Health benefits of bioactive molecules from spices and aromatic plants

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Abstract

Spices are essentially used to improve the appeal and sensory characteristics of food. The bioactive compounds, which are the key natural flavour and fragrance ingredients of various spices and other aromatic plants play a vital role in healthcare. These are discussed with reference to the recent research carried out in anti-inflammatory, anti-arthritic, neuro-protective, cardiovascular, diabetic support, body weight management, wound healing, antioxidants, antimicrobial as food preservatives, ocular and oral health as well as in aroma-therapy with emphasis on human health and green chemistry.

Keywords: bioactive molecules, flavour, fragrance, healthcare

Introduction

The principal use of spices is in flavouring food and beverages. All aromatic vegetable products used for this purpose are also sometimes included as spices. In general, the spices may be used as such, broken, powdered, pasted, extracted as oil or water soluble, distilled to separate the essential oil (EO) to add or enhance the flavour and taste of any food. Flavours are a combined organoleptic sensation of aroma and taste imparted to a food, that modify a flavour that is already present or mask some undesirable flavour to increase the acceptability of the end-products. Flavour is a basic characteristic stimulating the desirability of food and together with colour, texture and nutrition, it forms the cornerstone of contemporary food industries throughout the world (Burdock et al. 1970). Fragrance is a chemical or compound which gives pleasant smell on external application, while formulated fragrance chemicals or compounds are called perfumes. Mostly, spice essential oils and their isolates are the backbone of natural fragrance ingredients and fragrances are harmonious combination comprising of natural and /or synthetic ingredients with durability, diffusiveness and ability to get fixed in cosmetics and other products. In most cases fragrances are insoluble in water.

Spices are being traditionally used in India for several hundred years to treat diseases, other than the exotic properties of spicing up the food to impart taste and aroma. The rich tradition of India has optimized the applications of spices in food, beverages and as a medicine for preventive and curative purpose that is well documented. Recent scientific validation studies
indicate that spices play an important role in personal and health care without any significant addition of calorific value or deleterious side effects through an environment friendly green chemistry. The functional properties other than flavour and fragrance applications of various EOs have been reviewed and the role of spices beyond food applications as nutraceuticals with multiple health benefits of various ingredients have been compiled and discussed earlier by Srinivasan (2005) and Arvinder & Nomita (2011).

**Anti-inflammatory and Anti-arthritic**

Turmeric oil, a constituent of turmeric (*Curcuma longa* L.) rhizome showed a decrease in inflammatory swelling which when induced by Freund’s adjuvant was highly significant compared to control indicating anti-inflammatory and anti-arthritic activity in albino rats (Chandra & Gupta 1972). The anti-inflammatory activity was correlated to the inhibition of trypsin and hyaluronidase activity (Tripathi *et al.* 1973), anabolism of formaldehyde, a marker for inflammation and inhibition of synthesis co-related to anti-inflammation. Gupta & Modh (1969) reported the inhibition of formaldehyde at 0.04 mL kg⁻¹ of turmeric oil which was comparable with 5 mg kg⁻¹ of hydrocortisone, a synthetic drug used to cure inflammation.

Curcumin, the active component of yellow pigment from turmeric rhizome was found to inhibit arachidonic acid metabolism, cyclooxygenase (COX), lipoxygenase, cytokines, Nuclear factor kappa beta (NFkB) and release of steroidal hormones. Curcumin was reported to stabilize lysosomal membrane and caused uncoupling of oxidative phosphorylation and strong O₂ radical scavenging activity, which was responsible for its antiinflammatory property. In various animal studies, a dose range of 100-200 mg kg⁻¹ body weight exhibited good anti-inflammatory activity and seemed to have negligible adverse effect on human systems. Oral LD50 in mice was found to be more than 2.0 g kg⁻¹ body weight (Kohli *et al.* 2005). Banji *et al.* (2011) reported beneficial synergistic effect of curcumin with methotrexate, a chemical drug employed for the treatment of rheumatoid arthritis, in order to overcome the deleterious hepatotoxicity of the chemical curcumin, possessing both anti-arthritic and hepatoprotective potential. Curcumin (30 and 100 mg kg⁻¹) in combination with methotrexate (1 mg kg⁻¹) helped in salvaging hepatotoxicity, oxidative stress and producing synergistic anti-arthritic action with methotrexate to minimize liver damage. Turmeric is considered a safe food material having a long history of being eaten as a food and is capable of being utilized as activities/properties health food or functional health food (Mae *et al.* 2007). Recently, based on the curative properties of curcuminoids, bioavailability and mode of action, it was opined that the future pharmacotherapy will include turmeric from the local grocery (Vincent 2011).

Macelignan extracted from nutmeg (*Myristica fragrans* Houtt) suppressed the expression of COX-2 in Lipo polycarbaride (LPS) stimulated primary microglial cells and reduced the generation of intracellular ROS in glutamate–stimulated neuronal hippocampal cells (Jin *et al.* 2005). Their results showed that macelignan suppressed both phosphorylations of mitogen activated protein kinases (MAPKs) and the degradation of inhibitory–kappa B and increased NFkB in lipopolysaccharide LPS stimulated BV-2 microglial cells and thus, macelignan has an anti-inflammatory property (Ma *et al.* 2009).

