Traditional Indian Functional Foods

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3.1 INTRODUCTION

The curative effect of food has been a traditionally established belief for many generations in India. The current view that food can have an expanded role that goes well beyond providing a source of nutrients truly applies to many traditional Indian foods. In fact, the traditional Indian diet is "functional" as it contains high amounts of dietary fiber (whole grains and vegetables), antioxidants (spices, fruits, and vegetables), and probiotics (curds and fermented batter products), which are wise choices for health promotion. Many Indian traditional foods impart beneficial effects on human physiology beyond providing adequate nutrition. The health benefits thus derived may range from ensuring normal physiological functions in the body such as improving gastrointestinal health, enhancing the immune system, weight management, and providing better skeletal health, among others, in order to reduce blood cholesterol, oxidative stress, the risk of cardiovascular diseases, inflammatory diseases, various types of cancers, and possible prevention of diabetes, and neurodegenerative diseases. A dietary ingredient that affects its host in a targeted manner so as to exert positive effects on health can be classified as a "functional" ingredient. The functional components present in Indian traditional foods may be chemical or biological in nature and play a key role in imparting beneficial physiological effects for improved health. Some of the ingredients that make Indian traditional foods functional include dietary fiber, vitamins and minerals, oligosaccharides, lignins, essential fatty acids, flavonoids, miscellaneous phytochemicals, and lactic acid bacterial cultures. These functional ingredients are abundantly available in foods such as fruits, vegetables, cereals, legumes, nuts, and milk and milk-based products.

3.2 HISTORY OF INDIAN FOOD CULTURE AND TRADITIONAL FOODS

Indian heritage foods are of considerable antiquity and not much is known about their origin. There are a number of regional heritage foods that evolved locally, depending on the availability of raw ingredients. Heritage foods in India are an integral part of Indian culture. Traditional foods started with the inception of tradition, which dates back to Aryan civilization (3000 BC) followed by Harappan (2000 BC), Vedic (1500 BC), and later the Hindu culture as influenced by other cultures, and Indian food habits followed the changing cultural patterns. With a history of 3000 years or more, the Indian civilization has given food a prominent place in the social and cultural lives of its people. India has had several philosophies and religions which grew from within, such as pre-Buddhist Hinduism, Buddhism, Jainism, and post-Buddhist Hinduism. These philosophies interacted with each other and made their impact felt on Indian traditional food cultures (Achaya, 1994).

The cereal grain barley was the major grain eaten by the Aryans, followed by *Apupa*, *Lajah*, *Soma* juice, and rice. Wheat was introduced during the Vedic period. Cattle were an integral part of the Vedic culture, and the literature before 800 BC is full of references to the milk of the cow and other cattle. Vedic literature also refers to curdling of milk with starter from an earlier run. Curds thus prepared were eaten with rice, barley, or *Soma* juice. Ghee (*Ghrita*) was prepared by melting down and desiccating butter and was considered a commodity of prestige. Ghee was also used in Vedic rituals (as offerings to God), for frying, and for dipping to add relish to other foods, and for mixing with *Soma* juice. According to the sage Sushruta (600 BC), the profounder of Ayurveda, the indigenous system of medicine in India, cow's milk had a stabilizing effect on body secretions, while the fat-rich buffalo's milk was more healing. It is also mentioned by Sushruta that cream of milk called *Santanika* had many beneficial effects on health. Curds were distinguished as sweet, slightly acidic, and strongly acidic for consumption regionwise. Ghee prepared and stored for 10–100 years in a vessel was called “Kumbha ghrita” and ghee stored for more than a century was termed “Maha ghrita.” Such aged ghee preparations are of much value in the Ayurvedic system of medicine.

Diets were created by our ancestors originally to meet their survival needs. People of various Indian cultures gradually enriched them through long empirical experience using combinations of a variety of primary food materials, especially the locally available food grains and vegetables that nutritionally complement and supplement each other. This has contributed to better health protection, improvement of digestibility, resistance to health disorders, and increased human longevity. India has a heritage of many indigenous ethnic cultures, and thousands of delicious and functional diets have been developed over millennia. The foods of nearly 50 major Indian cultures and many minor cultures have created more than 5000 dietary preparations, which include many items for daily consumption to protect and sustain human health. People of these cultures have been brought together by several historic circumstances. One such occasion was the Empire of Ashoka (300–260 BC), which held almost the whole of India as one country and promoted Buddhism. Philosophies of both Buddhism and Jainism, which preached vegetarianism and reverence for all forms of life, had a significant impact on peoples’ outlook on life and consequently on their foods. The Mughal Empire (1250–1650 AD) that ruled most of India for 400 years also brought many traditional cultures together and made them interact meaningfully. The British colonial rule (nineteenth to twentieth century) in greater India tremendously contributed to people with different ethnicities coming together and sharing their wider variety of heritage foods (Parpia, 2006).

Indian heritage foods, many of which are incidentally functional foods too, have developed over a long period and include cereal-based items such as rice or wheat specialties, meal adjuncts such as pickles, chutneys, papads, and similar items, medium of cooking—ghee, butter, or vegetable oils, a variety of fermented batter foods (steam cooked or lightly fried), milk and non-milk-based sweets, and an innumerable variety of snack foods. The traditional food pattern in India is comprised of fiber-rich menus, with moderate fat, selective carbohydrate sources, and curds. They cover the functional components, imparting wider health benefits, and such systematic food habits are an excellent preventive measure to ward off many diseases. Indian traditional meals, which are mainly based on plant products such as grains, vegetables, and fruits, are very rich in natural dietary fiber. Fiber-rich and low-fat traditional foods reduce the risk of coronary heart disease. Traditional plant foods specifically based on fruits and vegetables provide functional components such as β-carotene, vitamin C, vitamin E, folates, and antioxidant phytochemicals. Cereals, which are the staple of Indian traditional foods, provide thiamine, tocopherols, selective starches, and minerals that play a role in regulating metabolic functions in the body.

The traditional food habits of each specific region of India are primarily a component of its culture, and India’s cultural diversity is reflected in the numerous traditional food preparations. Indian traditional dietary patterns have basically evolved from the combination of locally available crops. Every region of this vast country uses a different choice of ingredients with its own unique food. The cereals wheat and rice form the staple in Indian traditional food, followed by the coarse grains sorghum and finger millet. The whole meal flour from these grains is consumed Q1 traditionally in the form of roti (a wheat-based food) and as dumpling, or muddle. Traditionally, a typical North Indian meal consists of unleavened breads, *chapati* or *paratha* made of whole wheat flour, and an assortment of side dishes such as soups, fried vegetables, curries, chutney, pickles, and curd (*dahi*). South Indian food, which is largely nongreasy, consists of cooked rice usually served with *sambar* (seasoned lentil broth), *rasam* (a thin soup), dry and curried vegetables, a curd preparation called *pachadi*, and curd. Vegetables in Indian dishes are generally stir-fried, steamed, braised, or curried to create various textures and flavors. Commonly consumed vegetables include leafy greens, radish, yam, beans, bamboo shoots, ladies finger, and cabbage. The use of pickles and chutneys is predominant in arid regions of India due to the low availability of fresh vegetables in these hot and dry regions.

South Indian breakfast items are most commonly pancakes made from a rice batter known as *dosa*, steamed rice cakes known as *idli*, deep-fried doughnuts made from a batter of lentils known as *vada*, rice pancakes known as *appam*, *upma* (cooked semolina seasoned in oil with mustard, pepper, cumin, and dry lentils), and *pongal* (a mash of rice and lentils boiled together and seasoned with ghee, cashew nuts, pepper, and cumin). Coconut is an important ingredient in South Indian food. Coconut milk and desiccated coconut are important flavorings in South Indian cuisines. The presence of coconut mellows out the hot curries and chutneys, and is used as a topping for vegetables.

To neutralize the pungency of red chilli and soothen the stomach, curd is used in a variety of South Indian dishes. Curd *sambhar*, *thambli* (fenugreek or other seeds in curd), fried black gram powder in butter milk with seasonings known as *uddinettu*, thin soup prepared from *Garcinia indica* known as *punar puli rasam*, thin soup prepared from cumin (*Cuminum cyminum*) and black pepper seed (*Piper nigrum*) powders known as *jeerige menasu rasam*, *kosambari* (salads from dehusked gram sprouts mixed with fresh coconut kernel, green chillies, and seasonings), and watery buttermilk garnished with ginger, asafetida, coriander leaves, curry leaves, and salt are among the traditional functional foods commonly consumed. Thus a perfect combination of protein from legumes and coconut, carbohydrates from rice, fat both visible and invisible from curry and fried savory items, vitamins and minerals from sprouted grams of *kosambari* (salads from sprouted legumes), and vitamins from curd and vegetables are obtained through this combination. The regular use of curd and watery buttermilk with accompaniments aid in digestion and provide considerable health benefits.

3.3 BASIS OF EVOLUTION OF TRADITIONAL FUNCTIONAL FOODS IN INDIA

Ancient India seems to have realized the importance of health and wellness much ahead of its time. The Indian dietary pattern and the traditional foods evolved are based on the indigenous Ayurvedic system of medicine, which professes natural ways of achieving physical and mental wellness. A balanced meal recommended by

Ayurveda takes into account the properties of the food (*gunas*), the characteristics of the individual (*dosha*), and the assimilation by the body (*sadhana*). Traditional Indian food formulations show ingenuity in the choice of ingredients and additives with critical attention to wholesome nutrition beyond taste. Indian cuisines have great aromas and in-depth taste profiles, which are derived from a complex combination of spices and preparation techniques. The well-balanced Indian meal contains all the six defined tastes, namely sweet, sour, salty, spicy, bitter, and astringent. Indian cooking principles go beyond the balancing of tastes, however. Every meal aims to achieve a good balance between these sensations to promote digestion and well-being. Side dishes and condiments contribute to the overall flavor and texture of an Indian meal. The hot, sour, and crunchy side dishes and condiments, whether chutneys, curries, or soups, enhance and provide balance to the overall flavor and texture of the main staple. Inclusion of natural antimicrobials and antioxidants in the form of spices and condiments also improves the shelf-life of prepared foods against spoilage. Ayurveda has elaborated the curative and therapeutic functions of herbs and spices. This is manifested in the commonality among heritage foods from different parts of India, in that almost all of them are rich in spices.

