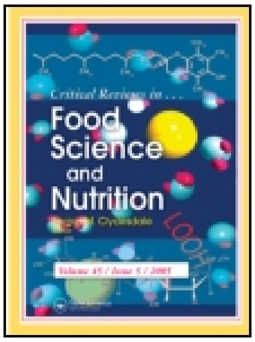

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Nutraceuticals and Functional Foods: The Foods for the Future World

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The health and wellness of human beings is largely dictated by the consumption of nutritious foods. Various studies have linked foods as helpful in combating a number of degenerative diseases; as such, a lot of research on functional attributes linked directly to the health benefits of various plant and animal foods have been witnessed in recent years. Although vast number of naturally occurring health-enhancing substances are of plant origin, there are a number of physiologically active components in animal products as well that deserve attention for their potential role in optimal health. Consumption of biologically active ingredients in fruits and vegetables has been linked to help combat diseases such as cancer, cardiovascular diseases, obesity, and gastrointestinal tract disorders. Lot of research is required to substantiate the potential health benefits of those foods for which the diet–health relationships are not sufficiently validated, and create a strong scientific knowledge base for proper application of naturally present foods in combating various diseases and disorders.

Keywords Nutraceuticals, functional foods, health benefits, cancer

INTRODUCTION

Foods contain various dietary components with an array of health benefits that offer an excellent opportunity to improve public health and well-being. The medical benefits of foods have been explored since time immemorial (Wildman, 2001). Epidemiologic studies have shown a link between the consumption of plant-derived foods (fruits, vegetables, and whole grains) and a range of health benefits.

Phytochemicals present in the diet that have been associated with health benefits are glucosinolates, sulfur containing compounds of the Alliaceae, terpenoids (carotenoids, monoterpenes, and phytosterols), and various groups of polyphenols (anthocyanins, flavones, isoflavones, stilbenoids, ellagic acid, etc.). This wide range of products cannot be truly classified as "food" and a new hybrid term between nutrients and pharmaceuticals, "nutraceuticals," has been coined to designate them. Nutraceuticals have received much attention in recent years from the scientific community, consumers, and food manufacturers. The list of nutraceutical compounds (vitamins, probiotics, bioactive peptides, antioxidants, etc.) is endless, and the scientific evidence to support the concept of health-promoting food ingredients is growing steadily (Chen et al., 2006). Functional foods are those that when consumed regularly exert a specific health-beneficial effect beyond their nutritional properties (i.e., a healthier status or a lower risk of disease), and this effect must be scientifically proven (ILSI, 2008).

Functional foods are similar to conventional foods, which are consumed as part of a usual diet but are known to improve health status beyond primary nutritional function. However, nutraceuticals are the products produced from foods but sold in medicinal forms of either a capsule, tablet, powder, solution, or potion, which is not generally associated with the food and have demonstrated physiological benefits and/or provide protection against chronic diseases; these are now referred to as "natural health products" in Canada (Shahidi, 2004). Nutraceuticals and functional foods provide a means to reduce the increasing burden on the health care system by continuous preventive mechanisms, and the interest in nutraceuticals and functional foods continues to grow and is powered by progressive research efforts to identify properties and potential applications of nutraceutical substances, coupled with public interest and consumer demand. The principal reasons for the growth of the functional food market are current population and health trends. This review is aimed to provide a brief account of the health benefits of some

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nutraceuticals and functional foods with special emphasis on cardiovascular diseases (CVDs), obesity, and cancer.

NUTRACEUTICALS AND FUNCTIONAL FOODS: TERMINOLOGY AND DEFINITIONS

Nutraceuticals, a hybrid term or a contraction of nutrition and pharmaceutical, was reportedly coined in 1989 by DeFelice and the Foundation for Innovation in Medicine (Espin et al., 2007). Nutraceutical, a dietary supplement, has a potential to deliver a concentrated form of a presumed bioactive agent from a food, presented in a non-food matrix and used with the purpose of enhancing health in dosages that exceed those that could be obtained from normal foods (Zeisel, 1999). These are sold in presentations similar to drugs: pills, extracts, tablets, etc. Functional foods are the foods or dietary components consumption of which may have associated health benefits beyond the basic nutritional properties that the foods possess. Health Canada defines functional food as a product that resembles a traditional food but possess demonstrated physiological benefits (Shahidi, 2009). In South Korea, functional foods are defined as dietary supplements whose function is to supplement normal diet, and have to be marketed in measured doses, such as pills, tablets, etc. (Kim et al., 2007). Functional food should be a food similar in appearance to a conventional food (beverage, food matrix), consumed as part of a usual diet, contains biologically active components with demonstrated physiological benefits, and offers the potential of reducing the risk of chronic diseases beyond basic nutritional functions (Food and Agricultural Organization of the United Nations (FAO), 2007). Table 1 shows some basic categories of functional foods.

