ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol. Technol. Aliment. 15(4) 2016, 353–365
www.food.actapol.net pISSN 1644-0730 eISSN 1889-9594 DOI: 10.17306/J.AFS.2016.4.34

REVIEW PAPER

Received: 22.06.2016
Accepted: 16.10.2016

THE INDUSTRIAL POTENTIAL OF HERBS AND SPICES – A MINI REVIEW

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ABSTRACT

Herbs and spices have been used for food and medicinal purposes for centuries – the first recorded evidence of their use dates back to 1500BC and the Ebers Papyrus, which mentioned spices such as anise, mustard, saffron, cinnamon, and cassia. Now, in the 21st century, a variety of secondary compounds produced by plants are used in many fields of industry, such as food production (to improve taste, to provide vitamins and macro- and microelements, and also to inhibit food spoilage caused by foodborne bacteria), in medicine (in the treatment of various diseases; in chemoprevention and cancer therapy; as a source of natural antimicrobials for the treatment of infectious disease), and in pharmacology and cosmetology (in dietary supplements, and as a result of the demand for preservative-free cosmetics, to reduce the risk of methylparaben allergies). The aim of this review is to present the major active compounds in herbs and spices and explore their potential applications in industry.

Key words: herbs, species, antimicrobial activity, food, natural cosmetics, natural medicine

INTRODUCTION

Some plant-derived substances have gained popularity recently, due to their versatility and range of applications (Ncube et al., 2008). However, the health benefits of herb and spice extracts have been discussed for centuries (Elgayyar et al., 2001). They have been used in many branches of industry such as medicine, pharmacy, cosmetology, and food production (Craig, 1999; Wallace, 2004).

Herbs and spices are a very rich source of bioactive compounds such as vitamins, micro- and macroelements, glycosides, alkaloids, tannins, essential oils, flavonoids, antracompounds, phenols, coumarin, organic acids, and saponins. Examples of compounds belonging to the particular groups, and their associated health benefits and potential industrial applications are presented in Table 1 (Skarżyński, 1994).

The antimicrobial activity of plant extracts is an important issue in dealing with the antibiotic resistance of microorganisms. Bacteria have the genetic ability to transmit and acquire resistance to drugs, so the rapid development of the pharmacological industries in the last three decades has caused increased resistance to drugs by microorganisms. As a consequence, new diseases have developed and, especially in immuno-compromised patients, resulted in high mortality. Therefore, in order to keep this problem under control, it is necessary to limit the use of antibiotics and research the mechanisms of genetic resistance in bacteria in order to develop new drugs, especially those of natural origin (Gislene et al., 2000). In order to investigate the bacterial growth-inhibiting properties of plant derivatives, bacteria

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Table 1. The bioactive ingredients of herbs and spices

Bioactive group	Examples	Function
1	2	3
Vitamins	A, E, D, K, C, B, PP	Most of these influence human health: A is responsible for growth, healthy mucous membranes and eyesight and E for fertility, redox processes, the prevention of premature aging, and also for giving us energy and vitality and improving mood; D takes part in the absorption of calcium and phosphorus into the body and makes the body resistant to infections; K is involved in blood clotting and sealing the endothelium of blood vessels; C increases the resistance of our body to various infections and accelerates wound healing; B enhances the metabolism of carbohydrates, is involved in tissue respiration and hemoglobin synthesis, and in conjunction with many proteins it forms enzymes needed for the transportation of oxygen around the body; PP is necessary for all cells in the body for oxidation and reduction reactions, particularly in the metabolism of sugars and blood hemoglobin, and is essential for the proper functioning of the nervous system, skin and mucous membranes.
Microelements	sodium, chlorine, potassium, calcium	Sodium and chlorine ions are necessary to maintain a constant osmotic pressure and for hydrochloric acid production in the stomach; potassium ions play an important role in oxidative processes and electrical polarization, and have a dehydrating effect; calcium has affects bone and tooth health, lowers cholesterol in blood, and also impacts on the functioning of nerves and muscles.
Macroelements	iron, copper, magnesium, zinc	Iron and copper are essential for blood clotting; copper is also necessary certain redox enzymes to operate effectively, and zinc is necessary for the metabolism of proteins and carbohydrates, and for the growth and development of the whole body.
Glycosides	cardiac glycosides antraglycosides, anthocyanin glycosides, phenolic glycosides, coumarin glycosides	From a medical point of view, the most important of these are cardiac glycosides (sometimes called steroid glycosides) that strengthen the heart muscle; antraglycosides are used in diseases of the gastrointestinal tract, particularly as laxatives; anthocyanin glycosides strengthen the capillary blood vessels, are involved in numerous oxidation and reduction reactions, and improve sight; phenolic glycosides have diuretic, disinfectant and anti-inflammatory properties; coumarin glycosides have relaxant, slightly diuretic and sedative properties.
Alkaloids	tropane derivatives (atropine, scopolamine cocaine) pyridine derivatives (nicotine) choline derivatives (quinine quinidine) indole derivatives (strychnine) purine derivatives (caffeine) phenanthrene derivatives (morphine, codeine)	Piperine (in paper) stimulates the nerve endings in the gastrointestinal tract, increasing primarily the secretion of gastric juice; capsaicin (in peppers) increases the synthesis of digestive enzymes and also increases blood circulation; caffeine (in Yerba Mate) accelerates the heart and reduces fatigue and sleepiness; theine in tea reduces fatigue, regulates intestinal peristalsis and relieves pain; codeine is used as a powerful painkiller.
Tannins	hydrolyzable tannins (tannoids and depsides); non-hydrolyzable tannins (catechins and ellagic acid derivatives)	These can act as an astringent to mucous membranes and inhibit their permeability, to prevent micro-bleeding of capillary blood vessels (primarily in the digestive tract), or inactivate bacteria and their toxins; they can also be used as a poultice for damaged skin; aqueous concentrated solutions of tannins are used for tanning hide so that it becomes impermeable to water.

