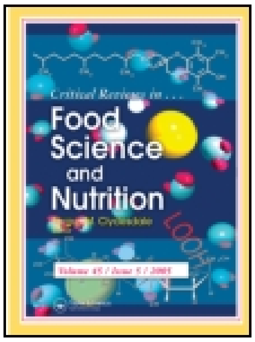

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Potential Herbs and Herbal Nutraceuticals: Food Applications and Their Interactions with Food Components

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Since ancient times, herbs have been used as natural remedies for curing many physiological disorders. Traditional medicinal literature appreciated their value as nature's gift to mankind for the healing of illnesses. Some of the herbs have also been used for culinary purposes, and few of them have been used in cheese manufacture both as coagulating agents and flavor ingredients. Scientific investigations regarding biological activity and toxicity of chemical moieties present in many herbs have been carried out over a period of time. Consequently, literature related to the use of herbs or their functional ingredients in foods and their interaction with food constituents has been appearing in recent times. This article presents the information regarding some biologically active constituents occurring in commonly used herbs, viz., alkaloids, anthraquinones, bitters, flavonoids, saponins, tannins, and essential oils, their physiological functionalities, and also the description of few herbs of importance, viz., Asparagus racemosus, Withania somnifera, Bacopa monniera, Pueraria tuberose, Emblica officinalis, Terminalia chebula, Terminalia belerica, Terminalia arjuna, and Aloe vera, in terms of their chemical composition, biological functionality, and toxicity. This article also reviews the use of herbs and their active ingredients in foods and their interactions with different food constituents.

Keywords Herbs, bioactive constituents, interactions, toxicity, applications

INTRODUCTION

Enormous changes in lifestyle, eating habits, and shifting rural habitations have a significant effect on diets in the developing countries leading to increase in assorted health problems. With millions being spent on healthcare each year, consumer's desire for food products with desired health benefits continues to grow. Furthermore, people want to take food with desired health benefits rather than taking medicine separately. "Nutraceuticals" often referred to as "phytochemicals" are natural bioactive, chemical compounds that have health promoting, disease preventing, or medicinal properties. Nutraceuticals may range from isolated nutrients, herbal products, dietary supplements, and diets to genetically engineered "designer" foods and processed products such as cereals, soups, and beverages. Nutraceuticals can be grouped into the following three broad categories (Dureja et al., 2003): (a) *Nutrients*—Substances with established nutritional functions, such as vitamins, minerals, amino acids, and fatty acids; (b) *Herbals* —Herbs or botanical products as concentrates and extracts; (c) *Dietary supplements*—Reagents derived from other sources (e.g., pyruvate, chondroitin sulphate, and steroid hormone precursors) serving specific functions, such as sports nutrition, weight-loss supplements, and meal replacements. Nutraceuticals are found in a mosaic of products emerging from (a) the food industry, (b) the herbal and dietary supplement market, (c) pharmaceutical industry, and (d) the newly merged pharmaceutical/agribusiness/nutrition conglomerates (Dureja et al., 2003). The ascribed health benefits of nutraceuticals are countless. Various products are claimed not only to reduce the risk of cancer and heart disease but also to prevent or treat hypertension, high cholesterol, excessive weight, osteoporosis, diabetes, arthritis, macular degeneration (leading to irreversible blindness), cataracts, menopausal symptoms, insomnia, diminished memory and concentration, digestive upsets and constipation,

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and not to mention headaches (Stauffer, 1999). Nutraceuticals are marketed either as a single substance or as combination of preparations (Stephen, 1998).

Herbs have been used as food and as medicine for centuries. Since the beginning of human civilization, herbs have been an integral part of the society, valued both for their culinary and medicinal properties. Herbs have played a significant role in maintaining human health, improving the quality of human life, and served us with valuable components of seasoning, beverages, cosmetics, dyes, and medicines. From 1960, interest in "natural health" and the use of herbal products has increased (Trevelyan, 1993). Herbal bioactives, an important category of nutraceuticals, are commonly used by people who seek conventional healthcare. Herbs harbor a wide variety of active phytochemicals including the flavonoids, terpenoids, lignans, sulfides, polyphenols, carotenoids, coumarins, saponins, plant sterols, uramins, and phthalates (Craig, 1999). In the present article, selected herbs, their chemical composition, biologically active ingredients, physiological functionality, their use in foods, and the interactions of various food ingredients with the herbal components are delineated.

CATEGORIES OF HERBS

Based on their use and toxicity, herbs can broadly be categorized into three categories. The first category is the "food herbs" which are gentle in action, have very low toxicity, and are unlikely to cause an adverse response when consumed. Food herbs can be utilized in substantial quantities over long periods of time without any acute or chronic toxicity (allergic responses with foods are possible, as are unique idiosyncratic reactions, and even common foods such as grapefruit juice, broccoli, and okra can interact with medications). The second category is the "medicinal herbs" which are strong acting and need to be used as drug for specific medical conditions (with a medical diagnosis) and usually for a limited period of time as prescribed by a medical practitioner. These herbs may often cause adverse reactions and in some cases may interact with drugs. The last category is the "poisonous herbs" which have strong potential for both acute or chronic toxicity and need to be utilized strictly under the supervision of trained clinicians (Winston, 1992). Traditional Chinese Medicine also categorizes herbs into three classes based on safety or potential toxicity. The upper class (superior) drugs are nontoxic and are tonic remedies. The middle class (ministerial) drugs may have some mild toxicity and they support the superior medicines. The last category is the lower class (inferior) remedies that are toxic and used only for specific ailments for limited periods of time. A clear understanding of a herb's benefits and possible risks as well as a clearly defined patient diagnosis are essential for the practitioner to safely and effectively counsel patients about the safe and effective choices in the use of a herb (Tierra and Tierra, 1999; Winston and Dattner, 1999; Dan, 2003).

COMMON BIOACTIVE INGREDIENTS IN HERBS

Herbs have many constituents including vitamins, minerals, and active ingredients that have a variety of medicinal benefits. These active components include: alkaloids, anthraquinones, bitters, flavonoids, saponins, tannins, and essential oils.

Alkaloids

Alkaloids come under a special group of chemicals that take part in the biological processes of plants, animals, and microorganisms. According to the database of the National Library of Medicine, alkaloids may even be artificially synthesized (NCBI, 2005). An alkaloid is a heterocyclic chemical compound that contains nitrogen and may possess some pharmacological activity and, in many cases, have medicinal or ecological use (Aniszewski, 1994). Alkaloids can create intense physiological action by acting at different cellular levels of organisms, and hence are widely used in the medical fields as curative drugs. They are only slightly soluble in water but soluble in ethanol, benzene, ether, and chloroform and some of them can also be highly toxic, even in very small doses (Becker et al., 1986). Physiological action of these alkaloids varies according to the species of the plants from which they are extracted. Some alkaloids act as a catalyst to other healing agents without being involved themselves. Natural plant alkaloids are used by pharmaceutical industry for the development of antimalarial agents (quinine and chloroquinine), anticancer agents (taxol, vinblastine, and vincristine), and agents promoting blood circulation in the brain (vincamine) (Pelletier, 1983). The most well known is the use of the quinine as a bitter in tonic water according to an established procedure. Theophylline is an important component of black tea and caffeine is a well-known component of coffee and both are known to possess pharmacological activity and have become a part of our day to day life (Aniszewski, 2007).

The alkaloid piperine containing spices namely the black, white, green (*Piper nigrum* L.), and long pepper (*Piper longum* L.) are widely used in food. Other alkaloid plants used in food are capsicum peppers such as chilli or red pepper (*Capsicum annuum* L.), peruvian pepper (*Capsicum baccatum* L.), ají pepper (*Capsicum chinese* Jacq.), bird pepper or tabasco (*Capsicum frutescens* L), and rocoto pepper (*Capsicum pubescens* Ruizet Pav.). According to recent studies, piperine is nontoxic and has a great deal of physiological activity. It has been recently documented that piperine interacts with a mammalian protein. This alkaloid is efficiently taken by calyx of bovine beta-lactoglobulin, which is the major whey protein in milk (Zsila et al., 2005). Dietary supplements containing ephedrine alkaloids are on the market (Brevoort, 1996; FDA, 1996). Ephedrine alkaloids have sympathominetic effects and cause weight loss and enhanced athletic performance. However, there are risks connected with the use of these alkaloids as supplements and determining a risk-free dosage is very essential (FDA, 2002). However, some alkaloids are used as additional components of food.

Anthraquinones

Anthraquinones represent a large family of compounds having diverse biological properties (Srinivas et al., 2007). They act to stimulate muscular contraction of the large intestine and so have a laxative effect. Herbs such as dock (*Rumex crispus*), cascara (*Rhamnus purshianus*), senna (*Senna alexandrina*), rhubarb (*Rheum palmatum)*, and aloe (*Aloe barbadensis Miller*) contain anthraquinones. Anthraquinones such as aloe-emodin are able to inhibit cell growth in several tumor cells, including human lung carcinoma (Lee et al., 2001), hepatoma (Kuo et al., 2002; Yeh et al., 2003), and leukemia cell lines (Chen et al., 2004b). Anthraquinones like emodin (Zhang et al., 1995; Kamei et al., 1998; Huang et al., 2007), rhein (Kuo et al., 2004b; Huang et al., 2007) from rhubarb, and aloe-emodin from *Aloe vera* (Kuo et al., 2002; Acevedo-Duncan et al., 2004; Chen et al., 2004b) have been found to have anticancer properties. Aloe-emodin, a hydroxyanthraquinone present in *Aloe vera* leaves also has a specific in vitro and in vivo antineuroectodermal tumor activity (Elsohly et al., 2007). Aloe latex contains anti-inflammatory anthraquinones, which are used in healing and arresting pain.

Bitters

Bitters are a mixed group of bitter-tasting compounds found in many naturally occurring herbs. Some common herbs containing bitter compounds are angelica *(Angelica archangelica),* chamomile *(Matricaria chamomilla),* dandelion *(Taraxacum),* goldenseal *(Hydrastis Canadensis),* horehound *(Marrubium vulgare),* milk thistle *(Silybum marianum),* peppermint *(Mentha piperita),* rue *(Ruta),* wormwood *(Artemisia absinthium)*, and yarrow *(Achilles millefolium)*. Bitter ingredients mainly affect the digestive tract, stimulating the secretion of digestive juices and enzymes in the stomach and the flow of bile from the liver. They enhance appetite and improve digestion as well as absorption of nutrients from food (Harrison and Bartels, 2006). They are prescribed for people with poor appetite, a sluggish bowel, gall bladder and liver problems, gastritis, and to aid convalescence after the flu and other illnesses and also acts as antioxidants (Liao et al., 2008). Other beneficial effects of bitter herbs include antimicrobial (Tan and Vanitha, 2004), antineoplastic (antitumor), relaxing effect on the nervous system, anti-inflammatory action, and antidiabetic action (Hui et al., 2009) and they also act on the immune system (Tan and Vanitha, 2004). The beneficial action of the bitters starts in the mouth, hence for best effect they need to be tasted (despite our dislike of their effect on our tongues).

It is mentioned in Indain Ayurveda that bitter herbs such as *neem* (*Azadirachta indica*)*, manjista or* Indian *madder (Rubia cordifolia Linn.)*, *haridra* (*Curcuma longa- zingiberaceae)*, and *guduchi or* Heart-leaved moonseed (*Tinospora cordifolia*) have an affinity to the liver and spleen, and are commonly used for such ailments.