The boundary between nutraceuticals and functional foods is not so clear and most of the consumers and industries use it interchangeably. Broadly speaking, functional foods are generally considered as those foods which are intended to be consumed as part of a normal diet but do contain biologically active components which have the potential to enhance health or reduce the risk of diseases. Examples of functional foods include foods that contain specific minerals, vitamins, fatty acids, or dietary fiber, foods with added biologically active substances such as phytochemicals or other antioxidants and probiotics. In the light if this definition, unmodified whole foods, such as fruits and vegetables, represent the simplest form of a functional food. For example, broccoli, carrots, or tomatoes would be considered functional foods because they are rich in physiologically active components such as sulforaphane, beta carotene, and lycopene, respectively.

HEALTH BENEFITS OF NUTRACEUTICALS AND FUNCTIONAL FOODS

The health and wellness of human beings is largely dictated by the consumption of nutritious foods. The surfacing of foods with health benefits offers an excellent opportunity to improve the public health; hence these compounds have received much attention in recent years from the scientific community, consumers, and food manufacturers.

Several epidemiologic studies over the last 50 years have clearly indicated that diets dominated by fruits, vegetables, and dietary fibers (plant-based foods) prevent and reduce the risk of chronic diseases (e.g., CVDs, obesity, diabetes, etc.) and promote sound human health. The generation of scientific research worldwide, linking foods of plant origin with health has resulted in the acknowledgement that plant bioactive compounds have beneficial healthy properties (Balsano and Alisi, 2009; Cencic and Chingwaru, 2010a). High dietary intake of fruits, vegetables, and whole grains is strongly related with reduced risk of developing chronic diseases such as cancer and CVDs, which are the main causes of death in Europe and the United States (European Food Safety Authority (EFSA), 2004; Liu, 2004). It is estimated that one-third of all cancer deaths in industrialized countries could be avoided through appropriate dietary formulations. This suggests that dietary behavioral changes, such as increasing consumption of fruits, vegetables, and whole grains, and related changes in lifestyle, are the practical strategies for significant reduction of cancer incidence (Terry et al., 2001). There is a huge amount of scientific literature linking consumption of diets rich in vegetables and fruits with reduced risk of cancer, particularly

Table 1 Functional food categories

Category	Definition	Examples
Basic Foods	Food or a food product that naturally contains bioactive compound	•Carrots naturally contain beta-carotene •Oat bran cereals naturally contain beta-glucan
Processed Foods with added bioactives	Bioactive is added to the food during processing	•Orange juice with added calcium • Milk with added omega-3 fatty acids
Foods enhanced to have more of a bioactive	The bioactive exists naturally in the food but the level of bioactive is modified or concentrated (e.g., by genetic engineering or breeding)	• Yoghurt with increased levels of prebiotic • Tomatoes with increased lycopene content • Eggs with increased levels of omega-3 fatty acids

epithelial cancers of the alimentary and respiratory tracts (Denny and Buttriss, 2005). Based on the results from 206 human epidemiologic studies and 22 animal studies, similar effects of plant-based diets are consistent for cancers of the stomach, esophagus, lung, oral cavity and pharynx, endometrium, pancreas, and colon (Denny and Buttriss, 2005). The types of vegetables or fruits that most often appear to be protective against cancer are raw vegetables, followed by allium vegetables, carrots, green vegetables, cruciferous vegetables, and tomatoes (Denny and Buttriss, 2005).

The health benefits and disease-preventive effects of functional foods and nutraceuticals, summarized in Table 2, are primarily in diverse areas. These include treatment of cancer, atherosclerosis and CVDs, the process of aging, immune response-enhancing effect as well as diabetes, among others.

