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Nutraceutical-prophylactic and Therapeutic Role of Functional Food in Health

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Abstract:

This paper reviews the potential of functional foods in our daily life. A functional food with new ingredients gives an additional function to human health. Above their basic nutritional value functional foods deliver enhanced benefits. The functional food industry is growing rapidly in recent years. Epidemiological studies as well as *in vivo*, *in vitro*, and clinical data showed that plant-based functional foods are able to reduce the risk of different chronic disease, such as cancer. These biologically active plant chemicals are known as 'phytochemicals'. Not only phytochemicals, also there are other animal products considered as functional foods for their potential role in human health. Foods containing probiotics, prebiotics, or plant sterols are also considered as functional foods. The aim of this review was to focus on the role of functional foods on human health. The research work to understand the relationship between different beneficial foods and human health system and to explore the role of the functional foods against various diseases will be an important aspect scientifically, clinically as well as socio-economically. Finally, functional foods will be successful depending on several factors including their effectiveness, safety, and quality.

Keywords: Inflammation; Anti-oxidant; Phenolic compounds; Scavenger activities; Phytochemicals; Anti-carcinogenic agents

Introduction

The industrialized world of this century forced to deal with new challenges such as excess healthcare costs, longer life expectancy and changes in living manner. Nutritionists have enthusiastically accepted the idea of 'optimal nutrition', which focuses on optimising daily diet quality in terms of its nutraceutical value for the proper health. As a result, development of functional foods or nutraceuticals comes into play [1,2]. The demand of functional food is increasing due to more health awareness.

The term 'nutraceutical' coined by DeFelice in 1989 and the Foundation for Innovation in Medicine [3,4]. The term 'functional foods' was first introduced in Japan. The processed foods containing nutritious ingredients that support healthy body functions are known as functional foods [5,6]. According to International Food Information Council (IFIC) the functional foods are dietary components with a health benefit beyond basic nutrition [4,7]. On the other hand, International Life Sciences Institute of North America (ILSI) also defines functional foods as physiologically active food components which provide health benefits [5,8]. Another definition by Health Canada described the functional food which is capable to reduce the risk of chronic diseases. To improve its bioavailability some components of functional foods could be changed by applying new technology [9]. Scientific research is very useful aspect for the production of 'functional food'. According to some journal, functional food is a food with added or concentrated ingredients, which improves health [10]. European consensus publication regarded functional food as healthy food with beneficial and additional nutritional effects on human body. On 10th International Conference in Santa Barbara, CA, 2012, a new definition for 'functional food' announced as 'natural or processed foods that contains known or unknown biologically-active compounds with health benefit for the prevention, management, and/or treatment of chronic disease' [11].

Baby foods, sport drinks, enriched cereals, breads and other foods are considered as functional foods. There were some reports that, the Vitamin B-enriched flour was found to protect pellagra; vitamin D-enriched milk was effective in eliminating rickets and iodine-fortified salt decreased incidences of goitre [12]. Functional foods are different from medical foods and are distributed and regulated separately. Functional foods could be consumed freely as part of our everyday life, whereas medical foods and drugs are consumed when recommended by medical professionals (Table 1). The aim of this review was to focus on the role of functional foods on human health and to understand its use against different diseases and about its production in the industry.

Functional Foods from Plant Sources

Epidemiological evidence (*in vivo* and *in vitro*) and clinical trial data indicates that a plant-based diet can reduce the risk of various chronic diseases. In 1992, a review of 200 epidemiological studies demonstrated that risk of cancer was half to the people who consumed more fruits [13]. This work demonstrated that, bioactive compounds of plant based diets can reduce risk of cancer. Cereals and its ingredients are very good source of dietary fibre, proteins, energy, minerals, vitamins. Wheat, oat, barley, flaxseed, brown rice and soy products are important cereal based functional food and nutraceuticals [14]. The fermented cereals can be used for the growth of probiotic microorganisms also [15]. This review demonstrates health benefits of some plant based functional food.

Difference	Functional foods	Medical foods	Prescription drugs
Uses	Energy enhancement; weight management; bolster gut, bone or heart health; disease risk reduction; memory improvement	Dietary management of a disease or condition with distinctive nutritional requirements (e.g. difficulty swallowing, loss of appetite, nutrition repletion post-surgery)	Treatment of disease, symptom, or condition
Method of obtainment	No prescription or supervision needed; consumer selects	Used with medical supervision	Prescribed by health provider
Distribution channels	Supermarkets, drugstores, online, major retailers	Hospitals, pharmacies, drugstores, online	Pharmacies, hospitals
Regulatory body	No specific body, but is considered food and is therefore subject to FDA regulation (FDA regulates any specific health claims that might be made)	No additional FDA review/approval needed, but must abide by regulations concerning foods, e.g. labeling (FDA regulates any specific health claims that might be made)	FDA approval needed, a multiyear, multistage review process
Amount consumed	As desired	As needed	As prescribed

Table 1: Comparing functional foods with medical foods and drugs.

