J Food Sci Technol (May 2015) 52(5):2522–2529
DOI 10.1007/s13197-014-1396-5

REVIEW

Functional components and medicinal properties of food: a review

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Revised: 23 April 2014 / Accepted: 24 April 2014 / Published online: 16 May 2014

Abstract Research has proved a relationship between functional components of food, health and well-being. Thus, functional components of food can be effectively applied in the treatment and prevention of diseases. They act simultaneously at different or identical target sites with the potential to impart physiological benefits and promotion of wellbeing including reducing the risk of cancer, cardiovascular disease, osteoporosis, inflammation, type II diabetes, and other chronic degenerative diseases, lowering of blood cholesterol, neutralization of reactive oxygen species and charged radicals, anticarcinogenic effect, low-glycaemic response, etc. Previously, it was thought that functional ingredients such as non-starchy carbohydrates including soluble and insoluble dietary fibres, fucoidan; antioxidants including polyphenols, carotenoids, tocopherols, tocotrienols, phytosterols, isoflavones, organosulphur compounds; plant sterols and soy phytoestrogens occur only in plant foods (whole grains, fruits, and vegetables) as phytochemicals. However, probiotics, prebiotics, conjugated linolenic acid, long-chain omega-3, −6 and −9-polyunsaturated fatty acids, and bioactive peptides have proved that functional components are equally available in animal products such as milk, fermented milk products and cold-water fish. The way a food is processed affects its functional components. Many processing techniques have been found to lower the concentration of functional components in food. Conversely, other techniques were found to increase them. Hence, in a time when the role of a healthy diet in preventing non-communicable diseases is well accepted, the borderline between food and medicine is becoming very thin.

Keywords Biomolecules · Foods · Functional · Medicine · Physiological · Phytochemicals

Introduction

Functional components are non-conventional biomolecules that occur in food which possess the capacity to modulate one or more metabolic processes or pathways in the body, resulting to health benefits and promotion of well-being (Swanson 2003). Research has proved a relationship between functional components in food, health and well-being (Shibamoto et al. 2008). Consequently, functional components have health-promoting roles at various stages of disease control that are associated with multiple progressive steps, from initiation to development. Thus, they can be effectively applied in the treatment and prevention of diseases (Wildman 2001). Hence, in a time when the role of a healthy diet in preventing non-communicable diseases is well accepted, the borderline between food and medicine is becoming very thin (Pravst 2012).

Functional components include phytochemicals which are plant-derived, non-nutritive and biologically active chemicals that function in the body to prevent the onset of certain non-communicable diseases (Murano 2003). There are over 900 phytochemicals found in foods. One serving (about 120 g) of a fruit or vegetables may have as many as 100 different phytochemicals (Srividya et al. 2010). Previously, it was thought that functional components occur predominantly only in plant foods including whole grains, fruits, and vegetables as phytochemicals. However, probiotics, conjugated linolenic acid, long-chain omega-3, −6 and −9 polyunsaturated fatty acids, and bioactive peptides are equally found in animal products such as milk, fermented milk products and cold-water fish. Table 1 gives some functional components of food, their biological functions and common sources. Functional components usually occur in multiple forms such as

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Table 1 Some functional ingredients of food, their sources and potential benefits