Cancer

The development of cancer is a dynamic and long-term process involving many complex factors with stepwise progression, eventually leading to an uncontrolled growth of cancerous cells throughout the body, called metastasis (Cencic, and Chingwaru, 2010b; Kalimuthu and Se-Kwon, 2013). Epidemiologic studies have provided credible evidence that dietary factors can modify carcinogenesis. Laboratory research has further demonstrated that a number of bioactive dietary components or natural products have the ability to prevent cancer (Liu, 2004; Balsano and Alisi, 2009). In addition, many food constituents with yet undefined nutritional benefits have been found to possess anti-mutagenic and anti-carcinogenic properties. Such promising research provides a strong support for the acceptance in the future of bioactive components of food as chemo-preventative agents (Pan et al., 2008).

The mechanisms which render anti-carcinogenic effects of phytochemicals present in plant foods are diverse but generally include a combination of possibilities such as antioxidant effects, increased activity of enzymes that detoxify carcinogens, effect on cell differentiation, inhibition of N-nitrosamine formation, change of estrogen metabolism, change of colonic milieu, maintenance of DNA repair, preservation of integrity of intracellular matrices, effect on DNA methylation, increase in apoptosis of cancer cells, and decrease in cell proliferation (Lampe, 1999; Liu, 2003; Surh, 2003; Liu 2004).

Cardiovascular Diseases

Cardiovascular diseases, including heart disease and stroke, represent the primary cause of death in western countries. CVDs and tumors together contribute to more than 60% of deaths in economically developed countries (Stramba-Badiale et al., 2006). In economically developed countries, CVDs have acquired an endemic proportion, and exceed infectious diseases in mortality. Recent studies associate reactive oxygen species (ROS) in the pathogenesis of both acute and chronic heart diseases as a result of cumulative oxidative stress (Wang et al., 2007). In particular, oxidation of low-density lipoproteins (LDL) has a key role in the pathogenesis of atherosclerosis and cardiovascular heart diseases through the instigation of the plaque formation process (Wang et al., 2007). Important risk factors for CVD include obesity, high blood cholesterol levels, high blood pressure, and type-2 diabetes. The risk of CVD is increased not only by the consumption of poor diets but also by lifestyle habits such as smoking and alcohol intake

Table 2 Some examples of functional foods and their potential health benefits

Functional foods	Potential health benefits
Whole foods	
Fruits and vegetables	Reduced risk of various cancers and heart diseases
Garlic	Reduced risk of heart diseases and cancers, reduces cholesterol
Flaxseed	Reduced risk of heart diseases and certain cancers, reduces triglycerides, increases blood-glucose control
Fish	Reduced risk of heart diseases, reduces cholesterol and triglycerides
Black and green tea	Reduced risk of cancer
Soybean	Reduced cholesterol and heart diseases, regulates menopause systems, and prevents osteoporosis
Enhanced foods	
Dairy products with probiotics	Reduced risk of colon cancer, controls diarrheal disorders and eczema
Fish oil with omega-3 fatty acids	Reduced risk of heart diseases
Fortified foods	
Milk with vitamin D	Reduces risk of osteomalecia and osteoporosis
Grains with added fiber	Reduced risk of certain cancers and heart diseases, reduce cholesterol and constipation, increase blood glucose control
Juices with calcium	Reduce risk of osteoporosis and hypertension
Grains with folic acid	Reduced risk of heart diseases and neural tube defects

From: American Dietetic Association (ADA) (1999); Mazza (1998); Wildman (2001); Singh et al. (2008).

(Riccioni et al., 2008). It has been revealed that people consuming healthy diets, living active lifestyles, not smoking, and not indulging in excessive alcohol consumption tend to have a reduced risk of CVDs (Riccioni et al., 2008). It is also known that diets leading to elevated serum total cholesterol, LDL-cholesterol, and triacylglycerol concentrations, and leading to reduced high-density lipoprotein (HDL) cholesterol concentrations lead to reduced risk of coronary artery disease.

Blood pressure control is important for the prevention of heart disease, kidney diseases, and stroke. Blood pressure is influenced by numerous factors, including atherosclerosis, imbalances in the rennin angiotensin system, and hyperinsulinemia; the latter increasing sodium retention in the body and speeding up atherosclerosis (Lampe, 1999). Consequently, a general nutritional plan to minimize hypertension risk includes attaining and maintaining a healthy body weight; consuming a diet rich in calcium, phosphorus, and magnesium; and consumption of sodium and alcoholic beverages in moderation (Dwyer, 1995).