Flavonoids

Flavonoids are primarily present as glycosides in nature and represent a major group of natural antioxidants. Herbs (e.g. *Sophora japonica, Citrus grandis,* and *Hypericum perforatum*), fruits (e.g., orange, grapefruit, apple, and grape), vegetables (e.g., onion, kale, broccoli, green pepper, spinach, and tomato), and soybeans are the major sources of flavonoids (Chao et al., 2002). Flavonoids posses beneficial pharmacological effects including protective role against coronary heart diseases (Hertog et al., 1993, 1995; Hertog and Hollman, 1996; Knekt et al., 1996; de Groot and Rauen, 1998) and also show anti-allergic (Middleton, 1998), antiviral (Kaul et al., 1985; Wang et al., 1998), anticancer (Fotsis et al., 1997; Knekt et al., 1997; Stefani et al., 1999), as well as antioxidant properties (Pietta, 2000; Ghasemzadeh et al., 2010). A variety of flavonoid products are either being actively developed or currently sold as dietary supplements and/or herbal remedies. But, literature regarding absorption, distribution, metabolism, and excretion of flavonoids glycosides in animals is limited and hence, the biological outcomes of flavonoids in herbs have not been fully understood (Hollman and Katan, 1997, 1999).

Saponins

The saponins are naturally occurring surface-active glycosides produced by plants (Francis et al., 2002). Herbs contain steroid saponins which are responsible for their health-promoting properties (Fenwick et al., 1991). Capsicum peppers (*Capsicum annuum*), aubergine (*Solanum aethiopicum* L.), fenugreek (*Trigonella foenum graecum* L.), yucca (*Yucca schidigera*)*,* and ginseng (*Panax ginseng*) are examples of some common herbs that contain steroid saponins.

Saponins perform many useful pharmacological functions which include hypoglycemic activity (Petit et al., 1993; Kim et al., 1998; Lee et al., 2000; Yoshikawa et al., 2001), lowering of serum cholesterol levels (Harwood et al., 1993; Potter et al., 1993; Matsuura, 2001; Wang et al., 2008), lowering of LDL-cholesterol levels (Harris et al., 1997; Morehouse et al., 1999), stimulation of the cell-mediated immune system (Kensil, 1996; Plohmann et al., 1997; Barr et al., 1998; Sjolander et al., 1998; Lacaille-Dubois et al., 1999; Oda et al., 2000), inhibition of the growth of cancer cells (Rao and Sung, 1995; Konoshima et al., 1998; Marino et al., 1998; Mimaki et al., 1998; Podolak et al., 1998), antifungal activity (Delmas et al., 2000; Miyakoshi et al., 2000; Wang et al., 2000), antioxidant effects (Yoshiki and Okubo, 1995; Yoshiki et al., 1998; Hu et al., 2002), virucidal activity (Sindambiwe et al., 1998; Apers et al., 2000; Mengoni et al., 2002), and neurotrophic and neuroprotective effects (improves learning ability and cognitive functions) (Kim et al., 1998; Zhao and McDaniel, 1998; Rudakewich et al., 2001; Yao and Li, 2001). In some cases, saponins consumption may lead to abortification and anti-implantation and they are antizygotic too (Tiwary et al., 1973; Stolzenberg and Parkhurst, 1976; Quin and Xu, 1998).

Tannins

Tannins are a group of complex phenol and polyphenol compounds that act as astringents, thus shrinking tissues and contracting structural proteins in the skin and mucosa (Nobre-Junior et al., 2007). Tannins have the ability to prevent lipid peroxidation, superoxide formation, and perform free radical scavenging activity (Giovannelli et al., 2000; Kaplan et al., 2001; Ying et al., 2001; Lin et al., 2001a, 2001b; Bhattacharya et al., 2002; Bors and Michel, 2002; Dufour et al., 2002; Gyamfi and Aniya, 2002; Mullen et al., 2002; Nakagawa and Yokozawa, 2002; Wei et al., 2004). Tannins exhibit several beneficial health properties such as anti-inflammatory (Viana et al., 1997), analgesic, antilymphocytic (Chen et al., 2000; Okoli and Akah, 2000; Kapu et al., 2001), antimicrobial (Akiyama et al., 2001; Ho et al., 2001; Cheng et al., 2002; Elegami et al., 2002; Silva et al., 2002; Adeleye et al., 2003), antileishmanial, immunomodulatory (Kiderlen et al., 2001; Kolodziej et al., 2001), neuroprotective (Nobre-Junior et al., 2007), antihypertensive (Liu et al., 2003), and antidiarrhoeal (Abdullahi et al., 2001) activities and are also useful in treatment of ulcerative colitis (Catherine Clinton, 2009).

Essential Oils

Essential oils (EOs), also known as volatile or ethereal oils, are natural mixtures of aromatic compounds obtained from plant materials (flowers, buds, seeds, leaves, twigs, bark, herbs, wood, fruits, and roots) that are extracted by steam or solvent distillation (Guenther, 1948). Generally, the EOs consist of a mixture of esters, aldehydes, ketones, terpenes, and phenolic compounds and harbor the characteristic flavor and aroma of the particular spice or herb.

EOs are slightly enriched in terpenoids (Guenther, 1999), posseses antiseptic and antimicrobial activity (Abed, 2007; Bansod and Rai, 2008), and enhance the body's ability to fight off a range of infections. They have anti-inflammatory and antispasmodic effects (chamomile and yarrow), anticancer effects (Zu et al., 2010), act as expectorants (thyme and hyssop), used in tonics enhancing the appetite and the digestion and absorption of food (rosemary, fennel, and marjoram), and also stimulate the heart and circulatory system (ginger, rosemary, and thyme).

SOME COMMON HERBS WITH POTENTIAL FOR INCORPORATION INTO FOODS

Asparagus racemosus

Asparagus racemosus belongs to the family *Liliaceae*. It is commonly known as *Satavar*, *Shatavari, Satawar*, or *Satmuli* in India. The plant grows throughout the tropical and subtropical parts of India. Its medicinal usage has been reported in the Indian and British Pharmacopoeias and in traditional systems of medicine such as Ayurveda, Unani, and Siddha. It is recommended in Ayurvedic texts for the prevention and treatment of gastric ulcers, dyspepsia, and as a galactogogue (Saxena and Bopana, 2009).

Biologically Active Constituents

The major active constituents of *A. racemosus* are steroidal saponins (Shatavarins I–IV) that are present in the roots. Shatavarin IV is a biologically active glycoside (Asmari et al., 2004) and consists of two molecules of rhamnose and one molecule of glucose. Other active compounds such as quercetin, rutin, and hyperoside are found in the flowers and fruits while diosgenin and quercetin-3 glucuronide are present in the leaves (Thomsen, 2002). Other active constituents of *A. racemosus* include racemofuran, an antioxidant (Wiboonpun et al., 2004), isoflavone (8-methoxy-5, 6, 4′s-trihydroxyisoflavone7-*o*-β-d-glucopyranoside) present in the roots of the plant (Saxena and Chourasia, 2001), asparagamine (polycyclic alkaloid) having remarkable anti-oxytocic activity (Sekine et al., 1994), racemosol (Sekine et al., 1997), sarsasapogenin, and kaempferol (Ahmad and Jain, 1991).

Physiological Functionalities

Ancient classical ayurvedic literature claims several therapeutic attributes for the roots of *A. racemosus* (*Shatavari*) and has been specially recommended in cases of threatened abortion and as a galctogogue (a substance that promotes lactation) (Nadkarni, 1954). Suggested beneficial effects of roots of *A. racemosus* are in nervous disorders, dyspepsia (upset stomach), diarrhoea, dysentery, tumors, inflammations, hyperdipsia, neuropathy, hepatopathy, cough, bronchitis, hyperacidity, and certain infectious diseases (Sharma et al., 2000).

A. racemosus has been reported to be an immunomodulatory and immunostimulant (Rege et al., 1989). After challenging with *Bordetella pertussis*, animals treated daily with *A. racemosus* aqueous root extract (100 mg/kg body weight) showed a significant increase in antibody titres to *Bordetella pertussis* as against the untreated animals. There was reduced mortality coupled with overall improved health status in treated animals which indicates the development of a protective immune response, confirming immunoadjuvant effects of *A. racemosus*. Extracts and formulations prepared from *A. racemosus* exhibited various immunopharmacological actions such as increase in white cell counts and haemagglutinating and haemolytic antibody titres in cyclophosphamide (CP)-treated mouse ascitic sarcoma (Diwanay et al., 2004). Shive et al. (2000) and Gautam et al. (2009) have also observed the immuostimulant effects of *A. racemosus.*

The hexane, aqueous, and alcoholic extracts of the root at a concentration of 200 mg/ml showed antibacterial activity against *Bacillus subtilis, Escherichia coli, Proteus vulgaris, Salmonella typhimurium, Pseudomonas aeruginosa*, and *Staphylococcus aureus* (Ahmed et al., 1998). Methanolic extract of the roots of *A. racemosus* has shown considerable antibacterial efficacy under in vitro conditions against *E. coli*, *Shigella dysenteriae*, *S. sonnei*, *S. flexneri*, *Vibrio cholerae*, *S. typhi*, *S. typhimurium*, *P. putida*, *B. subtilis*, and *S. aureus* (Mandal et al., 2000) and the fresh juice of the plant showed fungitoxicity against *Helminthosporium sativum*, *Colletotrichum falcatum, Fusarium oxysporum* (Singh and Sharma, 1978), and *Rhizoctonia solani* (Renu, 1983).

The aqueous solution of the crude alcoholic extract of the root at a dose of 10–20 mg has been found to be cardioprotective in frogs, mice, and rats. The extract also caused an increase in bleeding time in rabbits and a slight diuretic effect in rats (Roy et al., 1971). "Abana," a herbo-mineral formulation containing 10 mg *A. racemosus* extract per tablet, was found to have significant hypocholesterolaemic effect in rats (Khanna et al., 1991). *A. racemosus* root powder supplements have been found to reduce cholesterol levels in hypercholesteremic rats (Visavadiya and Narasimhacharya, 2005). *Shatavari* has been found to stimulate milk production in buffaloes (Patel and Kanitkar, 1969). The galactogenic effect has been confirmed by a clinical trial by Sharma et al. (1996). Joglekar et al. (1967) observed an increase in milk secretion after administration of *A. racemosus* in the form of Ricalex® tablets (40 mg concentrated root extract per tablet) to women suffering from deficient milk secretion. Both the crude extract as well as a polysaccharide-rich fraction of shatavari significantly inhibited lipid peroxidation and protein oxidation and also showed part protection against radiation-induced loss of protein thiols and inactivation of superoxide dismutase (Kamat et al., 2000).

The methanolic extract of *A. racemosus* roots played the role of an antioxidant by attenuating free-radical-induced oxidative damage in kainic acid (KA)-induced hippocampal and striatal neuronal damage in mice (Parihar and Hemnani, 2004). Rao (1981) demonstrated the inhibitory action of *A. racemosus* on DMBA (7, 12 dimethyl benza anthracene) induced mammary carcinogenesis in rats. *A. racemosus* is well known for its phytoestrogenic properties and use as a hormone modulator (Mayo, 1998). Rege et al. (1999) reported that aqueous extract of *A. racemosus* had shown adaptogenic effects by reversing the effects of cisplatin on gastric emptying, and also normalized cisplatin-induced intestinal hypermotility. Nanal et al. (1974) found *Satavari* to be extremely effective in the treatment of diarrhoea, dysentery, and gastritis as described in Ayurvedic texts such as *Sushruta Samhita* and *Sharangdhar Samhita*. Ethanol and aqueous extracts of *A. racemosus* roots exhibited significant antidiarrhoeal activity against castor-oil-induced diarrhoea in rats demonstrating an activity similar to Loperamide® (a commercial antidiarrhoeal drug) (Venkatesan et al., 2005). *A. racemosus* was also found to have an effect comparable to a modern allopathic drug, metoclopramide, which is a dopamine antagonist used in dyspepsia to reduce gastric emptying time (Dalvi et al., 1990).

Toxicity

No toxic effects or mortality were observed with doses of *A. racemosus* ranging from 50 mg/kg to 1 g/kg for four weeks. Acute and subacute (15–30 days administration) toxicity studies did not detect any changes in vital organ function tests (Rege et al., 1999).

