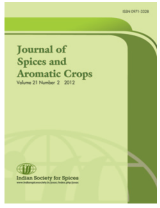
Journal of Spices and Aromatic Crops
Vol. 21 (2) : 87–101 (2012)

Indian Society for Spices

www.indianspicesociety.in/josac/index.php/josac



Health benefits of bioactive molecules from spices and aromatic plants

M Gunasekar, K Geemon & S J Mariwala

Kancor Ingredients Ltd, 7/138 Kancor Road,
Angamaly South, Ernakulam–683 573, Kerala, India.
E-mail: m.gunasekar@kancor.in

Received 21 June 2011; Revised 03 May 2012; Accepted 29 June 2012

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 O_2 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 polyraccharide (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, bisdemethoxy-curcumin (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-dependent *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 (*Brassica nigra* Koch) and clove (*Syzygium 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^{-1} and 72 mg mL^{-1} respectevely (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.*

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).

Curcumins 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, curcumins, 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, viricidal, fungicidal, anti-parasitical, 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 â-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 ã-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*, *Pasteurella multocida* and pathogenic fungi *A. niger*, *Mucor mucedo*, *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 amphotericin-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 synergetic 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. citrates,* 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 (Bassole *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 cuminlaldehyde (39.48%), gamma-terpinene (15.21%), O-cymene (11.82%), β-pinene (11.13%), 2-caren-10-al (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^{-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-cineol (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-cineol (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 neuro chemical 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) bio-molecules include caraway, basil, coriander, eucalyptus, lemon, lime and sage while middle note (neutral mood) include anise seed, fennel, thyme, black pepper, lavender (*Lavendula burmani* Benth.), hyssop, rosemary, peppermint and pine. Base note (relaxing or sedative) bio-molecules 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 1. Aromatherapy applications of essential oils

Ailment	Name of the Essential Oil	Botanical Name	Method of Application
Anxiety	Lavender	*Lavendula burmani* Benth.	Bath for at least 15 min
	Jasmine	*Jasminum sambac* (L.) Aiton	Inhalation
	Marigold	*Tagetes erecta* L.	Massage
	Neroli	*Citrus sinensis* L.	Apply on solar plexus[a]
	Vetiver	*Vetiveria zizaniodes* Statf.	Inhalation
	Clary sage	*Salvia sclarea* L.	Massage
Depression	Clary sage	*S. sclarea* L.	Bath
	Marjoram	*Oreganum vulgare* L.	Inhalation
	Chamomile	*Matricaria chamomilla* L.	Massage
	Sandalwood	*Santalum album* L.	Inhalation
	Lavender	*L. burmani* Benth.	Inhalation
	Frankincense	*Boswellia serrata* Triana & Plan.	Inhalation
	Ylang –Ylang	*Cananga odorata* Hook	Inhalation
Irritability	Chamomile	*M. chamomilla* L.	Bath
	Lavender	*L. burmani* Benth.	Steam Inhalation
	Marjoram	*O. vulgare* L.	Inhalation
	Neroli	*C. sinensis* L.	Inhalation
	Vetiver	*V. zizaniodes* Statf.	Inhalation
	Rosemary	*Rosmarinus officinalis* L.	Inhalation
Lack of Confidence	Rosemary	*R. officinalis* L.	Inhalation
	Petitgrain	*Citrus aurantium* L.	Inhalation
	Neroli	*C. sinensis* L.	Inhalation
	Jasmine	*J. sambac* (L.) Aiton	Inhalation
Aggressiveness	Lemon	*Citrus limon* (L.) Burm. F.	Apply on solar plexus
	Chamomile	*M. chamomilla* L.	Apply on solar plexus
	Juniper	*Juniperus communis* L.	Apply on solar plexus
	Marjoram	*O. vulgare* L.	Bath
	Ylang-ylang	*C. odorata* Hook	Bath
Pain / Sprain	Eucalyptus	*Eucalyptus globulus* Labilli	Massage
	Juniper	*Juniperus communis* L.	Bath
	Black pepper	*Piper nigrum* L.	Massage
	Lavender	*L. burmani* Benth.	Massage
	Rosemary	*R. officinalis* L.	Massage
Fatigue / Excessive Tiredness	Lavender	*L. burmani* Benth.	Bath
	Neroli	*C. sinensis* L.	Massage
	Juniper	*J. communis* L.	Apply on solar plexus
	Rosemary	*R. officinalis* L.	Massage
	Geranium	*Pelargonium graveolens* L'herit	Massage

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

The authors are thankful to Department of Scientific and Industrial Research, Government of India for recognizing the in-house R&D Laboratory of Kancor Ingredients Limited, Ernakulam, Kerala, India, in order to focus on innovative new product research and commercialization.