Bioactive components	Source	Potential benefits
Carotenoids		
Alpha-carotene/beta-carotene	Carrots, Fruits, Vegetables	Neutralize free radicals which may cause damage to cells.
Lutein	Green vegetables	Reduce the risk of muscular degeneration.
Lycopene	Tomato products (ketchup, sauces)	Reduce the risk of prostate cancer.
Non-starchy polysaccharide		
Fucoidan (fucose)	Mushrooms (maitake and reshi), brown seaweeds.	Immune modulation; apoptosis of cancer cells; stimulates brain development; anti-clotting effect; lower blood cholesterol levels; decrease high blood pressure, stabilize blood sugar.
Insoluble dietary fibre	Wheat bran	Reduces risk of breast or colon cancer.
Soluble dietary fibre (β-Glucans)	Oats, barley	Reduces risk of cardiovascular disease; protects against heart disease and some cancers; lower LDL and total cholesterol.
Soluble Fibre	Psyllium	Reduces risk of cardiovascular disease; protects against heart disease and some cancers; lower LDL and total cholesterol.
Fatty Acids		
Long chain omega-3 Fatty Acids-DHA/EPA	Salmon and other fish oils	Reduce risk of cardiovascular disease; improve mental and visual functions.
Conjugated Linoleic Acid (CLA)	Cheese, meat products.	Improve body composition; decrease risk of certain cancers.
Phenolics		
Anthocyanidins	Fruits	Neutralize free radicals; reduce risk of cancer.
Catechins	Tea	Neutralize free radicals; reduce risk of cancer.
Flavonones	Citrus	Neutralize free radicals; reduce risk of cancer.
Flavones	Fruits/vegetables	Neutralize free radicals; reduce risk of cancer.
Lignans	Flax, rye, vegetables	Prevention of cancer; renal failure.
Tannins (proanthocyanidines)	Cranberries, cranberry products, cocoa, chocolate	Improve urinary tract health; Reduce risk of cardiovascular disease.
Plant Sterols		
Stanol ester	Corn, soy, wheat, wood oils	Lower blood cholesterol levels by inhibiting cholesterol absorption.
Prebiotics and Probiotics		
Fructo-oligosaccharides (FOS);	Jerusalem artichokes, shallots, onion powder,	Improve quality of intestinal microflora; gastrointestinal health
Lactobacillus;		
Biofidobacterium	Yogurt, other dairy products	Improve quality of intestinal microflora; gastrointestinal health.
Soy Phytoestrogens		
Isoflavones: Daidzein Genistein	Soybeans and soy-based foods	Menopause symptoms such as hot flashes; protection against heart disease and some cancers; lowering of LDL and total cholesterol

Adapted from AAFC (2011)

glycosylated, esterified, thiolated, or hydroxylated materials in food. They also have multiple metabolic activities allowing for beneficial effects on several diseases and target tissues in the body (Swanson 2003). This paper, therefore, reviews functional components in food with focus on their types, nature, medicinal properties, functions, sources and effects of processing on them.

Functional components of food: an overview

Different types of functional components in food, their medicinal properties, functions and sources are overviewed below.

Type: Non-starchy carbohydrates (e.g. dietary fibre and fucoidan)

Basically, these are structural and storage carbohydrates which are polymers of glucose molecules and other sugars including galactose, fructose, xylose, arabinose, etc., but are not starchy in nature (i.e. their sugar units are not linked by either α [1,4] or α [1,6] glycosidic bonds). Thus, they are not hydolysable by the human digestive enzymes but undergo fermentation by the probiotic microbes in the colon. There are several kinds of non-starchy carbohydrates including dietary fibre and fucoidan.

Dietary fibres Dietary fibres (DF), which could be soluble or insoluble, are non-starchy polysaccharides and structural components of the cell walls of cereals and microorganisms. They are the indigestible part of plant foods composed of long straight and branched chains of carbohydrate molecules held together by bonds that cannot be hydrolysed by human digestive enzymes. Chemically, DF are glucose polymers in hetero-structural configuration of β (1, 3:1, 4) or β (1, 3:1, 6) bonds. The water-soluble fibres are mainly β-glucans, gums, pectin, mucilage and arabinoxylans while the water-insoluble fibres are composed of lignin, cellulose, and hemicellulose (AACC 2001; Andlauer and Furst 2002; Charalampopoulos et al. 2002).

Fucoidan Fucoidan is a non-starchy and sulphated polysaccharide. It is a polymer of α (1→3) linked fucose pyranose sugar subunits. Fucoidan also has traces of galactose, xylose and glucoronic acid (Becker and Lowe 2003; MSKCC 2011). Two structural features which distinguish fucose from other six-carbon sugars present in mammals are the lack of a hydroxyl group on the carbon at the six-position (C-6) and its L-configuration (Becker and Lowe 2003).