Withania somnifera

Withania somnifera belongs to the genus *Withania* and family *Solanaceae*. It is also known as *ashwagandha*, Indian ginseng, or winter cherry and belongs to major medicinal plants of India (Thakur et al., 1987). The species name *somnifera* means "sleep-bearing" in Latin, indicating it was considered a sedative, but it has been also used for sexual vitality and as an adaptogen (a plant derivative that increases resisitance to stress). It is found wild in the Mediterranean region in North America. In India, it is cultivated in Madhya Pradesh, Rajasthan, and other tropical and dry parts of the country (Thakur et al., 1987).

Biologically Active Constituents

Different parts of *Ashwagandha* plant harbors wide variety of active constituents. Steroidal lactone withaferin A (Lavie et al., 1965), which is thought to be the primary pharmacological agent present in the roots and leaves of *ashawagandha*, and another steroidal lactone withanolides are currently being explored for their brain-regenerative properties. Biologically active chemical constituents reported in *Ashwagandha* are alkaloids (isopelletierine and anaferine), saponins containing an additional acyl group (sitoindoside VII and VIII), and withanolides with a glucose at carbon 27 (sitoindoside IX and X) (Elsakka et al., 1990; Choudhary et al., 1995; Abou-Douh, 2002). Some of the other important withanolides present in *ashwagandha* are 27-deoxywithaferin A, 17-hydroxy-27-deoxy withaferin-A, withanolide A, 17-hydroxy withaferin A, 27-hydroxy withanolide B, withanone, and withanolide D.

Physiological Fnctionalities

In a double-blind clinical trial, *ashwagandha* (oral supplementation at a dosage of 3 g daily for one year) when tested for antiaging property in a group of 101 healthy males of 50–59 years old showed a significant improvement in hemoglobin and red blood cell count. Erythrocyte sedimentation rate decreased significantly and there is significant improvement in sexual performance (Bone, 1996). Root extract of *ashwagandha* had shown immunomodulatory effects in mice

(Ziauddin, 1996; Dhuley, 1997). Also, a significant increase in hemolytic antibody responses toward human erythrocytes indicated its immunostimulatory activity. Two new glycowithanolides, sitoindoside IX (1) and sitoindoside X (2), isolated from *W. somnifera* have shown immunomodulatory and central nervous system (CNS) effects such as antistress, improved memory, and learning in doses of 100–400 mg/kg body weight and 50–200 mg/kg body weight in mouse and rat, respectively (Ghosal et al., 1989).

Active glycowithanolides of *ashwagandha* given at a dose of 10 or 20 mg/kg intraperitoneally to mice have shown an antioxidant effect in the brain which may be responsible for its diverse pharmacological properties (Bhattacharya et al., 1997). Oral administration of powdered root of *ashwagandha* led to considerable reduction in inflammation and significant reduction in arthritis-linked paw swelling and degenerative changes (Anbalagan and Sadique, 1981; Begum and Sadique, 1988). The steroidal lactone withaferin-A displayed significant antitumor and radio sensitizing effects, inhibiting tumor growth and increasing survival rate in Swiss mice inoculated with Ehrlich ascites carcinoma (Devi et al., 1995; Sharad et al., 1996). The administration of methanolic extract of *ashwagandha* was found to significantly increase the white blood cell (WBC) count in mice and reduce leucopenia induced by a sublethal dose of gamma radiation (Kuttan, 1996). Antitumor activities of *ashwagandha* have been confirmed by Devi et al. (1996), Menon et al. (1997), and Davis and Kuttan (1998).

Hypoglycemic, diuretic, and hypocholesterolemic effects of *ashwagandha* root powder extract have been assessed in human subjects treated for 30 days. A decrease in blood glucose comparable to that of an oral hypoglycemic drug, significant increase in urine sodium and urine volume, and decrease in serum cholesterol, triglycerides, and low-density lipoproteins have also been reported (Andallu and Radhika, 2000). A commercial root extract of *ashwagandha* used repeatedly over nine days attenuated the development of tolerance to the analgesic effect of morphine and suppressed morphine-withdrawal jumps (Kulkarni and Ninan, 1997). Isolated constituents of *ashwagandha* (sitoindosides VII-X and withaferin-A) increased cortical muscarinic acetylcholine receptor capacity, partly explaining the cognition-enhancing and memory-improving effects traditionally attributed to *ashwagandha* (Schliebs et al., 1997).

Toxicity

Ashwagandha appears to be very safe. Aphale et al. (1998) reported that 50% alcohol extract at a dose of 1000 mg/kg in rats did not show any toxic effects.

Bacopa monniera

Bacopa monniera (family *Scrophulariaceae*) is also called as *brahmi* in the Indian subcontinent. *Brahmi* has been used by Ayurvedic medical practitioners in India for almost 3000 years as a drug to improve memory and intellect and is currently recognized as an effective herb in the treatment of mental illness and epilepsy (Russo and Borrelli, 2005). In Sri Lanka, *brahmi* is prescribed for fevers and in the Philippines, it is used as a diuretic (Uphof, 1968).

Biologically Active Constituents

The active constituents responsible for the pharmacological effects of *brahmi* include alkaloids, saponins, and sterols. Many active constituents, viz., the alkaloids, namely, brahmine (Bose and Bose, 1931) and herpestine (Chopra et al., 1956), saponins namely, d-mannitol and hersaponin (Sastri et al., 1959), and monnierin were isolated in India over 40 years ago. Other active constituents have since been identified, including betulic acid, stigmasterol, beta-sitosterol, as well as numerous bacosides and bacopasaponins. The bacosides A and B are the constituents responsible for *brahmi's* cognitive effects (Kapoor, 1990; Mahato et al., 2000; Chakravarty et al., 2001, 2003; Hou et al., 2002).

Physiological Fnctionalities

Two singe-blind open clinical studies have reported memory and learning enhancing effects of chronic *brahmi* treatment in patients with anxiety neurosis (Singh and Singh, 1980; Sharma et al., 1987; Singh and Dhawan, 1997). *Brahmi* plant (Malhotra and Das, 1959) and its alcoholic extract (Singh and Dhawan, 1982) have been shown to enhance learning ability in rats. The alcoholic extract of *brahmi* has also been found to inhibit the amnesia effects in rats (Dhawan and Singh, 1996). Subsequent studies indicated that the memory enhancing or beneficial effect of this plant (also known as the cognition-facilitating effect) is due to two active saponins; Bacosides A and B, present in the ethanol extract (Singh and Dhawan, 1992). It has been suggested that the bacosides induce membrane dephosphorylation, with a concomitant increase in protein and RNA turnover in specific brain areas (Singh et al., 1990). Dave et al. (1993) reported that the commercial preparation of *brahmi* has shown a remarkable nootropic activity (memory enhancing activity). The mechanism of these pharmacological actions of *brahmi* in enhancing memory power is not clearly known yet. *Brahmi* has been found to have anxiolytic properties with a distinct advantage over a commonly administered drug lorazepam (LZP) since it does not induce amnesia and has, instead, a memory-promoting action in animals and man (Singh and Dhawan, 1992; Dhawan and Singh, 1996). Shanker and Singh (2000) also reported that *brahmi* extract possessed an anxiolytic effect.

Standardized methnolic extract of *brahmi* has potential antidepressant activity (Sairam et al., 2002). Another important use of *brahmi* in traditional medicine is anticonvulsive action. Shanmugasundaram et al. (1991) have reported that the crude water extract of *brahmi* controls epilepsy in experimental animals. The cognition-promoting functions (Nathan et al., 2001; Roodenrys et al., 2002) of *brahmi* may be partly attributed to the antioxidant effects of the bacosides (Tripathi et al., 1996). Brahmi counteracts the effects of mental stress and neurosis and revitalizes sensory organs (Sivarajan and Balachandran, 1994), and acts as a cardiotonic (Mathur et al., 2002), bronchovasodilatory (Channa et al., 2003), hepatoprotective (Sumathi and Nongbri, 2008), muscle relaxant (Dar and Channa, 1997), cell stabilizing (Samiulla et al., 2001), antiulcer (Sairam et al., 2002), antioxidant (Bhattacharya et al., 2000), and effective against cigarette smoking induced brain damage (Anbarasi et al., 2005a, 2005b, 2006). *Brahmi* has been introduced into the market in India and other countries, alone or in association with other phytocomplexes, and utilized in the treatment of memory and attention disorders (Shukla et al., 1987).

Toxicity

Aqueous crude extract or crude alcoholic extract of *Bacopa monniera* has been found to be well tolerated and without any problematic reaction or side effects in regulatory pharmacological and toxicological studies (Martis et al., 1992; Asthana et al., 1996; Russo and Borrelli, 2005). It was found that single oral doses of 20–200 mg or 100 and 200 mg once daily for 4 weeks were safe and did not produce any reaction or side effect. Even repeated doses of bacosides A and B were tolerated well with no side effects experienced by any subject (Singh and Dhawan, 1997).

Pueraria tuberosa

Pueraria tuberosa is one among more than 100 species of the genus *Pueraria* which is native to northern India, Pakistan, and Nepal. *Pueraria* is one of the most versatile and promising of all the plants found in Asia. In Ayurveda, "Vidari" is botanically equated to *Pueraria tuberosa* DC of the *Fabaceae* family and it is also known as *vidharikand* and Indian *kudzu* (Rathore and Shekhawat, 2009).

Biologically Active Constituents

The major active components of *P. tuberosa* include coumarin, alkaloids, volatile oils, anthocyanin, lupinoside (Palpu and Dhan, 2003), and isoflavonoids namely puerarin (Prasad et al., 1984), genistin, genistein, daidzein and dadzin (Debra et al., 2006; Pandey et al., 2007), and tuberosin (Joshi and Kamat, 1973).

Physiological Fnctionalities

Pueraria tuberosa is used in traditional medicine as a fertility control agent, and as cardiotonic, diuretic, and galactogogue. In Ayurveda, the flowers of *vidharikand* are used as cooling agent and as aphrodisiac (a substance that increases sexual desire), while roots act as a demulcent (mucoprotective agent used to treat coughs) and refrigerant in fevers. It is also used to cure leprosy and diseases of blood and urinary discharges. It is employed as an emetic and also believed to be a galactagogue (Kirtikar and Basu, 1933). In folk medicine, the root tuber is applied for blood purification and to improve sperm production. The root powder of *vidharikand* controls overgrowth in stomach. The consumption of raw root for one month leads to sterilization in women.

Vidharikand has been reported to contain lupinoside which acts as an antidiabetic agent by improving insulin activity and decreasing palmitate thus inhibiting the glucose uptake (Palpu and Dhan, 2003). Recently, it has been demonstrated that puerarin reduced the atherogenic properties of dietary cholesterol in rats. It was observed that the decrease in total cholesterol was 25% when puerarin was given along with a high-cholesterol diet compared to animals fed with only high-cholesterol diet (Yan et al., 2006). Indian *kudzu* has been reported to show antioxidant activity against lipid peroxidation in egg yolk by chelating iron and trapping of free radical but less than butylated hydroxyl toulene (BHT) because of its glycosidic nature and because it contains less free hydroxyl groups (Pandey et al., 2007). Tanwar et al. (2008) reported that *P. tuberosa* possessed potent hypolipidemic activity as elucidated by concurrent feeding of *Pueraria tuberosa* extract to Wistar rats. The cholesterol lowering effects of *vidharikand* are mainly due to isoflavonoids present in it. *Micrococcus luteus*, *B. cereus, S. aureus*, *E. coli, P. aeruginosa*, *S. typhimurium*, and *Candida albicans* have been inhibited by organic solvent extracts of *vidharikand* (Ratnam and Raju, 2009). The flavonoids (puerarin, daidzein, and genistein) induced lymphocyte proliferation in mouse spleen and also showed immunomodulatory effect through phagocytic activity (Lacaille-Dubois, 2005). Immunomodulatory activity of *P. tuberosa* has also been reported by Oh et al. (2000) and Venkat (2009). Antimutagenic activity of *P. tuberosa* has been reported by Miyazawa et al. (2001). Recently, Rao et al. (2008) reported that aqueous and alcoholic extracts of *P. tuberosa* have shown nootropic effects which was ascribed to the presence of flavonoids in it.