References

Abdullah I H, Farooq A, Poonam S N, Satyajit D S, John E M, Juluri R R & Anisha M 2011 Antibacterial activity of some *Lamiaceae* essential oils using resazurin as an indicator of cell growth. LWT - Food Sci. Tech. 44: 1199–1206.

Alam K, Goher Z & Anderson R A 2009 Bay leaves improves glucose and lipid profile of people with type 2 diabetes. J. Clin. Biochem. Nutri. 44: 52–56.

Anderson R A, Broadhurst C L, Polansky M M, Schmidt W F, Khan A, Flanagan V P, Schoene N W & Graves D J 2004 Isolation and characterization of polyphenol type-A polymers from cinnamon with insulin-like biological activity. J. Agric. Food Chem. 52: 65–70.

Arvinder S & Nomita L 2011 Properties of essential oils: A review. Ind. Perf. 55: 23–27.

Bakkali F, Averbeck S, Averbeck D & Idaomar M 2008 Biological effects of essential oils - A review. Food Chem. Toxicol. 46: 446–475.

Banji D, Pinnapureddy J, Banji O J F, Saidulu A, Hayath Md S 2011 Synergistic activity of curcumin with methotrexate in ameliorating Freund's Complete Adjuvant induced arthritis with reduced hepatotoxicity in experimental animals. Eur. J. Pharmacol. 668: 293–298.

Bassolé I H N, Lamien-Meda A, Bayala B, Obame L C, Ilboudo A J, Franz C, Novak J, Nebié R C & Dicko M H 2011 Chemical composition and antimicrobial activity of *Cymbopogon citratus* and *Cymbopogon giganteus* essential oils alone and in combination. Phytom. 18: 1070–1074.

Bendahou M, Muselli A, Grignon-Dubois M, Benyoucef M, Desjobert J M. & Bernardini A F 2008 Antimicrobial activity and chemical composition of *Origanum glandulosum* Desf. Essential oil and extract obtained by microwave extraction. Comparison with hydro distillation. Food Chem. 106: 132–139.

Broek van der H, Robbins K & Randall J 2004 Rosemary extract: Taking freshness back to basics. In: Fats and oils-their role in food and health (pp 14). Proceedings of the biennial conference, Nov.30–Dec.1, 2004, Australian section of the American Oil Chemists Society, Adelaide.

Bone R A, Landrum J T, Fernandez L & Tarsis S L 1988 Analysis of the macular pigment by HPLC: Retinal distribution and age study. Invest. Ophthalmol. Vis. Sci. 29: 843–849.

Bone R A, Landrum J T, Hime G W, Cains A & Zamor J 1993 Stereochemistry of the human macular carotenoids. Invest. Ophthalmol. Vis. Sci. 34: 2033–2040.

Burdock G A, Furia T E, Bellanca N & Fenaroli G 1970 Handbook of Flavour Ingredients, Vol. 3, CRC Press, New York.

Busatta C, Vidal R S, Popiolski A S, Mossi A J, Dariva C, Rodrigues M R A, Corazza F C, Corazza M L, Oliveira J V & Cansian R L 2008 Application of *Origanum majorana* L. essential oil as an antimicrobial agent in sausage. Food Microbiol. 25: 207–211.

Chacon P A, Buffo R A & Holley R A 2006 Inhibitory effects of microencapsulated allylisothiocyanate (AIT) against *Escherichia coli* O157:H7 in refrigerated, nitrogen packed and finely chopped beef. Intl. J. Food Microbiol. 107: 231–237.