Functions The long fibrous structures of dietary fibre allow them to entrap harmful toxins and carcinogens in the digestive tract. Cereal β-glucan, the soluble dietary fibre, has gained special attention for their many health benefits such as lowering serum cholesterol. In addition it is attributed to having a good water retention capacity, gelling ability and hydro-colloidal forming properties which have influenced their use as substitutes for fat (Izydorczyk and Dexter 2008). Fungi β-glucans, a family of diversified structures found in the cell wall of yeast and molds, modulate immune system by enhancing leucocytes activity that is responsible for enhancing body defence mechanism. Inulin has successfully replaced fat in dairy products (Duss and Nyberg 2004; Chan et al. 2009; Srividya et al. 2010; Havrlentova et al. 2011; Ahmad et al. 2012b). Soluble dietary fibre can dissolve in or absorb water and is effective in binding toxins and cholesterol in the intestinal tract. Insoluble dietary fibre, on the other hand, cannot dissolve in water and is effective in adding faecal bulk and increasing the rate of passage of food through the intestinal tract. Insoluble dietary fibre also dilutes out potential carcinogens and decreases contact of toxins and carcinogens with the intestinal tract and speeds up their passage out of the body (Duss and Nyberg 2004; Ahmad et al. 2009; Havrlentova et al. 2011; Ahmad et al. 2012). Similarly, fucoidan inhibits the spread of cancerous cells by preventing the adhesion of tumor cells to the extracellular matrix as well as induce apoptosis, or programmed self-destruction, in human T-cell leukemia virus type I (HTLV-1) which causes adult T-cell leukemia. The polysaccharide paves way for apoptosis by inactivating NF-kB, a naturally occurring substance that regulates anti-apoptotic proteins (MSKCC 2011).

Fucoidan have also been shown to stimulate the phagocytic action of macrophages and synthesis of several immune cell types, which increase protection against infection (Akramiene et al. 2007; Chan et al. 2009; Ahmad et al. 2012b). The nutritional makeup of fucoidan could be likened to that of breast milk which is the most perfect immune-supporting food known. The polysaccharide gives the immune system a big boost by enhancing phagocytosis, the process through which white blood cells attack and destroy pathogens. Fucoidan also increases the number of mature white blood cells that are circulating in the body, thereby bolstering the first line of defence against infections and diseases (Babal and Gionta 2010).

Sources Foods rich in soluble dietary fibre include apples, cranberries, mango, oranges, asparagus, broccoli, carrots, peanuts, walnuts, most legumes, oats, and psyllium while those rich in insoluble dietary fibre are apples, bananas, berries, broccoli, green peppers, spinach, almonds, sesame seeds, most legumes, brown rice, whole-wheat breads, and cereals. Cereals and bacteria are rich sources of β-(1,3:1,4)-glucan (a DF with strong colloidal properties which is considered as good functional ingredient in foods for its cholesterol-lowering and low-glycaemic index functions). The highest amount of β-(1,3:1,4)-glucan occur in oat (2.2–7.8 %) and barley (2.5–11.3 %) bran, aleurone and subaleurone layers (Charalampopoulos et al. 2002; Havrlentova and Kraic 2006). Brown seaweeds and some medicinal mushrooms are high in fucoidan (WineBrenner 2007). In addition, mushroom and yeast's polysaccharides such as β-(1,3:1,6)-glucan have been in focus for their antitumor activity and the chemical diversity of these glycans ranges from homopolymers to highly complex heteropolymers. Varieties of sugars such as glucose, galactose, mannose, xylose, arabinose, sucrose ribose, glucouronic acid etc. are involved in the formation of such polysaccharides. Some of the glycans form conjugates with proteins and peptides with higher potent antitumor activity (Akramiene et al. 2007; Chan et al. 2009; Ali et al. 2009).

Type: Antioxidants, anti-cancerous and immune-modulating agents

Antioxidants are groups of compounds which neutralise free radicals and reactive oxygen species (ROS) in the cell. A free radical is a carbon or oxygen atom that has an unpaired electron and is highly charged and unstable. Free radicals can form in lipids, proteins, and carbohydrates. Examples of antioxidants are as follows:

Carotenoids (e.g. lycopene, lutein) The carotenoids are lipid-soluble plant pigments that are either oxygenated or non-oxygenated hydrocarbons containing at least 40 carbons and an extensive conjugated double bond system. Alpha-carotene, beta-carotene, and lycopene are the predominant non-polar functional carotenoids and lutein is the primary polar functional carotenoid. Carotenoids can be found esterified to fatty acids or unesterified in plant tissues. Lycopene are the most active oxygen neutralizer with potential chemo-preventive activities. The total carotenoid content of fruits and vegetables varies with age and storage (Parker 2000).