Table 1 – cont.

1	2	3
Essential oils	peppermint oil, eucalyptus oil, marjoram, pine oil, thyme oil	Many essential oils improve the taste of food and beverages; they are widely used in industry, for soap and household chemical production; moreover, they also have a beneficial effect on human health due to their antimicrobial properties (peppermint, pine oil, anise, and marjoram oils), sedative properties (lemon balm, valerian, and sweet flag oils), expectorant properties (pine, eucalyptus, sage, and peppermint oils), diuretic properties (parsley and juniper oils), and bile properties (peppermint and thyme oils).
Flavonoids	flavones and anthocyanins	Flavones participate actively in oxidation and reduction reactions, have diuretic properties, and are able to lower blood pressure and enhance absorption of vitamin C; anthocyanins have a beneficial influence on digestion, act as respiratory enzymes, and disinfect the urinary tract.
Phenols	resveratrol, hydroxytyrosol	Phenols are associated with the antioxidant activity of plant extract and display significant antimicrobial activity.
Organic acids	acetic acid, formic acid, malic acid, valeric acid	These act positively on digestion and the whole metabolism, and prevent excessive fermentation in the gut.
Saponins	soyasapogenol A, soyasapogenol B, dioscin	Used as natural medicine expectorants.

Based on: Embuscado, 2015a; Motilva et al., 2013; Skarżyński, 1994; Rajakannu et al., 2015; Zachariah et al., 2012.

are treated with a sub-lethal concentration of essential plant oils and individual compounds. According to research which has been carried out, exposure of cells to concentrations of natural antimicrobial agents does not cause selective pressure and the resulting development of resistance mechanisms in bacterial cells (Bakkali et al., 2008; Dimitrijevic et al., 2007).

Plant extracts containing polycyclic compounds with estrogenic activity (the so-called phytoestrogens) may also be used in pharmacy as an alternative method of hormone replacement therapy for treatment of menopausal disorders. It is important to note that many epidemiological studies suggest that women in countries with a high dietary intake of such phytoestrogens demonstrate a decreased risk of breast cancer (Beck et al., 2003).

Extracts of herbs and spices have also been shown to possess health-promoting properties (Hinneburg et al., 2006). The interest in plant-derived food additives has rapidly increased in recent years. Commonly, synthetic antioxidants, such as butylhydroxyanisole or butylhydroxytoluene, are added to food products to inhibit the processes that lead to the deterioration of food quality (including the degradation of lipids, carbohydrates and proteins). However, such antioxidants are volatile and easily decompose at high temperatures and, moreover, it is still unclear whether chronic consumption can lead to health risks. Many herbs and spices are an excellent source of phenolic compounds which have been reported to show good antioxidant activity and can be used as natural food preservatives (Hinneburg et al., 2006).

Due to the beneficial potential of plant extracts, they can be also effectively used in maintaining and enhancing human beauty. Alongside the antimicrobial activity of herb and spice extracts, they have also other advantageous properties, such as sunscreen, anti-aging, moisturizing, antioxidant, and anti-cellulite activity. Furthermore, natural products, in comparison to synthetic cosmetics, are mild, biodegradable and have a low toxicity profile (Chanchal and Swarnlata, 2008).