Chandra D & Gupta S S 1972 Anti-inflammatory and antiarthritic activity of volatile oil of *Curcuma longa*. Ind. J. Med. Res. 60: 138–142.

Chen N, Chang C C, Ng C C, Wang C Y, Shyu Y T & Chang T I 2008 Antioxidant and antimicrobial activity of *Zingiberaceae* plants in Taiwan. Pl. Foods for Human Nutr. 63: 15–20.

Chung J Y, Choo J H, Lee M H, & Hwang J K 2006 Anticariogenic activity of macelignan isolated from *Myristica fragrans* (nutmeg) against *Streptococcus mutans.* Phytom. 13: 261–266.

Cirigliano M C, Sekula B C, Hamm D J & Gallagan L A 2008 Low fat consumer product comprising a natural preservative system and a method for making the same. United States Patent Application Publication No: US2008/0193615 A1, 1–8.

Deis R C 2008 Food Product Design: The Secret World of Spices, Virgo Publishing, UK.

Delamare A P L, Moschen-Pistorello I T, Artico L, Atti-Serafini L, Echeverrigaray S 2007 Antibacterial activity of the essential oils of *Salvia officinalis* L. and *Salvia triloba* L. cultivated in South Brazil. Food Chem. 100: 603–608.

Delaquis P J, Stanich K, Girard B, Mazza G 2002 Antimicrobial activity of individual and mixed fractions of dill, cilantro, coriander and eucalyptus essential oils. Intl. J. Food Microbiol. 74: 101–109.

Erturk O 2006 Antibacterial and antifungal activity of ethanolic extracts from eleven spice plants. Biologia Bratislava 61: 275–278.

FFDC 2003 Value added products covering aromatic chemical, fragrance and flavour creation methodology. Fragrance & Flavour Development Centre, Kannauj, India. pp 95–96.

Gee J M, Blackburn N A & Johnson I T 1983 The influence of guar gum on intestinal cholesterol transport in the rat. *Brit. J. Nutri.* **50:** 215–224.

Ghanbari H, Saghravanian N & Zakery M 2008 Histological evaluation of *Curcuma longa* ghee formulation and hyaluronic acid on gingival healing in dog. J. Ethanopharmacol. 120: 335–341.

Gulluce F, Sahin F, Sokmen M, Ozer H, Daferera D, Sokmen A, Polissiou M, Adiguzel A & Ozkan H 2007 Antimicrobial and antioxidant properties of the essential oils and methanol extract from *Mentha longifolia* L. ssp. *Longifolia*. Food Chem. 103: 1449–1456.

Gupta S S & Modh P R 1969 Anti-inflammatory effect of *Curcuma longa* in relation to inhibition of histamine release and mast cells. Ind. J. Pharmacol. 1: 22–25.

Gupta A, Gupta R & Lal B 2001 Effect of *Trigonella foenum-graecum* (fenugreek) seeds on glycemic control and insulin resistance in type-2 diabetes mellitus: a double blind placebo controlled study. J. Assoc. Physi. Ind. 49:1057–61.

Gutierrez J, Barry-Ryan C & Bourke P 2008 The antimicrobial efficacy of plant essential oil combinations and interactions with food ingredients, Intl. J. Food Microbiol. 124: 91–97.

Gutierrez J, Barry-Ryan C & Bourke P 2009 Antimicrobial activity of plant essential oils using food model media: Efficacy, synergistic potential and interactions with food components. Food Microbiol. 26: 142–150.

Haeri M R, Izaddoost M, Ardekani M R, Nobar M R & White K N 2008 The effect of fenugreeek 4-hydroxyisoleucine on liver function biomarkers and glucose in diabetic and fructose-fed rats. Phytoth. Res. 23: 61–64.

Hajlaoui H, Mighri H, Noumi E, Snoussi M, Trabelsi N, Ksouri R & Bakhrouf A 2010 Chemical composition and biological activities of Tunisian *Cuminum cyminum* L. essential oil: A high effectiveness against Vibrio spp. Strains. Food Chem. Toxicol. 48: 2186–2192.

Hayouni E A, Chraief I, Abedrabba M, Bouix M, Leveau J Y, Mohammed H & Hamdi M 2008 Tunisian *Salvia officinalis* L. and *Schinus molle* L. essential oils: Their chemical compositions and their preservative effects against *Salmonella* inoculated in minced beef meat. Intl. J. Food Microbiol. 125: 242–251.