Traditional Indian food formulations show ingenuity in the choice of ingredients and additives with adequate attention to wholesome nutrition and tastes. Another feature of traditional Indian foods is the effective utilization of natural resources and minimization of waste. Historically, cooking techniques have been developed for the protection, storage, and preparation of diets, the ingredients of which mutually supplement and complement each other to provide nutritionally balanced and also delicious diets. Indian traditional foods are noteworthy not only for their food quality but also from the food safety perspective. Since some of them are steam-cooked, they are generally free from microorganisms. Others are boiled to the desired temperatures. As a general rule, they have to be consumed fresh and hot. Generally, Indian traditional foods, once cooked, are not preserved for future use.

Indian traditional foods can be classified into eight broad categories (Table 3.1): (1) processed grain products, (2) fermented foods, (3) dehydrated products, (4) pickles, chutneys, sauces, and relishes, (5) ground spice and spice mixtures, (6) fried food products, (7) dairy products, and (8) confections and sweets. The functionality of the majority of these categories of Indian traditional foods is delineated in the later paragraphs of this chapter.

3.4 TRADITIONAL FUNCTIONAL FOODS

Various Indian traditional foods with bioactive substances provide additional health benefits over and above the physiological roles of the nutrients present in such foods. Sprouting, malting, and fermentation are processes that enhance the functional properties of food and are widely used in the daily diet of Indians.

3.4.1 Traditional Foods Based on Whole Grain Cereals and Legumes

The staples of Indian cuisine are rice, whole wheat flour, sorghum, finger millet, and a variety of pulses. Pulses are the main source of protein supplement for a large

TABLE 3.1
Categories of Typical Traditional Foods of India

Raw Material	Traditional Products	Food Category
Cereals and grains	Rice-based: parboiled rice, hand-pounded rice, flaked rice, puffed rice	Processed grain products
	Wheat-based products like *chapati*, *puri*, bread, *naan*, biscuit	
	Extruded products like rice noodles, vermicelli, snack items—*murukku*	
	Fermented products like *idli, dosa, vada*	Fermented foods
Coarse cereals	Puffed sorghum, maize, finger millet, pearl millet	Processed grain products
Legumes	Pulses (split legumes without husk), puffed legumes, sprouted legumes, legume flours (e.g., Bengal gram, soy), *papads*	Processed grain products
Gram flour, sugar/jaggery	*Jilebi, laddu, chikki, Mysore pak*	Confections and sweets
Milk	*Peda, burfi, rasgolla, jamun, sandesh, kheer, halwa*	Confections and sweets
	khoa, rabri	Dehydrated dairy products
	Chhana, paneer	Coagulated dairy products
	Dahi (curd), butter milk, *lassi*, butter	Fermented dairy products
	Ghee, *malai, makkhan*	Fat-rich dairy products
Fruits/vegetables	Fruit leather, dried fruits, dehydrated vegetables	Dehydrated products
	Pickles, chutneys, murabbas, petha, candied fruits, amchur, and pickled vegetables	Pickles, chutneys, sauces
Spices and Condiments	Spice powders, spice mixes (e.g., *garam masala*, *sambar* powder, *rasam* powder)	Ground spices and spice mixes
Drinks and beverages	Neera, toddy, arrack, khanasari, rice beer, Indian beer, honey, vinegar, jaggery	Beverages (alcoholic/nonalcoholic)

majority of the cereal-based ethnic diets because they are easy to cook and fit well into the traditional diets. A large variety of savory and sweet processed products are made from them. Each Indian ethnic culture has developed its own diets based on the variety of pulses that they grow. While pulses may be used whole, dehusked, or split, most of the grain legume-based or mixed grain preparations are made by using dehusked or split pulses. The most important pulses are red lentil (*masoor*), chickpea (Bengal gram), red gram (pigeon pea), black gram (*urad*), and green gram (*mung*). Some of the pulses, like chickpea and green gram, are also processed into flour. Pulses, commonly used in Indian cuisines, are fried, roasted, or boiled with spices and herbs for making fermented breads, soups, chutneys, snacks, purees, and sweets. Chickpea is used raw in chutneys, roasted whole for spicy snacks, and ground for sweets, or is used whole with vegetables. Black gram is popular in southern India, where it is fermented with rice and mixed with spices to make *dosa*, steamed *idli*, and snacks such as *vada* or papad. Red gram, which exhibits a thick and more gelatinous consistency, is combined with chickpea, spices, and red chilli for making the lentil broth *sambhar*. The use of whole grain cereals and legumes in these traditional foods ensures provision of the highly desirable dietary fiber and also the polyphenols and the micronutrients, vitamins, and minerals associated with the bran portion of the grain.

Unleavened breads from whole grain: Chapati and *paratha* are processed from whole wheat; hence they contain all the natural components (bran, endosperm, and germ) of wheat. *Chapati* is unleavened bread baked on a griddle while *paratha* is unleavened bread fried on a griddle. *Parathas* are rich in crude fiber (1.3–5.8%) and protein content (8.5–12.6%) and low in fat (7.5–12.8%). The assorted *paratha* formulations that contain soy protein isolate are supposed to contain all the essential amino acids. As these are made out of whole wheat, they provide the full complements of fiber, minerals, and polyphenols associated with the bran portion of the grain. Unleavened breads baked on a griddle made out of the coarse cereals sorghum and finger millet are also widely consumed by sections of the Indian population. The use of whole grain cereals in these traditional staple foods ensures provision of the highly desirable dietary fiber and also the polyphenols and micronutrient vitamins and minerals associated with the bran portion of the grain.

Finger millet dumpling: Finger millet dumpling is a common traditional food in southern India. Finger millet, although a minor cereal, has a major impact on health with functionalities of high dietary fiber and 20% resistance starch with a 30–40% slowly digestible starch fraction, a rich calcium content of 400 mg%, and an iron content of 17–20 mg%. Malted finger millet is traditionally consumed as a healthy beverage and is used in the preparation of weaning and geriatric foods.

Sprouted legumes as salads: Green gram and chickpea are commonly germinated prior to use in the preparation of specific traditional salad dishes, especially in southern India. Germination and malting have been found to enhance iron absorption due to elevated vitamin C content or reduced tannin or phytic acid content, or both (Tontisirin et al., 2002). These processes are known to activate endogenous phytases, which in turn hydrolyze phytate, rendering iron and zinc more available. During germination, endogenous phytase activity in cereals and legumes increases as a result of *de novo* synthesis and/or activation, resulting in reductions in the inositol phosphates (Lorenz, 1980; Chavan and Kadam, 1989; Reddy et al., 1989). Sprouting of legumes, green gram, chickpea, and finger millet is associated with significantly improved bioaccessibility of iron, which is due to a reduction in tannin content (Hemalatha et al., 2007; Prabhavathi and Rao, 1979). Studies *in vitro* on iron bioavailability have shown a twofold increase on germination and a five- to tenfold increase upon malting of the minor millets (De Maeyer et al., 1989).

Fermented batter foods from cereals and legumes (Figure 3.1): Fermented batter foods from cereals and legumes are the most common and nutritious Indian traditional breakfast items in the southern states of India. These include *dosa* (a pancake made from a fermented batter of rice and black gram (3:1), *idli* (steamed rice cakes made from a fermented batter of rice and black gram (2:1), and *vada* (a deep-fried doughnut made from a batter of lentils, usually black gram). Traditionally, for making these products, the mixtures of grains are soaked for 6–8 h and then ground. After grinding, the batter is allowed to undergo fermentation overnight, which makes use of the naturally occurring microorganism *Leuconostoc mesenteroides* present in

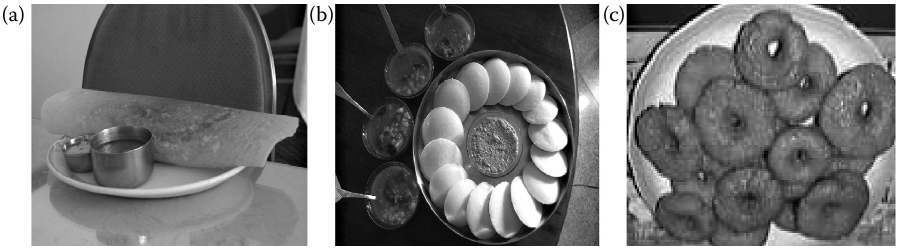

FIGURE 3.1 Fermented batter foods from grains: (a) *dosa*, (b) *idli*, (c) *vada*.

the batter. The microorganisms ferment the mixed batter and generate a unique flavor and texture. The fermented batter has an excellent foam-holding capacity to give the steamed/fried product an appetizing spongy texture. In the case of *idli*, the fermented batter is put into the cups of a special steaming vessel in the form of dumplings, after which it is consumed with a variety of garnishes (chutney) prepared from various natural flavorful ingredients such as coriander leaves, green chillies, and freshly ground coconut kernel, or with a thick soup (*sambhar*) made from legumes and vegetables flavored with spices. *Dosas* prepared by baking the batter with oil on a pan are often consumed with rolled-in or flavored vegetables.

These two fermented batter preparations are a rich source of good nutrients such as the essential amino acids methionine from rice and lysine from pulses as well as vitamins and minerals from the parboiled rice, vegetables, and nutrients generated by the fermentation of the batter. The products are also low in fat and rich in dietary fiber. Fermentation of the batter of cereal–pulse combinations in the preparation of *idli* and *dosa* is known to enhance the bioaccessibility of the micronutrients zinc and iron (Hemalatha et al., 2007). Fermentation of cereal–legume combinations of the *idli* and *dosa* batter significantly reduces both the phytate and tannins associated with the legumes. Food processing by fermentation is known to improve mineral bioavailability by reducing their absorption inhibitors such as the phytic acid present in the grains (Gibson and Hotz, 2001; Kaur and Kawatra, 2002). Besides reducing such factors, fermentation could also improve mineral bioavailability by virtue of the formation of organic acids, which form soluble ligands with the minerals, thereby preventing the formation of insoluble complexes with phytate (Tontisirin et al., 2002). A reduction in the pH by 1.5 units as a result of fermentation of the *idli* and *dosa* batters has been observed, which is attributable to the synthesis of organic acids during fermentation (Hemalatha et al., 2007). *Idli* can also be made using parboiled rice (which helps preserve vitamins, unlike regular rice) along with black gram, taken in the right combinations, and then fermented and steamed to deliver a profoundly nutritious, balanced, and tasty meal.