Functional foods when eaten in adequate amounts can aid in decreasing the risk of CVDs by several potential mechanisms. These include lowering blood lipid levels, decreasing the plaque formation, reducing lipoprotein oxidation, improving arterial compliance, scavenging free radicals, and inhibiting platelet aggregation (Hasler et al., 2000).

Obesity

Obesity is a characteristic disease of modern age for which entire world is fighting as it is the fifth leading risk factor for global deaths (Chuadhary and Grover, 2012) . Obesity is a medical condition characterized by the accumulation of excess body fat. As a condition, obesity is associated with reduced life expectancy and/or increased health problems (Haslam and James, 2005). Numerous studies indicate that higher levels of body fat are associated with an increased risk of many adverse health conditions. Weight loss is increasingly recognized as bringing major health benefits to overweight people, and is linked with increased life expectancy of people having obesity-related complications (Rayalam et al., 2008). Overweight and obesity have increased over the past 20 years in many regions of the world, particularly the prevalence of obesity in childhood. Obesity is not only restricted to the developed world; it is also becoming a growing burden for the developing countries (Martorell et al., 2000). Data from the International Obesity Task Force (IOTF) indicate that over 20 million children aged less than six years are obese or overweight worldwide (International Obesity Task Force (IOTF), 2005). Obesity is a multi-factorial problem and its development is due to multiple interactions between genes and environment. There is a need to identify aspects of behavior that curtail excessive energy intake while enhancing energy expenditure. These include making appropriate dietary choices, embarking on good eating behavior, and having an active lifestyle (International Obesity Task Force (IOTF), 2005). Fiber-rich foods can have promising effects in tackling this menace since fiber contributes more to food weight than to calorie intake. Increasing fiber is believed to aid in weight management and helps reduce obesity problems (Pereira and Ludwig, 2001).

FUNCTIONAL FOODS FROM PLANT SOURCES

Overwhelming evidence from epidemiologic (in vivo, in vitro, and clinical trials) data indicates that a plant-based diet can reduce the risk of chronic diseases, particularly cancer. Block et al. (1992) showed that cancer risk in people consuming diets rich in fruits and vegetables was only one-half than in those consuming less of these foods. It is now clear that there are components in a plant-based diet, other than traditional nutrients, that can reduce cancer risk. Steinmetz and Potter (1991a) identified more than a dozen classes of these biologically active plant chemicals, now known as "phytochemicals."

The most important phytochemicals are phenolics and carotenoids in fruits and vegetables, and lignans, β-glucan, and inulin in cereal-based products. Preventing cancer and CVDs, reducing tumor incidence, lowering of blood pressure, risk of heart disease, cholesterol, and delaying gastric emptying are some of the important protective effects of plant-based foods. Health professionals are gradually recognizing the role of phytochemicals in health enhancement (American Dietetic Association (ADA), 1995; Howard and Kritcheveky, 1997), aided in part by the Nutrition Labeling and Education Act (NLEA) of 1990. The NLEA required nutrition labeling for most of the foods and allowed disease- or health-related messages on food labels.

Rice

Rice is one of the major cereals and staple food for half of the world's population (Wani et al., 2012). Until recently, rice was just considered as a source of carbohydrates; however, rice bran, a valuable by product, contains high concentration of nutritionally important compounds. Rice bran contains high level of dietary fibers (β-glucan, pectin, and gum), tocotrienols, γ-oryzanol, and β-sitosterol, which help in lowering of the plasma level of various parameters of lipid profile (Chaturvedi et al., 2007). Rice bran contains α-lipoic acid, which assists in metabolizing carbohydrates and fats, thus lowering glycemic index and controlling the body weight.

Rice bran is potentially a valuable source of natural antioxidants such as tocopherols, tocotrienols, and oryzanol (Godber and Wells, 1994). Antioxidants from rice bran can potentially satisfy the demand of finding effective and economical natural antioxidants, and is one of the interesting areas of research.

Oats

Oats are gaining an increasing scientific and public interest for their antioxidant-associated health benefits (Chu et al., 2013). Oat products are the widely studied dietary source of the cholesterol-lowering soluble fiber known as β-glucan. Apart from this, various studies focus on some specific oat extracts such as tocols (Vitamin E) and aventhramides. There is now significant scientific agreement that consumption of this particular plant food can reduce total and LDL cholesterol, thereby reducing the risk of coronary heart disease (CHD) (Truswell, 2002).