Hussain A I, Anwar F, Sherazi S T H & Przybylski R 2008 Chemical composition, antioxidant and antimicrobial activities of basil (*Ocimum basilicum*) essential oils depends on seasonal variations. Food Chem. 108: 986–995.

Hussien J, Teshale C & Mohammed J 2011 Assessment of the antimicrobial effects of some Ethiopian aromatic spice and herb hydrosols. Intl. J. Pharmacol. 7: 635–640.

Hwa J S, Jin Y C, Lee Y S, Ko Y S, Kim Y M, Shi L Y, Kim H J, Lee J H, Ngoc T M, Bae K H, Kim Y S & Chang K C 2012 2-Methoxycinnamaldehyde from *Cinnamomum cassia* reduces rat myocardial ischemia and reperfusion injury *in vivo* due to HO-1 induction. J. Ethnopharmacol. 139(2): 605–615.

Kawaguchi T & Kida N 1987 Natural bactericides for the control of infections in animals. Japanese Patent No 6259214, Japan.

Khan A, Safdar M, Ali Khan M M, Khattak K N, & Anderson R A 2003 Cinnamon improves glucose and lipids of people with type-2 diabetes. Diab. Care: 26: 3215–3218.

Kohli K, Ali J, Ansari M J, Raheman Z 2005 Curcumin: A natural antiinflammatory agent. Ind. J. Pharmacol. 37: 141–147.

Jiang Y, Wu N, Fu Y J, Wang W, Luo M, Zhao C J, Zu Y G & Liu X L 2011 Chemical composition and antimicrobial activity of the essential oil of rosemary. Environ. Toxicol. Pharmacol. 32: 63–68.

Jin D Q, Lim C S, Hwang J K, Ha I, Han J S 2005 Anti-oxidant and anti-inflammatory activities of macelignan in murine hippocampal cell line and primary culture of rat microglial cells. Biochem. Biophy. Res. Comm. 331: 1264–1269.

Lee S S, Zhang W & Li Y 2004 The antimicrobial potential of 14 natural herbal dentrifrices: Results of an *in vitro* diffusion method study. J. Am. Dent. Assoc. 135: 1133–1141.

Lejeune M P, Kovacs E M, & Westerterp-Plantenga M S 2003. Effect of capsaicin on substrate oxidation and weight maintenance after modest body-weight loss in human subjects. Brit. J. Nutr. 90: 651–659.

Li T Y, Brennan A M, Wedick N M, Petersen J M, Stonehouse O W, Jerling J C, Hanekom S M, & White Z 2006 Anti-oxidant rich spice added to hamburger meat during cooking results in reduced meat, plasma, and urine malondialdehyde concentrations. Amer. J. Clin. Nutr. 84: 95–135.

Lim G P, Teresa Chu, Fusheng Yang, Walter Beech, Sally A. Frautschy & Greg M. Cole 2001 The Curry Spice Curcumin Reduces Oxidative Damage and Amyloid Pathology in an Alzheimer Transgenic Mouse. J. Neurosci. 21: 8370–8377.

Ling J, Wei B, Lv G, Ji H & Li S 2012 Anti-hyperlipidaemic and antioxidant effects of turmeric oil in hyperlipidaemic rats. Food Chem. 130: 229–235.

Lv F, Lianga H, Yuana Q & Li C 2011 *In vitro* antimicrobial effects and mechanism of action of selected plant essential oil combinations against four food-related microorganisms. Food Res. Intl. 44: 3057–3064.

Ma J, Hwang Y K, Cho W H, Han S H, Hwang J K & Han J S 2009 Macelignan attenuates activations of mitogen-activated protein kinases and nuclear factor kappa B induced by lipopolysaccharide in microglial cells. Biol. Pharm. Bull. 32: 1085–1090.

Mae T, Nishiyama T, Kishida H, Takagaki R & Yamamoto M 2007 Agent for preventing/ ameliorating life style related diseases containing turmeric essential oil component. European Patent Application, Intl. Nat. Pub No. WO 2005/115366, EP1752144A1, 1–12.