**Neuro-protective**

Inflammation in Alzheimer’s disease (AD) is characterized by increased cytokines and activated microglia, reduced AD risk associates with long-term use of non-steroidal anti-inflammatory drugs (NSAID), which are reported to have gastro-intestinal, liver and renal toxicity. One alternative NSAID is curcumin, tested at low (160 ppm) and a high dose of dietary curcumin (5000 ppm) on inflammation, oxidative damage and plaque pathology. The low and high doses of curcumin significantly lowered oxidized proteins and interleukin-1β, a proinflammatory cytokine
elevated in the brains of mice and plaque burden was significantly decreased by 43–50% (Lim et al. 2001). The neuro-protective effect of black cumin (Nigella sativa L.) was investigated against beta amyloid induced cell death in primary rat cerebella granule neurons. Neuro-degeneration in AD has been associated with the toxic effect of amyloid, a by-product of β amyloid precursor protein (Norsharina et al. 2008).

Cardio-vascular protection

Li et al. (2006) reported that antioxidant rich spice mix showed potential for heart health. Ingestion of high-fat foods that contain lipid peroxidation products can lead to increase in plasma concentration of malondialdehyde as well as other cytotoxic and genotoxic compounds which are responsible for stress related risk of heart disease and common forms of cancer. It has been reported that application of antioxidant rich spice blend of clove (Eugenia caryophyllata Thunb), oregano (Oreganum majorana L.), ginger (Zingiber officinale Rosc.), cinnamon (Cinnamomum zeylanicum Blume) and turmeric in meat products during cooking significantly reduced the level of malondialdehyde.

Sharma et al. (1996) reported lipid lowering activity of fenugreek (Trigonella foenum graecum L.) seeds in 60 non-insulin dependent diabetic subjects. Ingestion of an experimental diet containing 25g fenugreek seed powder resulted in a significant reduction of total cholesterol (CL), low density lipoprotein (LDL) and very low density lipoprotein (VLDL) cholesterol and triglyceride levels. Galactomannans (GAL) rich fenugreek fibres showed a reduction in body weight gain in parallel with less food intake. All GAL-fed rats had significantly reduced plasma levels of triglycerides and total cholesterol in association with a reduction in epididymal adipose weight. Overall, this study demonstrated that fenugreek seeds have the potential to alter glycemic and lipidemic status and reduce abdominal fat in normal rats (Gee et al. 1983; Srichamroen et al. 2008) and reduced the risk of heart-attack.

Effect of garlic (Allium sativum L.) on ischemic preconditioning and ischemia reperfusion induced cardiac injury has been studied in albino rats. The study demonstrated that the extract exaggerates the cardio protection offered by ischemic precondition and protects the myocardium against ischemia reperfusion induced cardiac injury (Rajbir et al. 2008). Wongcharoen et al. (2012) demonstrated that curcuminoids significantly decreased myocardial infarction (MI) associated with coronary artery bypass grafting (CABG); the antioxidant and anti-inflammatory effects of curcuminoids may account for their cardio-protective effects. It is well established that MI associated with CABG predicts a poor outcome. A well designed, systematic study carried out on 121 consecutive patients undergoing CABG showed that incidence of in-hospital MI decreased from 30% of placebo to 13.1% when treated with curcuminoids. Earlier, curcumin has been reported to improve left ventricular diastolic function regardless of blood pressure in hypertensive patients (Morimoto et al. 2012).

Turmeric oil has been reported the significantly decrease the levels of serum total CL, LDL-CL, triglyceride and free fatty acid (FFA) and increase the level of high density lipoprotein (HDL)-CL. Histological morphology examination showed that turmeric oil prevented the damage of liver tissues due to high-fat diet and might provide protection against cardiovascular diseases (Ling 2012). Hwa et al. (2012) reported that 2-methoxycinnamaldehyde of cassia (Cinnamomum cassia Blume) protects from myocardial I/R-injury due to antioxidant and anti-inflammatory action and might be the reason for using cassia a traditional medicine to cure inflammatory disorders. Persson et al. (2011) reported the beneficial effects of cocoa polyphenols on cardiovascular disease. A significant inhibition of angiotensin converting enzyme (ACE) activity in vitro and in vivo due to dark chocolate could be important for heart health.
Diabetic Support

Fenugreek seeds as adjunct improved glycemic control and decreased insulin resistance in mild type-2 diabetic patients and had a favorable effect on hypertriglyceridemia (Gupta et al. 2001). A clinical study on the effect of fenugreek on type-1 diabetes showed a significant reduction in fasting blood sugar levels and improved glucose tolerance. For type-2 diabetes, fenugreek showed significant improvements in insulin resistance and it was concluded that fenugreek seeds are effective as an adjunct to conventional treatment, improving glycemic control and decreasing insulin resistance (Sharma et al. 1990; Haeri et al. 2008; Vijayakumar & Bhat 2008).