3.4.2 *Dahi* and Ghee: The Two Classical Milk-Based Traditional Health Foods of India (Figure 3.2)

Traditional Indian foods make use of dairy products such as curds (yogurt), cheese, buttermilk, and ghee. Ghee (clarified butter) and *dahi* (curd) are the two most

FIGURE 3.2 *Dahi* (curd) and ghee (dehydrated butter).

important age-old traditional milk products consumed in India. Ghee is a fat-rich dairy product whereas *dahi* is a fermented milk product. Both these milk products have higher keeping qualities than the other traditional dairy products. Several studies have been conducted on ghee and *dahi* by many investigators, and numerous claims have been made about their different nutritional and therapeutic values. Ghee is used as a cooking oil and for flavoring, especially in vegetarian cuisines. Fresh cheeses are added to vegetable curries or desserts, and are often mixed with sugar, milk, cardamom, and fruits for savory applications and desserts. In North India, yogurt and buttermilk are consumed as beverages. Yogurt provides consistency and flavor to Indian curries. Yogurt is also used in salads with cucumbers, onions, and tomatoes.

The gastrointestinal microflora in humans plays a key role in nutrition and health. A portion of the consumed food unabsorbed in the small intestine gets fermented in the large intestine. These foods, which are known as colonic foods, are metabolized through anaerobic fermentation by the gut microflora and the end products are usually short-chain fatty acids that are absorbed in the colon. Such foods are credited with protection from colon cancer, immune modulatory action, systemic effects on blood lipids, and a reduction of pathogens. Fermented milk products such as *dahi* are probiotics and are associated with positive effects such as reductions in cholesterol and triacylglycerols, protection against gastroenteritis, improved lactose intolerance, and stimulation of the immune system.

Dahi is traditionally consumed by Indians either as a part of their daily diet or as a refreshing beverage. It is characterized by its firm curd and delicate flavor. Investigations by various researchers have shown that regular consumption of *dahi* has many beneficial effects such as improvements in appetite and vitality, curing of dyspepsia, dysentery, and other intestinal disorders; removal of adverse effects of drugs, encouragement of thiamine synthesis, lowering the cholesterol level of blood, controlling cancer, easy digestion by lactose-intolerant persons, and so on. In addition, *dahi* has a high nutritive value due to the presence of all milk constituents and the various health-promoting lactic acid bacteria in it.

Dahi is considered as a functional food ingredient by virtue of its health-promoting probiotic effects. Probiotics fall within the realm of functional foods containing certain biologically active components that beneficially contribute to human health beyond basic nutrition. While earlier reports on the health-promoting effects of probiotics were largely limited to yogurt and other fermented dairy products containing *lactobacilli*, many reports since have shown that gut organisms such as bifidobacteria and other *lactobacilli* also beneficially affect the host through the development of resistance factors against diseases, the protective effect of the flora, and the production of microbial products. Several workers have corroborated the protective effect of gut flora and have shown that germ-free animals are more prone to diseases than
Q2 their peers carrying a complete gut flora (Pollman et al., 1980; Saavendra, 1995). The documented beneficial effects of probiotics include their use in the treatment of various kinds of diarrhea, the alleviation of the gastrointestinal side effects of antibiotic treatment, the alleviation of lactose intolerance, relief during constipation, and the general balancing and stabilizing of the host's intestinal microbial integrity.

Ghee constitutes an important part of Indian life. Ghee is chiefly used in India as a part of the diet and as a cooking medium. It is valued for its pleasant cooked, caramelized flavor and granular texture. Ghee is made up mainly of fat, which gives energy to the body and forms an integral part of the body's cells. It helps to maintain the body's temperature. Recent studies have indicated that milk fat contains some anticarcinogenic substances such as conjugated linoleic acid, butyric acid, and vitamins, among others. Formerly, intake of ghee was presumed as one of the causes for the high incidence of heart ailments. However, paradoxically, later it was found that consumption of ghee has a hypocholesterolemic effect. Moreover, in the indigenous Ayurvedic medical treatments ghee is used for heart patients. Ghee contains the fat-soluble vitamins A, D, E, and K. The Indian Ayurvedic medical literature mentions various types of medicated ghee that can be used for the treatment of many diseases such as asthma, antiaging, cough, dermatitis, digestive problems, heart, hysteria, leprosy, leucoderma, and piles. Medicated ghee is used for either internal or external applications. Sometimes, various herbs are used along with ghee to enhance its therapeutic efficiency.

3.4.3 Traditional Food Adjuncts from Legumes and Spices

Food adjuncts include an assortment of items that are consumed as side dishes to staple foods. They add variety, spice, and crunch to the common menu with standard items. Traditional Indian food adjuncts may broadly be classified as pickles, chutneys, preserves, and dried vegetable products such as *sandige* and dry semiprocessed adjuncts such as *papad* (which are consumed after frying) (Table 3.2). Although consumed in small portions, adjuncts play an important role in nutrition and health. The wide range of ingredients used in the various types of adjuncts makes it difficult to generalize their nutritional importance.

Pickles are a good source of vitamin C, in spite of the fact that part of it is lost during processing and storage. Pickles and chutneys provide other valuable nutrients such as minerals, carotenoids, isoflavones, and antioxidants. Pickles and chutneys may thus

TABLE 3.2
Common Indian Traditional Food Adjuncts

Food Adjunct	Ingredients	Description of Preparation
Papads	Pulse flours (black gram/green gram) Starchy materials (rice flour/wheat starch/sorghum/minor millets/sago) Salt, spices, leavening agent	Pulse flour is made into a dough with spices; small dough balls are rolled and dried Starchy flours are mixed with water to a slurry; allowed to ferment; cooked and spread as thin sheets. The cooked slurry may also be extruded to a noodle-like structure, dried, and stored. Papads may be roasted or fried prior to consumption
Wadis	Legumes (green gram/black gram/ Bengal gram) Rice, millets, vegetables (ash gourd, okhra, etc.)	Pulses are soaked and coarsely ground after draining excess water; mixed with shredded vegetables and allowed to ferment overnight; cooked and mixed with salt and spices; deposited as small masses or balls; dried. They are consumed after frying
Chutneys	Fruits, spices, jaggery, coconut, salt	The fruit pulp is mixed with jaggery, salt, spices, acidulants, and coconut, cooked to a viscous consistency, and seasoned
Dry *chutney* powders	Oil seeds (peanut, gingely, dry coconut) Legumes (Bengal gram/black gram) Salt, curry leaves, spices and condiments	Oil seeds and pulses are roasted and powdered with salt, spices, and condiments. Stable for 6 months. They are consumed as such or mixed with oil, and freshly cut vegetables
Pickles	Acidic fruits, salt, spices (especially chillies), condiments, optionally vegetable oil and vinegar	Acidic fruits are cut into small pieces; mixed with salt and spices fried in oil

extend the supply of nutrients from seasonal perishable items into the lean period. Mango pickle is the most widely consumed variety among pickles followed by lemon, emblica, swallow root, and mixed pickles. Chutneys usually accompany any traditional Indian meal. There are diverse varieties among chutneys; green chutneys are rich sources of nutraceuticals in the Indian meal. They can be served with assorted *parathas* to complement the nutritional requirement. Coriander chutney, mint chutney, and drumstick-curry leaf chutney are other chutneys whose ingredient herbs are good sources of vitamins and minerals. Chutneys generally contain pulses and oilseeds (e.g., black gram, chickpea, sesame seed, peanut, and coconut, among others) and are an excellent supplement to the cereal-based vegetarian staple diet by improving the protein quality. *Papads* are high-protein foods made from different pulses and certain cereals; they are flat, thin, round circular products that can be roasted or fried instantly. Legumes being the main ingredients, *papads* provide 7–15% protein. Legume-based *papad* and *wadi* add to the protein value of staple diet, and can act as a replacement for vegetables and legumes during the lean season. Fermentation in some *papad* and *wadi* products improves their digestibility and reduces antinutritional factors. Roasted *papad* is a healthy alternative to fried *papad*.

3.4.4 Indian Acidulant Fruits with Functional Properties (Figure 3.3)

Food acidulants such as lime, emblica, tamarind, kokum, and amchur are commonly used in traditional Indian culinary to impart a desirable sour taste to certain food preparations. Organic acids are known to promote the absorption of iron from plant foods (Gillooly et al., 1983). The food acidulants amchur and lime have been reported to significantly enhance the bioaccessibility (*in vitro* bioavailability) of zinc and iron from the food grains consumed in India (Hemalatha et al., 2005) and of β-carotene from green leafy or yellow-orange vegetables (Veda et al., 2008). This positive influence of food acidulants on the bioaccessibility of micronutrients from food grains or vegetables has been seen in both raw and cooked forms.

