (2012): Phenolic constituents of *Lamium album*: Focus on isoscutellarein derivatives. Food Research International, 48: 330–335.

Petek M., Herak Ćustić M., Čoga L., Pecina M. (2008): Phosphorus content in soil and in fresh and cooked red beet in dependence on different fertilization. Cereal Research Communications, 36 (Suppl.): 435–438.

Petek M., Herak Ćustić M., Toth N., Slunjski S., Čoga L., Pavlović I., Karažija T., Lazarević B., Cvetković S. (2012): Nitrogen and crude proteins in beetroot (*Beta vulgaris* var. *conditiva*) under different fertilization treatments. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 40: 215–219.

Radulovic N., Denic M., Stojanovic-Radic Z. (2010): Antimicrobial phenolic abietane diterpene from *Lycopus europaeus* L. (Lamiaceae). Bioorganic and Medicinal Chemistry Letters, 20: 4988–4991.

Rahman M.S., Sadhu S.K., Hasan C.M. (2007): Preliminary antinociceptive antioxidant and cytotoxic activities of *Leucas aspera* root. Fitoterapia, 78: 552–555.

Rao B.R.R., Kothari S.K., Rajput D.K., Patel R.P., Darokar M.P. (2011): Chemical and biological diversity in fourteen selections of four *Ocimum* species. Natural Product Communications, 6: 1705–1710.

Raskin I., Ribnicky D.M., Komarnytsky S., Ilic N., Poulev A., Borisjuk N., Brinker A., Moreno D.A., Ripoll C., Yakoby N., O'Neal J.M., Cornwell T., Pastor I., Fridlender B. (2002): Plants and human health in the twenty-first century. Trends in Biotechnology, 20: 522–531.

Reyes-Caudillo E., Tecante A., Valdivia-Lopez M.A. (2008): Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (*Salvia hispanica* L.) seeds. Food Chemistry, 107: 656–663.

Rivlin R.S. (2001): Historical perspective on the use of garlic. Journal of Nutrition, 131 (Special Issue): 951S–954S.

Rota C., Carraminana J.J., Burillo J., Herrera A. (2004): *In vitro* antimicrobial activity of essential oils from aromatic plants against selected foodborne pathogens. Journal of Food Protection, 67: 1252–1256.

Saller R. (2004): Peppermint (*Mentha* × *piperita*) medicinal plant of the year. Forschende Komplementarmedizin und Klassische Naturheilkunde, 11: 6–7.

Sarac N., Ugur A. (2007): Antimicrobial activities and usage in folkloric medicine of some Lamiaceae species growing in Mugla, Turkey. EurAsian Journal of BioSciences, 4: 28–37.

Sellamuthu P.S., Sivakumar D., Soundy P. (2013): Antifungal activity and chemical, composition of thyme, peppermint and citronella oils in vapor phase against avocado and peach postharvest pathogens. Journal of Food Safety, 33: 86–93.

Seok J.K., Kwak J.Y., Choi G.W., An S.M., Kwak J.H., Seo H.H., Suh H.J., Boo Y.C. (2016): *Scutellaria radix* extract as a natural UV protectant for human skin. Phytotherapy Research, 30: 374–379.

Sfeir J., Lefrancois C., Baudoux D., Derbre S., Licznar P. (2013): *In vitro* antibacterial activity of essential oils against *Streptococcus pyogenes*. Evidence-Based Complementary and Alternative Medicine, 2013: Article ID 269161. doi: 101155/2013/269161

Sharma S.M., Bhadange D.G. (2013): Antimicrobial potential of Lamiaceae members. International Journal of Pharmacy and Pharmaceutical Sciences, 3: 324–327.

Singh P.P., Jha S., Irchhaiya R. (2012): Antidiabetic and antioxidant activity of hydroxycinnamic acids from *Calamintha officinalis* Moench. Medicinal Chemistry Research, 21: 1717–1721.

Sliumpaite I., Venskutonis P.R., Murkovic M., Ragazinskiene O. (2013): Antioxidant properties and phenolic composition of wood betony (*Betonica officinalis* L., syn. *Stachys officinalis* L.). Industrial Crops and Products, 50: 715–722.

Sodré A.C.B., Luz J.M.Q., Haber L.L., Marques M.O.M., Rodrigues C.R., Blank A.F. (2012): Organic and mineral fertilization and chemical composition of lemon balm (*Melissa officinalis*) essential oil. Revista Brasileira de Farmacognosia/Brazilian Journal of Pharmacognosy, 22: 40–44.

Stankovic M.S., Topuzovic M., Solujic S., Mihailovic V. (2010): Antioxidant activity and concentration of phenols and flavonoids in the whole plant and plant parts of *Teucrium chamaerdys* L. var. *glanduliferum* Haussk. Journal of Medicinal Plants Research, 4: 2092–2098.

Stefanovic O., Stankovic M.S., Comic L. (2011): In vitro antibacterial efficacy of *Clinopodium vulgare* L. extracts and their synergistic interaction with antibiotics. Journal of Medicinal Plants Research, 5: 4074–4079.

Suhaj M. (2006): Spice antioxidants isolation and their antiradical activity: a review. Journal of Food Composition and Analysis, 19: 531–537.

doi: 10.17221/504/2015-CJFS

Sun D.H., Huang S.H., Han Q.B. (2006): Diterpenoids from *Isodon* species and their biological activities. Natural Product Reports, 23: 673–698.