Toxicity

Toxicity studies with the butanol extract of *P. tuberosa* in rats at a dose of 150 mg/kg for 24 days have shown that it is generally safe (Shukla, 1995).

Combination of Herbal Preparations

Emblica officinalis (*Amalaki*), *Terminalia chebula* (*Haritaki*), and *Terminalia belerica* (*Bibhitaki*) have an esteemed place in Ayurveda and are very widely used in treating various diseases (Frawley, 2003). All these herbs are mixed in equal proportion by weight to obtain a combination of herbal preparation called *triphala*. It nourishes the nervous system, blood, and muscles and increases digestion. *Triphala* is also widely used for all eye diseases including the treatment of conjunctivitis, progressive myopia, and cataracts.

Emblica officinalis

Emblica officinalis (*Amalaki*) also called as *amla* is a fruit which is counted as among the highest known land sources of vitamin C, having 20 times that of an orange and 160-fold than that of apple.

Biologically Active Constituents

The *amalaki* fruit contains cytokinine-like substances identified as zeatin, zeatin riboside, zeatin nucleotide, and phyllembin. The leaves contain gallic acid, besides ascorbic and music acid. The bark contains tannin identified as mixed type of proanthocyanidin. *Amla* also contains superoxide dismutase which exhibits antisenescent (antiaging) activity (Anonymous, 2006).

Physiological Functionalities

E. officinalis is highly valued in traditional Indian medicine (Scartezzini et al., 2006). In Unani medicine, the dried fruits of *amla* are used to treat hemorrhage, diarrhoea, and dysentery (Parrotta, 2001). Several other medicinal effects such as antioxidant activity (Ghosal et al., 1996), antimicrobial properties (Ahmed et al., 1998), adaptogenic (Rege et al., 1999), antioxidant (Bhattacharya et al., 1999), hepatoprotective (Jeena et al., 1999), antitumor (Jose et al., 2001), antiulcerogenic (Sairam et al., 2002), anti-inflammatory (Sharma et al., 2003), analgesic, antipyretic (Perianayagam et al., 2005), hypocholesterolemic (Kim et al., 2005), and diuretic properties (Anonymous, 2006) have also been reported.

Terminalia chebula

Terminalia chebula also called *haritaki* or *harada,* is widely distributed throughout India, Burma, and Sri Lanka. It is commonly known as Black Myrobalans and has traditionally been used in the treatment of asthma, sore throat, vomiting, hiccough, diarrhoea, bleeding piles, gout, and heart and bladder diseases. *Harada* contains B-complex vitamin (vitamin B12) that protects the lung from any damage. The dried ripe fruit of *T. chebula* Retz. (*Combretaceae*) is used extensively in Ayurveda (Khan and Jain, 2009).

Biologically Active Constituents

The fruit is a rich source of tannins, amino acids, fructose, succinic acid, and β-sitosterol. It contains, shikimic, gallic, triacontanoic and palmitic acids, β-sitosterol, daucosterol, triethyl ester of chebulic acid and ethyl ester of gallic acid, terchebulin, punicalagin and teaflavin A, chebupentol, arjungenin, terminoic acid, and arjunolic acid. The antioxidant constituents of the plant present in this fruit include phloroglucinol and pyrogallol and ferulic, vanillic, *p*-coumaric, and caffeic acids (Kumar and Bhatnagar, 2007; Kumar et al., 2010; Naik et al., 2010).

Physiological Functionalities

T. chebula along with *A. racemosus* has been reported to protect gastric mucosa against pentagastrin- and carbachol-induced ulcers, by significantly reducing both severity of ulceration and ulcer index (Dahanukar et al., 1983). A herbal combination of *T. chebula* and *Glycyrrhiza glabra* (part of Abana extract formulation) has been reported to reduce cysteamine-induced duodenal ulcers in rats by increasing the β-glucuronidase activity in the Brunner's glands (Nadar and Pillai, 1989). *T. chebula* has also been reported to protect epithelial cells against the cytopathic effects of Influenza-A virus and indomethacin-induced gastric ulcers in rats (Badmaev and Nowakowski, 2000). Khayyal et al. (2001) reported the antiulcerogenic effect of *T. chebula.* A combination of *T. chebula* and chebulinic acid has been found to exhibit anticancer activity (Saleem et al., 2002).

Terminalia bellerica

Terminalia bellerica, also called as *Bibhitaki* or *Behada*, is a perennial herb mainly distributed in the tropical regions and commonly found in South-East Asia, including Thailand. This formulation, rich in antioxidants, is frequently used in Ayurvedic medicine to treat many diseases such as anemia, jaundice, constipation, asthma, fever, and chronic ulcers. It possesses antimucal, laxative, astringent, digestive, and antispasmodic properties. It is also used as a tonic and an expectorant and helps deal with allergies (Gilani et al., 2008; Khan and Gilani, 2008).

Biologically Active Constituents

T. bellerica is the richest source of vitamin A and β-sitosterol, gallic and ellagic acids, ethyl gallate, galloyl glucose, chebulagic acid, and a cardiac glycoside, bellaricanin (Yadava and Rathore, 2001; Gilani et al., 2008; Khan and Gilani, 2008, 2010).

Physiological Functionalities

The three herbs that make up *triphala* have laxative actions. *Triphala* is known to have no side effects over long-term use (Tierra, 1992). It works by stimulating the mucosa of the gastric-intestinal tract, improving and balancing digestion, and further aids in digestion by eliminating toxins from the intestinal tract. People suffering from constipation will benefit from regular use of *triphala* and it functions as a metabolic regulator (Frawley, 2003). Alcoholic and water extracts of *triphala* have successfully cured castor-oil induced diarrhea (Biradar et al., 2007). *Triphala* has also shown hypolipidemic (Saravanan et al., 2007) and cytotoxic and apoptotic activities (Kaur et al., 2005).

Triphala has been shown to be effective against cancer cells and *Helicobacter pylori* (Malekzadeh et al., 2001; Rani and Khullar, 2004). It also acts as immunomodulator (Srikumar et al., 2005). The effect of *triphala* on experimental gouty arthritis in mice was evaluated by Sabina and Rasool (2008). The study compared *triphala* to Indomethacin, an anti-inflammatory drug. Compared with the control group, a clear anti-inflammatory effect against gouty arthritis was reported in mice orally administered by *triphala*.

Gamma-Radiation-induced strand break formation in plasmid DNA (pBR322) was effectively inhibited by aqueous extract of *triphala* and its constituents *E. officinalis*, *T. chebula*, and *T. bellerica*. These herbs also inhibited radiation-induced lipid peroxidation in rat liver microsomes effectively. *E. officinalis* showed greater efficiency in lipid peroxidation and plasmid DNA assay, while *T. chebula* had shown greater radical scavenging activity (Naik et al., 2005). The cytotoxic effects of *triphala* on a cell line of human breast cancer cells and a thymic lyphoma transplanted from a mouse were studied by Sandhya et al. (2006). The study found that the viability of the cell lines decreased when the concentration of *triphala* was increased. Further, it was discovered that normal breast cells, along with other normal cells weren't significantly affected which strengthens the role of *triphala* as a potential cancer inhibitor.

Terminalia arjuna

The herb, *Terminalia arjuna*, which belongs to the family *Combertaceae* is native to India and has been known from Vedic period for its various therapeutic values (Nadkarni, 2000). It is also called by the names *Arjuna myrobalan, arjuna,* and *arjun* (Kiritkar and Basu, 1935).

Biologically Active Constituents

Biologically active constituents of *arjuna* include tannins containing catechin, gallocatechin, epicatechin, epigallocatechin (Rastogi and Mehrotra, 1993c; Kandil and Nassar, 1998), triterpinoids (Tripathi et al., 1992; Patnaik et al., 2007), phenolics (Anjaneyulu and Prasad, 1982a), saponins namely arjunic acid (Row et al., 1970), arjunolic acid (Rastogi and Mehrotra, 1993a), arjungenin, arjunglycosides I and II (Rastogi and Mehrotra, 1993b), arjunglucoside III (Rastogi and Mehrotra, 1993c), arjunglucoside IV, V (Wang et al., 2010a), arjunasides A–E (Wang et al., 2010b), termonic acid (Ahmad et al., 1983), flavonoids (arjunon, arjunolone, and luteolin) (Ghosal et al., 1971; Sharma et al., 1982), gallic acid, ellagic acid, oligomeric proanthocyanidins (OPCs), phytosterols (Row et al., 1970; Miller, 1998), β-sitosterol (Anjaneyulu and Prasad, 1982b), and calcium, magnesium, zinc, and copper (Kiritkar and Basu, 1935).

Physiological Functionalities

In the Indian system of medicine, the bark of *arjuna* is used as astringent, cooling, aphrodisiac, cardiotonic, tonic in fractures, ulcers, spermatorrhoea, leucorrhoea, diabetes, cough, tumor, excessive perspiration, asthma, inflammation, and skin disorders, etc. (Dwivedi and Udupa, 1989; Warrier et al., 1994).

Arjunolic acid from the bark of *arjuna*, has been shown to provide significant cardiac protection in isoproterenol-induced myocardial necrosis in rats (Sumitra et al., 2001). *Arjuna* showed significant DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity (similar to L-ascorbic acid) in Wistar rats which can be used in the therapy of cardiovascular disease by exerting its beneficial effects via antioxidant activity (Munasinghe et al., 2001). Karthikeyan et al. (2003) reported that chronic administration (6.75 mg/kg) of the alcoholic extract of *arjuna* augments endogenous antioxidant compounds of the rat heart and also prevents the myocardium from isoproterenol-induced myocardial ischemic reperfusion injury. Intravenous administration of 70% alcoholic extract of *arjuna* (5–15 mg/kg) produced dose-dependent hypotension in anesthetized dogs which lends support to the claims of its traditional usage in cardiovascular disorders (Nammi et al., 2003). The cardioprotective effects of *arjuna* have been confirmed in animal models also by Ramesh et al. (2004), Pawar and Bhutani (2005), Manna et al. (2006), Sinha et al. (2008), Singh et al. (2008), and Kumar et al. (2009).

The anti-inflammatory activity of *arjuna* has been demonstrated by Tripathi et al. (2004) and Halder et al. (2009). The antitumor effects of *arjuna* have been reported by Sivalokanathan et al. (2005), Kuo et al. (2005a, 2005b) Saxena et al. (2007), Reddy et al. (2008), and Verma and Vinayak (2009). The antiulcer effect of methanol extract of *T.arjuna* (TA) has been reported by Devi et al. (2007a, 2007b, 2008). The wound healing activity of *arjuna* was reported by Mukherjee et al. (2003), Rane and Mengi (2003), and Chaudhari and Mengi (2006).