Emblica fruit (*Emblica officinalis*), commonly known as *amla* or Indian gooseberry, is one of the important subtropical fruits belonging to the family Euphorbaceae. Dried shreds of amla fruits are used as a food acidulant in Indian traditional foods. The fruits of *Emblica* are widely consumed raw, cooked, or pickled, but they are also principal constituents of many medicinal preparations in the indigenous system of

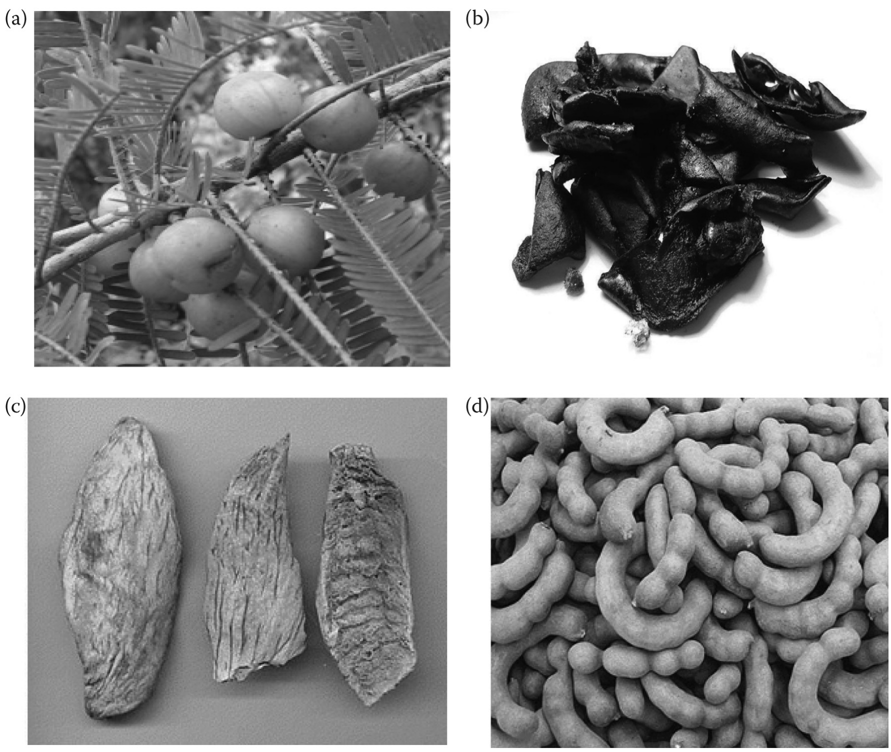

FIGURE 3.3 Food acidulants: (a) emblica fruit, (b) kokum, (c) amchur, and (d) tamarind.

medicine in India. Emblica occupies an important place in the preserve industry. Amla preserves, candy, squash, and burfi are some major traditional products of *amla*, which are widely used as health foods and as natural sources of vitamin C. Emblica fruits are highly nutritious and are very rich in vitamin C. These fruits have an ascorbic acid content of up to 950 mg/100 g, which is the second highest among all fruits, next only to Barbados cherry. The fruit contains considerable amounts of polyphenols that retard the oxidation of ascorbic acid. Emblica fruits are well known for their medicinal properties. These fruits, possessing rich antioxidant potency by virtue of both vitamin C and polyphenols, are used for curing chronic dysentery, bronchitis, diabetes, liver ailment, diarrhea, jaundice, and dyspepsia. Emblica fruits are valued highly among indigenous medicines in India and form the major ingredient in Ayurvedic preparations such as *Chavanprash* and *Trifala*.

Emblica fruit extract has been reported to have hypolipidemic, antidiabetic, and anti-inflammatory activity, and to inhibit retroviruses such as HIV-1, tumor development, and gastric ulcer (Sabu and Kuttan, 2002). Emblica fruit extract exhibits antioxidant properties, its aqueous extract being a potent inhibitor of lipid peroxidation and a scavenger of hydroxyl and superoxide radicals *in vitro* (Scartezzini and Speroni, 2000). Emblica fruit extract inhibits micronuclei formation, sister chromatid exchanges, clastogenesity, and mutagenesity induced by metals; it protects against radiations (Scartezzini and Speroni, 2000), inhibits clastogenesity of benzopyrene and cyclophosphamide (Sharma et al., 2000), and is gastroprotective (Al-Rehaily et al., 2002), cytoprotective, and immunomodulating (Sairam et al., 2002). Emblica fruits have been reported to protect against oxidative stress in ischemic reperfusion injury (Rajak et al., 2004), show antivenom capacity (Alam and Gomes, 2003), ameliorate hyperthyroidism and hepatic lipid peroxidation, display antiproliferative activity in breast cancer cell lines, show antitussive activity, and induce apoptosis in lymphoma ascites (Rajeshkumar et al., 2003).

The dried fruit rinds of kokum (*Garcinia indica*), commonly known as "Malabar tamarind," are liberally used in the coastal regions of India as a traditional food acidulant in culinary practices. The dark red fruit of *Garcinia indica* is valued for its nutritive value and outstanding medicinal properties. This fruit is known to reduce obesity and to beneficially regulate blood cholesterol levels. The antiobesity influence of kokum fruits is attributable to its organic acid constituent, hydroxycitric acid, present at a level of 22%. Hydroxycitric acid is a potent competitive inhibitor of ATP citrate lyase, the enzyme that catalyzes the cleavage of citrate to acetyl coenzyme A and oxaloacetate (Watson et al., 1969). As a consequence of this inhibition, a reduction in the rates of the *de novo* synthesis of fatty acids and cholesterol has been demonstrated in animal systems (Lowenstein, 1971; Sullivan et al., 1972). Kokum is also a source of pectin (6%) and fat (10%). Fresh fruits are cut into halves and the fleshy portion containing the seed is removed. The rind constitutes about 50–55% of the fruit and is generally sun-dried for future use. The kokum rind is used to make an attractive, red, pleasantly flavored extract for use as a beverage. Syrup from the fruit as traditionally prepared is popularly known as "Amrit kokum." Kokum seed is a good source of fat called "Kokum butter." The rind of fully ripe kokum contains 2–3% anthocyanin pigments and thus is a promising source of natural color.

Tamarind is the most common food acidulant used in southern India. The fruit rinds of tamarind (*Tamarindus indica*) have a fruity and sweet-and-sour taste and are used in sweetened drinks, curries, stews, or soups of South India. The food acidulants amchur and lime generally enhance the bioaccessibility of zinc and iron from the food grains (Hemalatha et al., 2005). This positive influence of acidulants on zinc bioaccessibility from food grains is seen in both the raw and cooked form. Tamarind is regarded as a refrigerant, digestive, carminative, and laxative. It is useful in diseases supposed to be caused by deranged bile (The Wealth of India, 1976). Tamarind has been shown to increase bile secretion with enhanced bile acid concentration (Sambaiah and Srinivasan, 1991).

3.4.5 Functional Oil Seeds

Vegetable oil is an important part of Indian culinary; mustard oil is most commonly used in northern India while sesame and coconut oils are used abundantly in the south. Most Indian curries are fried in vegetable oil. Sesame oil is an edible vegetable oil derived from sesame seeds. Besides being used as cooking oil in South India, it is often used as a flavor enhancer in Indian cuisine. Sesame seeds were one of the first crops processed for oil as well as one of the earliest condiments. Sesame oil is considered to be more stable than most vegetable oils due to the antioxidants contained in the oil. Sesame oil is least prone, among the cooking oils, to turn rancid. Because it has a very high boiling point, sesame oil retains its natural structure and does not break down even when heated to a very high temperature.

Sesame oil is a source of vitamin E, an antioxidant that protects low-density lipoproteins from oxidation. As with most plant-based condiments, sesame oil contains magnesium, copper, calcium, iron, zinc, and vitamin B_6. Copper provides relief for rheumatoid arthritis. Magnesium supports vascular and respiratory health. Calcium helps prevent colon cancer, osteoporosis, migraine, and postmenopausal syndrome. Zinc promotes bone health. It is suggested that due to the presence of high levels of polyunsaturated fatty acids in sesame oil, it may help to control blood pressure. Sesame oil is unique in that it has one of the highest concentrations of ω-6 fatty acids. At the same time, the oil contains two naturally occurring preservatives, sesamol and sesamin. The effect of this oil on blood pressure may be due to polyunsaturated fatty acids and the compound sesamin, a lignan present in sesame oil. There is evidence suggesting that both compounds reduce blood pressure in hypertensive rats and in humans (Matsumura et al., 1998; Miyawaki et al., 2009). Sesame lignans also inhibit the synthesis and absorption of cholesterol in these rats. Various constituents present in sesame oil have antioxidant and antidepressant properties. Hence its use may help fight senile changes and bring about a sense of well-being. It is suggested that regular topical application and/or consumption of sesame oil should mitigate the effects of anxiety, nerve and bone disorders, poor circulation, lowered immunity, and bowel problems. It is suggested that such use would also relieve lethargy, fatigue, and insomnia, while promoting strength and vitality, and enhancing blood circulation. There are claims that its use has relaxing properties, which eases pain and muscle spasm, such as sciatica, dysmenorrhea, colic, backache, and joint pain. There are claims similar to those for other therapeutic medicines that its having antioxidants explains the beliefs that it slows the aging process and promotes longevity. It is suggested that sesame oil could be used for the reduction of cholesterol levels (due to the presence of lignans, which are phytoestrogens), antibacterial effects, and even slowing down certain types of cancer (due to the antioxidant properties of the lignans).

Mustard seeds, a source of edible oil, are also a main ingredient of seasonings in Indian cuisine and a component of curry powders. Mustard possesses vermicidal, antihelminthic, and appetite-improving properties (Kirtikar and Basu, 1935). Mustard belongs to the cruciferous family, whose members include cabbage, broccoli, and cauliflower. All the above vegetable extracts have the property of inactivating the mutagenicity of food mutagens such as tryptophan pyrolysate. The active principle of mustard, namely dithiolthione, is also used as an antischistosomal drug. From epidemiological studies, it has been established that the regular consumption of cruciferous vegetables is associated with reduced cancer risk. Mustard seeds are rich in sulfur-containing compounds (dithiolthiones), which have a protective effect against liver toxicity induced by some chemicals and aflatoxins, potent toxic compounds present in fungal-contaminated peanuts. A concentration of 0.05% of dithiolthiones in the diet was found to stimulate the activity of protective enzymes. The mutagenic effects of mustard seed powder have been assessed in experimental animals treated with potent carcinogens. These experiments suggested that mustard, like turmeric, has excellent antimutagenic properties (NIN Annual Report, 1993–94).

3.4.6 Betel Leaves

Fresh green leaves of the betel vine (*Piper betle*), locally known as *paan*, are traditionally chewed, especially after meals, along with areca nut and lime, or with many other additional ingredients, mainly for mouth-freshening and digestive-stimulating effects. Betel leaf is aromatic and carminative. It is also an aphrodisiac and antiseptic. The habit of chewing betel leaves is claimed to be responsible for preventing osteoporosis among the economically weaker sections of the population in India.