The turmeric extract significantly reduced blood glucose level in type 2 diabetic KK-A(y) mice in an in vitro evaluation and stimulated human adipocyte differentiation in a dose-dependent manner and showed human peroxisome proliferator-activated receptor (PPAR)-gamma ligand-binding activity in a GAL4-PPAR-gamma chimera assay. The main constituents of the extract identified as curcumin, demethoxycurcumin, bisdemethoxycurcumin (BDMC), and ar-turmerone could be responsible for the prevention and/or amelioration of type-2 diabetes (Minpei et al. 2005).

Anderson et al. (2004) reported that cinnamon polyphenol polymers increased insulin-independent in vitro glucose metabolism roughly 20-fold and also displayed antioxidant activity. These polymers were found to potentiate insulin action and might be beneficial in the control of glucose intolerance and diabetes. Earlier, Khan et al. (2003) experimented with a human model consisting of 60 people with type-2 diabetes; they were divided into 3 groups (I, II, III) and provided 1, 3 or 6 g/day of cinnamon respectively with suitable placebo. After 40 days, all three levels of cinnamon reduced the mean fasting serum glucose (18–29%), triglyceride (23–30%), LDL cholesterol (7–27%) and total CL (12–26%) levels. This study demonstrated that the inclusion of cinnamon in the diet of people with type-2 diabetes will reduce risk factors associated with diabetes and cardiovascular diseases. Soliman et al. (2012) concluded that cinnamon extract has anti-diabetic and insulin-mimetic actions through the regulation of genes related to lipid and glucose metabolism. Cinnamon extract lowered glucose levels through the increase of insulin secretion from still working β cells confirming the anti-diabetic action.

Consumption of bay leaf (Laurus nobilis L.) powder reduced serum glucose significantly to 21–26%; total CL decreased 20–24%; LDL-CL to 32–40% and increase of HDL-CL to 29%, this demonstrated the curative benefits of bayleaf in type-2 diabetic patients (Alam et al. 2009).

Weight-management

Capsaicin, the hot principle of chilli (Capsicum annum L.) caused sustained fat oxidation during weight maintenance compared to placebo. However, capsaicin treatment had no limiting effect on 3-month weight regain after modest weight loss (Lejeune et al. 2003). Another study carried out on anti-obesity suggested that capsaicin enhances the use of fats as a fuel source during rest and exercise and may increase weight loss during a controlled diet or exercise plan and the supplementation did not cause any adverse effects on cardiac function despite significantly improved lipolysis (Tallon 2008). Herbal mixture containing turmeric as one of the main ingredients is reported to provide therapeutic weight loss due to lipid reduction and changed body composition. The mixture taken as dietary supplement is effective in the treatment of obesity, including both weight loss and reduction of weight gain (Wei & Xu 2003). Srichamroen et al. (2008) reported that GAL at 2.5–5.0% reduced plasma triglyceride, CL and hepatic cholesterol. GAL at 5.0% resulted in lower food intake, which might have enhanced the release of plasma FFA and in turn, led to reduction in the weight of epididymal adipose tissue. This clearly demonstrated that GAL a novel source of dietary fiber, has the potential benefits in modifying both glycemic and lipidemic status as well as body weight.
Wound healing

Despite the enormous advances made in health care, infectious diseases account for 25.0% of the mortality worldwide and 45.0% in low income countries. Moreover, the causative agents are also developing increased resistance against many of the commonly used antibiotics and currently the cost of many drugs are not affordable to most people (Hussien et al. 2011). Curcumin containing extracts have been reported to be effective in controlling infection in animals (Kawaguchi & Kida 1987; Ghanbari et al. 2008). Mahattanadul et al. (2009) discovered the anti-ulcer property of curcumin and BDMC in gastric ulcer model. BDMC inhibited inducible nitric oxide synthase (NOS) production significantly, whereas curcumin showed stronger suppression of inducible NOS and inhibited tumor necrosis factor (TNF)-alpha protein production significantly. Curcumin and BDMC possessed similar potency in scavenging nitric oxide and BDMC directly accelerated gastric ulcer healing with potency equal to curcumin.

Antimicrobial effects of the hydrosols made from the EO of sweet basil (Ocimum basilicum L.), thyme (Thymus schimperi L.), cardamom (Elettaria cardamomum Maton), cinnamon, mustard (Szygium aromaticum Merrill & Perry) against Staphylococcus aureus, Escherichia coli, Salmonella typhimurium, Pseudomonas aeruginosa and Candida albicans were studied in vitro. Minimum inhibitory concentration (MIC) was determined and concluded that the hydrosols of basil, cardamom, clove, cinnamon and thyme were effective to elicit inhibitory effect against S. typhimurium, S. aureus and E. coli (Hussien et al. 2011).