The cytoprotective role of arjunolic acid against arsenic (Sodium arsenate; 1 mM) induced cytotoxicity in isolated murine hepatocytes was found to be comparable to that of a known antioxidant, vitamin C, suggesting that arjunolic acid protects arsenic-induced cytotoxicity in murine hepatocytes (Manna et al., 2007). Earlier, the hepatoprotective effects of *arjuna* were reported by Manna et al. (2006) and Sivalokanathan et al. (2006a, 2006b). The Antimicrobial activities of *arjuna* extract on *E. coli*, *P. aeruginosa*, *B. subtilis*, *S. aureus*, *S. epidermidis* (Shinde et al., 2009), *Klebsiella pneumoniae*, *C. albicans*, *S. mutans*, *Enterococcus faecalis*, *S. bovis*, *S. typhimurium*, (Khan et al., 2009), *S. typhi* (Rani and Khullar, 2004), *K. aerogenes*, *Proteus vulgaris*, *P. aerogenes* (Perumal Samy et al., 1998), and *Neisseria gonorrhoeae* (Petit et al., 1996) were

Table 1 Some biologically active constituents of *Aloe vera*

Class	Compounds
Anthraquinones/anthrones	Aloe-emodin, aloetic-acid, anthranol, aloin A and B (or collectively known as barbaloin), isobarbaloin, emodin, ester of cinnamic acid
Carbohydrates	Pure mannan, acetylated mannan, acetylated glucomannan, glucogalactomannan, galactan, galactogalacturan, arabinogalactan, galactoglucoarabinomannan, pectic substance, xylan, cellulose
Chromones	8-C-glucosyl-(2'-O-cinnamoyl)-7-O-methylaloediol A, 8-C-glucosyl-(S)-aloesol, 8-C-glucosyl-7-O-methyl-(S)-aloesol, 8-C-glucosyl-7-O-methylaloediol, 8-C-glucosyl-noreugenin, isoaloeresin D, isorabaichromone, neoaloesin A
Non-essential and essential amino acids	Alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, hydroxyproline, isoleucine, leucine, lysine, methionine, phenylalanine, proline, threonine, tyrosine, valine
Vitamins	B1, B2, B6, C, β-carotene, choline, folic acid, α-tocopherol
Inorganic compounds	Calcium, iron, magnesium, potassium, zinc
Organic compounds	γ-linolenic acid, steroids (campestrol, cholesterol, β-sitosterol)

(Source: Femenia et al., 1999; Dagne et al., 2000; Choi and Chung, 2003; Ni and Tizard, 2004).

also been reported. The antioxidant and free radical scavenging capacities of *Arjuna* were reported by Chen et al. (2004a) and Sun et al. (2008). Antidiabetic activity (Raghavan and Kumari, 2006), antiviral activity (Cheng et al., 2002), antiatherslerotic activity (Shailaa et al., 1998), immunomodulatory activity (Halder et al., 2009), and reproductive activity (Manna et al., 2008) of *arjuna* have also been documented.

Clinical trials have shown that alcoholic decoction of bark was beneficial in stable cases of ischemic heart disease (Anand, 1994). Beneficial effects of *arjuna* in modifying various coronary risk factors have been reported in clinical studies (Gupta et al., 2001; Malik et al., 2009). Some clinical studies have also supported the antianginal (drug used to cure coronary heart disease) activity of *arjuna* (Bharani et al., 2002 and Dwivedi et al., 2005).

Aloe vera

Aloe barbadensis Miller, also known as *Aloe vera*, is a member of the tree, Lily family (*Aloaceae*). It is related to other members of the Lily family such as the onion, garlic, and turnip. Throughout recorded history, *Aloe vera* has been given a high ranking as an all-purpose herbal plant (Lee, 2006). More than 360 species of aloe are known worldwide and are classified into two groups according to their use: for production of extract as crude drugs and for production of gel for functional foods. Among the different varieties of *Aloe vera*, only a few species have been used commercially, others are merely of decorative value. The species for the production of crude drugs are *Aloe vera* L. (*A. Barbadensis* Mill.), *A. ferox* Mill., *A. perryi* Baker, etc., and species for use in functional foods are *Aloe vera* L., *A. arborescens* Mill., *A. saponaria*, etc. Only two species are grown today commercially, with *Aloe barbadensis* Miller and *Aloe arborescens* being the most popular (Chauhan et al., 2007). *Aloe vera* gel consists of more than 99% water. The remaining less than 1% of *Aloe vera* gel consists of 200 different biologically active constituents including a diverse mixture of antibiotics, pain inhibitors, cell growth stimulators, inflammation fighters, burn healers, capillary dilators, vasoconstrictor inhibitors, and moisturizers. Thus, aloe possesses almost a complete drug store of medically useful ingredients (Waller et al., 1978). Some biologically active constituents of *Aloe vera* are given in Table 1.

Physiological Functionalities

The first somewhat detailed description of the pharmacological effects of aloe is recorded in "The Greek Herbal," written by Dioscorides in the first century AD. According to such literature, aloe has multiple pharmacological effects in healing wounds, burns and frostbite, constipation, insomnia, stomach disease, pain, hemorrhoids, itching, headache, hair loss, gum disease, kidney disease, blisters, sunburn, and more (Lee, 2006). Reports credit *Aloe vera* as an all-purpose medicinal plant having diverse physiological functionalities like antitumor (Pecere et al., 2000), antidiabetic (Rajasekaran et al., 2006; Tanaka et al., 2006; Kim et al., 2009), wound and burn healing (Davis et al., 1987; Schmidt and Greenspoon, 1991; Heggers and Winters, 1993), curing gastric ulcers (Teradaira et al., 1993; Suvitayavat et al., 2004; Yusuf et al., 2004; Eamlamnam et al., 2006; Metowogo et al., 2008) and peptic ulcers (Blitz et al., 1963), and hypolipidemic (Kim et al., 2009) and immunomodulatory properties (Hart et al., 1988; Womble and Helderman, 1988; Tizard et al., 1991; Winters, 1993; Im et al., 2005; Madan et al., 2008). Recently, Sinnott et al. (2007) reported that aloe polysaccharides (approx. MW 50,000–1,000,000) are better utilized by human colonic bacteria.

APPLICATION OF HERBS/HERBAL NUTRACEUTICALS IN FOODS

The use of herbs as a food source appears in the history of many parts of the world including Persia, Mesopotamia, Greece, Rome, India, and Arabian countries. Ayurveda, the Indian traditional medical science has found several ways in which the

Table 2 Bioactive components present in some culinary herbs

Herb	Bioactive components
Basil (*Ocimum basilicum*)	Eugenol, apigenin, limonene, ursolic acid, methyl cinnamate, 1,8-cineole, α-terpinene, anthocyanins, β-sitosterol, carvacrol, cintronellol, farnesol, geraniol, kaempherol, menthol, p-coumaric acid, quercetin, rosmarinic acid, rutin, safrole, tannin, catechins
Coriander (*Coriandrum sativum*)	Quercetin, caffeic acid, cineole, geraniol, borneol, 1,8-cineole, α-terpinene, β-carotene, β-pinene, β-sitosterol, cinnamic acid, ferrulic acid, γ-terpinene, kaempferol, limonene, myrcene, p-coumaric acid, p-cymene, quercetin, rutin, vanillic acid
Dill (*Anethum graveolens*)	Carvone, limonene, isorhamnetin, kaempferol, myricetin, quercetin, catechins
Lemongrass (*Cymbopogon citratus*)	Farnesol, geraniol
Licorice (*Glycyrrhiza glabra*)	Glycyrrhizin
Marjoram (*Origanum majorana*)	Eugenol, limonene, ursolic acid, 1,8-cineole, α-pinene, α-terpinene, carvacrol, farnesol, geraniol, p-cymene, rosmarinic acid, sterols, thymol, apigenin
Oregano (*Origanum vulgare*)	Apigenin, luteolin, myricetin, quercetin, caffeic acid, p-coumaric acid, rosmarinic acid, carvacrol, thymol
Parsley (*Petroselinum crispum*)	Apigenin, luteolin, kaempferol, myricetin, quercetin, caffeic acid
Rosemary (*Rosmarinus officinalis*)	Carnasol, carnosic acid, cineole, geraniol, α-pinene, β-carotene, apigenin, limonene, naringin, luteolin, caffeic acid, rosmarinic acid, rosmanol, vanillic acid
Sage (*Salvia officinalis*)	α-pinene, β-sitosterol, citral, farnesol, ferulic acid, gallic acid, geraniol, limonene, cineole, perillyl alcohol, β-carotene, catechin, apigenin, luteolin, saponin, ursolic acid, rosemarinic acid, carnosic acid, vanillic acid, caffeic acid, thymol, eugenol
Tarragon (*Artemisia dracunculus*)	Luteolin, isorhamnetin, kaempferol, quercetin, caffeic acid
Green tea (*Camellia sinensis*)	Epigallocatechin gallate, epigallocatechin, catechin, theophylline, gallic acid, theanine
Thyme (*Thymus vulgaris*)	Thymol, carvacrol, cineole, α-pinene, apigenin, β-carotene, eugenol, limonene, ursolic acid, luteolin, gallic acid, caffeic acid, rosmarinic acid, carnosic acid, hispidulin, cismaritin

(Source: Kaefer and Milner, 2008).

medicinal benefits of herbs could be conveyed via certain foods as carriers. It has also suggested several forms, viz., paste, tray-dried and freeze-dried powders, and solvent-extracted herbal ingredients of herbs for incorporation into foods. Recently, much attention has been paid to resolve the biologically active ingredients present in herbs (Table 2) and their physiological health benefits so that they could be extracted and incorporated into a food matrix to prepare/formulate functional foods.

Milk

Milk and ghee (clarified butter) are the most important carriers of herbal nutraceuticals illustrated by Ayurveda. Colahan-Sederstrom and Peterson (2005) found that UHT milk processed with three levels of epicatechin (EC) (0.01%, 0.1%, and 0.2%) had obtained significantly less cooked flavor than the corresponding UHT control milk sample. However, the 0.2% EC containing milk sample had a significantly higher level of bitterness. The authors also found that EC had the largest inhibitory effect on Maillard browning compounds as compared to those of lipid oxidation or decomposition. Peterson and Totlani (2005) reported that EC and epigallocatechin gallate (EGCG) were able to inhibit Maillard browning aroma compounds in a model food system. Addition of epicatechin (EC) and epigallocatechin gallate (EGCG) at levels of 0.l and 1.0 mmol/l into UHT milk reduced the production of Maillard-associated fluorescence with UHT processing. During the storage also, these compounds reduced Maillard-associated fluorescence in milk (Schamberger and Labuza, 2007). Phenolic compounds of herbs are a good alternative for the syntheitic antimicrobial agents used in food industry. Phenolic compounds namely, ferulic acid, tea catechins, oleuropein, ellagic acid, and p-coumaric acid have been reported to inhibit the growth of bacteria (*S. enteritidis, S. aureus,* and *Listeria monocytogenes*) and fungi in milk (Payne et al., 1989; Tassou and Nychas, 1994, 1995; Rosenthal et al., 1997, 1999; Schaller et al., 2000).

Fat-Rich Dairy Products

Milk fat, particularly ghee has the characteristics to absorb all the medicinal properties of the herbs with which it is fortified, without losing its own qualities. Exploiting this concept, several medicated ghee preparations have been developed and about 55–60 medicated ghee types are reported in Ayurvedic literatures and they have also been used in the treatment of various diseases (Pandya and Kanawajia, 2002). Presently, the herbal ghee being marketed in the global market is mostly sold as medicine (medicinal ghee). These products possess typical flavor, bitter or pungent taste, and a dark color. Such therapeutic preparations are therefore not acceptable for regular consumption. At the author's institute, herbal ghee incorporating functional attributes of *arjuna* has been developed for providing beneficial effects against cardiovascular diseases and the product was more stable to oxidative deterioration as compared to conventional ghee. The consumer acceptability of this product was also very good (Hussain et al., 2011).

Butter deteriorates by auto-oxidation of fat that leads to generation of flavors accompanied by the formation of hydroperoxides which are harmful to human health (Walstra et al., 1999).

The process of fat oxidation can be prevented by adding natural or synthetic antioxidant substances. The increasing sensitivity of consumers to synthetic additives as well as their increasing awareness about the effect of diet on their health has contributed to the increasing trend of using natural additives for the stabilization of fat-containing foodstuffs. Herbs being high in phenolic content possess a great potential as the natural antioxidants in food (Najgebauer-Lejko et al., 2009). Sage (*Salvia officinalis*) and rosemary (*Rosmarinus officinalis*) extracts are one of the most widely used for this purpose (Shiota et al., 1999; Özcan, 2003; Rižnar et al., 2006). These extracts have antioxidant activity many times stronger than synthetic antioxidants like BHA or BHT (Lee et al., 2003; Estévez et al., 2007). Phenolic compounds such as catechin, catechol, resorcinol, quercetin, and kaempferol inhibit oxidative rancidity in margarine, milk powder, ghee, and buttermilk (Radayeva et al., 1974; Bokukhava et al., 1975; Gupta et al., 1978; Chandan, 1997) and photo-oxidation in milk (Rosenthal et al., 1999). The addition of phenolic compounds at a level of 0.0002–0.004 mg/kg, preferably in liquid products prior to heat treatment or to powdered products after heat treatment, was recommended to prevent auto-oxidation (Morgan et al., 1971).