3.4.7 Traditional Indian foods as Abundant Providers of Dietary Fiber

Traditional Indian cuisines are providers of liberal amounts of dietary fiber due to the extensive use of whole grains, vegetables, and fruits. For example, ash gourd fiber has a soluble fiber content of 22% while radish fiber has 16% and pea peels have 8–10%, with a total dietary fiber of 65–80%. Dietary fiber comprises a diverse group of compounds: insoluble cellulose, hemicelluloses, and lignins, and soluble gums and mucilages. These substances are exceedingly complex both chemically and morphologically and are resistant to hydrolysis by digestive enzymes in the human gut. The physiological roles of fiber in the diet are (1) filling the diet without adding calories, (2) increasing intestinal motility, (3) helping to reduce obesity, (4) preventing the absorption of cholesterol, (5) reducing the postprandial rise in blood glucose, (6) preventing diverticular diseases, and (7) softening of stools through absorption of water (preventing hemorrhoids) and promoting the growth of bifidobacteria in the gut.

A considerable body of evidence is available to show that dietary fiber improves glucose tolerance; soluble fiber has been especially effective in retarding postprandial glucose uptake in the intestine, thus reducing the insulin requirement. Soluble fiber has also been shown to enhance insulin receptor binding and improve glycemic response (i.e., increasing peripheral tissue insulin sensitivity). Ingestion of fiber suppresses energy intake by inducing satiety (by virtue of their bulking and viscosity-producing capabilities). Dietary fiber that forms viscous dispersions when hydrated affects every aspect of gastrointestinal function, gastric emptying, intestinal transit time, and absorption of digested products of fat and carbohydrates. Increased fecal bulk from dietary fiber is mainly due to the insoluble fiber fraction (cellulose, hemicellulose, and lignins), increased fecal water, and an increase in bacterial mass caused by soluble fiber (gums, mucilages, and pectins) fermentation. Dietary fiber has been shown to protect against colon cancer. Carcinogenic substances, either ingested as such or more likely produced by metabolic activation in the gut, are thought to induce malignant changes in mucosal cells. The protective effect of dietary fiber is thought to be due to its ability to increase stool bulk (dilution of toxic substances), increased transit duration (decreasing exposure duration), and altered fecal bacterial flora.

3.4.8 Traditional Indian Foods as Providers of Polyphenols

Traditional Indian cuisines also provide liberal amounts of polyphenols due to the extensive use of vegetables and fruits. Phenolic compounds are plant secondary metabolites, with a large variety of chemical structure. Phenols occurring in nature are of interest for many reasons, such as antioxidants, astringents, bitterness, browning reactions, color, and oxidation substrates, among others. They include simple phenols, hydroxycinnamates, and flavonoids. Phenols are responsible for the majority of the oxygen-utilizing capacity in most plant-derived products. With the exception of carotenes, the antioxidants in foods are phenolic compounds. Among those added to prevent oxidative rancidity in fats are the monophenols. Phenolic compounds have a wide range of biological properties. Of particular note are their antiplatelet aggregation property, anti-inflammatory potential, and antioxidant, antitumoral, and estrogenic activities, and hence they can potentially prevent coronary heart disease and cancer. Flavonoids are polyphenolic compounds that include flavonols, flavones, isoflavones, and anthocyanins, which have been suggested to play a dominant role in the prevention of cancer and heart diseases. Over 4000 flavonoids have been identified, many of which occur in fruits, vegetables, and beverages (tea, coffee, beer, wine, and fruit drinks). Epidemiological data indicate that high fruit and vegetable consumption has health benefits in the prevention of chronic diseases, including cardiovascular disease and certain types of cancer. Phytic acid present in legumes, oil seeds, and cereal bran is known to reduce blood glucose response to starchy foods. It is also known to lower blood cholesterol.

3.5 SPICES AS FUNCTIONAL FOOD ADJUNCTS WITH MULTIPLE HEALTH EFFECTS

Spices, which are used to enhance the flavor of a dish, form a vital part of Indian traditional food preparation. A correct blend of aromatic spices is crucial to every Indian cuisine. The most commonly used spices in Indian cuisine are black pepper,

FIGURE 3.4 Spices as components of *masala* powders (spice mixes).

chilli pepper, mustard seed, cumin, turmeric, fenugreek seed, ginger, coriander, asafetida, curry leaves, and garlic (Figure 3.4). Popular spice mixes are *garam masala* (which is usually a powder of five or more dried spices, commonly comprised of cardamom, cinnamon, and clove) and *sambar* masala powder (a popular spice mix in South India). The common use of curry leaves is typical of all Indian cuisine. In sweet dishes, cardamom, nutmeg, and saffron are used. The essential oils from spices and condiments enhance salivation and stimulate the digestion process. The abundance and variety of Asian spices and other flavorings creates a fresh taste found in no other cuisine. Spices in Indian cuisines create hot, sweet, sour, savory, and aromatic sensations all in one meal. Ginger, cumin, cassia, coriander, star anise, chilli peppers, coriander leaf, spearmint, turmeric, clove, and garlic are commonly used in Indian cooking. A few spices are pickled when fresh, such as ginger, mango ginger, and chilli peppers. Seasonings are a must for flavoring foods in India. Spice ingredients such as garlic, ginger, turmeric, chilli, and fenugreek seeds are known to contain functional constituents such as curcumin, capsaicin, flavonoids, and essential oils.

Besides contributing flavor, color, and aroma to the diet, spices have also long been recognized to possess physiological effects supposed to be beneficial to human health. They act as stimuli to the digestive system and relieve digestive disorders, and some are of antiseptic value. Their attributes such as tonic, carminative, stomachic, diuretic, and antispasmodic, largely empirical nevertheless efficacious, have earned them pharmacological applications in the indigenous systems of medicine in India and other countries (Table 3.3). With a long history of the use of spices and herbs dating back to 5000 years BC, and spices significantly contributing to human health by providing bioactives, they may be considered as one of the first

TABLE 3.3
Medicinal Properties of Spice Ingredients Recognized for a Long Time

Spice	Medicinal Properties
Turmeric (*Curcuma longa*)	Anti-inflammatory, diuretic, laxative, good for affections of the liver, jaundice, diseases of blood
Red pepper (*Capsicum annuum*)	Anti-inflammatory, for pain relief (rheumatism/neuralgia); useful in indigestion, rubefacient
Garlic (*Allium sativum*)	Antidyspeptic, antiflatulent, for ear infection, duodenal ulcers, as rubefacient in skin diseases
Onion (*Allium cepa*)	Diuretic, emmenagogue, expectorant, for bleeding piles
Fenugreek (*Trigonella Foenum-graecum*)	Diuretic, emmenagogue, emollient, useful in heart diseases
Cumin (*Cuminum cyminum*)	Antispasmodic, carminative, digestive stimulant
Coriander (*Coriandrum sativum*)	Antidyspeptic

ever recorded functional foods. Spices may also act synergistically to enhance the health-related properties of other food ingredients. Spices make foods palatable without salt, and hence may assist in meeting the recommended reduced daily intake of sodium. Similarly, they make foods palatable without fat, thus assisting in meeting the guidelines for healthy fat intake levels. During the last three decades, the beneficial effects of spices have been experimentally documented, which suggests that the use of these food adjuncts extends beyond taste and flavor (Srinivasan, 2005a, 2005b). The emerging research literature suggests that specific spices may confer unique health benefits. Although human studies are limited, considerable attention to this has been drawn because of the positive results from *in vitro* and *in vivo* animal studies.

3.5.1 Digestive Stimulant Action

The digestive stimulant action of spices is probably the most common experience. Several spices such as ginger, mint, ajowan, cumin, fennel, coriander, and garlic are common remedies used in traditional medicines or ingredients of pharmacological preparations to cure digestive disorders. The mechanism for the digestive stimulant action of spices has recently been understood through extensive animal studies (Platel and Srinivasan, 2004) (Figure 3.5). It has been shown that many commonly consumed spices (curcumin, capsaicin, ginger, fenugreek, mustard, cumin, coriander, ajowan, tamarind, and onion) stimulate bile acid production by the liver and its secretion into the bile (Sambaiah and Srinivasan, 1991; Platel and Srinivasan, 2000a). Bile acids play a major role in fat digestion and absorption. Several spices have also been shown to stimulate the activity of digestive enzymes from the pancreas, particularly lipase, and the terminal digestive enzymes from the small intestinal mucosa (Platel and Srinivasan, 1996, 2000b, 2001a). As a result of increased digestive capability, the spice-fed animals showed a reduced food transit time (Platel and Srinivasan, 2001b).

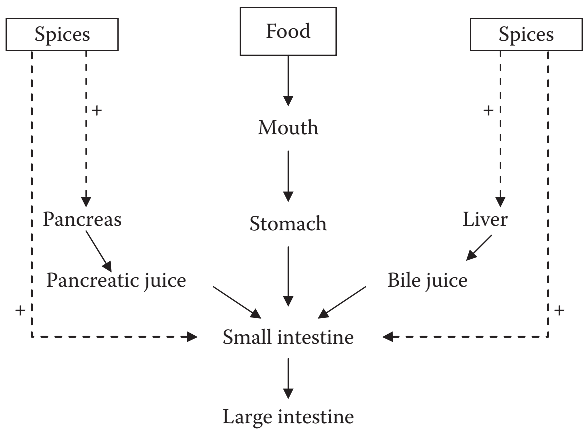

FIGURE 3.5 Digestive stimulant action of spice ingredients.

3.5.2 Antidiabetic Potential

Diet has been recognized as a corner stone in the management of diabetes mellitus. Among spices, the natural food adjuncts that have been evaluated in this context, fenugreek seeds, garlic and onion, and their sulfur compounds, turmeric and its yellow principle, curcumin, have been found to be effective in improving the glycemic status and glucose tolerance in diabetic animals and type 2 diabetic patients (Srinivasan, 2005c). Animal studies and clinical trials on antidiabetic properties of fenugreek and onion have been particularly extensive, while human studies are limited in the case of garlic and turmeric. Studies have unequivocally demonstrated the antidiabetic potential of fenugreek in both type 1 and type 2 diabetes. The addition of fenugreek seeds to the diets of diabetic patients or animals resulted in a fall in blood glucose and improvement in glucose tolerance (Sharma, 1986a, 1986b; Sharma **Q3** et al., 1996; Srinivasan, 2005c). The hypoglycemic effect is attributed to the fiber and gum, which constitute as much as 52% of the seeds. The fiber-rich fenugreek is believed to delay gastric emptying by direct interference with glucose absorption.