ACTIVE COMPOUNDS IN HERBS AND SPICES

Antioxidants are compounds that inhibit or delay the onset of oxidation. Demand for natural antioxidants is increasing, due to the safety concerns around synthetic antioxidants. Additionally, consumers increasingly prefer natural products, clean labels and fewer additives in food products (Embuscado, 2015a). Herbs and spices are very rich sources of antioxidants, as they contain flavonoids, terpenoids, lignans, sulfides, polyphenolics, carotenoids, coumarins, saponins, plant sterols, curcumins, and phthalides. The most effective antioxidants found in herbs and spices are the phenolic substances, which contain at least two hydroxylic groups in the *ortho* or *para* positions, e.g. caffeic acid. These substances have been used as antioxidants in the form of ground spices and herbs, extracts, emulsions, or in encapsulated form (Embuscado, 2015b; Pokorný and Pánek, 2012).

The antioxidants occurring in herbs and spices can be divided into groups according to chemical structure. The main groups of compounds are phenolic acids, flavonoids and catechins, phenolic diterpens, volatile phenols, polyalkoxybenzenes, ligans, sulphuric compounds, and ascorbic acid (Embuscado, 2015b).

There are more than 6,000 known flavonoids. They are ubiquitous in photosynthesizing cells and are commonly found in fruit, vegetables, nuts, seeds, stems, flowers, tea, wine, propolis and honey (Cushnie and Lamb, 2005). Phenolic compounds have various functions in the plant, including structure, defense, and attracting pollinators and seed-dispersing animals. Plants also produce these substances to protect themselves against UV light and for adaptation to their environment (Embuscado, 2015a). It has also been suggested that flavonoids also act as beneficial agents in human body, treating a multitude of ailments, including colds and flu (due to their antifungal, antiviral and antibacterial activity), allergies (quercetin), cancer (especially lycopene and quercetin), cardiovascular disease, and neurodegenerative disorders (including Alzheimer's disease, Parkinson's disease, multiple sclerosis, amyotrophic lateral sclerosis, and Huntington's disease). It may also act prophylactically against diseases of the eye (cataract, macular degeneration) (lycopene and anthocyanins) (Solanki et al., 2015), and in protecting the eye against the harmful effects of UV radiation (lutein and zeaxanthin). Some of the circulating metabolites of flavonoids (such as glucuronides, sulphates, and O-methylated forms) may participate directly in plasma antioxidant reactions by scavenging reactive oxygen and nitrogen species in the bloodstream (Spencer et al., 2004). Common antioxidants that occur in herbs and spices are presented in Table 2.

APPLICATION OF HERBS AND SPICES EXTRACT IN INDUSTRY

Herbs and spices in medicine

A century ago, most drugs were plant-based. Synthetic drugs first appeared on the market at the end of the 19th century (Wichtl, 2004). Even so, in recent decades, the school of thought which believes that natural medicine is used only in Third World countries and among uneducated people has dominated in the developed world. It became synonymous with tricksters and outlandish New Age practitioners. However, the rapid and intense development of knowledge and technology has simultaneously lead to adverse health effects, and consequently the so-called 'diseases of civilization' are on the increase. Thus, recently, an increased interest in natural therapies has been observed. Herbal medicine has been in use since ancient times and there is no shortage of evidence attesting to its efficacy. Over the last 20 years, as the medical applications of plants has been further investigated and our knowledge of their potential benefits has increased, there has been a fundamental change in the perception of botanical drugs (Wichtl, 2004). The pro-health potential of herbs and spices is more and more accepted, *inter alia* in the treatment of bacterial infections (e.g., Jäger et al., 2013; Rajakannu et al., 2015), gastric ulcers (Farzaei et al., 2015), Alzheimer's dementia (Volak et al., 2012), cardiovascular disease (Davison et al., 2012) and in cancer prevention and treatment (Assaf et al., 2013; Kris-Etherton et al., 2002; Shanmugam et al., 2013; Volak et al., 2012), etc.