Majeed M 1995 Curcuminoids: Antioxidant Phytonutrient. NutriScience Publishers Inc. New Jersey, USA.

Mahattanadul S, Nakamura T, Panichayupakaranant P, Phdoongsombut N, Tungsinmunkong K & Bouking P 2009 Comparative anti-ulcer effect of bisdemethoxycurcumin and curcumin in a gastric ulcer model system. Phytom. 16: 342–351.

Minpei K, Yoshihiro Mi, Tozo N, Tatsumasa M, Hideyuki K, Misuzu T, Kazuma T, Teruo K, Kaku N & Mikio K 2005 Hypoglycemic effects of turmeric (*Curcuma longa* L.) rhizomes on genetically diabetic KK-Ay mice. Biol. Pharm. Bull. 28: 937–939.

Morimoto T, Wada H, Sunagawa Y, Fujita M, Kakeya H, Imaizumi A, Hashimoto T, Akao M, Katanasaka Y, Osakada G, Kambara H, Shiomi H, Kimura T, Shimatsu A & Hasegawa K 2012 Highly absorptive curcumin improve left ventricular diastolic function irrespective blood pressure in hypertensive patients. J. Amer. College Cardiol. 59 Supplement, 27, E987.

Norsharina I, Maznah I, Latiffah L, Musalmah M, & Abdalbasit M 2008 Black cumin seed (*Nigella sativa* L.) oil and its fractions protect against beta amyloid peptide-induced toxicity in primary cerebellar granule neurons. J. Food Lipids. 15: 519–533.

Persson I A, Persson K, Hägg S & Andersson R G 2011 Effects of cocoa extract and dark chocolate on angiotensin-converting enzyme and nitric oxide in human endothelial cells and healthy volunteers-a nutrigenomics perspective. J. Cardiovasc. Pharmacol. 57: 44–50.

Rajbir B, Singh K, Ishar M P S & Singh J 2008 The effect of *Alliun sativum* on ischemic preconditioning and ischemia reperfusion induced cardiac injury. Ind. J. Pharmacol. 40: 261–265.

Ramanathan L & Das N P 1993 Natural products inhibit oxidative rancidity in salted cooked ground fish. J. Food. Sci. 58: 318–320.

Ramaswamy T S & Banerjee B N 1948 Vegetable dyes as antioxidants for vegetable oils. Ann. Biochem. Exptl. Med. 8: 55–68.

Sandasi M, Leonard C M, & Viljoen A M 2008 The effect of five common essential oil components on *Listeria monocytogenes* biofilms. Food Cont. 19: 1070–1075.

Santos F S, Guadalupe M & Novales M 2012 Essential oils from aromatic herbs as antimicrobial agents. Curr. Opin. Biotech. 23: 136–141.

Secondini O 1998 Hand book of Perfumes & Flavours, Affiliated East-West Press Pvt Ltd, New Delhi.

Seddon J M, Ajani U A & Sperduto R D 1994 Dietary carotenoids, vitamins A, C, and E, and advanced age related macular degeneration. J. Amer. Med. Assoc. 272: 1413–1420.

Shahidi F, Pegg R B & Saleemi Z O 2007 Stabilization of meat lipids with ground spices. J. Food Lipids. 2: 145–153.

Sharma R D, Sarkar A, Hazra D K, Misra B, Singh J B, Maheshwara, B B & Sharma S K 1996 Hypolipidaemic effect of fenugreek seeds: a chronic study in non-insulin dependent diabetic patients. Phytoth. Res. 10: 332–334.

Shahzad M, Yang X, Raza Asim MB, Sun Q, Han Y, Zhang F, Cao Y & Lu S 2009 Black cumin seed oil ameliorates allergic airway inflammation by inhibiting T-Cell proliferation in rats. Pulm. Pharmacol. Therap. 22: 37–43.

Sharma R D, Raghuram T C & Rao N S 1990 Effect of fenugreek seeds on blood glucose and serum lipids in type I diabetes. Eur. J. Clin. Nutr. 44: 301–306.