Polyphenols Polyphenols are the most numerous and widely distributed group of functional molecules. Polyphenols are diverse groups of plant substances that contain one or more benzene rings and varying number of hydroxyl (OH), carbonyl (CO), and carboxylic acid (COOH) groups. They commonly exist in conjugated forms with one or more attached sugar residues. The most common class of polyphenols is the flavonoids. Other types of polyphenols include catechins, thearubingens, theaflavins, isoflavones, and over 8000 others (Lobo et al. 2010). The polyphenol content can vary tremendously between food sources and within foods of the same type. The following ranges were reported for total polyphenol content in some food materials and fruits: barley and millet (590–1,500 mg/100 g dry matter); oats and corns (8.7–30.9 mg/100 g dry matter); fresh onions and leeks (20–20.25 mg/100 g dry matter), fresh brussel sprouts (6–15 mg/100 g dry matter), blueberries, strawberries, cranberries, and raspberries the total polyphenol content is about 37–429 mg/100 g dry matter (Bravo 1998).

Phytosterols Phytosterols are the plant equivalent of cholesterol in animals. Their structures are similar. However, the side-chain in plant sterols contains additional double bonds and methyl and/or ethyl groups. The most common bioactive phytosterols are beta-sitosterol, campesterol, and stigmasterol. A daily non-vegetarian diet contains approximately 250 mg of unsaturated phytosterols while a vegetarian diet contains over 500 mg. The saturated derivatives of plant sterols are plant stanols such as sitostanol. (Swanson 2003; Anon 2013).

Tocopherols and tocotrienols The tocopherols and tocotrienols are lipid-soluble functional components which contain a phenolic-chromanol ring linked to an isoprenoid side chain that is either saturated (tocopherols) or unsaturated (tocotrienols). There are also four primary forms of tocopherols and tocotrienols, alpha, beta, gamma, and delta that differ in the number and position of methyl groups on the phenolic-chromanol ring. In addition, the tocopherols have three asymmetrical carbons at positions two, four, and eight of the isoprenoid side chain. Consequently, there are eight isomeric forms of tocopherols, of which RRR-a-tocopherol has the greatest bioactivity and is also the most abundant in human blood and tissues (Lobo et al. 2010; Srividya et al. 2010).

Organo-sulphur compounds The organosulfur compounds are commonly found in cruciferous vegetables such as broccoli, cauliflower, and brussel sprouts or allium vegetables (vegetables in the same class with onions and garlic) such as leeks. Organosulfur compounds contain sulfur atoms that are bound to a cyanate group or a carbon atom in a cyclic or non-cyclic configuration. The functional ingredients of foods containing organosulfur compounds are obtained only after cutting, chewing, or crushing has disrupted the cells to expose them. In cruciferous vegetables various isothiocyanates such as sulforaphane, phenethyl isothiocyanate, and benzyl isothiocyanate are formed from glucosinolyates by the action of myrosinase. In alliums, allicin is formed from alliin and then rapidly converted to diallyl sulfide, diallyl disulfide or diallyl trisulfide by the action of allinase. In both cruciferous and allium vegetables, these hydrolytic breakdown products are the health-promoting functional components (Swanson 2003; Anon 2013).

Functions The primary functions of antioxidants include the regulation of the redox potential within a cell and the reduction of potential initiators of cell death and carcinogenesis. Hence antioxidants are anti-carcinogenic agents. The redox potential refers to the balance of the reducing and oxidizing reactions that occur within the cell. Redox changes within a cell are able to trigger various molecular responses such as induction of apoptosis (cell death) and activation of signal transduction (the transfer of messages between cells and within a cell). Therefore, redox regulation of physiological and pathological processes is important in optimizing health and disease prevention (Lobo et al. 2010; Kumar 2011).