Farag et al. (1990) reported the antimicrobial and antioxidative effect of herbal extracts and EOs in butter. Amr (1990) reported that addition of rosemary (*Rosmarinus officinalis* L.) at 7.5% (DM basis) in sheep ghee has shown an antioxidant effect equivalent to that of mixture of BHA and BHT (250 p.p.m. of a 1:1 mixture of BHA and BHT) during storage at 78°C. Addition of same level of sage (*Artemisia herba-alba* Asso.), fennel (*Foeniculum vulgare* Mill.), and rue (*Ruta graveolens* L.) did not show any antioxidant effect in sheep ghee. Shahidi et al. (1995) reported that ground sage and rosemary inhibited the formation of Thiobarbituric acid reactive substances (TBARS) by more than 10% over 21-days storage at 4°C in comminuted pork system. The study of Żegarska and Rafałowski (1997) revealed that addition of the ethanolic extract of sage in the amount of 0.1–0.2 to the sweet cream directly before churning affected lower level of peroxide value during storage of butter and butter fat at 20°C and 60°C, respectively. Methanolic extracts of sage, rosemary, and oregano were also found to be effective in retardation of oxidation (TBA test and peroxide value) and lypolisis (FFA) processes in butter (Ayar et al., 2001). Ozkan et al. (2007) reported that addition of *Satureja cilicica* EO (at 0.5, 1.0, and 2.0% levels) in butter exhibited strong antioxidant activity in a concentration-dependant manner. However, the addition of dried sage and rosemary did not prevent the lipolysis and formation of peroxides during low-temperature storage of the sour-cream butter (Najgebauer-Lejko et al., 2009). Freeze-dried hydrodistilled extract of clove (*Syzygium aromaticum* L.), caraway (*Carum carvil* L.), and coriander (*Coriandum sativum* L.) exhibited antioxidant effect in terms of acid value, peroxide value, and thiobarbituric acid test in the order of clove > coriander > caraway when added at 400 ppm level in butter oil (Ali, 2009).

Cheese

Herbs have also found their applications in cheese making and herbal cheeses are produced with different names in many countries worldwide. Ripened cheese varieties containing herbs are traditional in Turkey and Syria. The most popular of these cheeses are Otlu, Otlu Cacik, and Otlu Lor which are consumed during meals (Tarakçi et al., 2004; Hayaloglu and Fox, 2008). The typical character of herby cheeses is to include various types of herbs after coagulation with the addition of the cheese ferment into the milk (Tekinşen, 1997). Besides providing characteristic appearance, flavor, and aroma, herbs also enhance the shelf-life of cheeses (Ağaoğlu et al., 2005). Herbs show antimicrobial activity against many pathogenic bacteria without having any adverse effect on the added starter culture in cheese manufacture. Oleuropein has been reported to enhance the growth of fungi but markedly inhibited the production of aflotoxins (Bullerman and Gourma, 1987). This property could be advantageous in mould-ripened cheeses where the growth of moulds is desirable while the production of mycotoxins may present a health risk (Jarvis, 1983). Along with increased proteolysis and lipolysis, herbs also provide a typical vitamin and mineral profile in herby cheeses leading to better digestibility and sensory quality when added at desired levels (Hayaloglu and Fox, 2008). About 25 kinds of herbs especially, *Allium* spp., *Thymus* spp., *Ferula* spp., *Anthriscus nemorosa,* etc., in single or in combination were used to make herby cheeses and the rate of addition of herbs varies from 0.5–2.0 kg to the curd obtained from 100 L of milk (Tarakçi et al., 2004). Indian herbs, such as coriander (*Coriandrum sativum L.*), curry leaf (*Murraya koenigii L.*), spinach (*Spinacia oleracea*), and amla (*Emblica officinalis*), have been incorporated separately at 10% level into *sandesh* (a sweetened heat-desiccated product of coagulated milk protein mass) (Bandyopadhyay et al., 2007) to get the beneficial effects of these herbs upon *sandesh* consumption. Sadeghi et al. (2010) reported that incorporation of EO of *Cuminum cyminum* at 0.03 and 0.015% in feta cheese have had the highest inhibitory effect on the growth of *Staphylococcus aureus* and the combination of EO with *Lactobacillus acidophilus* further reduced the counts of the pathogen in feta cheese.

Herbal extracts have also been used as coagulants in the preparation of cheese. The flowers of *Cynara cardunculus* L. and *Cynara humilis* L. have been used from long time as successful rennets in Portugal and neighboring regions of Spain for the manufacture of farm cheeses like Serra da Estrela, Serpa, Castelo Branco, Azeitao, Evora, and Niza from ovine milk. Lamas et al. (2001) reported that proteases extracted from *Cynara cardunculus* L. and immobilized on highly activated agarose lutaraldehyde selectively hydrolyse whey proteins which may eventually lead to more digestible and functional peptides that can be incorporated into food formulas, to bring about favorable contribution to texture and taste, as well as reduction of allergenic effects (Asselin et al., 1988; Schmidt and Poll, 1991; Boza et al., 1995). Even though the rheological properties of milk gels made using coagulants obtained from the plants *Cynara cardunculus L.* and *Cynara humilis L.* were almost similar to that of the milk gels prepared using chymosin, plant coagulants, being slightly more proteolytic than chymosin, caused hydrolysis of casein leading to lower gel firmness (Esteves et al., 2002). *Cynara cardunculus L.* extract was also used to prepare cheese from ultrafiltered milk (Agboola, 2002) but the texture of the resultant cheese was undesirable (Agboola et al., 2009). However, Ekici et al. (2006) reported that addition of herbs may facilitate histamine formation in herby cheese which may lead to histamine poisoning. The authors suggested that the herbs used for herby cheese should be examined for histidine-decarboxylating strains of the microorganisms to avoid histamine poisoning.

EOs derived from herbs were successfully used for preservation of cheese. Smith-Palmer et al. (2001) reported that EOs namely bay, clove, cinnamon, and thyme, added at concentrations of 0.1%, 0.5%, and 1% (v/w) were effective in inhibiting *Listeria monocytogenes* and *Salmonella enteritidis* in low- and full-fat soft cheese. The inhibitory action of these EOs against tested microorganisms was more in case of cheese having low fat than their high-fat counterparts. In low-fat cheese, all four oils at 1% reduced *L. monocytogenes* to less than 1.0 log cfu/ml over a 14-day period. The use of EOs in food products is limited by their characteristic flavors which they impart to the food products. In this case, a combination of other preserving methods along with reduced concentration of EOs may be effective in achieving the desired purpose. Tsiraki and Savvaidis (2011) compared the effect of basil essential oil (BEO) (added at 0.4%) and various packaging conditions on "Anthotyros" a Greek whey cheese. The sensory and microbiological data showed that the combined use of modified atmosphere packaging (MAP) with added BEO extended the shelf-life of fresh Anthotyros (stored at 4°C) by approximately 10–12 days.

Yoghurt

The addition of catechins, at 100–2000 mg/kg, to bifidobacteria-containing yoghurt has been reported to improve the survival of the bifidobacteria during storage (Akahoshi and Takahashi, 1996). It has also been reported that the addition of *Aloe vera* to yoghurt, which has a high concentration of aloin (10-glucopyranosyl 1, 8-dihydroxy-3-[hydroxymethyl]-9 [10]-anthracenone) to yoghurt increased bifidobacteria (Pszczola, 1998). Rosenthal et al. (1997, 1999) reported that tea catechins and ferulic acid inhibited the growth of pathogenic bacteria (coliforms and salmonella) with little effect on lactic acid bacteria. Bakirci (1999) reported that addition of herbs, *Allium* sp., *Thymus* sp., *Anhriscus* sp., and *Ferule* sp. each at different concentrations (0.5, 1, 2, and 3% (w/w)) resulted in stimulated acid production by *Streptococcus thermophilus* and *Lactobacillus bulgaricus* and with the increasing concentration of herb the acid production also increased. While Sarabi-Jamab and Niazmand (2009) found no significant difference in viability of *Lactobacillus acidophilus* among samples containing various concentrations of EO of *Mentha piperita* and *Ziziphora clinopodioides* and control bioyoghurt during storage at 4°C, Peng et al. (2010) developed a process for the manufacture of dealcohol yogurt beverage using herbs, namely, *Pueraria lobata* and *Hovenia dulcis.* Improved quality yoghurt was prepared by using aqueous extract of garlic (0.1% level) (Hassan et al., 2010).

Meat and Meat Products Including Fish

Herbs and their extracts are richest in flavoring substances and when added to sauces, fricassees, stews, and other foods impart their finer flavor to those foods. Because of their fresh colors and crispness, fresh green herbs are extensively used in salads also. Appearance of meat products is one of the major determinants of their appeal to consumers and, consequently, sales of the product (Williams et al., 1992; Clydesdale, 1998). The food industry has an interest in developing new technologies that allow processing of meat and poultry products with less quality changes. Comminuted herbs or herbal extracts were used in the manufacture of sausages and other meat products (Guseinov et al., 1992). Mamedov et al. (1984) and Dinarieva et al. (1984) reported that addition of basil oil (5–10% w/w) results in better flavor and color intensity, and caused less microbial deterioration in meat products. Microencapsulated basil oleoresin was incorporated into sausages for better retention of flavor (Flint and Seal, 1985).

The oxidative deterioration of lipids and proteins especially in case of meat and poultry is a major concern for food industries due to the loss of quality associated with those processes. Poultry meat is very sensitive to oxidative deterioration because 70% of its fat is unsaturated (Racanicci et al., 2004). Lipid oxidation decreases nutritional and sensory properties of foods leading to flavor, texture, and color deterioration, and it also generates toxic compounds leading to health problems (Morrissey et al., 1998). Protein oxidation results in polymerization and degradation leading to decreased protein solubility, functionality, and colour and texture changes in food products (Rowe et al., 2004; Estévez and Cava, 2004).

Due to the possible negative effects of synthetic preservatives on human health and also due to the increased consumer awareness of this problem, in recent years, there is a growing demand for natural preservatives in human diet. In this regard, herbs and their EOs being rich in polyphenols act as potential replacers for synthetic antioxidants in food industry (Formanek et al., 2001; Estévez et al., 2004). The main advantage of EOs is that they possess GRAS status (USFDA, 2006) and can be used in any food as long as their maximum effects are attained with minimal change in the organoleptic properties of the food (Viuda-Martos et al., 2008). A number of researchers have reported the effectiveness of rosemary extracts for achieving higher sensory scores and retarding lipid oxidation in various foods. Dried leaves of Rosemary (*Rosmarinus officinalis* L.) added to cooked minced pork meat balls retarded the formation of warmed-over flavor during chill storage. Addition of rosemary (0.05%) and application of modified atmospheric conditions in the package of pork meat successfully retarded the oxidative changes and the product had better sensory quality (Huisman et al., 1994).

Addition of oregano EO (*Origanum vulgare subsp. Hirtum*) and packaging under modified atmospheric conditions has resulted in longer shelf life of fresh meat stored at 5°C. Oregano EO delayed glucose and lactate consumption by microbes (indicators of meat spoilage) (Skandamis and Nychas, 2002). Preseasoning of beef sirloin steaks with ginseng and garlic followed by treatment with electron beam irradiation (4 kGy) were effective at reducing the population of psychrotrophic bacteria. Inhibition of lipid oxidation by ginseng also minimized the discoloration of surface redness on sirloin steaks. The preapplication of garlic to irradiated steaks resulted in a lower hardness value and relative moisture loss (Wong and Kitts, 2002). Food products are subjected to several processing conditions before they are released into the market. Thermal processes and novel nonthermal processes such as high-pressure processing are applied to foods to inactivate or kill the microorganisms or to induce desirable changes in the texture and sensory characteristics. But these processing conditions especially high pressure and heat may have some pro-oxidant effect on the food lipids which should be carefully controlled by the addition of antioxidants.