Food Preservation

Processed food spoilage is due to oxidation and microbial contamination. Synthetic antioxidants and anti-microbial agents are widely used to preserve food and there are food regulations restricting the use of synthetic agents. Busatta et al. (2008) have experimented with marjoram (Origanum majorana L.) EO to preserve sausage by testing on 10 selected aerobic heterotrophic bacterial species and found that addition of EO to fresh sausage exerted bacteriostatic effect. Gutierrez et al. (2008) examined the antimicrobial properties of basil, lemon balm (Melissa officinalis L.), marjoram, oregano (Origanum vulgare L.) rosemary (Rosemarinus officinalis L.), sage (Salvia officinalis Wall.) and thyme (Thymus vulgaris L.) EO against Bacillus cereus, E. coli, Listeria monocytogenes and P. aeruginosa. All the oregano combinations showed additive efficacy against B. cereus, E. coli and P. aeruginosa. The mixtures of marjoram and thyme combinations also had inhibitory effect on L. monocytogenes. This suggested that synergistic effect of EO might be more against food-borne pathogens and spoilage bacteria when applied to ready to use foods. Gutierrez et al. (2009) further continued the study on lettuce (Lactuca sativa L.), meat and milk and reported that Listeria strains were more sensitive than spoilage bacteria. Oregano and thyme were found to be most effective EO and suggested selected EO might be more effective against food-borne pathogens and spoilage bacteria in order to preserve food.

Sage and Peruvian pepper (Schinus molle L.) EO was analysed and 68 and 67 constituents were identified, respectively and their in vitro antimicrobial activity was studied on gram-negative and gram-positive bacteria and yeast (Saccharomyces cerevisiae). MICs were between 4.5 mg mL\textsuperscript{-1} and 72 mg mL\textsuperscript{-1} respectively (Hayouni et al. 2008). Five common antimicrobial compounds, β-pinene, cineole, limonene, linalool and geranylacetate, were found to be effective against food-borne pathogens, S. aureus, B. cereus, E. coli and Campylobacter jejuni (Chen et al. 2008; Sandasi et al. 2008). Oregano, savory and thyme, which have terpenes, carvacrol, p-cymene and thymol are reported to have antifungal and antibacterial activity for potential food safety applications (Bendahou et al. 2008). Tajkarimi et al. (2010) reviewed the in-food applications of EOs and synergy for the control of pathogens, such as S. typhimurium, E. coli O157:H7, L. monocytogenes, Bacillus cereus and S.
*S. aureus*, in food preservation systems. Terpenes and terpenoids of EO showed inhibitory activity against *S. aureus*. Carvacrol has specific effects on *S. aureus* and *Staphylococcus epidermidis*. Seasonal variations on the EO of dill (*Anethum graveolens* L.) and parsley (*Petroselinum crispum* Airy-Shaw) have been investigated on several food contaminating microorganisms like *E. coli*, *Staphylococcus albus*, *Bacillus mesentericus* and *Aspergillus flavus*. About 25 and 34 biomolecules compounds were identified in dill and parsley, respectively using GC-MS and relatively higher inhibitory activity was reported in summer crop (Vokk et al. 2011).

The antimicrobial activity of eucalyptus (*Eucalyptus globulus* Labill.) EO against 14 food spoilage microbes indicated that MIC varied from 2.25 to 9 mg mL\(^{-1}\) for bacterial and fungal strains, and from 1.13 to 2.25 mg mL\(^{-1}\) for yeast strains. The chemical composition was determined by GC-MS and it was found that 1, 8-cineole (45.4%), limonene (17.8%), p-cymene (9.5%), β-terpinene (8.8%), β-pinene (4.2%), β-terpineol (3.4%) and β-phellandrene (2.4%) were the major constituents (Tyagi & Malik 2011). Perilla (*Perilla frutescens* Britton) oil suppressed expression of β-toxin, *Staphylococcus enterotoxin A & B* and toxic shock syndrome toxin. Geraniol showed good activity in modulating drug resistance in several gram-negative species and suggested that EO could act as bio-preservatives by reducing or eliminating pathogenic bacteria and increasing the overall shelf-life (Santos et al. 2012).

**Antioxidants**

Certain biomolecules in processed food easily get oxidized with atmospheric oxygen and the resultant end products bring undesirable sensory characteristic to food. It has been reported that few functionally active compounds in rosemary extract and certain other plants have the ability to inhibit oxidation and thus the food is protected and preserved. Addition of rosemary extract to vegetable oils at 250 to 500 ppm provided freshness similar to the synthetic antioxidants, butylated hydroxyanisole (BHA)/ butylated hydroxytoluene (BHT) at 200 ppm. Application of 1500 ppm increased the stability of canola oil by almost 70% over a synthetic alternative. Use of rosemary and sage extract of 0.1% alone and rosemary in combination with sage at 0.05% each effectively retarded the oxidative rancidity and increased the stability of minced meat during refrigerated and frozen storage (Broek van der 2004).

Stabilization of meat lipids with ground spices of clove, ginger, oregano, rosemary, sage and thyme tested in comminuted pork between 200–2000ppm indicated inhibition of 2-Thiobarbituric acid reactive substances (TBARS) by 12–96.0% and reported that sage and rosemary powders were most effective in creasing the shelf-life of meat products (Shahidi et al. 2007). The free radical scavenging activity of black pepper (*Piper nigrum* L.) extract increased in a concentration dependent manner and one of the fractions inhibited 55.68 ± 4.48% nitric oxide radicals generated, whereas curcumin in the same concentration inhibited 84.27 ± 4.12%. Moreover, black pepper extract scavenged the superoxide radical generated by the xanthine/xanthine oxidase system suggesting that black pepper could be a potential source of natural antioxidant (Singh et al. 2008).