Number of authors have found a positive relationship between the consumption of β-glucan and lower glucose levels in humans (Casiraghi et al., 2006; Tosh et al., 2008). The Food and Drug Administration (1997, 2005) advocated a health claim associated with daily consumption of 3-g glucan/day or 0.75-g serving of soluble fiber glucan from oats or their milled fractions (bran, rolled or whole oat flour). As a grain without gluten, oat flour and bran are used as an alternative food for persons suffering from celiac diseases (Butt et al., 2008), as it helps in delaying gastric emptying, diminishes absorption of nutrients, affects the motility in the small bowel, and prolongs satiety after the meal (Malkki and Virtanen, 2001).

Soy

Soybeans are nutrient-dense, fiber-rich, and good source of proteins and have been recently in focus for the possible role with their presence in diet for the prevention and treatment of degenerative diseases (Anderson et al., 1995a, 1995b; Potter, 1998; Singh et al., 2008). Soybeans are unique source of isoflavones (genistein and diadzein) which have numerous biological functions. It is thought to play preventive and therapeutic roles in CVD, cancer, osteoporosis, and the alleviation of menopausal symptoms (Potter, 1995).

The cholesterol-lowering effect of soy is the well-documented physiological effect. A 1995 meta-analysis of 38 separate studies (involving 743 subjects) found that the consumption of soy protein resulted in significant reductions in total cholesterol (9.3%), LDL cholesterol (12.9%), and triglycerides (10.5%), with a small but insignificant increase (2.4%) in HDL cholesterol (Anderson et al., 1995a, 1995b). Regarding the specific component responsible for the cholesterol-lowering effect of soy, recent attention has focused on isoflavones (Potter, 1998). Isoflavones, however, are found not effective in lowering cholesterol in two recent studies (Nestle et al., 1997; Hodgson et al., 1998) . The exact mechanism by which soy exerts its hypocholesterolemic effect has not been fully elucidated. Soy may also benefit bone health (Anderson and Garner, 1997). A recent clinical study involving 66 postmenopausal women conducted at the University of Illinois (Erdman and Potter, 1997) found that 40-g isolated soy protein (ISP) per day (containing 90-mg total isoflavones) significantly increased (approximately 2%) both bone mineral content and density in the lumbar spine after six months. With shift toward consumption of more plant-based diet, soybean can be a potent tool in the treatment and prevention of chronic disease.

Flaxseed

Flax (*Linum usitatissimum)* is an important oil seed crop, and among the major seed oils, flaxseed oil contains mainly (57%) the omega-3 fatty acid, i.e., α-linolenic acid. It contains a variety of essential and protective nutritive compounds, some of which are rarely available from other foods (Oomah, 2001). Recent research, however, has focused more specifically on fiber-associated compounds known as lignans. Flaxseed is the richest source of mammalian lignan precursors (Thompson et al., 1991). Since flaxseed is a leading source of omega-3 fatty acid, α–linolenic acid, and phenolic compound lignan, it is for these compounds that incorporation of flaxseed in diet has been attractive for the development of functional foods with specific health benefits. The two primary mammalian lignans, enterodiol and its oxidation product, enterolactone, are formed in the intestinal tract by bacterial action on plant lignan precursors (Setchell et al., 1981). Because enterodiol and enterolactone are structurally similar to both naturally occurring and synthetic estrogens, and have been shown to possess weak estrogenic and anti-estrogenic activities, these may play a role in the prevention of estrogen-dependent cancers. However, there are no epidemiologic data, and relatively few animal studies, to support this hypothesis. In rodents, flaxseed has been shown to decrease tumors of the colon and mammary gland (Thompson, 1995) as well as that of the lungs (Yan et al., 1998).

Fewer studies have evaluated the effects of flaxseed feeding on risk markers for cancer in humans. Adlercreutz et al. (1982) found that the urinary lignan excretion was significantly lower in postmenopausal breast cancer patients compared with the controls eating a normal mixed or a lactovegetarian diet. Consumption of flaxseed has also been shown to reduce total and LDL cholesterol (Bierenbaum et al., 1993; Cunnane et al., 1993) as well as platelet aggregation (Allman et al., 1995).