Oats

Oats, commonly known as *Avena sativa* are considered as a minor cereal crop which comes under Poaceae family. Higher level of protein, lipids, vitamins, minerals antioxidants and phenolic compounds accounts for the nutritional significance of oats (Table 2) [16]. Oat products are good source of β-glucan, a soluble fibre which has the cholesterol-lowering capacity [17], reduce low density lipoprotein [7], contain antioxidant compounds [17], and improves gastrointestinal function and glucose metabolism [18]. Human clinical trials conducted on hyper-cholesterolemic subjects demonstrated 5% reduction in serum cholesterol due to intake of 60 g oatmeal or 40 g oat bran containing 3 g of β-glucan [7].

Components	Oat groat	Oat gum	Oat bran	Oat hull fibre
Total dietary fibre	60-90	-	120-240	900-970
β-glucan	35-50	600-800	55-90	-

Table 2: Composition of oat fibre and β-glucan (g/kg dry weight) [16,18].

Soy

Asian countries are consuming soy foods for centuries [19]. Soy has been in the spotlight during the 1990s. Soybean (*Glycine max*) consists of mainly isoflavones which are a group of naturally occurring heterocyclic phenols which perform several health-promoting functions [20]. Soy contains high quality protein and it plays preventive and therapeutic roles against diseases like cardiovascular disease (CVD), cancer, osteoporosis, and the alleviation of menopausal symptoms [7,21]. The cholesterol-lowering effect of soy is the well-documented physiological effect. There is strong evidence that soy-based diets consumption leads to decrease total cholesterol, LDL cholesterol, serum lipid concentration, and triglyceride levels [22]. According to meta-analysis of 38 separate studies (involving 743 subjects), consumption of soy protein significantly reduced LDL cholesterol (12.9%), total cholesterol (9.3%), and triglycerides (10.5%) [23]. Isoflavones is the key component for the cholesterol-lowering effect of soy. Soy proteins help to decrease LDL synthesis in liver and it can reduce insulin/glucagon ratio [24]. Isoflavones are heterocyclic phenols structurally similar to the estrogenic steroids. Among the isoflavone, genistein and daidzein are the most notable and soybeans are the significant dietary source [7,25]. Various studies reported that isoflavones can prevent intestine, prostate, stomach and breast cancers [26-29]. Another study described that soybeans contain several classes of anti-carcinogens, including protease inhibitors, phytosterols, phenolic acids, saponins, isoflavones and phytic [26,30,31]. The molecular structure of Isoflavones is similar to human estrogens and bind to both estrogen receptors ERα and ERβ but prefer ERβ [32]. Reports demonstrated that, consumption of soy decreases the chance of estrogen-dependent cancer [33]. Soy increases bone density [34,35] and also helps to reduce menopausal symptoms.

Rice

Rice is the most significant cereal crops and a staple food for most of the world's population. Rice is a very good reservoir of hypoallergenic protein and lysine. Protein quality of rice superior to that of wheat and corn [36]. Amino acid composition of rice protein was better than soy protein and casein [37]. It can be a suitable ingredient for infant food formulations [38]. Rice based fermented foods are highly acceptable because of its calorie value [39]. Chung et al. [40] stated that white rice with combination of 8% pigmented giant embryonic rice (Keunnunjami) is functional food which has strong hypolipidemic and anti-obesity properties. Choi et al. [41] described the anti-diabetic property of germinated brown rice extract.

Wheat

The most widely cultivated cereal crop in the World is wheat which is mainly used for milling and baking [42]. Wheat was cultivated first about 10000 years ago [43]. Common wheat (*Triticum aestivum*), also known as bread wheat, is suitable for biscuits [44]. Free and esterified phenolic acids of wheat have the greatest potential health benefit [36,45,46]. Whole wheat and wheat bran based cereals are significant source of dietary antioxidants. Red wheat generally contains higher levels of antioxidants than white wheat [47]. Wheat is a source of zinc, iron and selenium [43]. Recently it was demonstrated that whole wheat flour and bread have more antioxidant capacity then refined flour [48]. Wheat bran are rich in phytochemical like phenolic acids and betaine which are beneficial for [49].

Maize

Among the versatile emerging crops, maize is the most important because of its adaptability with varied agro-climatic conditions. Globally, it is considered as queen of cereals for its highest genetic yield potential. After rice and wheat, maize is the third most important cereal for human food stuff by contributing 9% to Indian basket and 5% to World's dietary energy supply [50]. Decortications by abrasion are feasible to obtain smooth texture of cooked products from maize because of its hardness and size and fine grinding is essential [51]. In Pharmaceutical industry, to release tablet formulation immediately pre-gelatinized maize starch was used and it was also considered for sustained release formulations [52,53].