Curcuminoids possess excellent antioxidant properties, potent in preventing lipid peroxidation than β-tocopherols, pine bark extract (*Pinus sylvestris* L.), grape seed extract (*Vitis vinifera* L.) or the commonly used synthetic antioxidant BHT (Toda et al. 1985; Sreejayan & Rao 1994; Majeed 1995). The three components of curcuminoids, curcumin, demethoxy-curcumin and BDMC have strong antioxidant property and the property is attributed to their phenolic structure. Turmeric is sometimes added to oils as a preservative. Ramasamy & Banerjee (1948) demonstrated that turmeric dye exhibited excellent antioxidant properties on several vegetable oils. Turmeric was also reported to inhibit oxidative rancidity in salted, cooked fish and is said to be more potent than garlic and onion (Ramanathan & Das 1993). Curcuminoids scavenged or neutralized the free radicals by interacting with oxidative
chemical chain reactions and prevented the deleterious outcome by quenching the available oxygen making it less available for oxidative reactions; inhibited oxidative enzymes like cytochrome P-450 and chelated (Majeed 1995).

**Antimicrobials**

Since the middle ages, EOs have been widely used for bactericidal, viridal, fungicidal, antiparasitical, insecticidal, medicinal and cosmetic applications. In general, spices, herbs and their components are used to preserve fresh meat and meat products, which could be easily contaminated by microbes. Seasonings of rosemary, turmeric powder, essential oils and extracts are the oldest natural food preserving ingredients. EOs of dill, coriander (*Coriandrum sativum* L.) and eucalyptus (*Eucalyptus dives* Schauer) were determined for MIC on gram-positive bacteria, gram-negative bacteria and yeast. EO of cilantro was effective against *L. monocytogenes*, likely due long chain (C6–C10) alcohols and aldehydes. The strength and spectrum of inhibition for the fractions often exceeded those determined in the crude oils. Mixing of fractions resulted in additive, synergistic or antagonistic effects against individual test microorganisms (Delaquis et al. 2002).

Eleven extracts of spices *viz.*, lemon balm, peppermint (*Mentha piperita* L. emend. Huds), bay, Sicilian sumac (*Rhus coriaria* L.), carnation (*Dianthus caryophyllus* L.), black pepper, chilli, cade (*Juniperus oxycedrus* L.), briar (*Erica arborea*), bladder senna (*Colutea arborescens* L.), and cumin (*Cuminum cyminum* L.) were tested in vitro for the antibacterial activity against three gram-\(^+\) (*Bacillus subtilis*, *S. aureus* and *S. epidermidis*) and two gram-\(^-\) bacteria (*E. coli* and *P. aeruginosa*) and the possible toxicity to *Candida albicans* and *Aspergillus niger* was also determined (Erturk 2006). MIC of peppermint, bay and cade was found to be 5 mg mL\(^{-1}\) for all the microorganisms tested, *P. aeruginosa* was the most sensitive bacterial strain to black pepper and briar extracts among both gram-positive and gram-negative bacteria tested with MIC of 5 mg mL\(^{-1}\). The extracts of bay, carnation, cade and bladder senna showed higher inhibitory activity against *C. albicans* and *A. niger* than the standard antifungal nystatin, a synthetic chemical drug.

The major constituents of EOs of two species of sage analyzed in GC–MS was β-thujone, 1,8-cineole, camphor, borneol and α-pinene in *Salvia officinalis*, whereas in *S. triloba* camphor and β-caryophyllene were also present. Both the species exhibited remarkable bacteriostatic and bactericidal activities against *B. cereus*, *Bacillus megatherium*, *Bacillus subtilis*, *Aeromonas hydrophila*, *Aeromonas sobria*, and *Klebsiella oxytoca*. Moreover, the EO of *S. triloba* efficiently inhibited the growth of *S. aureus* and *A. hydrophila* even at 0.05 mg mL\(^{-1}\) (Delamare et al. 2007).

EO of horsemint (*Mentha longifolia* L. ssp. *longifolia*) showed strong inhibitory activity against all 30 microorganisms tested and the GC–MS analysis of the oil resulted in the identification of about 45 constituents (Gulluce et al. 2007). Chemical composition, antioxidant and antimicrobial activities of EOs of basil and seasonal variations were investigated by Hussain et al. (2008). They found that linalool was the most abundant component (56.7–60.6%), followed by epi-α-cadinol (8.6–11.4%), α-bergamotene (7.4–9.2%) and α-cadinene (3.2–5.4%). The EO exhibited good antioxidant activity and antimicrobial activity when tested along with linalool against *S. aureus*, *E. coli*, *B. subtilis*, *Pasturella multocida* and pathogenic fungi *A. niger*, *Mucor mucido*, *Fusarium solani*, *Botryodiplodia theobromae* and *Rhizopus solani*. Depending on type, concentration and chemical compositions they exhibited cytotoxic effects on living cells but were usually non-genotoxic and suggested that at least in part, the encountered beneficial effects of EO are due to pro-oxidant effects at the cellular level (Bakkali 2008).