Garlic

Potential health benefits of *Allium* vegetables, in particular, garlic (*Allium sativum*) has its origin in antiquity. Healthful properties of garlic are numerous, including cancer chemopreventive, antihypertensive, and cholesterol-lowering properties, free radical scavenging activities, immune stimulation, curing CVDs, and anti-infectious properties (Srivastava et al., 1995; Borek, 2006; Singh et al., 2007). Its potential in combating lifestyle-related disorders, such as hypercholesterolemia, dyslipidemia, and high blood pressure that lead to several cardiovascular disorders, has been the major focus of research in recent years (Mahmoodi et al., 2006; Kojuri et al., 2007; Butt et al., 2009).

The characteristic flavor and pungency of garlic are due to an abundance of oil- and water-soluble, sulfur-containing elements, which are probably responsible for the various medicinal effects ascribed to this plant. However, intact, undisturbed bulbs of garlic contain only a few medicinally active components. The intact garlic bulb contains an odorless amino acid, alliin, which is enzymatically converted by allinase into allicin when the garlic cloves are crushed (Block, 1992). This latter compound is responsible for the characteristic odor of fresh garlic. Allicin then spontaneously decomposes to form numerous sulfur-containing compounds, some of which have been investigated for their chemopreventive activity (Butt et al., 2009).

Garlic components have been shown to inhibit tumorigenesis in several experimental models (Reuter et al., 1996). However, additional reports have shown garlic to be ineffective. Inconclusive results are likely due to differences in the type of garlic compounds or preparations used by various investigators. Considerable variation in the quantity of organosulfur compounds available in fresh and commercially available garlic products has been demonstrated (Lawson et al., 1991).

Of the many beneficial actions of garlic, inhibition of the growth of cancer is perhaps the most remarkable one (Matsura et al., 2006). Several epidemiologic studies have shown that garlic may be effective in reducing human cancer risk (Dorant et al., 1993). During the last decade, antitumor activity has been demonstrated against the gastrointestinal tract cancer, colon cancer, prostate cancer, mammary carcinoma, hepatocellular carcinoma, lung cancer, and sarcoma and squamous cell carcinoma of the skin and esophagus (Kalra et al., 2006; Ban et al., 2007; Kim et al., 2007; Zhang et al., 2007; Butt et al., 2009) An investigation conducted in China showed a strong inverse relationship between the stomach cancer risk and increasing intake of garlic (You et al., 1988). More recently, in a study of more than 40,000 postmenopausal women, garlic consumption was associated with nearly 50% reduction in the colon cancer risk (Steinmetz et al., 1994). Not all epidemiologic studies, however, have shown garlic to be protective against carcinogenesis. A 1991 review of 12 case-control studies (Steinmetz and Potter, 1991b) found that eight of these studies showed a negative association, one showed no association, and three studies showed a positive association. A more recent review of 20 epidemiologic studies (Ernst, 1997) suggests that allium vegetables may confer a protective effect on cancers of the gastrointestinal tract.

Garlic has also been advocated for the prevention of CVD, possibly through antihypertensive properties. According to Silagy and Neil (1994b), however, there is still insufficient evidence to recommend it as a routine clinical therapy for the treatment of hypertensive subjects. The cardioprotective effects are more likely due to its cholesterol-lowering effect. Warshafsky et al. (1993), while summarizing the results of five randomized, placebo-controlled clinical trials involving 410 patients, showed that an average of 900-mg garlic/day could decrease total serum cholesterol levels by approximately 9%. Silagy and Neil (1994a) reported that 800-mg garlic/day reduced total cholesterol levels by 12%.

Garlic and its supplements are also consumed in many cultures as immune boosters in addition to other health benefits (Amagase et al., 2001). The immuno-stimulating effects of garlic and its components include increase in total white blood cell (WBC) count and enhanced bone marrow cellularity (Kuttan, 2000). Inclusion of garlic in diet especially designed for patients suffering from cancer and other problems can impart a beneficial impact.

Wine

Wines, especially red wines, contain compounds that have promising health benefits. There is growing evidence that wine can reduce the risk of CVD. The link between wine intake and CVD first became apparent in 1979 when St. Leger et al. (1979) found a strong negative correlation between wine intake and death from ischemic heart disease in both men and women. France in particular has a relatively low rate of CVD in spite of diets high in dairy fat (Renaud and de Lorgeril, 1992). Although this can be partly explained by the ability of alcohol to increase HDL cholesterol, more recent investigations have focused on the non-alcohol components of wine, in particular, the flavonoids.