Tadic V.M., Jeremic I., Dobric S., Isakovic A., Markovic I., Trajkovic V., Bojovic D., Arsic. I. (2012): Anti-inflammatory gastroprotective and cytotoxic effects of *Sideritis scardica* extracts. Planta Medica, 78: 415–427.

Topcu G., Ozturk M., Kusman T., Barla Demirkoz A.A., Kolak U., Ulubelen A. (2013): Terpenoids essential oil composition and fatty acids profile and biological activities of Anatolian *Salvia fruticosa* Mill. Turkish Journal of Chemistry, 37: 619–632.

Toroglu S. (2011): *In-vitro* antimicrobial activity and synergistic/antagonistic effect of interactions between antibiotics and some spice essential oils. Journal of Environmental Biology, 32: 23–29.

Trakoontivakorn G., Tangkanakul P., Nakahara K. (2012): Changes of antioxidant capacity and phenolics in *Ocimum* herbs after various cooking methods. Jarq-Japan Agricultural Research Quarterly, 46: 347–353.

Vaishali Rai M., Ramanath Pai V., Pratapchandra Kedilaya H., Hegde S. (2013): Preliminary phytochemical screening of members of Lamiaceae family: *Leucas linifolia*, *Coleus aromaticus* and *Pogestemon patchouli*. International Journal of Pharmaceutical Sciences Review and Research, 21: 131–137.

Weststrate J.A., van Poppel G., Verschuren P.M. (2002): Functional foods trends and future. British Journal of Nutrition, 88: 233–235.

Wink M. (2003): Evolution of secondary metabolites from an ecological and molecular phylogenetic perspective. Phytochemistry, 64: 3–19.

Xu D.H., Huang Y.S., Jiang D.Q., Yuan K. (2013): The essential oils chemical compositions and antimicrobial, antioxidant activities and toxicity of three *Hyptis* species. Pharmaceutical Biology, 51: 1125–1130.

Yalçın F.N., Kaya D., Kılıç E., Özalp M., Ersöz T., Çalış I. (2007): Antimicrobial and free radical scavenging activities of some *Lamium* species from Turkey. Hacettepe University Journal of the Faculty of Pharmacy, 27: 11–22.

Yesiloglu Y., Sit L., Kilic I. (2013): *In vitro* antioxidant activity and total phenolic content of various extracts of *Satureja hortensis* L. collected from Turkey. Asian Journal of Chemistry, 25: 8311–8316.

Yi L.-T., Li J., Geng D., Liu B.-B., Fu Y., Tu J.-Q., Liu Y., Weng L.-J. (2013): Essential oil of *Perilla frutescens*-induced change in hippocampal expression of brain-derived neurotrophic factor in chronic unpredictable mild stress in mice. Journal of Ethnopharmacology, 147: 245–253.

Yildirim A.B., Karakas F.P., Turker A.U. (2013): *In vitro* antibacterial and antitumor activities of some medicinal plant extracts growing in Turkey. Asian Pacific Journal of Tropical Medicine, 6: 616–624.

Yilmaz O., Akkaya H. (2012): Radical scavenging, activity of *Thymbra spicata* and *Quercus ithaburensis* in a fenton reagent environment and their protective effects on unsaturated fatty acids. Ekoloji, 21: 34–40.

Yosr Z., Hnia C., Rim T., Mohamed B. (2013): Changes in essential oil composition and phenolic fraction in *Rosmarinus officinalis* L. var. *typicus* Batt. organs during growth and incidence on the antioxidant activity. Industrial Crops and Products, 43: 412–419.

Yucharoen R., Anuchapreeda S., Tragoolpua Y. (2011): Anti-herpes simplex virus activity of extracts from the culinary herbs *Ocimum sanctum* L., *Ocimum basilicum* L. and *Ocimum americanum* L. African Journal of Biotechnology, 10: 860–866.

Yvon Y., Raoelison E.G., Razafindrazaka R., Randriantsoa A., Romdhane M., Chabir N., Mkaddem M.G., Bouajila J. (2012): Relation between chemical composition or antioxidant activity and antihypertensive activity for six essential oils. Journal of Food Science, 77: H184–H191.

Zarai Z., Kadri A., Ben Chobba I., Ben Mansour R., Bekir A., Mejdoub H., Gharsallah N. (2011): The *in-vitro* evaluation of antibacterial, antifungal and cytotoxic properties of *Marrubium vulgare* L. essential oil grown in Tunisia. Lipids in Health and Disease, 10: 161.

Zerroug M.M., Zouaghi M., Boumerfeg S., Baghiani A., Nicklin J., Arrar L. (2011): Antibacterial Activity of Extracts of *Ajuga iva* and *Teucrium polium*. Advances in Environmental Biology, 5: 491–495.

Zhang C.J., Li H.Y., Yun T., Fu Y.H., Liu C.M., Gong B., Neng B.J. (2008): Chemical composition, antimicrobial and antioxidant activities of the essential oil of Tibetan herbal medicine *Dracocephalum heterophyllum* Benth. Natural Product Research, 22: 1–11.

Zhilyakova E.T., Novikov O.O., Naumenko E.N., Krichkovskaya L.V., Kiseleva T.S., Timoshenko E.Y., Novikova M.Y., Litvinov S.A. (2009): Study of *Monarda fistulosa* essential oil as a prospective antiseborrheic agent. Bulletin of Experimental Biology and Medicine, 148: 612–614.

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