Garlic and onion are two other spices that have been widely tested for their antidiabetic potential. Both these spices have been shown to be hypoglycemic in different diabetic animal models and in limited human trials (Srinivasan, 2005c). The hypoglycemic potencies of garlic and onion are attributed to the disulfide compounds present in them, di(2-propenyl) disulfide and 2-propenylpropyl disulfide, respectively, which cause direct or indirect stimulation of insulin secretion by the pancreas (Kumudkumari et al., 1995; Augusti and Sheela, 1996). In addition, they may also have insulin-sparing action by protecting against sulfhydryl inactivation by reacting with endogenous thiol-containing molecules such as cysteine, glutathione, and serum albumin. Nephropathy is a common complication in chronic diabetes.

Turmeric is another spice that is claimed to possess beneficial hypoglycemic effects and to improve glucose tolerance in a limited number of studies (Tank et al., 1990). Nephropathy is a common complication in chronic diabetes. High blood cholesterol is an added risk factor that determines the rate of decline of kidney function in a diabetic situation. Dietary curcumin (of turmeric) and onion have been found to have a promising ameliorating influence on the severity of renal lesions in streptozotocin diabetic rats (Babu and Srinivasan, 1998, 1999). The hypocholesterolemic effect of these spices as well as their ability to lower lipid peroxidation under diabetic conditions is implicated in the amelioration of renal lesions. Capsaicin, the pungent principle of red pepper, has been shown to be useful in diabetic neuropathy (The Capsaicin Study Group, 1992).

3.5.3 Cardioprotective Effect

Specific spices exert cardioprotective influence through one or more of the following attributes: (1) hypolipidemic influence, (2) antithrombotic properties, (3) suppression of LDL oxidation, and (4) thermogenic influence (Srinivasan, 2008).

3.5.3.1 Hypolipidemic Influence

The importance of high blood cholesterol levels in relation to atherosclerosis and coronary heart disease is well known. Several spices consumed in India have been evaluated for their possible cholesterol-lowering effect in a variety of experimental situations with both animals and humans (Srinivasan et al., 2004). Garlic, onion, fenugreek, turmeric, and red pepper are found to be effective as hypocholesterolemic agents under various conditions of experimentally induced hypercholesterolemia or hyperlipidemia. Garlic, fenugreek, and onion are effective in humans with hyperlipidemic condition.

The consumption of garlic or garlic oil has been associated with a reduction in total cholesterol, low-density lipoprotein cholesterol, and triacylglycerol levels. There have been more than 25 clinical research publications concerning garlic and its preparations (Kleijnen et al., 1989). With the introduction of dehydrated garlic powder containing a standardized level of the parent sulfur compound alliin, effective clinical work could be undertaken with a relatively low and acceptable daily dosage of 300–900 mg (equivalent to 1 clove of garlic). Many clinical studies have indicated that consuming one clove of garlic (or equivalent) daily will have a cholesterol-lowering effect of up to 10% (Warshafsky et al., 1993; Gore and Dalen, 1994). This is consistent with a recent trial involving 780 patients taking 600–900 mg standardized garlic extract per day as a supplement that evidenced a modest 0.41 mmol/L decrease in serum cholesterol (Stevinson et al., 2000). Dietary supplementation with aged garlic extract showed better beneficial effects than fresh garlic on the lipid profile and blood pressure of moderately hypercholesterolemic subjects (Steiner et al., 1996). While garlic supplementation significantly decreased both total and LDL-cholesterol in hypercholesterolemic subjects, coadministration of garlic with fish oil had a more beneficial effect on serum lipid and lipoprotein concentrations by providing a combined lowering of total cholesterol, LDL-cholesterol, and triacylglycerol concentration as well as on the ratios of total cholesterol to HDL-cholesterol and LDL-cholesterol to HDL-cholesterol (Adler and Holub, 1997).

Fenugreek seeds were hypocholesterolemic in rats with hyperlipidemia induced by either high fat (Singhal et al., 1982) or a high cholesterol diet (Sharma, 1984, 1986). Defatted fenugreek seed was effective in treating diabetic hypercholesterolemia in dogs (Valette et al., 1984) and in humans (Sharma, 1986a, 1986b). The hypolipidemic effectiveness of turmeric and curcumin (Srimal, 1997), red pepper, and capsaicin (Suzuki and Iwai, 1984; Govindarajan and Satyanarayana, 1991; Surh and Lee, 1995) and of onion and garlic (Fenwick and Hanley, 1985; Carson, 1987; Jain and Apitz-Castro, 1994) has been periodically reviewed in recent years by different authors. The spice compounds curcumin and capsaicin have been associated with a reduction in LDL-cholesterol and an increase in HDL-cholesterol levels, but these results have been limited to animal studies.

3.5.3.2 Antithrombotic Properties

Besides the beneficial effect on serum lipid profiles (lowering of LDL-cholesterol and triglyceride levels), the antiplatelet aggregation and antiplatelet adhesion properties of several spices also contribute to cardiovascular protection. The spices or spice compounds thus far documented that have inhibitory effects on platelet aggregation are garlic, onion, curcumin, cuminaldehyde, eugenol, and zingerone. Garlic in particular exhibits antithrombotic and hypotensive properties, both of which also contribute to cardiovascular protection in addition to their hypolipidemic properties. Aged garlic extract (7.2 g) has been associated with anticlotting as well as modest reductions in blood pressure (an approximately 5.5% decrease in systolic blood pressure) (National Centre of Excellence, 2006). According to Lin (1994), the antiplatelet aggregation, antiplatelet adhesion, and antiproliferation properties of aged garlic extracts appear to contribute more to cardiovascular protection than the hypolipidemic properties.

3.5.3.3 Suppression of LDL Oxidation

The antioxidant properties of spices are of particular interest in view of the impact of oxidative modification of low-density lipoprotein (LDL)-cholesterol in the development of atherosclerosis. In recent years, a substantial body of evidence has indicated that free radicals contribute to cardiovascular disease. Oxidative modification of LDL is hypothesized to play a key role during the development of atherosclerosis. Since spices have high antioxidant concentrations that have the potential to inhibit the oxidation of LDL, the use of antioxidant spices is a promising proposition.

3.5.3.4 Thermogenic Influence

Obesity-related insulin resistance has emerged as a potent risk factor for cardiovascular disease. Dietary factors that affect satiety and thermogenesis could play an important role in determining the prevalence and severity of this problem. Among spices that may have a role to play in this regard, red pepper (or its pungent principle capsaicin) (Kawada et al., 1986) and garlic are promising, although more data are required to substantiate the benefits. The use of spices to displace fats and salt in the diet may reduce cardiovascular risk.

3.5.4 Antilithogenic Effect

A persistent lithogenic diet leads to cholesterol saturation in the bile, resulting in the formation of cholesterol crystals, that is, gallstones, in the gall bladder. The inhibitory effect of a curcuma mixture (Temoe Lawak Singer) on lithogenesis in rabbits has been reported (Beynen et al., 1987). Studies on the experimental induction of cholesterol gallstones in mice and hamsters by feeding a lithogenic diet have revealed that the incidence of gallstones is 40–50% lower when the animals are maintained on 0.5% curcumin or 0.015% capsaicin-containing diets (Hussain and Chandrasekhara, 1992, 1993). Animal studies have also revealed significant regression of preformed cholesterol gallstones by these spice principles in a 10-week feeding trial (Hussain and Chandrasekhara, 1994a). The antilithogenic potential of other known hypocholesterolemic spices (garlic, onion, and fenugreek seeds) has also been recently demonstrated in animal studies (Reddy and Srinivasan, 2009a, 2009b; Vidyashankar et al., 2009a, 2009b). The antilithogenicity of these spices is considered to be due to the lowering of cholesterol concentration and the enhancing of bile acid concentration, both of which contribute to lowering of the cholesterol saturation index and hence its crystallization. In addition to their ability to lower the cholesterol saturation index, the antilithogenecity of these spice principles may also be due to their influence on biliary proteins (Hussain and Chandrasekhara, 1994b).

3.5.5 Anti-Inflammatory Properties

Turmeric happens to be the earliest anti-inflammatory drug known in the indigenous system of medicine in India. Turmeric extract, curcuminoids, and volatile oil of turmeric have been found to be effective as anti-inflammatories in several studies involving mice, rats, rabbits, and pigeons. The efficacy of curcuminoids was also established in carrageenan-induced foot paw edema in mice and rats, and in cotton pellet granuloma pouch tests in rats (Srimal, 1997). Curcumin was considered to be advantageous over aspirin because it selectively inhibits the synthesis of the anti-inflammatory prostaglandin T_xA_2 without affecting the synthesis of the prostacyclin (PgI_2), which is an important factor preventing vascular thrombosis (Srivastava, 1986). Both *in vitro* and *in vivo* animal studies have documented the anti-inflammatory potential of the spice principles curcumin (of turmeric), capsaicin (of red pepper), and eugenol (of clove). Animal studies have revealed that curcumin and capsaicin also lower the incidence and severity of arthritis and delay the onset of adjuvant-induced arthritis. These spice principles also inhibited the formation of arachidonate metabolites (PgE_2, leukotrienes).