Grapes, one of the most popular fruits from which most of the wines, in particular red ones, are made, contain large amounts of phytochemicals, including resveratrol, which offer health benefits (Pezzuto, 2008). The high phenolic content of red wine, 20–50 times higher than white wine, is due to the incorporation of grape skins into the fermenting grape juice during production. Kanner et al. (1994) showed that black seedless grapes and red wines (i.e., Cabernet Sauvignon and Petite Sirah) contain high concentrations of phenolics: 920, 1800, and 3200 mg/L, respectively, while green Thomson grapes contain only 260 mg/kg phenolics. Frankel et al. (1993) attributed the positive benefits of red wine to the ability of phenolic substances to prevent the oxidation of LDL, a critical event in the process of atherogenesis.

Although the benefits of wine consumption on CVD risk reduction seem promising, a note of caution is in order as alcoholic beverages of all kinds have been linked to increased risk of several cancer types, including breast cancer (Bowlin et al., 1997). Moderate wine consumption has, however, been associated with a decreased risk of age-related macular degeneration (Obisesan et al., 1998).

Tea

Tea is the most popular and the most widely consumed beverage in the world after water (Awasom, 2011). A great deal of attention has been directed to the polyphenolic constituents of tea, particularly green tea (Harbowy and Balentine, 1997). The important constituents of green tea are polyphenols, particularly flavonoids. Polyphenols comprise up to 30% of the total dry weight of fresh tea leaves. Catechins are the predominant and the most significant of all tea polyphenols (Graham, 1992). The four major green tea catechins are epigallocatechin-3-gallate, epigallocatechin, epicatechin-3-gallate, and epicatechin (Hayat et al., 2013).

In recent years, there has been a great deal of interest in pharmacological effects of tea (American Health Foundation (AHF), 1992). By far, most of the research on health benefits of tea has focused on its cancer chemopreventive effects, although the epidemiologic studies are inconclusive at the present time (Katiyar and Mukhtar, 1996). Yang and Wang (1993) reviewed certain studies on tea consumption and its relationship to cancer, and found that two-third of the studies found no relationship between tea consumption and cancer risk, while 20 found a positive relationship and only 14 studies found that tea consumption reduced cancer risk. A review suggests that benefits of tea consumption are restricted to high intake in high-risk populations (Kohlmeier et al., 1997). This hypothesis supports the recent finding that the consumption of five or more cups of green tea per day was associated with decreased recurrence of stage I and II breast cancer in Japanese women (Nakachi et al., 1998). Numerous population-based studies in Japan and China revealed inverse association of green tea with colon cancer (Khatiwada et al., 2006; Xu et al., 2010).

The relationship between tea consumption and CVD risk has been investigated in a number of epidemiologic studies. Hertog et al. (1993) reported that tea consumption was the major source of flavonoids in a population of elderly men in the Netherlands. Intake of five flavonoids (quercetin, kaempferol, myricetin, apigenin, and luteolin), derived from tea consumption, was inversely associated with mortality from CHD in this population. Black tea polyphenols reduce platelet activation in vitro, whereas arachidonic acid-induced inhibitory effect of peroxinitrite on platelet aggregation is eradicated by epigallocatechin gallate (ECCG), another compound of black tea (Hayat et al., 2013). Hence, the anti-inflammatory effects of black tea are responsible for guarding against CVD development (Steptoe et al., 2007).

FUNCTIONAL FOODS FROM ANIMAL SOURCES

Although a vast number of naturally occurring health-enhancing substances are of plant origin, there are a number of physiologically active components in animal products as well that deserve attention for their potential role in optimal health.

Dairy Products

There is no doubt that dairy products are functional foods; milk in itself being a complete food (Rogelj, 2000). They are one of the best sources of calcium, an essential nutrient which can prevent osteoporosis and possibly colon cancer (Alvarez-Leon et al., 2006). In addition to calcium, however, recent research has specifically focused on other components of dairy products, particularly fermented dairy products, known as probiotics. Probiotics are live microbial feed supplements which beneficially affect the host animal by improving its intestinal microbial balance (Fuller, 1994). These have been historically used to rebalance disturbed intestinal microflora and to diminish gastrointestinal disorders, such as diarrhea or bowel disorders.