Ethanol extracts of white peony (*Paeonia lactiflora*), red peony (*P. lactiflora*), sappanwood (*Caesalpinia sappon*), Moutan peony (*Paeonia moutan*), rehmania (*Rehmania glutinosa*), or angelica (*Angelica gigas*) were individually added to raw and cooked ground goat meat at 0.5–2.0% to retard the oxidative changes. The results indicated that all the herbal extracts successfully retarded lipid oxidation in the raw and cooked goat (Han and Rhee, 2005). In addition to inhibition of lipid oxidation, Formanek et al. (2003) found that color changes during storage were inhibited by the addition of rosemary extract in irradiated ground beef. The effect of rosemary extract, chitosan, and α-tocopherol, added individually or in combination, on lipid oxidation and color stability of frozen (−18°C) beef burgers stored for 180 days was investigated by Georgantelis et al. (2007). The burgers' lipid oxidation and appearance were evaluated through measurement of primary (conjugated dienes and peroxide value) and secondary (malondialdehyde) oxidation products, together with visual assessment and instrumental measurement of color. The combination of chitosan and rosemary had a noteworthy effect on the burgers' appearance as it contributed to red color retention for a much longer period compared to all other treatments and controls. Viuda-Martos et al. (2010a) observed that a combination of orange dietary fiber (1%) and oregano EO (0.02%) was effective in reducing the oxidation of bologna sausage stored under vacuum packaging conditions. Addition of rosemary EO (200 mg/kg) and citrus fiber washing water (50 g/kg), were also found to have effectively retarded lipid oxidation in bologna sausages (Viuda-Martos et al., 2010b).

Rosemary extract (400 ppm) was also successfully employed to inhibit the oxidative changes in pressurized minced chicken (Beltran et al., 2004). Dietary supplementation of oregano EO in chicken feed (100 mg/kg feed) resulted in lower oxidative changes in raw, cooked breast, and thigh muscle meat during refrigerated storage (Botsoglou et al., 2002). The protective effect of oregano EO in the frozen chicken meat upon 90 days of storage was also reported (Botsoglou et al., 2003). Mate, an aqueous extract made from dried leaves of *Ilex paraguariensis, St. Hilaire*, is generally accepted for human consumption and is known to have a high content of phenols. Mate was shown to be effective during chilled storage for up to 10 days in protecting lipids and vitamin E against oxidation in precooked meat balls made from chicken breast and packed in atmospheric air. Mate at concentrations of 0.05 and 0.10% was found to give better protection against formation of secondary lipid oxidation products (Racanicci et al., 2008). Aqueous extracts of curry leaves (*Murraya koenigii*) and fenugreek leaves (*Trigonella foenum-graecum*) acted as sources of natural antioxidants for preventing lipid oxidation in raw chicken meat (Devatkal et al., 2012). The authors reported that water extracts obtained from curry leaves and fenugreek leaves could be explored as natural antioxidants in poultry meat and meat products in place of synthetic antioxidants such as BHA and BHT.

Addition of rosemary extracts effectively reduced the pressure-induced lipid oxidation in gels made from the flesh of mackerel (*Scomber scombrus*) (Pérez-Mateos et al., 2002). The antioxidant activity of quercetin and rosemary extracts was also studied in minced fish and gels made after subsequent treatment given to the fish. FRAP (reducing capacity) and DPPH (antiradical scavenging) results showed that the rosemary extract was more effective at protecting from lipid oxidation; whereas protein oxidation was prevented by both antioxidants. Quercetin was the most efficient antioxidant in those batches subjected to thermal treatment for gel formation (Montero et al., 2005). Recently, Mexis et al. (2009) reported that combination of an oxygen absorber and oregano EO (0.4% v/w) were effective in reducing the microbial, sensory, and chemical deteriorative changes in rainbow trout fillets (*Onchorynchus mykiss*) stored under refrigeration (4°C) and the product was reported to have a shelf life of about 17 days.

Bakery Products

Bread is an important staple food consumed worldwide. Since time immemorial, herbs and spices have been used in bread manufacture mainly as aroma contributing agents (Markova, 2010). Presently, herbs are being investigated as functional ingredients in bread manufacture to impart health attributes to the finished product (Siró et al., 2008). Musalevkaia and Baturina (2004) used four types of dried and ground herbs, viz., primrose (*Primula vulgaris*), dandelion (*Tarataxum officinale*), peppermint (*Mentha piperita*), and wild thyme (*Thymus *sp. diversa*) for production of bakery products and reported that herbs addition at higher concentrations (>2.5%) had negatively influenced the color and taste of bakery goods. Herbs retarded the microbiological spoilage in bakery goods up to 7 days (Davidova and Kruk, 2007). Addition of wild thyme (*Thymus sp. diversa*), wild marjoram, or oregano (*Origanum vulgare*) and the lemon balm or common balm (*Melissa officinalis*), in 1:1:1 proportion to the wheat flour (1.0–1.5%) imparted a pleasant aroma to the bread, without any detrimental effects. The herbs added to the bakery products resulted in increased biological value (Krasteva et al., 2011). Turmeric wheat breads were prepared by incorporating turmeric (*Curcuma longa* L.) powder in wheat flour. Breads containing turmeric powder have shown good antioxidant activity as tested by the β-carotene-linoleate bleaching assay. A 4% substitution of wheat flour with turmeric powder showed acceptable sensory scores which were comparable to wheat bread (Lim et al., 2011). Acceptable sensory quality breads having good antioxidant potential were developed by adding ginger at 3% to dough (Balestra et al., 2011).

Biscuits occupy a major portion of the snack food market. Refined wheat flour, deficient in iron, is the principal ingredient in biscuit manufacture. Iron-deficiency anemia is considered as one of the important nutritional disorder in developing countries among different age groups. Hence, a study was conducted by Soliman (2010) to fortify wheat flour with iron from natural sources such as celery seeds and cinnamon bark meal. The authors reported that total iron and available iron increased in biscuits with increasing levels of celery seeds and cinnamon additives compared with control biscuits. The odor and taste of biscuits were also improved significantly. A process for the manufacture of herbal biscuits was developed by Singh et al. (2003). The authors reported that the dietary supplement is associated with galactagogue, adaptogenic, and hepatoprotective properties. Incorporation of either fine powder or extracts of marjoram, spearmint, peppermint, and basil, into a soda cracker biscuit at 0·5% gave an antioxidant effect on the biscuit, compared to the control sample (Bassiouny et al., 1990). Mint (*Mentha spicta* L) as a source of natural antioxidant in different forms, viz., 1% mint powder, 500 mg mint extract, and 100 ppm pure menthol was incorporated in biscuits. The biscuits with different mint forms were packed in unit pouches of metallized polyester/polylaminate and stored at room temperature for five months. Addition of mint in all forms reduced the oxidative changes in biscuits and biscuits added with mint powder were highly acceptable compared to those added with mint extract and pure menthol (Bajaj et al., 2006). The effects of cumin and ginger as antioxidants (at 5% of dough) on dough mixing properties and cookie quality were evaluated by Abdel-Samie et al. (2010) and it was reported that the DPPH assay of dough confirmed the antioxidant activity and sensory analysis revealed that the cookies with cumin and ginger additions had overall acceptability similar to that of the control with a slightly darker appearance.

Taga et al. (1993) reported a process for the manufacture of baked snacks added with herbal leaves. Blanched and dried lemon balm leaves were attached to dough sheets which were then baked to produce snacks. Limsangouan et al. (2010) studied the effects of extrusion processing on the functional properties such as antioxidant capacity and total phenolic compounds of extruded snack foods fortified with herbs, viz., garlic (*Allium sativum*), egoma (*Perilla flutescens var. flutescens*), and Japanese green tea (*Camellia sinensis*). The authors reported that the extrusion processing applied did not affect the functional properties of herbs.

Fruits and Vegetables

Fruit and vegetable deterioration during postharvest are associated with fungal growth that causes great economic losses. Growing consumer demand for both high quality and safe fruit and vegetables has restricted the use of synthetic antimicrobials. There is a need to have available natural alternatives to these synthetic antimicrobials and special attention has been paid to the use of EOs as natural antimicrobials with effectiveness being reported for carvacrol (Martínez-Romero et al., 2007), thymol, menthol, and eugenol (Valverde et al., 2005; Serrano et al., 2008). The use of EOs was effective in reducing decay of table grapes (Valverde et al., 2005; Martínez-Romero et al., 2007) and sweet cherry (Serrano et al., 2005).

Sweet cherry is easily prone to decay with loss of sensory quality which affects its commercialization. Cherries treated with eugenol, thymol, or menthol and packed under MAP conditions showed benefits in terms of reduced weight loss, delayed color changes, and maintenance of fruit firmness compared with control (Serrano et al., 2005). *Aloe vera* gel applied as an edible coating in sweet cherry fruit revealed beneficial effects in terms of delaying stem browning and dehydration and maintenance of fruit visual aspect without any detrimental effect on taste, aroma, and flavors (Martínez-Romero et al., 2006). Application of *Aloe vera* gel to table grape vineyards before harvesting inhibited the growth of two common fungi (*Penicillium digitatum* and *Botrytis cinerea*) responsible for its decay and thereby enhanced its shelf life (Castillo et al., 2010). Addition of *Aloe vera* gel alone or in combination with thymol was found to be effective in reducing the decay incidence caused by the three fungi species namely *Rhizopus stolonifer, Botrytis cinerea*, and *Penicillium digitatum* (Navarro et al., 2011). EOs of thyme, coriander, and rosemary applied under in vivo and in vitro conditions to white and red cabbage samples have shown good antioxidant potential evaluated by peroxidase reduction assay (Mousavizadeh et al., 2011).

Confectionary

Candies or confectionaries are mostly made from concentrated solution, to which flavorings, colorants, and other ingredients are added. Their high sugar content may create risk of dental caries. Ning et al. (2004) developed a candy using a mixture of green tea extract, magnolia extract, goldthread extract, and honeysuckle extract. The mixture also contained certain oral care agents like anticalucs, antiplaque, and oral malodour agents. Lutz and Richterich (2005) developed a confectionary comprising herbal mixtures along with *Stevia rebaudiana*. The confectionary was claimed to be possessing the health benefits of herbs as well as free from risk of dental caries as the herb *Stevia rebaudiana* imparts a high natural sweetening effect without any addition of sugar to the confectionary mixture. Several medicated candies or herbal candies such as menthol-based are available on the world market.

Other Food Products

Herbs not only impart flavor but also enhance shelf life of sauces when incorporated into them. Pesto, a sauce native to Italy and also popular in Mediterranean countries, consists of herbal extracts of garlic and basil as its principal ingredients (Dziezak, 1991). Due to its herbal ingredients, pesto is shelf-stable and is thus said to be unique (Ranch, 1990). Many alcoholic beverages obtain their characteristic flavors from herbs (Anon, 1984). A method to improve the storage stability and organoleptic properties of a carbonated fermented milk beverage by adding a mixture of EOs of coriander, basil, and fennel to a salt solution of whey was reported by Askerova et al. (1993).