Other functional antioxidant compounds are able to bind to toxins or carcinogens in the intestinal tract, such as the binding of *N*-nitroso compounds by polyphenols in tea, thereby preventing their transformation or even absorption. The lipid-lowering mechanism of phytosterol/stanols occurs by sequestering cholesterol in the intestinal tract and reducing its absorption. Epidemiological and experimental studies suggest that dietary phytosterols may offer protection from most of the common cancers in western societies such as colon, breast and prostate cancers (Boothe 1978). The possible mechanism by which phytosterols offer this protection include its effects on membrane structure, tumor and host cell tissues, signal transduction pathways that regulate tumor growth and apoptosis, immune functions of the host and cholesterol metabolism by the host (Akramiene et al. 2007; Chan et al. 2009; Ahmad et al. 2012b).

The structural similarity between several isoflavone metabolites and those of estrogens and estradiols suggests the possibility of estrogen-like biological activities in isoflavones. Isoflavones or phytoestrogens, however, exhibit antagonist estrogen activity resulting in lower overall exposure to estrogen in premenopausal women and reducing breast cancer risk (Shimizu et al. 1990; Cassidy et al. 1994; Cassidy et al. 1995).

In postmenopausal women, phytoestrogen-rich diets reduce the hormone-sensitive increases in plasma cholesterol levels and bone loss (Potter et al. 1998; Setchell and Cassidy 1999).

pt?>Similarly, the induction of enzyme systems that detoxify toxic chemicals including the phase I (e.g. cytochrome P450 group of oxidases) and phase II (e.g. N-acetyl transferase, glutathione S-transferase, UDP-glucoronyl transferase, etc.) detoxifying enzymes is thought to reduce one's susceptibility to mutagenic effects. Functional food components with antioxidant functions are able to activate phase II detoxifying enzymes via the antioxidant responsive element pathway such as the nuclear factor [erythroid-derived 2]-like two also known as Nrf2 pathway (Mukhtar and Ahmad 2000; Lobo et al. 2010; Kumar 2011). Organo-sulphur compounds such as isothiocyanates, in particular sulforaphane, are potent mono-inducers of phase II detoxifying enzymes (Zhang et al. 1994) while diallyl sulfides from garlic preparations are inducers of both phases I and II detoxifying enzymes (Yang et al. 2001).

A primary mechanism for immune-modulation is the multiple antioxidant capability of polyphenols, tocopherols, carotenoids, isothiocyanates, and allyl sulfides, lycopene being the most active oxygen neutralizer with potential chemo-preventive activities. Together, these compounds are able to reduce the deleterious effects of reactive oxygen species (ROS) and free radicals, which cause premature death of immune cells (Brennan et al. 2000). Garlic is found to be a superior phytochemical in the reduction of total cholesterol levels (Dureja and Kaushik 2003) and is also reported to control arterial stiffness by increasing the good cholesterol: high density lipoprotein (HDL) and decreasing the bad cholesterol: low density lipoprotein (LDL). It also inhibits inducible nitric oxide synthase by reducing the protein and mRNA and thus promotes vasodilatation of blood vessels. Garlic has strong immunopotential capacity and enhances the natural killer (NK) activity and proliferation of T- Lymphocytes by delaying the hypersensitivity reaction.

Aged garlic extract is found to be a promising immune modifier with internal body regulatory function, particularly in the control of sarcoma-180 and lung carcinoma as well as inhibition of platelet aggregation. Both the oil- and water-soluble components of garlic extract have shown health benefits. Specifically, its oil extract reduces serious mental disorder and prevents blood coagulation even in diabetics while its water extract is effective in cell cycle and viability of HG2 hepatoma cells (Srividya et al. 2010). Since garlic extract reversed oxidant responses it seems likely that it protects tissues from oxidative damages (Crandell and Duren 2007).

Sources Food sources of polyphenols and flavonoids include vegetables, fruits, cereals, legumes, nuts, tea, wines and other beverages made with fruits, vegetables and grains (Mandal et al. 2009; Srividya et al. 2010). Carrots, squash, sweet potato, and spinach are abundant in both beta-and alpha-carotene and the dark green leafy vegetables such as kale, spinach, mustard greens, and green beans are good sources of lutein. Lycopene is found predominately in tomatoes. Other bioactive components in tomato are kaempferol or chlorogenic acid, which have anti-mutagenic activities. This suggests that tomato suspension have a protective effect on colon cancer which is mediated by the modulation of different biological pathways during carcinogenesis (Hardy et al. 2002). Typical dietary sources which are rich in tocopherol and tocotrienols include vegetable oils, nuts and the germ portion of grains (Swanson 2003).