Plant extracts in biliary and gastrointestinal tract disorders. Natural drugs are widely used to stimulate the secretion of gastric juice and the appetite (drugs with a bitter component), and also for the alleviation of constipation (drugs with a swelling capacity). An important group of drugs used to treat the digestive

Table 2. Antioxidants isolated from herbs and spices

Spice/herb	Scientific name	Antioxidant compounds	Mode of action
1	2	3	4
Rosemary	*Rosemarinus officinalis*	carnosol, carnosic acid, rosmanol, rosmadial, diterpenes (epi-rosmanol, isorosmanol, rosmaridiphenol), rosmariquinone, rosmarinic acid	scavenge superoxide radicals, lipid antioxidant, and metal chelator
Sage	*Salvia officinalis*	carnosol, carnosic acid, rosmanol, rosmadial, methyl and ethyl esters of carnosol, rosmarinic acid, ascorbic acid, beta carotene, beta-sitosterol, camphene, gamma-terpinene, hispidulin, labiatic acid, oleanolic acid, terpinen-4-ol, ursolic acid, selenium, salvigenin, nevadensin, apigenin, cirsileol, cirsimaritin	free radical scavenger
Oregano	*Origanum vulgaris*	rosmarinic acid, caffeic acid, protocatechuic acid, 2-caffeoyloxy--3-[2-(4-hydroxybenzyl)-4,5-dihydroxy] phenylpropionic acid; flavonoids – apigen, eriodictyol, dihydroquercetin, dihydrokaempherol; carvacrol, thymol, Camphene, gamma-terpinene, terpinen-4-ol, myricene, linalyl-acetate	free radical scavenger
Thyme	*Thymus vulgaris*	thymol, carvacrol, *p*-Cumene-2,3-diol, phenolic acids (gallic acid, caffeic acid, rosmarinic acid), phenolic diterpenes, flavonoids, ascorbic acid, beta carotene, isochlorogenic acid, labiatic acid, p-coumaric acid, rosmarinic acid	free radical scavenger, oxygen scavenger
Ginger	*Zingiber officinale*	gingerol, shogaol, zingerone, ascorbic acid, beta carotene, caffeic acid, camphene, gamma-terpinene, p-coumaric-acid, terpinen-4-ol	free radical scavenger, oxygen scavenger
Turmeric	*Curcuma domestica*	curcumins, 4-hydroxycinnamoyl methane	free radical scavenger
Black pepper	*Piper nigrum*	kaempherol, rhamnetin, quercetin, ascorbic acid, beta carotene, ubiquinone, camphen, carvacrol, eugenol, gamma-terpinene, methyl eugenol, piperine	free radical scavenger
Chili pepper	*Capsicum frutescence*	capsaicin, capsaicinol	free radical scavenger
Clove	*Eugenia caryophyllata*	phenolic acids (gallic acid), flavonol glucosides, phenolic volatile oils (eugenol, acetyl eugenol, isoeugenol), tannins	free radical scavenger, metal chelator
Marjoram	*Majorana hortensis*	beta-carotene, beta-sitosterol, caffeic acid, carvacrol, eugenol, hydroquinone, linalyl-acetate plant, myricene, rosmarinic acid, terpinen-4-ol, beta carotene, caffeic acid, tannin, myricene, phenol, trans-anethole, ursolic acid, oleanolic acid	free radical scavenger
Cumin	*Cumimum cyminum*	cuminal, γ-terpinene, pinocarveol, linalool, 1-methyl-2-(1--methylethyl)benzene, carotol, apigenin, luteolin, cuminaldehyde, cuminic alcohol, p-cymene, β-pinene	free radical scavenger, metal chelator
Peppermint	*Mentha xpiperita*	ascorbic acid, beta-carotene, narirutin, eriodictyol, eriodictyol 7-O-β-glucoside, eriocitrin, hesperidin, isorhoifolin, luteolin 7-O-β-glucoside, luteolin 7-O-rutinoside, diosmin, rosmarinic acid, caffeic acid, piperitoside, menthoside, lithospermic acid	free radical scavenger, oxygen scavenger
Garlic	*Allium sativum*	caffeic, vanillic, p-hydroxybenzoic, and p-coumaric acids, allicin	free radical scavenger, metal chelator

Table 2 – cont.

1	2	3	4
Onion	*Allium cepa*	quercetin, kaempferol, cyanidin glucosides, peonidin glucosides, taxifolin, allicin	free radical scavenger
Laurel or bay leaf	*Laurus nobilis*	ascorbic acid, beta carotene, tocopherols, eugenol, methyl eugenol, eudesmol, kaempferol, kaempferol-3-rhamnopyranoside, kaempferol-3,7-dirhamnopyranoside, 8-cineole, α-terpinyl acetate, terpinen-4-ol, catechin, cinnamtannin B1	free radical scavenger, oxygen scavenger
Turmeric	*Curcuma domestica*	ascorbic acid, carotenes, caffeic acid, curcumin, p-cumaric acid	free radical scavenger, metal chelator, oxygen scavenger
Coriander	*Coriandrum sativum*	beta-carotene, beta-sitosterol, caffeic acid, camphene, gamma-terpinene, isoquercitrin, myricene, myristicin, p-hydroxy-benzoic acid, protocatechuic acid, quercetin, rhamnetin, rutin, scopoletin, tannin, terpinen-4-ol, trans-anethole, vanillic acid	free radical scavenger, metal chelator
Mustards	*Brassica nigra, alba, juncea*	carotenes, glucosinolates	free radical scavenger