The anti-inflammatory effects of curcumin (400 mg) in patients undergoing surgery for hernia or hydrocele were found to be comparable to those of phenylbutazone (100 mg) (Satoskar et al., 1986). In rheumatoid arthritis patients, administration of curcumin (1.2 g/day) produced a significant improvement similar to phenylbutazone (Deodhar et al., 1980). Recently, capsaicin has received considerable attention as a pain reliever. In two trials with 70 and 21 patients with osteoarthritis and rheumatoid arthritis, topical application of creams containing 0.025% or 0.075% capsaicin was an effective and safe alternative to analgesics employed in systemic medications, which are often associated with potential side effects (Deal, 1991; McCarthy and McCarthy, 1991). Capsaicin has been suggested for the initial management of neuralgia consequent to herpes infections (Bernstein, 1989). There is also evidence for the benefit of ginger in ameliorating arthritic knee pain, although the effectiveness is lesser than that of ibuprofen. Ginger doses of 0.5–1.0 g per day have been found to be efficacious in osteoarthritis and rheumatoid arthritis. Experimental studies have shown that ginger constituents inhibit arachidonic acid metabolism, which is involved in the inflammation process (a key pathway in inflammation).

Natural anti-inflammatory compounds of spices (curcumin, capsaicin, gingerol) appear to operate by inhibiting one or more of the steps linking proinflammatory stimuli with cyclooxygenase activation, such as the blocking by curcumin of NFκB translocation into the nucleus. It has recently been shown that the natural anti-inflammatory compounds such as curcumin were as effective as indomethacin (a nonsteroidal anti-inflammatory drug) in inhibiting aberrant crypt foci in the rat.

3.5.6 Antimutagenicity and Anticancer Effects

Considerable attention has currently been paid to identifying naturally occurring chemopreventive substances capable of inhibiting, retarding, or reversing multistage carcinogenesis. A wide array of phenolic substances, some of those present in spices, have been reported to possess substantial anticarcinogenic activities (Milner, 1994; Coney et al., 1997; Guhr and LaChance, 1997). The majority of these naturally occurring phenolics possess antioxidative and anti-inflammatory properties, which appear to contribute to their chemopreventive or chemoprotective activity (Surh, 2002).

There are a number of *in vitro* and *in vivo* studies on rodents suggesting that spices may have a chemopreventive effect against the early initiating stages of cancer. Spices may act through several mechanisms to provide protection against cancer (Figure 3.6). Certain phytochemicals from spices have been shown to inhibit one or

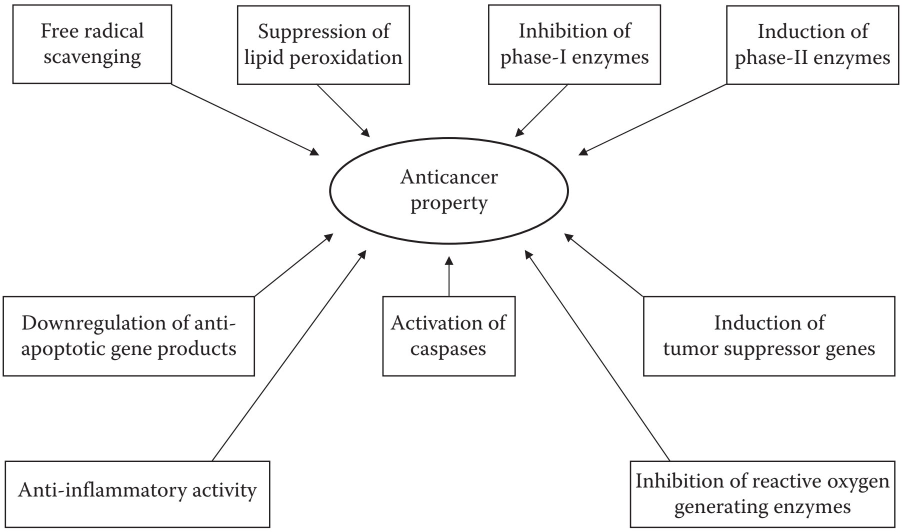

FIGURE 3.6 Mechanism of the anti-initiation, antipromotion, antiprogression, and antimetastasis potential of cancer-preventive spice ingredients.

more of the stages of the cancer process (initiation, promotion, growth, and metastasis). Inhibition of phase I metabolic enzymes (involved in procarcinogen activation) and induction of phase II metabolic enzymes (involved in carcinogen deactivation) may account for the chemopreventive effects of spices. Spices may also protect against oxidative stress and inflammation, both of which are risk factors for cancer initiation and promotion (as well as other pathological conditions). Spices contain several natural lipid-soluble antioxidant biomolecules that may protect against the generation of genotoxic lipid peroxidation products.

Spices that have antioxidant properties can function as antimutagens. Since mutagenesis has a direct bearing on cancer initiation, antimutagenic spices can probably be anticarcinogenic. Turmeric or its bioactive compound curcumin, and garlic or its sulfur compounds have been shown to be antimutagenic in several experimental systems. Turmeric and curcumin were effective against benzo(α)pyrene and dimethyl benzanthracene in the Ames test (Nagabushan and Bhide, 1986). *In vivo* studies on experimental animals suggest that turmeric and curcumin inhibit the formation of mutagens. Mice and rats maintained on turmeric or curcumin-containing diet excreted lower levels of mutagenic metabolites as well as of carcinogens than the controls (Usha, 1994; Polasa et al., 1991). Turmeric and curcumin also inhibited the mutagenicity of cigarette and beedi smoke condensates as well as that of a tobacco-based dentifrice (Nagabushan et al., 1987). Further, curcumin was found to inhibit nitrosation of methylurea *in vitro* (Nagabushan et al., 1988). Studies on smokers revealed that administration of curcumin (1.5 g/day) for 30 days resulted in a significant reduction in the urinary excretion of mutagens (Polasa et al., 1992). Turmeric protected DNA against lipid peroxide-induced damage and against fuel smoke
Q4 condensate-induced damage (Shalini and Srinivas, 1990). Eugenol (the flavour constituent of cloves) and mustard seeds (that contain dithiolthione) also produced antimutagenic effects by protecting the cells from damage to their DNA (NIN Annual Report, 1993–94). Dithiolthiones have been documented to have protective effects against liver toxicity induced by some chemicals and fungal aflatoxin (Ansher et al., 1986).

Spices (or their extracts and constituents) with known anticarcinogenic effects in animal models of cancer include turmeric, garlic, and ginger. Turmeric has been found to have chemopreventive effects against cancers of the skin, forestomach, liver, and colon, and oral cancer in mice. The anticancer potential of curcumin as evidenced by both preclinical and clinical studies has been exhaustively reviewed (Aggarwal et al., 2003). Animal studies involving experimental induction of tumors in specific tissues with potent carcinogens (such as benz(α)pyrene, 7,12-dimethylbenzanthracene, 3-methylcholanthrene, 12-*O*-tetradecanoylphorbol-13-acetate, and 1,2-dimethylhydrazine) have revealed significant reductions in the incidence of tumors by curcumin treatment. Several studies indicate that curcumin can suppress both tumor initiation and tumor promotion. Some of these studies, especially studies of skin tumorigenesis, have also employed topical application of curcumin (Aggarwal et al., 2003). It has been shown that the inhibition of arachidonic acid metabolism, modulation of cellular signal transduction pathways, and inhibition of hormones, growth factor, and oncogene activity are some of the mechanisms by which curcumin causes tumor suppression (Gescher et al., 1998). Chemopreventive activity of curcumin is observed when administered prior to, during, and after carcinogen treatment as well as when it is given only during the promotion or progression phase of colon carcinogenesis in rats (Kawamori et al., 1999). Curcumin is a powerful inhibitor of the proliferation of several tumor cells (Chuang et al., 2000a, 2000b; Dorai et al., 2001). With much evidence suggesting that curcumin can suppress tumor initiation, promotion, and metastasis, and with proven safety of its consumption (up to 10 g/day), curcumin offers enormous potential in the prevention and therapy of cancer (Aggarwal et al., 2003).

The cancer-preventive ability of garlic has been indicated by etiological studies wherein higher intakes of *Allium* products are associated with reduced risks of several types of cancer, especially stomach and colorectal (Fleischauer and Arab, 2001). Garlic is effective in the detoxification of carcinogens through its effects on phase I and phase II enzymes. The diallyl disulfide of garlic is an efficient inhibitor of the phase I enzyme cytochrome P-450 and significantly enhances a variety of phase II enzymes, including glutathione-*S*-transferase, quinone reductase, and UDP-glucuronyl transferase, which are responsible for the detoxification of carcinogens. Several mechanisms have been proposed to explain the cancer-preventive effects of garlic and its organosulfur compounds, as has been recently reviewed (Sengupta et al., 2004). These include inhibition of mutagenesis, modulation of enzyme activities thus suppressing bioactivation of carcinogen molecules, inhibition of carcinogen–DNA adduct formation, free radical scavenging, inhibitory effects on cell proliferation and tumor growth, and induction of apoptosis.

Pungent vanilloids, especially [6]-gingerol present in ginger (*Zingiber officinale*), have been found to possess potential chemopreventive activities. Prior topical applications of [6]-gingerol significantly suppressed the tumor promoter (phorbol ester)-stimulated skin inflammation initiated by 7,12-dimethylbenz [α] anthracene in mice (Surh et al., 1999). Reactive nitrogen species (RNS) such as nitric oxide (NO) have been proposed as being able to influence signal transduction and cause DNA damage, contributing to the carcinogenic processes. The pungent phenolic compound [6]-gingerol present in ginger has been shown to be a potent inhibitor of NO synthesis and also an effective protector against peroxynitrite-mediated damage in macrophages (Ippoushi et al., 2003). Dietary ginger constituents, galanals A and B, are potent apoptosis inducers in human T lymphoma cells (Miyoshi et al., 2003). **Q4**
Myristicin, a major volatile constituent of parsley, has been shown to strongly induce GSH-transferase in the liver and small intestinal mucosa of mice. This compound has been shown to lead to a 65% inhibition of tumor multiplicity in a rodent lung cancer model (Zheng et al., 1992a, 1992b). **Q5**

3.5.7 Antioxidant Activity

The generation of reactive oxygen species and other free radicals during metabolism is a normal process that is ideally compensated for by an elaborate endogenous antioxidant defense system. Excessive free radical generation overbalancing the rate of their removal leads to oxidative stress. Oxidative damage has been implicated in the etiology of disease processes such as cardiovascular disease, inflammatory disease, cancer, neurodegenerative disease, and other degenerative diseases. Antioxidants are compounds that hinder the oxidative processes and thereby delay or suppress oxidative stress. There is a growing interest in the natural antioxidants found in herbs and spices. The bioactive compounds present in spices that possess potent antiatherogenic, anti-inflammatory, antimutagenic, and cancer-preventive activities are in fact antioxidants that have been experimentally shown to control cellular oxidative stress and thereby exert a beneficial role in preventing oxidative stress-mediated diseases.