Since, microbial resistance to multiple antibiotics is a serious health problem, certain spices EOs was tested alone and in combination with synthetic antibiotic. Coriander EO with amphotercin-B studied for synergistic effect of fungicidal activity against *Candida* strains with minimal lethal concentration (MLC) values.
equal to the MIC value ranging from 0.05 to 0.4%, indicated that the fungicidal effect was a result of cytoplasmic membrane damage. A synergistic effect between coriander oil and amphotericin B was also obtained for *C. albicans* strains and could be useful in designing new formulations for candidosis treatment (Silva et al. 2011).

EOs of West Indian lemon grass (*Cymbopogon citratus* Stapf) and another spp. *Cymbopogon giganteus* L. were analyzed in GC-MS and the antimicrobial properties were studied alone and in combination against nine bacteria. Five major constituents, which accounted for 96.3% of the EO were identified in *C. citratus*, while *C. giganteus* showed up to a total of eight compounds which represented 86.0% of EO. EO of *C. giganteus* showed antimicrobial effects against all microorganisms tested whereas *C. citratus* EO failed to inhibit *P. aeruginosa* and the combination of the two EOs exerted synergistic, additive and indifferent antimicrobial effects (Bassolle et al. 2011). GC–MS analysis of rosemary EO revealed 22 components with the major constituents being 1,8-cineole (26.54%) and α-pinene (20.14%). MIC of minimal bactericidal concentration (MBC) and time–kill dynamic processes against three gram – bacteria (*S. epidermidis, S. aureus* and *B. subtilis*), three gram + bacteria (*Proteus vulgaris, P. aeruginosa* and *E. coli*) and two fungi (*C. albicans* and *A. niger*) were determined for the oil and the isolates, 1,8-cineole and α-pinene. The EO showed pronounced antibacterial and antifungal activity than the isolates, 1,8-cineole and α-pinene against all the tested microbes (Jiang et al. 2011). Hajlaoui et al. (2010) characterized EO of cumin in GC–MS and found 21 components, predominantly cuminaldehyde (39.48%), gamma-terpinene (15.21%), O-cymene (11.82%), β-pinene (11.13%), 2-carene-10-α (7.93%), trans-carveol (4.49%) and myrtenal (3.5%) as major components and reported that cumin oil exhibited antibacterial and antifungal activities and specifically high effectiveness against *Vibrio* spp. with MIC and MBC values of 0.078–0.31 mg mL⁻¹ to 0.31–1.25 mg L⁻¹.

Thymol is an active ingredient of thyme, ajowan (*Trachyspermum ammi* Sprague) and basil (*Ocimum* spp). Thymol and its isomer were reported effective on gram + and gram – bacteria, fungi and yeast with reference to BHA. The active ingredient of mustard, allylisothiocyanate was reported to be very effective on various food pathogens (Chacon et al. 2006), and a natural food preservative system has been developed and patented by Cirigliano et al. (2008). Biochemical profile and antibacterial activity of six *Lamiaceae* EOs were studied in GC-MS and against pathogenic food spoilage bacteria respectively. The major constituents of the oils were 1,8-cineole (29.2%), camphor (17.2%), α-pinene (11.5%) in rosemary; citronellal (20.5%), β-geraniol (17.0%), β-citronellol (11.5%) in lemon balm; 1,8-cineole (27.4%), α-thujone (16.3%), β-thujone (11.2%), borneol (10.4%), camphor (7.98%) in sage; linalool (25.1%), linalyl acetate (22.5%) in lavender; thymol (52.4%), p-cymene (17.9%) in thyme; and patcholene alcohol (22.7%), α-bulnesene (17.1%), α-guaine (13.8%) in patchouli. All the EOs possessed antibacterial activity on most of the bacterial strains tested and thyme showed the highest inhibition, which could be due to higher level of oxygenated monoterpenes in *Lamiaceae* (Abdullah 2011).

Oregano, basil, bergamot and perilla EOs effectively controlled the microbes *E. coli, S. aureus, B. subtilis* and *S. cerevisiae* (Lv et al. 2011). The highest efficacy against all the tested strains was shown with oregano. Basil and bergamot were active against the gram + bacteria (*S. aureus* and *B. subtilis*), while perilla strongly inhibited the growth of yeast (*S. cerevisiae*). The chemical profiling in GC-MS showed that phenols and terpenes were the major antimicrobial compounds in oregano and basil, while alcohols, esters and terpenes were the active components of bergamot (*Citrus bergamia* L.) and ketones were the major active constituents of perilla. The synergistic effect of EOs studied in combination revealed oregano-basil (0.313–0.313 μL mL⁻¹) for *E. coli*, basil–bergamot (0.313–0.156 μL mL⁻¹) for *S. aureus*, oregano–bergamot (0.313–0.313 μL mL⁻¹) for *B. subtilis* and oregano–perilla (0.313–0.156 μL mL⁻¹) for *S. cerevisiae*. Seasonal influenza-A infection results in
considerable morbidity and mortality. Patchouli alcohol (PA), a chemical constituent of patchouli oil strongly inhibited influenza H1N1 replication in vitro. Oral administration of PA (20 mg kg\(^{-1}\) to 80 mg kg\(^{-1}\)) significantly increased the survival rate and time and appears to be able to augment protection against IFV infection in mice via enhancement of host immune responses and attenuation of systemic and pulmonary inflammatory responses (Yu-Cui 2012).