Based on: Cazzola and Cestaro, 2014; Embuscado, 2015a; Embuscado, 2015b; Pokorný and Pánek, 2012.

tract are drugs that exhibit carminative action (with essential oils) as well as spasmolytic activity (Wichtl, 2004). The use of herbal drugs in the treatment of liver disease has a long history. Herbal preparations are used by 20% of liver disease patients (Seeff et al., 2001). Some natural extracts promoted for gastrointestinal or biliary disorders contain potent hepatotoxic alkaloids. However, a few of them contain molecules, often related to flavonoids, with proven antioxidative, antifibrotic, antiviral, or anticarcinogenic properties, including glycyrrhizin, phyllanthin, silibinin, picroside, and baicalein (which are derived from licorice root), *Phyllanthus amarus*, milk thistle, *Picrorhiza kurroa* and sho-saiko-to, that can serve as primary compounds for the development of specific hepatotropic drugs (Schuppan et al., 1999).

Plant extracts in psychological disorders. The role of herbal medicine in the supportive treatment of various psychological disorders has become well established over the past two decades (Sarris, 2007). Drugs containing essential oils are used for stress, difficulties in falling asleep (Wichtl, 2004), major depressive disorders, dysthymic disorders, anxiety disorders, obsessive-compulsive disorder, agoraphobia, social phobia (Sarris, 2007), epilepsy and dementia (including Alzheimer's dementia) (Stafford et al., 2008). Commonly, herbs such as hops (*Humulus lupulus*), lemon balm (*Mellisa officinalis*), St. John's wort (*Hypericum perforatum*), ginseng (*Panax ginseng*), and valerian (*Valeriana officinalis*) are used (Wichtl, 2004).

Plant extracts in cough and cold symptoms. For these illnesses, mostly drugs with secretolytic and secretomotor actions, containing samonins and essential oils, are used (Wichtl, 2004). *Echinacea* is commonly used as it enhances the immune system and supports cold treatments (Giles et al., 2000; Goel et al., 2004; Goel et al., 2005). Additionally, Ballabh and Chaurasia (2007) reported that plants such as *Azadirachta indica*, *Emblica officinalis*, *Ficus religiosa*, *Ferula assafoetida*, *Punica granatum*, *Terminalia chebula*, *Ocimum sanctum* and *Zingiber officinale* can be effectively used against colds, coughs and fevers.

Plant extracts in kidney and bladder disorders. A few natural drugs are used as supportive treatments for these illnesses due to their effective application as urinary disinfectants and as diuretics (Wichtl, 2004), such as *Rosmarinus officinalis* and *Centaurium erythraea* (Haloui et al., 2000). It has been also reported that cranberry juice (because of its high tannin and

flavonoid content, citric and benzoic acids) has a beneficial influence on the urinary tract (it decreases urinary pH value, and inhibits growth of undesirable bacteria) (Kessler et al., 2002). Cranberry fruits also have diuretic, anti-diarrheal and astringent, anti-inflammatory properties, and also demonstrate the ability to dissolve kidney stones (Pascu et al., 2015).

Plant extracts in cardiovascular disease. Cardiovascular disease is a complex and multifactorial disease characterized by factors such as high cholesterol, hypertension, reduced fibrinolysis, increased blood-clotting time and increased platelet aggregation. Dietary therapy is the first step in the treatment of cardiac problems (Rahman, 2001). Garlic and onion have been used for millenia in the traditional medical practices of many cultures to treat cardiovascular disease and other disorders (Ali et al., 1999; Banerjee et al., 2002; Bordia et al., 1998; Davison et al., 2012; Kendler, 1987; Kleijnen et al., 1989; Rahman, 2001). Both *Allium* species, their extracts, and the chemical constituents of these plants have been investigated for combatting cardiovascular disease risk factors (hyperlipidemia, hypertension and hyperglycemia) and suspected risk factors (platelet aggregation and blood fibrinolytic activity) (Kendler, 1987). Also, several botanicals, including *Crataegus oxycantha*, *Terminalia arjuna*, *Inula racemosa* and *Astragalus membranaceus*, have been found to have therapeutic benefits in the treatment of cardiovascular ailments, such as hypertension, arrhythmias, arteriosclerosis, congestive heart failure, coronary artery disease, hypercholesterolemia, and myocardial infarction (Kris-Etherton et al., 2002; Lafuente et al., 2009; Miller, 1998).