Snodderly D M, Brown P K, Delori F C & Auran J D 1984 The macular pigment. Absorbance spectra, localization and discrimination from other yellow pigments in primate retinas. Investigative Ophthalmol. Vis. Sci. 25: 660–673.

Silva F, Ferreira S, Duarte A, Mendonça D I & Domingues F C 2011 Antifungal activity of *Coriandrum sativum* essential oil, its mode of action against *Candida* species and potential synergism with amphotericin B. Phytomed. 19: 42–47.

Singh R, Singh N, Saini BS & Rao HS 2008 *In vitro* antioxidant activity of pet ether extract of black pepper. Ind. J. Pharmacol. 40: 147–51.

Soliman M M, Attia H F, El-Shazly S A & Saleh O M 2012 Biomedical effect of cinnamon extract on obesity and diabetes relevance in wistar rats. Amer. J. Biochem. Molec. Biol. 2: 133–145.

Sreejayan N & Rao M N A 1994 Curcuminoids as potent inhibitors of lipid peroxidation. J. Pharm. Pharmacol. 46: 1013.

Srichamroen A, Field C J, Thomson A B & Basu T K 2008 The modifying effects of galactomannan from canadian-grown fenugreek (*Trigonella foenum-graecum* L.) on the glycemic and lipidemic status in rats. J. Clin. Biochem. Nutr. 43: 167–174.

Srinivasan K 2005 Role of spices beyond food flavouring: Nutraceuticals with multiple health effects. Food Rev. Intl. 21: 167–188.

Tajkarimi M M, Ibrahim S A & Cliver D O 2010 Antimicrobial herb and spice compounds in food. Food Cont. 21: 1199–1218.

Tallon M J 2008 Spicing up health with capsaicin. Nat. Foods Merchand. 28: 38–40.

Toda S, Miyase T & Arich H 1985 Natural Antioxidants. III. Antioxidative components isolated from rhizomes of *Curcuma longa* L. Chem. Pharm. Bull. 33: 1725–1728.

Tripathi R M, Gupta S S & Chandra D 1973 Antitrypsin and antihyaluronidase activity of volatile oil of *Curcuma longa* (Haldi). Ind. J. Pharmacol. 5: 260–261.

Tyagi A K & Malik A 2011 Antimicrobial potential and chemical composition of *Eucalyptus globulus* oil in liquid and vapour phase against food spoilage microorganisms. Food Chem. 126: 228–235.

Vijayakumar M V & Bhat M K 2008 Hypoglycemic effect of a novel dialysed feungreek seeds extract is sustainable and is mediated, in part, by the activation of hepatic enzymes. Phytoth. Res. 22: 500–505.

Vincent O D 2011 Natural chemopreventive therapy: Curcumin. Osteopathic Family Physician 3: 74–76

Vokk R, Lõugas T, Mets K & Kravets M 2011 Dill (*Anethum graveolens* L.) and Parsley (*Petroselinum crispum* (Mill.) Fuss) from Estonia: seasonal differences in essential oil composition. Agro. Res. 9: 515–520.

Wei K & Xu X 2003 Herbal composition and method for controlling body weight and composition. United States Patent 6541046, USA.

Wright J 2005 Flavour Creation, Allured Publishing Corporation, Illinois, USA.

Wongcharoen W, Jai-aue S, Phrommintikul A, Nawarawong W, Woragidpoonpol S, Tepsuwan T, Sukonthasarn A, Apaijai N & Chattipakorn N 2012 Effects of curcuminoids on frequency of acute myocardial infarction after coronary artery bypass grafting. Amer. J. Cardiol. Online Ed. 05 April 2012 (10.1016/j.amjcard. 2012.02.043.

Yuan W 2011 Nutraceutical Products - China 2011, Ingredients - South Asia. Saffron Media Publication, Mumbai India 4: pp 30.

Yu-Cui L, Shao-Zhong P, Hai-Ming C, Feng-Xue Z, Pei-Ping X, Jian-Hui X, Jing-Jin H, Jian-Nan C, Xiao-Ping L, Zi-Ren S 2012 Oral administration of patchouli alcohol isolated from *Pogostemonis herba* augments protection against influenza viral infection in mice. Intl. Immunopharmacol. 12: 294–301.