The concept of creating beneficial health effects through the ingestion of living bacteria has been primarily derived from original studies made by Metchinkoff (1907), suggesting that the good health and longevity of certain ethnic groups was due to their frequent ingestion of fermented dairy products. It is estimated that over 400 species of bacteria inhabit the human gastrointestinal tract, including those considered to be beneficial (e.g., *Bifidobacterium* and *Lactobacillus* spp.) and those considered detrimental (e.g., *Enterobacteriaceae* and *Clostridium* spp.). Of the beneficial microorganisms traditionally used in food fermentation, lactic acid bacteria have attracted the most attention (Sanders, 1994). Although a variety of health benefits have been attributed to probiotics, their anti-carcinogenic, hypocholesterolemic, and antagonistic actions against enteric pathogens and other intestinal organisms have received the maximum attention (Mital and Garg, 1995).

More evidence supports the role of probiotics in cancer risk reduction, particularly colon cancer (Mital and Garg, 1995). This observation may be due to the fact that lactic acid bacteria can alter the activity of fecal enzymes (e.g., b-glucuronidase, azoreductase, and nitroreductase) that are thought to play a role in the development of colon cancer. Relatively less attention has been focused on the consumption of fermented milk products and breast cancer risk, although an inverse relationship has been observed in some studies (Talamini et al., 1984; van't Veer et al., 1989).

Fish

In addition to providing high-quality protein, essential fatty acids, and other nutrients, fish consumption is associated with certain health benefits as well. Omega-3 (n-3) fatty acids are an essential class of polyunsaturated fatty acids (PUFAs) derived primarily from fish oil. Possible association between eating fish and inflammation-related diseases, such as rheumatoid arthritis, has been observed since the omega 3- fatty acids present in fish oil is believed to have anti-inflammatory effects (Simopoulos, 1991). This has prompted researchers to examine the role of n-3 fatty acids in a number of diseases, particularly cancer and CVD, and more recently in early human development as well. There is evidence that consuming substantial amounts of fish during pregnancy may lengthen gestation (Daviglus et al., 2010), thus result in higher birth weights.

During pregnancy and lactation, there is a demand on the mother to supply the fetus and infant with omega-3 PUFAs, which are required for the development of the central nervous system. There is some evidence that increased maternal LC n-3 PUFA intake produces beneficial effects, especially in lower birth weight populations, and this may be more relevant in populations that tend to have a lower background intake of LC n-3 PUFA, i.e. where fish intake is low (Scientific Advisory Committee on Nutrition (SACN), 2004).

It is now well established that eating fish regularly helps in protecting against the development of heart diseases. Omega-3 fatty acids may play an important role in CVD was first brought to light in the 1970s when Bang and Dyerberg (1972) reported that Eskimos had low rates of this disease in spite of consuming a diet which was high in fat (Daviglus et al., 2010). The cardioprotective effect of fish consumption has been observed in some prospective investigations (Krumhout et al., 1985) but not in others (Ascherio et al., 1995). Negative results could be explained by the fact that although n-3 fatty acids have been shown to lower triglycerides by 25–30%, they do not lower LDL cholesterol. In fact, a recent review showed that n-3 fatty acids increased LDL cholesterol (Harris, 1996).

CONCLUSIONS

Rising evidences support the observation that functional foods containing physiologically active components, either from plants or animal sources, may enhance health. Nutraceuticals and functional foods can provide means to address the increasing burden on the health care system by promoting health through prevention rather than treatment.

Health-conscious consumers are increasingly seeking functional foods in an effort to control their own health and well-being. The field of functional foods, however, is in its infancy. Claims about health benefits of functional foods must be based on sound scientific criteria (Clydesdale, 1997). A number of factors complicate the establishment of a strong scientific foundation; however, these factors include the complexity of the food substance, effects on the food, compensatory metabolic changes that may occur with dietary changes, and lack of surrogate markers of disease development. In addition, it is difficult to identify appropriate bioactive substances and establish their role in combating or curing various diseases. Additional research is necessary to substantiate the potential health benefits of these foods for which the diet–health relationships are not sufficiently scientifically validated. Finally, the foods whose health benefits are supported by sufficient scientific literature have a great potential to be an increasingly important component of a healthy lifestyle and to be beneficial to the public and the food industry.

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