Plant extracts in chemoprevention and cancer therapy. In cancer therapy, natural compounds are most commonly used. A very important class of bioactive phytochemicals in this area are triterpenoids, which represent a large family of compounds classified according to the number of isoprene units. Triterpenoids (i.e., dammarane, ergostane, friedelane, lupane, oleanane, taraxastane, and ursane) are synthesized in plants by cyclization of squalene and are ubiquitously present in nature. In cancer therapy, Lykopodium clovatum (*Lykopodium clovatum*), nettle (*Urtica dioica*), flag rhizome (*Acarus calamus*), mistletoe (*Viscum album*), Calendula officinalis (*Calendula officinalis*), milfoil (*Achillea millefolium*), horsetail (*Equistetum arvense*), and cranberry fruits (especially in breast cancer) are used (Boshra and Hussein, 2016; Kris-Etherton et al., 2002; Shanmugam et al., 2013).

Plant extracts in some bacterial infections. The antimicrobial activity of both herbs and species and their extracts and essential oils has been known since ancient times. Many of these substances demonstrate significant antimicrobial activity, which in many cases is due primarily to a particular constituent.

Oregano, one kind of labiate *Origanum* plant that has been popular for a long time in folk medicine, is a very versatile plant. The antibacterial activity of the essential oils of oregano and thyme have been documented against *Escherichia coli* O157:H7 and *Listeria monocytogenes* (Aboaba et al., 2006; Dimitrijevic et al., 2007; Firouzi et al., 2007; Govaris et al., 2011; de Medeiros Barbosa et al., 2016). In the work by Medeiros Barbosa et al. (2016) the antibacterial effects of oregano and rosemary essential oils against *Escherichia coli*, *Listeria monocytogenes* and *Salmonella* were presented. Dimitrijevic et al. (2007) investigated the antimicrobial properties of the essential oils of *Thymus vulgaris*, *Rosmarinus officinalis* and *Origanum vulgare* against *L. monocytogenes*. Cranberry extracts were also seen to demonstrate activity against *L. monocytogenes* (Adeyinka and Richard, 2015). Garlic extract has been shown to have a bactericidal effect on *Staphylococcus epidermidis* and *Salmonella typhi* (Arora and Kaur, 1999). In the work of Shan et al. (2007), the antimicrobial effect of *Origanum vulg*are, *Piper nigrum*, *Rosmarinus officinalis*, *Salvia officinalis* and *Thymus vulgaris* against *Bacillus cereus*, *L. monocytogenes*, *Salmonella aureus*, *E. coli*, and *Salmonella anatum* was described. A very broad spectrum of antimicrobial properties is exhibited by herbs such as cardamom, cinnamon, cloves, cumin, kaffir lime leaves and peels and lemongrass (Nanasombat and Lohasupthawee, 2005). They act against bacteria such as *Salmonella agona*, *S. anatum*, *S. Choleraesuis*, *S. Derby*, *S. Enteritidis*, *S. Lexington*, *S. London*, *S. Newport*, *S. Senftenberg*, *S. Virchow*, *S. Weltevreden*, *S. Typhimurium*, *Citrobacter freundii*, *Enterobacter aerogenes*, *E. coli*, *Klebsiella pneumoniae*,

and *Serratia marcescens* (Nanasombat and Lohasupthawee, 2005). The wide range of antibacterial activities exhibited by garlic has been recognized for a long time. It acts against Gram-negative and Gram-positive bacteria including species of *Escherichia*, *Salmonella*, *Staphylococcus*, *Streptococcus*, *Klebsiella*, *Proteus*, *Bacillus*, and *Clostridium* (except *C. botulinum*). Even the acid-resistant bacteria *Mycobacterium tuberculosis* are sensitive to garlic. Garlic extracts are also effective against *Helicobacter pylori*, the cause of gastric ulcers, and can prevent the formation of *Staphylococcus* enterotoxins A, B, and C1 and thermonuclease (Ankri and Mirelman, 1999).