**Ocular health**

Macular carotenoid levels decline with age called age related macular deterioration (AMD), reaching a stable low level and after the age of 60 yrs, AMD incidence begins to rise dramatically. Macular pigment levels in the eyes of AMD patients not consuming high-dose lutein supplements were 32.0% lower than elderly normal eyes (Snodderly et al. 1984; Bone et al. 1988). In marigold (Tagetes erecta L.) flowers, lutein is the major carotenoid with 3.0-6.0% zeaxanthin. Bone et al. (1993) demonstrated that the human macular pigment is a combination of lutein and zeaxanthin and speculated that these dietary carotenoids may play an important role in the prevention of AMD. This was further confirmed by Seddon et al. (1994) who reported a 43.0% lower risk of AMD due to supplementing with lutein and zeaxanthin. Lutein is a food additive and has E-Number of E161b, used in pharmaceutical, nutraceutical, food, pet food as animal and fish feeds. Although, lutein is one of the colour constituents of various fruits and vegetables, commercial extraction is carried out from the petals of marigold.

**Oral-care**

Macelignan isolated from nutmeg reported preferential activity against other oral organisms such as Streptococcus sobrinus, S. salivarius, S. sanguis, Lactobacillus acidophilus and L. casei in the MIC range of 2.0-31.3 μg mL\(^{-1}\). In particular, the bacterial test showed that macelignan at a concentration of 20 μg mL\(^{-1}\) completely inactivated S. mutans in 1 min. MIC of macelignan on S. mutans was 3.9 μg mL\(^{-1}\), which was much lower than the other natural anticariogenic agent, sanguinarine at 15.6 μg mL\(^{-1}\). Other reported anticariogenic flavour compounds are 1,8-cineol, menthol, thymol and methyl salicylate (Chung et al. 2006). A formulation containing juniper berry (Juniperus communis L.), peppermint, orris (Iris germanica L.) root extracts in toothpaste inhibited the growth of S. sanguis (Lee et al. 2004). Nutmeg, eucalyptol, menthol, thymol, methyl salicylate, eugenol from clove, juniper berry, peppermint and orris are the commonly used important flavour and fragrance ingredients (Burdock et al. 1970; Wright 2005).