Among the foods that have been shown to have beneficial immuno-modulatory effects are broccoli, garlic, onions, vegetable oils, almonds, and walnuts (Swanson 2003; Srividya et al. 2010). Similarly, garlic, soy bean, cabbage, ginger, licorice root extract (extract of the root of *Glycytthiza glabra*) and umbelliferous vegetables (vegetables that grow or produce its plant beneath the ground, e.g. carrots) have been identified as foods and herbs with the highest anticancer activity. Citrus in addition to providing an ample supply of vitamin C, folic acid, potassium and soluble fibre contains a host of active phytochemicals (Dzanis 1998).

Green tea enhances humoral and cell-mediated immunity while decreasing the risk of certain cancers and cardio-vascular disease. On the other hand, ginseng enhances production of macrophages and T-cells, natural killer cells and colony forming activity of bone marrow (Diplock et al. 1999). Soy bean, garlic, ginger and green tea which have been suggested, in epidemiological studies, to reduce the incidence of cancer may do so by inducing programmed cell death. Soybean extract has been shown to prevent the development of polycystic kidneys (Chang 2000). Turmeric is most potent against skin tumors (Halt 1998).

Type: Probiotics and prebiotics

Probiotics are the beneficial live microorganisms, which, when administered in adequate amounts, confer health benefits on the host (Iwe 2006), e.g. Lactobacillus (LAB), Biofidobacterium, etc.

Prebiotics Are the non-digestible food ingredients that stimulate the growth and activity of probiotics in the digestive system in ways claimed to be beneficial to health (Anon 2011). Thus, prebiotics are healthy non-digestible food ingredients that make their way through our digestive system and help the beneficial or good bacteria grow and flourish (Jegtvig 2012; Iwe 2006).

Functions Probiotics are believed to protect us in two major ways. The first is the role that they play in our digestive tract. Our digestive tracts need a healthy balance between the *good* and *bad* microorganisms. But our lifestyles such as poor food choices, emotional stress, and lack of sleep, antibiotic over use, other drugs, and environmental influences can shift the balance in favour of the bad microorganisms (Kovacs 2012). When the digestive tract is healthy, it filters out and eliminates things that can damage it, such as harmful microbes, toxins, chemicals, and other waste products. On the flip side, it takes in the things that our body needs (nutrients from food and water) and absorbs and helps deliver them to the cells where they are needed. The idea is not to kill off all of the microbes. Our bodies do have a need for the bad ones and the good ones. The problem is when the balance is shifted to have more bad than good. An imbalance has been associated with diarrhoea, urinary tract infections, muscle pain, and fatigue (Kovacs 2012).

The second major benefit of probiotics is the impact they have on our immune system. Our immune system is our protection against pathogens. When it doesn't function properly, we can suffer from allergic reactions, autoimmune disorders (for example, ulcerative colitis, Crohn's disease, and rheumatoid arthritis), and infections (for example, infectious diarrhoea, *Helicobacter pylori*, skin infections, and vaginal infections). By maintaining the correct balance from birth, these ailments are prevented (Iwe 2006; Kovacs 2012). During delivery through the birth canal, a newborn picks up the beneficial bacteria from his/her mother. These good bacteria are not transmitted when a Caesarean section is performed and have been shown to be the reason why some infants born by Caesarean section have allergies, sub-optimal immune systems, and lower levels of gut microflora (Kovacs 2012).

Some of the specific mechanisms by which probiotics exclude undesirable microorganisms include the production of inhibitory substances, blocking of adhesion sites, competition for nutrients, degradation of toxin receptors, and stimulation of immunity (Chow 2002).

Prebiotics stimulate the growth of beneficial and healthy microorganisms (probiotics) in the gut with a resultant increase resistance to invading pathogens. This positive impact of prebiotics, in an unaltered form, in the human intestine is known as the *prebiotic effect*. However, such prebiotic effect is manifested when there is increase in the number and activity of probiotics. This effect is induced by consuming functional foods that contain prebiotics. The prebiotic definition does not emphasize a specific microbial group.