Herbs and spices in the food industry

Herbs and spices have a long history of culinary use as functional food ingredients. Their applications, among others, may be to help to lower the salt, fat and sugar content of food products. For example, instead of salt, basil, marjoram, bay leaves, tarragon, thyme, rosemary, coriander or lovage may be used. Moreover, some herbs and spices are a rich source of vitamins, such as A, E, D, K, C, B (especially parsley and dill), B and PP (especially in onion). Other compounds found herbs and spices also have an important part to play – micro- and macroelements. Such bioelements maintain osmotic pressure and are a component of many enzymes or influence their activity, participating directly or indirectly in a number of biochemical reactions, therefore performing an essential role in digestion (Skarżyński, 1994).

Additionally, herbs and spices can be used to inhibit the growth of undesirable microorganisms in foods. Food poisoning is a serious problem for both consumers and food producers. Food producers, food safety researchers and regulatory agencies are always concerned with the high and growing number of disease outbreaks caused by pathogenic and spoilage microorganisms in foods. Moreover, the abuse of antibiotics has caused some pathogens associated with foodborne illnesses to develop antimicrobial resistance. However, due to increasing consumer awareness of methods of production, people often do not want to eat foods containing synthetic preservatives. Therefore, there has been an increasing interest in the development of new types of effective and nontoxic natural antimicrobial compounds, such as extracts of herbs and spices, for food preservation (Shan et al., 2007). Herbs and spices, due to their antimicrobial activity, can be effectively used by the food industry as natural agents for extending the shelf life of foodstuffs. A variety of plant- and spice-based antimicrobials are used for reducing or eliminating pathogenic bacteria, and increasing the overall quality of food products (Tajkarimi et al., 2010). There are more than 1,340 plants with defined antimicrobial compounds. Oregano, cloves, cinnamon, garlic, coriander, rosemary, parsley, lemongrass, sage and vanillin demonstrate particularly high antibacterial activity (Tajkarimi et al., 2010).

Some herbs and spices, such as rosemary, sage, oregano, thyme, ginger, summer savory, black pepper, red pepper, clove, marjoram, basil, peppermint, spearmint, common balm, fennel, parsley, cinnamon, cumin, nutmeg, garlic and coriander, are added to lipid-containing foods. Oxidative rancidity, a major cause of food deterioration, causes food to deteriorate and ultimately be rejected by consumers due to the formation of undesirable aromas and off-flavors, or color degradation (Embuscado, 2015b). Due to their antioxidative properties, herbs and spices stabilize lipids in food products (Yanishlieva et al., 2006). Moreover, herbs and spices have been used not only for the preservation of foodstuffs and beverages but also for maintaining the flavor, color and aroma of food products for centuries (Embuscado, 2015b).

Plant essential oils can be also used in new active packaging, as additives in biodegradable films and coatings in order to extend shelf-life and add value to the product (Atarés and Chiralt, 2016; Llana-Ruiz-Cabello et al., 2016). The addition of essential oils has a positive influence on the continuity of the polymer matrix, leading to physical changes depending on the specific polymer-oil component interactions. The film structure is therefore weakened by the oil, whereas the water barrier properties are improved and the transparency is reduced. Films supplemented with essential oils have antioxidant and antimicrobial properties (Atarés and Chiralt, 2016). Also alginate-based edible films including bioactive compounds can be used to preserve some food products. Because of their low water solubility, they can be applied as nanoemulsions which improve water dispersion and protect active ingredients from degradation (Acevedo-Fani et al., 2015).

Herbs and spices in cosmetology and pharmacy

Cosmetology. Herbal cosmetics are cosmetics including active bio-ingredients, nutraceuticals and pharmaceuticals. The use of active phytochemicals has many beneficial effects – they serve as cosmetics while the natural compounds influence biological processes taking place in the skin and provide nutrients (vitamins, antioxidants, essential oils, hydrocolloids, terpenoids, proteins, etc.) for healthy skin and hair (Kapoor, 2005).

Herbs are used in maintaining and enhancing human beauty due to their many beneficial properties, such as sun protection, anti-aging, moisturizing, antioxidant, anti-cellulite, and antimicrobial effects. Compared to synthetic cosmetic products, herbal products are mild, biodegradable and have a low toxicity profile (Chanchal and Swarnlata, 2008).