**Aromatherapy**

Aromatic EOs are used to preserve the mind and modify the mood or healing by many cultures for centuries. The word ‘aromatherapy’ is new to this century, but perfumes, incense and extracts of aromatic plants have been extensively used for therapeutic purpose. Inhalation of aromatic volatiles triggers a neurochemical release in the brain through the receptors in the nose and mouth, causing induction of desirable mood. Aromatherapy EOs are associated with moods or notes are broadly categorized into three major groups. Top note (stimulating) biomolecules include caraway, basil, coriander, eucalyptus, lemon, lime and sage while middle note (neutral mood) include anise seed, fennel, thyme, black pepper, lavender (Lavandula burmanni Benth.), hyssop, rosemary, peppermint and pine. Base note (relaxing or sedative) biomolecules are derived from cinnamon, clove, ginger, nutmeg, sandalwood and cedar wood. EOs are often used as a part of aromatherapy massage, where the oils can be worked into the skin, muscles and joints (Deis 2008). The uses and the type of application of aromatherapy EOs as per flavor and fragrance related development organisation (FFDC) (2003) have been given in Table 1. It has been reported that oil extracted from black cumin seeds ameliorates allergic airway inflammation by decreasing T-Cell response evident by lesser delayed type hypersensitivity and lower T-Cell proliferation in spleen (Shahzad et al. 2009). Aromatherapy EOs listed in the table 1 and black cumin oil
<table>
<thead>
<tr>
<th>Ailment</th>
<th>Name of the Essential Oil</th>
<th>Botanical Name</th>
<th>Method of Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety</td>
<td>Lavender</td>
<td><em>Lavandula burmani</em> Benth.</td>
<td>Bath for at least 15 min</td>
</tr>
<tr>
<td></td>
<td>Jasmine</td>
<td><em>Jasminum sambac</em> (L.) Aiton</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Marigold</td>
<td><em>Tagetes erecta</em> L.</td>
<td>Massage</td>
</tr>
<tr>
<td></td>
<td>Neroli</td>
<td><em>Citrus sinensis</em> L.</td>
<td>Apply on solar plexus*</td>
</tr>
<tr>
<td></td>
<td>Vetiver</td>
<td><em>Vetiveria zizaniodes</em> Statf.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Clary sage</td>
<td><em>Salvia sclarea</em> L.</td>
<td>Massage</td>
</tr>
<tr>
<td>Depression</td>
<td>Clary sage</td>
<td><em>S. sclarea</em> L.</td>
<td>Bath</td>
</tr>
<tr>
<td></td>
<td>Marjoram</td>
<td><em>Oreganum vulgare</em> L.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Chamomile</td>
<td><em>Matricaria chamomilla</em> L.</td>
<td>Massage</td>
</tr>
<tr>
<td></td>
<td>Sandalwood</td>
<td><em>Santalum album</em> L.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Lavender</td>
<td><em>L. burmani</em> Benth.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Frankincense</td>
<td><em>Boswellia serrata</em> Triana &amp; Plan.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Ylang –Ylang</td>
<td><em>Cananga odorata</em> Hook</td>
<td>Inhalation</td>
</tr>
<tr>
<td>Irritability</td>
<td>Chamomile</td>
<td><em>M. chamomilla</em> L.</td>
<td>Bath</td>
</tr>
<tr>
<td></td>
<td>Lavender</td>
<td><em>L. burmani</em> Benth.</td>
<td>Steam Inhalation</td>
</tr>
<tr>
<td></td>
<td>Marjoram</td>
<td><em>O. vulgare</em> L.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Neroli</td>
<td><em>C. sinensis</em> L.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Vetiver</td>
<td><em>V. zizaniodes</em> Statf.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Rosemary</td>
<td><em>Rosmarinus officinalis</em> L.</td>
<td>Inhalation</td>
</tr>
<tr>
<td>Lack of Confidence</td>
<td>Rosemary</td>
<td><em>R. officinalis</em> L.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Petitgrain</td>
<td><em>Citrus aurantium</em> L.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Neroli</td>
<td><em>C. sinensis</em> L.</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td>Jasmine</td>
<td><em>J. sambac</em> (L.) Aiton</td>
<td>Inhalation</td>
</tr>
<tr>
<td>Aggressiveness</td>
<td>Lemon</td>
<td><em>Citrus limon</em> (L.) Burm. F.</td>
<td>Apply on solar plexus</td>
</tr>
<tr>
<td></td>
<td>Chamomile</td>
<td><em>M. chamomilla</em> L.</td>
<td>Apply on solar plexus</td>
</tr>
<tr>
<td></td>
<td>Juniper</td>
<td><em>Juniperus communis</em> L.</td>
<td>Apply on solar plexus</td>
</tr>
<tr>
<td></td>
<td>Marjoram</td>
<td><em>O. vulgare</em> L.</td>
<td>Bath</td>
</tr>
<tr>
<td></td>
<td>Ylang-ylang</td>
<td><em>C. odorata</em> Hook</td>
<td>Bath</td>
</tr>
<tr>
<td>Pain / Sprain</td>
<td>Eucalyptus</td>
<td><em>Eucalyptus globulus</em> Labilli</td>
<td>Massage</td>
</tr>
<tr>
<td></td>
<td>Juniper</td>
<td><em>Juniperus communis</em> L.</td>
<td>Bath</td>
</tr>
<tr>
<td></td>
<td>Black pepper</td>
<td><em>Piper nigrum</em> L.</td>
<td>Massage</td>
</tr>
<tr>
<td></td>
<td>Lavender</td>
<td><em>L. burmani</em> Benth.</td>
<td>Massage</td>
</tr>
<tr>
<td></td>
<td>Rosemary</td>
<td><em>R. officinalis</em> L.</td>
<td>Massage</td>
</tr>
<tr>
<td>Fatigue / Excessive Tiredness</td>
<td>Lavender</td>
<td><em>L. burmani</em> Benth.</td>
<td>Bath</td>
</tr>
<tr>
<td></td>
<td>Neroli</td>
<td><em>C. sinensis</em> L.</td>
<td>Massage</td>
</tr>
<tr>
<td></td>
<td>Juniper</td>
<td><em>J. communis</em> L.</td>
<td>Apply on solar plexus</td>
</tr>
<tr>
<td></td>
<td>Rosemary</td>
<td><em>R. officinalis</em> L.</td>
<td>Massage</td>
</tr>
<tr>
<td></td>
<td>Geranium</td>
<td><em>Pelargonium graveolens</em> L’herit</td>
<td>Massage</td>
</tr>
</tbody>
</table>

**Note:** Application of aroma therapy oils to be done after suitably dilution in appropriate carrier oils under the prescription of aroma therapy experts.

*Solar plexus is the place between chest & navel.

**Courtesy:** Fragrance & Flavour Development Centre, Kannauj, India–Training Manual.
are widely used in flavour and fragrance formulations as reported by Burdock et al. (1970), Secondini (1998) and Wright (2005).

**Conclusion**

Aromatic spices are no more considered as a food additive to enhance the appeal of food. Extensive experiments have proved the health benefits of spices in an eco-friendly manner without any deleterious side-effects. Most of the bioactive compounds are secondary metabolites in the plant system developed for their own immune system and have great diversity, but are under-utilized. In depth scientific application studies will exploit their potential in promoting the quality of healthy living. More and more people prefer nature based bioactive ingredients for health benefits and the nutraceutical market is expected to reach USD 450 billion in 2015 from USD 50 billion in 2000 (Yuan 2011). This will reduce the dependency on environmentally and physiologically unfriendly synthetic chemicals and their residual side effects. Further research need to be focused to investigate and validate the traditional claims in order to optimize the potency and new delivery technologies to widen the applications of various spices and their isolates for preventive, curative and cosmetic solutions towards happy and healthy living of mankind.

**Acknowledgment**

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Spices and aromatic plants—health benefits


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