Sources Dietary supplements and fermented food products have been advertised as containing beneficial cultures. These cultures are what would now be considered probiotics (Asmahan 2010). Other foods currently claimed to provide probiotics are cereal juice, frozen yogurt, granola, candy bars, and cookies. While they may contain probiotics, there is no guarantee that they have them in optimal levels. Only the manufacturer of the product can confirm if there are any studies to support his specific claims (Kovacs 2012).

The most common types of prebiotics are non-starchy carbohydrates such as soluble dietary fibre (e.g. β-glucan, inulin, etc.) and other oligosaccharides such as fructo-oligosaccharide (fructans), galacto-oligosaccharide, etc. Many of the plants frequently eaten as vegetables - asparagus, garlic, leek, onion, artichoke – are excellent sources of inulin. β-glucan and inulin are common in many plants containing dietary fibre and fructan. Traditional dietary sources of prebiotics also include soybeans, raw oats, unrefined wheat and unrefined barley. Some of the oligosaccharides that naturally occur in breast milk are believed to play an important role in the development of a healthy immune system in infants through the prebiotic-probiotic relationship (Anon 2011).

Effect of processing on functional components in food

The way a food is processed affects its functional components. Some food processing techniques increase the concentration of these functional components in food while others reduce it (Table 2). It has been shown that the length of post-harvest

Table 2 Effect of processing on the antioxidant content of some foods

S/N	Food	Type of processing	Effect of processing on antioxidant content (%) compared to non-processed food
1.	Apple	Peeling	(−) 33–66 %
2.	Carrots	Steaming	(+) 291 %
3.	Carrots	Boiling	(+) 121–159 %
4.	Cucumbers	Peeling	(−) 50 %
5.	Asparagus	Steaming	(+) 205 %
6.	Broccoli	Steaming	(+) 122–654 %
7.	Green cabbage	Steaming	(+) 448 %
8.	Red cabbage	Steaming	(+) 270 %
9.	Green pepper	Steaming	(+) 467 %
10.	Red pepper	Steaming	(+) 180 %
11.	Potatoes	Steaming	(+) 105–242 %
12.	Tomatoes	Steaming	(+) 112–164 %
13.	Spinach	Boiling	(+) 114–184 %
14.	Sweet potatoes	Steaming	(+) 413

Source Hadvorsen et al. (2006)

storage, steam blanching, and thermal processing all influence the retention of functional compounds in allium vegetables (Howard et al. 1997; Song and Milner 2001). However, losses of about 30–80 % of bioactive isothiocyanates through heat processing have been reported (Howard et al. 1997). In addition, high temperatures (100 °C and above) inactivates key enzymes, myrosinase in cruciferae and allinase in allium vegetables, thereby reducing the amount of functional components. However, temperatures associated with normal cooking have shown little evidence of substantial loss of isothiocyanates. Leaching of glucosinolates and their hydrolysis products also results in a reduction in total phytochemical content following cooking. Research has shown that microwave-heating garlic for 30–60 s or heating it to a temperature of 60–100 °C results in significant losses of its anti-inflammatory, anticancer, antimicrobial, and anti-oxidative activities (Song and Milner 2001).

The bioavailability of carotenoids and other lipid-soluble functional food components have been shown to improve with processing technique that increase surface area, such as cutting and chopping, as well as heat treatment that breaks down protein and carbohydrate matrix (Stahl and Sies 1992; Parker 2000). The brewing of tea leaves, whether black or green, releases 69–85 % of their bioactive flavonoids within 3–5 min in hot water (Trevisanato and Kim 2000).

However, drying pre-treatment before boiling was found to reduce cooking time thereby leading to less leaching of antioxidants in edible Irish seaweed *Homanthalia elongata*. In terms of extract, drying followed by boiling of *H. elongata* had the most significant effect on phytochemicals as its total phenolic content increased by 174 %. However, this processing treatment reduced its anti-microbial activity compared to extracts from fresh samples (Cox et al. 2011) Table 2 below gives a summary of the effect of processing on the antioxidant content of some foods.

Conclusion

Clearly, functional components in food will play an important role in health maintenance in the future as a result of their medicinal properties. However, the bioavailability of these functional food components and the levels required in humans are critical factors necessary to optimize health benefits. Current information in this regard is insufficient and hazy. Consequently, there is need to provide consumers with more information to effectively guide them in making wider choices of diets that contain optimal levels of health-promoting functional food components.

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