Some plants can be used as cosmetics in anti-aging treatments (*Rhodiola rosea*, *Ginko biloba* and carrot), dry skin treatment (aloe, coconut oil from *Cocos nucifera*, sunflower oil from *Helianthus annuus*), dandruff treatment (henna from *Lawsonia inermis*, neem from *Azadirachta indica*), in skin protection (green tea from the leaves of *Camellia sinensis*, *Calendula*, *Curcuma longa)*, and in hair care (amla from *Emblica Officinalis*, *Bacopa monnoria*, *Acacia Concinna*, almond oil from *Prunus dulcis*, eucalyptus oil from the leaf of *Eucalyptus*). There are natural cosmetics based on active compounds from herbal extracts widely available on the market, such as herbal skin care products (lavender silk soaps, lotions, creams, body powder, lavender herbal body powder, skin care creams), herbal eye care cosmetics (eye make-up, eye shadow, eye gloss, liquid eye liner), herbal creams, lotions, gel (aloe moisturizing hand cream, rich face and hand cream, herbal moisturizers), herbal oils (herbal oils are effective for baldness and preventing hair from falling out or and thinning, fighting dandruff, scalp irritation and patchy baldness and the maintenance of a fine head of hair) and herbal perfumes and fragrances (citrus and chypre fragrance) (Patel et al., 2013).

Pharmacy. Herbs and spices are also used in pharmacology in many drugs and dietary supplements. Thus, the 'green pharmacy', in many cases, proves to be more economical, more effective and safer than regular pharmaceuticals. Important herbs used in pharmacology include calendula (to treat bruises, cuts, and scrapes), chamomile (to treat stomach ache, sleep disorders, depression, and to relieve pain during teething in infants) (Cauffield and Forbes, 1999; McIntyre and McIntyre, 2002; Vickers and Zollman, 1999), *Echinacea* (to stimulate the immune system to help fight disease), evening primrose (to treat premenstrual syndrome, and in anti-wrinkling cosmetics) (Barre, 2001; Budeiri et al., 1996; Cho et al., 2007), gingko (to treat dementia) (Hashiguchi et al., 2015; Kanowski et al., 1996), ginseng (to enhance neurocognitive function) (Scholey et al., 2015), hawthorn (for treating heart problems), kava kava (to help with relaxation during stressful times), licorice (an anti-ulcer herb), milk thistle (to treat liver disease) (Flora et al., 1998; Jacobs et al., 2002; Piscitelli et al., 2002), and tea tree (wildly used aseptic) (Duke, 1997). Allspice (effective against indigestion), cardamom (a mild stimulant), cinnamon (demonstrates antimicrobial action and can settle an upset stomach), cloves (pain-relief and aseptic properties), garlic (also known as 'Russian penicillin', useful for preventing disease and cancer), ginger (useful for treating arthritis, and in a preventive therapy for motion sickness), red pepper (contains a pain-relieving substance – capsaicin), sesame (a rich source of antioxidants) and turmeric (useful for treating arthritis and diabetes) are some of the herbs and spices most commonly used for pharmaceutical purposes (Duke, 1997).

To summarize, plant bioactive compounds have many potential industrial and medical applications. However, it should be noted that some may prove to have toxic effects, especially when used on an industrial scale. For example, strychnine stimulates the spinal cord but in higher concentration begins to stimulate other centers of the nervous system, and at high doses can cause potentially fatal convulsions throughout the entire body. Digitalis glycosides have strong physiological effects and are toxic even in extremely low doses. Nutmeg oil demonstrates psychoactive and toxic activity. The consumption of about 12 teaspoons of nutmeg can cause deliriousness, hallucinations and anxiety. Also, bay leaf, a common ingredient in many dishes, when consumed in high concentration may have toxic effects on humans (Negi, 2012; Skarżyński, 1994). These are just a few examples, but toxic effects have been detected in many other plant derivatives.

Thus, extreme care must be taken when choosing plants for industrial and medical usage.

CONCLUSION

Herbs and spices are a rich source of valuable bioactive ingredients. They are commonly used in many branches of industry and also in the treatment of some diseases. The usage of medicinal plants to relieve symptoms and treat various ailments is as old as humankind itself. Even today, medicinal plants provide a cheap source of drugs for much of the world's population. Plants have provided, and will continue to provide, not only directly available treatments but also a great variety of chemical compounds that can be used as starting points for the synthesis of new drugs with improved pharmacological properties. The potential of plant extracts is also appreciated by the food industry – and not only because of their dietary value. Plant essential oils are also used as additives in biodegradable or edible films and coatings for active food packaging in order to extend shelf-life and add value to the product. Research into new potential applications is still ongoing. However, the potential toxic effects of certain phytocompounds should also be take into account and carefully investigated.

ACKNOWLEDGMENT

We would like to thank the Poznańskie Zakłady Zielarskie Herbapol S.A. Company for supporting our planned research by providing us with herb and spice extracts.

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