Polyphenol-rich extracts of green tea (catechins) were being incorporated to fruit-flavored milk drinks, as well as other products like chewing gum and sweet paste biscuits (O'Connell and Fox, 2001a; Pandey, 2001; Ravindran and Kalluparackal, 2001; Vasala, 2001; Bender and Bender, 2005). Green tea extracts were also used at a level of 150 mg/100 g flour in breadmaking with no color acceptability problems (Wang and Zhou, 2004). Recently, Mocanu et al. (2009) prepared a probiotic product named "*rosalact*" with the addition of medicinal plant (*Rosa canina L.* and *Glycyrrhiza glabra L.* each added at 6% level) extracts and mixed culture of probiotic bacteria ABT 5 (*Lactobacillus acidophilus*, *Streptococcus thermophilus*, and *Bifidobacterium* ssp. added at 5% level) into pasteurized milk. Tarakci et al. (2011) studied the influence of different herbs on physicochemical and organoleptic quality of labneh during storage. They reported that the sensorial scores of the labneh samples were influenced by the variety of herb added and the storage times. Addition of dill and parsley to labneh resulted in the highest sensory scores. *Bacopa monniera, Aloe vera*, *Vidharikand*, *Shatavari*, and *Triphala* were successfully incorporated into different food products to develop acceptable quality functional foods at author's laboratory.

INTERACTION OF HERBAL INGREDIENTS WITH FOOD CONSTITUENTS AND THEIR IMPLICATIONS

Functional foods containing herbal components are occupying a major portion in today's functional food market. When herbal ingredients and milk constituents are mixed together, there might be some reactions occuring possibly at molecular level which may lead to alterations in the basic properties of the herbal ingredients as well as milk constituents. The functionality of herbs in food products could be attributed to the functional ingredients occurring in herbs or their possible interaction with food components mainly proteins and carbohydrates. The mechanisms through which these interactions occur will define the functional characteristics of the food product. Hence, it is worthwhile to know the interactions of herbal components with food constituents so that alterations in the physiological functionality of the active herbal ingredients or toxicological effects if any could be predicted. Interaction of each and every component of the herb with food ingredients has not yet been studied but the interactions of polyphenols with proteins/amino acids and interaction of polysaccharides with food proteins and resulting implications thereby have been well studied.

Many phenolic compounds have the ability to interact with food proteins especially with proline-rich proteins (caseins) (Spencer et al., 1988; Luck et al., 1994) through hydrophobic and hydrogen bonding (Haslam and Lilley, 1988; Spencer et al., 1988; Luck et al., 1994; Haslam, 1998). The flexible secondary structure and the greater extent of hydrogen bonding exhibited by proline-rich proteins will be the factors responsible for their interaction with phenolic compounds (Asquith et al., 1987; Haslam and Lilley, 1988; Spencer et al., 1988; Luck et al., 1994). Under specific conditions, phenolic compounds can also covalently interact with proteins. Interaction of polyphenols with food proteins may have implications in terms of their bioavailability (Serafini et al., 1996; Wollgast and Anklam, 2000) and antioxidant capacity (Arts et al., 2001, 2002; Riedel and Hagerman, 2001). The addition of milk to tea has been considered to interact with the intake of flavonoids from tea (Hertog et al., 1997), and the addition of milk to tea is known to prevent the vascular protective effects of tea in human (Lorenz et al., 2007).

Brown and Wright (1963) investigated the interaction of black tea polyphenols with milk proteins. The authors reported that, when a tea infusion is mixed with milk, the colored tea polyphenols interact mainly with the α-casein and the β-casein of the milk to form soluble casein–polyphenol complexes. β-lactoglobulin and α-lactalbumin, the main whey proteins, appear to be unaffected by the polyphenols in the presence of the casein. In the absence of the casein, both α-lactalbumin and β-lactoglobulin interact with the colored tea polyphenols, forming either soluble or insoluble protein–polyphenol complexes depending on the relative and overall proportions of protein and polyphenol present in the mixture. They also suggested that the milk protein–tea polyphenol interactions were initiated by the formation of hydrogen bonds. When casein solution reacted with enzymically-oxidized caffeic acid, isochlorogenic acid, and other unidentified polyphenols, brown colored protein having lower biological value (BV) and digestibility than the original casein was obtained (Horigome and Kandatzu, 1968). Horigome and Kandatzu (1968) and Dryden and Satterlee

(1978) reported that the biological value of casein was reduced by incubation with chlorogenic acid. Hurrell et al. (1982) observed no reduction in biological value of casein when incubated with caffeic acid, but there was reduction in the availability of amino acids namely lysine (35%), tryptophan (58%), tyrosine (14%), histidine (24%), and methionine (24%). When solutions containing phenolic compounds and casein are aerated at 80°C for 10 h, browning occurs (presumably a consequence of oxidation) and the extent of which is dependent on the phenolic compounds (Igarashi et al., 1978). Phenolic compounds when incubated with oxido-reductases in the presence of protein and polysaccharides, the phenol moiety in such systems may be free (caffeic acid and chlorogenic acid), protein-bound (tyrosine), or polysaccharide-bound (feruylated polysaccharides) (Matheis and Whitaker, 1984). Phenolic compounds when incubated with proteins and an electron acceptor (e.g., hydrogen peroxide, peroxides, oxidise tyrosine residues) form inter- and intramolecular crosslinks through the formation of dityrosine and tertyrosine residues (Matheis and Whitaker, 1984; Færgemand et al., 1998).

Sarker et al. (1995) reported that, catechin, a green tea polyphenol increased the volume and improved the stability of β-lactoglobulin (β-LG) foams by forming hydrophobic and hydrogen bonds between proteins absorbed at the interface, thereby inhibiting the competitive adsorption of low molecular weight surfactants (Tween 20). Phenolic compounds also undergo enzymatic, thermal, or alkaline-catalyzed oxidation to form quinones which interact with reactive amino acid residues such as lysine, tryptophan, methionine, histidine, tyrosine, and cysteine. O'Connell and Fox (1999a) reported that green tea extracts increased the heat stability and rennet coagulation time of milk. Addition of *Aloe vera* extract (added at a level of 0.4% w/v to skim milk and 0.8% w/v to concentrated milk) also increased the heat stability of skim milk (at 140°C) and concentrated milk (at 120°C) and retarded rennet coagulation without affecting the alcohol stability of milk (O'Connell and Fox, 1999a). The authors suggested that the high content of polyphenols in these extracts which can chelate metals and interact with proteins (Radhakrish and Sivaprasad, 1980; Haslam and Lilley, 1988) might be responsible for the enhanced stability of casein micelles. The stabilizing effect of phenolic compounds could be due to their ability to get thermally oxidized to quinones, which are extremely electrophilic and interact with nucleophilic amino acid residues, e.g., lysine and cysteine, to maintain micellar integrity, which is compromised on heating (O'Connell and Fox, 1999b; O'Connell and Fox, 2001). Rawel et al. (2003) have also shown that the flavonols, quercetin, and rutin bind to β-LG. The interactions between β-LG with resveratrol, curcumin, and diacetylcurcumin revealed that these compounds do bind to β-LG (Liang et al., 2008; Mohammadi et al., 2009). The binding ability of quercetin to bovine serum albumin (BSA) was also studied (Papadopoulou et al., 2005; Rawel et al., 2005). Alexandropoulou et al. (2006) conducted an in vitro digestion study and reported that the presence of casein (4g/100 ml sample) decreased the antioxidant effect of green tea polyphenols. Black tea, a product obtained after fermentation of *Camellia sinensis* is very often consumed with milk. Sharma et al. (2008) reported that addition of milk and sugar enhances and stabilizes the antioxidant effect of black tea. This has been attributed to the possible noncovalent interactions between tea polyphenols and polar milk proteins (Bartolome et al., 2000; Prigent et al., 2003) that might have enhanced the antioxidant potential of black tea polyphenols (Arts et al., 2001). Polyphenols have been reported to increase the stability of casein micelles to oxidative degradation (Rosenthal et al., 1999) and foaming (O'Connell and Fox, 2001; Sausse et al., 2003). The interactions between bovine milk β-LG and a group of plant-based phenolic compounds with their derivatives were investigated by Riihimäki et al. (2008). In the binding studies, a total of 44 phenolic compounds were evaluated. Almost all of the flavonoids studied bound to β-LG. Most of the compounds that bound tightly to β-LG belonged to the groups of flavonones, flavones, flavonols, and isoflavones. Rutin from *U. dioica* was slightly bound to β-LG. None of the compounds of *C. sinensis* bound to β-LG, indicated that β-LG does not prevent favorable health-promoting effects of black tea by binding phenolic compounds (Riihimäki et al., 2008).

Naturally occurring polyphenolic compounds get damaged when exposed to high pH (Friedman and Jürgens, 2000). Conjugated forms of genistein and daidzein isoflavones, quercetin, and rutin had undergone a considerable loss at elevated pH (Buchner et al., 2006; Mathias et al., 2006). Yang et al. (2008) and Belgorodsky et al. (2007) found that binding of vitamin D_3 and carboxyfullerene to β-LG was unaffected by pH changes. Riihimäki et al. (2008) reported that β-LG might protect the flavonoids and alkaloids in food exposed to high pH during food processing. Many phenolic compounds are known to have poor water solubility and are poorly absorbed in their natural form in the intestine (Rezende et al., 2009), β-LG might increase their solubility and in this way enhance their bioavailability (Riihimäki et al., 2008).

Many herbs contain polysaccharide units which may also interact with food proteins when they are processed together. The overall interaction between two biopolymers is made up from an average over the large number of different intermolecular forces (Israelachvili, 1992) arising between the various segments and side-chains on the two macromolecules. Depending on the aqueous environmental conditions and the distribution of the different kinds of groups (charged, hydrophobic, hydrogen bonding, etc.), the overall bipolymer interaction may be net-attractive or net-repulsive. The molecular rather than its granular structure of the starch had great impact on the heat stability of milk (Tziboula and Muir, 1993). Dickinson (1998) reviewed the impact of milk protein–polysaccharide interactions on stability and rheology of the different solutions. It was concluded that whether insoluble precipitates or soluble complexes are formed depends especially on the pH conditions. Complex formation between milk proteins and charged polysaccharides arises mainly as a result of electrostatic interactions. Carrageenans and other polysaccharides have been found to inhibit the ability of polyphenols to precipitate sodium caseinate. Hence, encapsulation of phenolic compounds by polysaccharides and/or an increase in the solubility of protein–polyphenol complexes through the formation of a ternary complex with polysaccharides has been suggested (Luck et al., 1994). Perez et al. (2009) studied milk whey protein and anionic polysachharide (spdium alginate and λ-carrageenan) interactions. They reported that the interactions between whey protein and polysaccharides depend on the polysaccharide type, relative concentration in the system and also on the type of whey protein fraction, and the pH of the medium. The presence of lactose and minerals even in small amounts has been found to affect the properties of the starches in the milk–starch-based system (Considine et al., 2010).

CONCLUSION

Herbs are considered as nature's gift to human beings in the form of natural remedies to prevent and treat many illnesses. Herbs harbor a wide variety of functional components which can perform a wide range of biological functionalities. In the recent past, research regarding functionality of herbal components, their toxicity, and use in food products has been the matter of interest. Food manufacturers are finding ways to incorporate these herbal nutraceuticals into food products without having any adverse effect on their esthetic quality. However, depending upon the concentration and type, the incorporation of herbs into food products may have certain undesirable effects on their sensory properties like color and appearance, flavor, body, and texture which, in turn, could affect their overall acceptability (Tarakçi et al., 2004; Tarakci et al., 2011). Incorporation of these nutraceuticals into food systems may therefore require use of technological modifications/alterations so that the sensory quality of the final product remains unaltered. Literature about the effect of processing conditions especially heat treatment on the functional components of herbs is scanty. More research should be directed toward the effect of processing conditions like heat treatment, freezing, pH, and acid on the bioavailability of functional components of the herbs so that the processes will be designed in such a way that little or no damage will occur to the functional components during their incorporation into food matrix. The microbial instability of herbs and spices seem to be the major problem for their addition into foods. Furthermore, very limited information is available for ascertaining the residual levels of these functional components in herbal food preparations. Knowledge of interactions of herbal and food constituents leading to changes in sensory, textural, and their effect on human health is essential for many reasons and has to be studied thoroughly. Although incorporation of herbs into foods is increasing, the scientific community must apply modern technologies to assure the efficacy and safety of herbs and their bioactive components for their safe use in food formulations.

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