Most of the health effects of spices on cancer, cardiovascular disease, inflammatory disease, and neurodegenerative disease may be mediated through their potent antioxidant effects. The antioxidant properties of spices are of particular interest in view of the impact of oxidative modifications of low-density lipoprotein cholesterol in the development of atherosclerosis. Suppression of oxidative stress and inflammation by spices is important in their cancer-preventive role, since both oxidative stress and inflammation are risk factors for cancer initiation and promotion (as well as other pathological conditions). Spices contain several natural antioxidant biomolecules: either water-soluble that can scavenge reactive oxygen species or lipid-soluble that may protect against the generation of genotoxic lipid peroxidation peroxides.

The antioxidative effects of curcumin, eugenol, capsaicin, piperine, gingerol, garlic, onion, and fenugreek have been experimentally evidenced (Srinivasan, 2009). The studies on this effect are exhaustive and experimental evidences are many in the case of curcumin of turmeric and eugenol of clove. Studies with several *in vitro* systems as well as *in vivo* animal studies have shown that the spice principles curcumin, eugenol, and capsaicin have beneficial antioxidant properties by quenching oxygen free radicals, by inhibiting the production of reactive oxygen radicals, and by enhancing antioxidant enzyme activities.

The antioxidant activities of spice compounds in mammalian systems involve one or more of the following: (1) free radical scavenging, (2) suppressing lipid peroxidation, (3) enhancing antioxidant molecules in tissues, (4) stimulating the activities of endogenous antioxidant enzymes, (5) inhibiting the activity of inducible nitric oxide synthase, (6) inhibiting LDL oxidation, and (6) inhibiting enzymes of arachidonate metabolism—5-lipoxygenase and 2-cyclooxygenase. By virtue of its antioxidant activity, curcumin has been documented to be anti-inflammatory, antimutagenic and cancer preventive, antiatherogenic and cardioprotective, hepatoprotective, neuroprotective, anticataractogenic, and an effective wound healant (Figure 3.7).

Thus, the multiple health beneficial attributes of these common food adjuncts include digestive stimulant action, cardioprotective potential, antilithogenic properties, protective effect on erythrocyte integrity, antidiabetic influence, anti-inflammatory properties, and cancer-preventive potential (Figure 3.8). The antioxidant and hypolipidemic properties of spices have far-reaching nutraceutical values. The antioxidant properties of the bioactive compounds present in spices are of particular interest in view of the impact of suppression of oxidative stress in the development of degenerative diseases such as cardiovascular disease, neurodegenerative disease, inflammatory disease, and cancer. In addition, by making the food attractive and palatable through flavor, aroma, and color, spices can reduce the need to use other less healthy ingredients such as salt, fat, or sugar. Spices thus deserve to be considered as a natural and necessary component of our daily nutrition, beyond their role in imparting taste and flavor to our food. It is presumed that the additive and

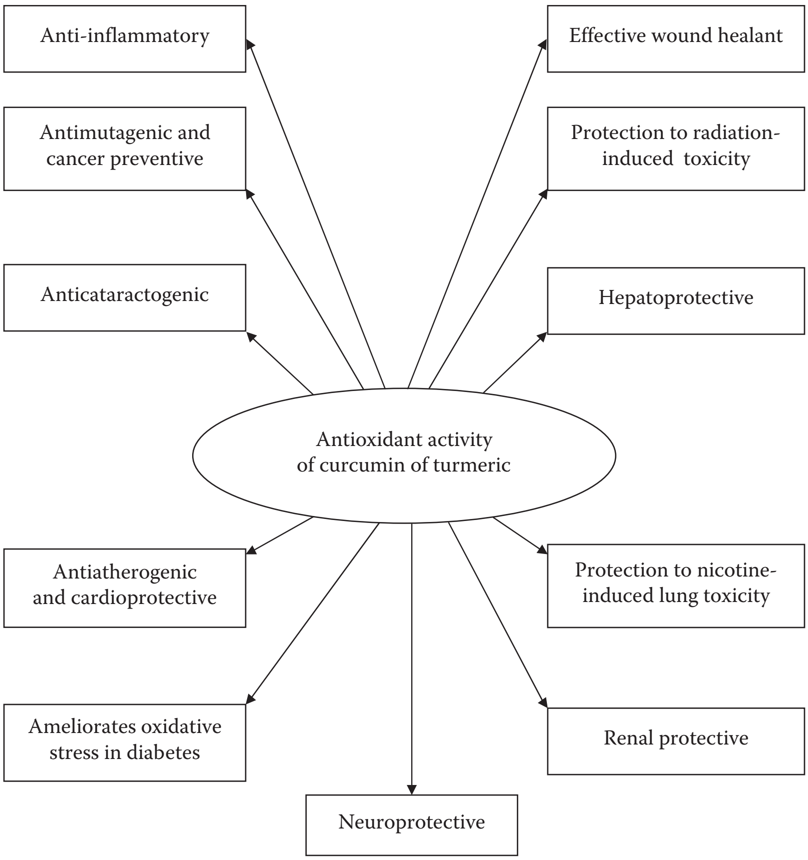

FIGURE 3.7 Health implications of the antioxidant property of spice ingredients.

synergistic effects of the complex mixture of phytochemicals present in vegetables, fruits, herbs, and spices are largely responsible for the health effects offered by those traditional Indian diets that are generally associated with lower incidence rates of some of the chronic diseases of aging, including cardiovascular disease and certain forms of cancer. The liberal consumption of spices is proved to be safe to derive their beneficial effects. Since each of the spices possesses more than one health beneficial property and there is also a possibility of synergy among them in their action when consumed in combination, a spiced diet is likely to make life not only more "spicy" but also more healthy.

3.6 SUMMARY

There is an abundance of scientific evidence which indicates that certain naturally occurring nonnutritive and some nutritive substances of spices, whole grain cereals and legumes, vegetables, fruits, sprouted grains, fermented grain products, and fermented milk products may prevent or reduce the risk of some chronic diseases

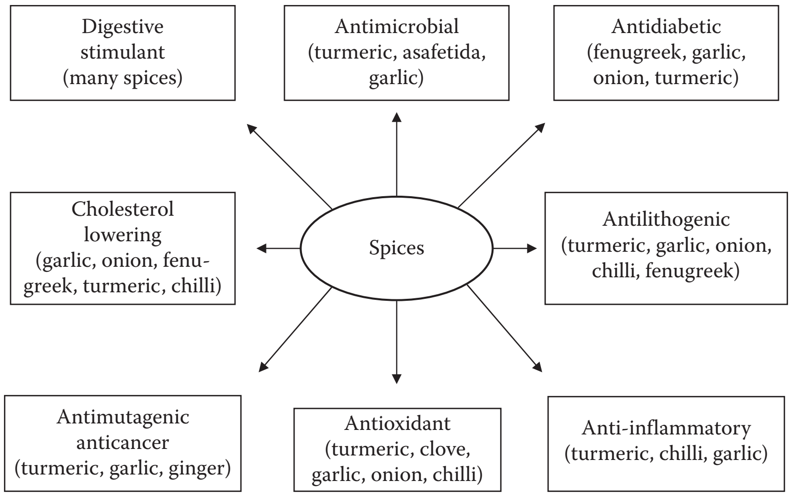

FIGURE 3.8 Summary of the multiple health effects of spices that are widely used in Indian traditional foods.

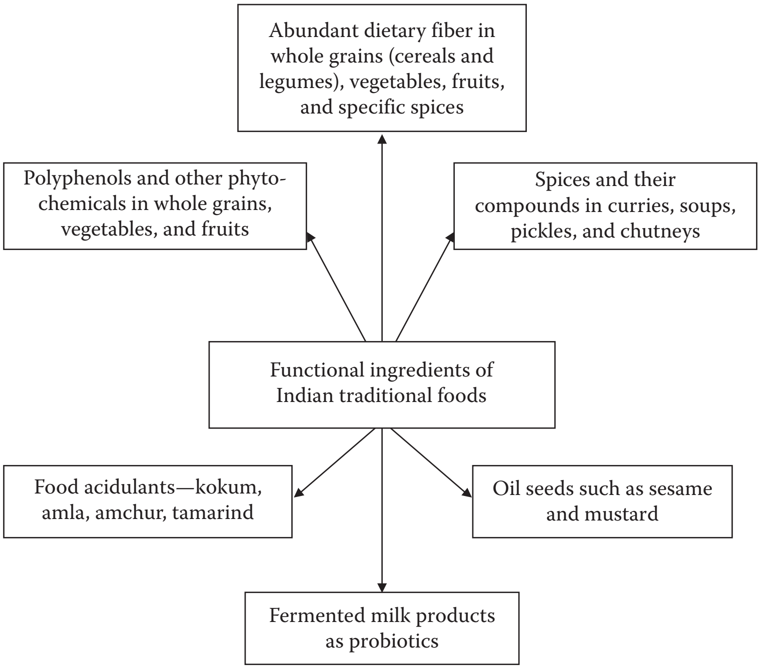

FIGURE 3.9 Functional ingredients of Indian traditional foods.

such as various cancers and cardiovascular disease. The health benefits of Indian heritage foods containing liberal quantities of these components may range from ensuring normal physiological functions in the body such as improving gastrointestinal health, enhancing the immune system, weight management, providing better skeletal health, and so on, to reduction of blood cholesterol, reduction of oxidative stress, reducing the risk of cardiovascular diseases, inflammatory diseases, and various types of cancers, and possible prevention of diabetes, neurodegenerative diseases, and so on. A perfect combination of protein from legumes, carbohydrates from rice, fat both visible and invisible from curry and fried savory items, vitamins and minerals from sprouted grains, and vitamins from curds and vegetables is obtained through typical Indian traditional meals (Figure 3.9).

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