Barley

Barley (*Hordeum vulgare*) grain is used as feed, malt, and food [36]. Barley is used as flour, as semolina, and as whole-dehulled grain. Barley is rich in dietary fibre, both insoluble and soluble fibre. Fibre constituents of barley have protective and therapeutic effects against various metabolic disorder like cardiovascular diseases, certain cancers and type-2 diabetes [54-57] β-glucan, which is a key component of soluble fibre implicated in hypercholesterolemia, hypoglycemia, and decreases the incidence of chemically induced colon cancer in preclinical model, lowers postprandial plasma glucose and ameliorates insulin resistance [58,59]. Multiple varieties of dishes such as soups, couscous and bread are made by barley products [60].

Millets (*Eleusine coracana*)

Millets belongs to the family Poaceae. Millets are small seeded, annual cereal grasses which can survive in less fertile soil [61]. Millets include sorghum (Jowar), proso millet (Chena), pearl millet (Bajra), foxtail millet (Kakum), finger millet (Ragi), little millet (Kutki), kodo millet (Kodon), barnyard millet (Sanwa), and brown top millet [61,62].

Eleusine coracana is widely cultivated in the arid areas of Africa and Asia. Finger millet is one of the oldest crops in India [63]. In India, it is cultivated over an area of 2.65 million hectares [64]. Milet is considered as one of the important staple foods in some parts of Africa and India (FAO). In India, finger millet was processed by grinding, malting, and fermentation for products like beverages, idli, dosa, and roti [65]. Germinated finger millet can be a good substrate for statins (anti-hypocholestrolemic metabolites) production [66]. Various *in vitro* and *in vivo* studies demonstrated its blood glucose lowering, cholesterol lowering and wound healing properties [67]. It can be used for the preparation of dietetic foods for anaemia patients and geriatric food formulation [68]. Several work demonstrated the antioxidant properties of millet [69-74]. Finger millet also possesses antimicrobial activities [72,75,76]. Protein glycation, one of the complications of diabetes, was inhibited by methanolic extract of finger millet [67,77]. Chethan et al. [78] reported that finger millet phenolics can inhibit aldose reductase and snake venom phospholipases (PLA2) too. Among the cereals and millets, finger millet is the richest source of calcium (344 mg%) and potassium (408 mg%).

Sorghum (Sorghum bicolor)

Sorghum is a cereal which belongs to the family Poaceae. It is considered as major source of carbohydrates and proteins. Sorghum is used as human food worldwide [79]. Pigmented sorghum is a good source of dietary phenolics, mainly flavones, flavanones and deoxyanthocyanidins. Several research has demonstrated anti-cancer activities of phenolic compounds of sorghum, especially 3-deoxyanthocyanidins and it is effective on various cancer such as skin melanoma, liver, colon, breast, esophagus, and bone marrow [80-86]. Other than cancer, sorghum also effective against several diseases such as diabetes, dyslipidemia, hypertension, obesity and inflammation [87].

Table 3 showing composition of different varieties of cereals expressed as 100 g of edible portion.

Parameter	Rice	Wheat	Maize	Sorghum	Millets
Water (%)	12	12	13.8	11	11.8
Protein (g)	7.5	13.3	8.9	11	9.9
Fat (g)	1.9	2	3.9	3.3	2.9
Carbohydrates (g)	77.4	71	72.2	73	72.9
Fibre (g)	0.9	2.3	2	1.7	3.2
Ash (g)	1.2	1.7	1.2	1.7	2.5
Ca (mg)	32	41	22	28	20
P (mg)	221	372	268	287	311
Fe (mg)	1.6	3.3	2.1	4.4	68
K (mg)	214	370	284	350	430
Mg (mg)	88	113	147	n.d.	162
Riboflavin (mg)	0.05	0.12	0.12	0.15	0.38
Niacin (mg)	1.7	4.3	2.2	3.9	2.3
Thiamin (mg)	0.34	0.55	0.37	0.38	0.73

Table 3: Composition of different varieties of cereals expressed as 100 g of edible portion [88].

Fig (Ficus carica)

Figs belongs to the Moraceae family. Semi-arid climate is suitable for fig. Figs are usually dried and stored for later consumption. Medicinal value of figs already documented in various research papers and it has been demonstrated that figs has positive impact to treat respiratory, anti-inflammatory disorders, anti-cancer, antiviral, cardiovascular, aphrodisiac, hairnutritive [89,90], anti-diabetic, hypolipidemic [91,92], antipyretic [93], antibacterial [94,95], antifungal [96], scavenging activity and immune response [97]. It was demonstrated that ripe dried fig has potential effect on gastrointestinal, inflammatory disorders [98], and anti-infertility [99,100]. The Wildlife Conservation Society of New York reported that, wild figs are considered as 'keystone' fruit due to its high calcium content [101]. Hepatoprotective activity of figs has been demonstrated previously [102]. Other than fruits, latex of fig also has various medicinal importance. Leaves of fig tree are very useful to treat diabetes and contact dermatitis [92].

Fenugreek (Methi)

Fenugreek (*Trigonella foenum-graceum*) is a semi-arid crop belongs to Fabaceae family and is cultivated worldwide [103,104]. Fenugreek seeds and green leaves are used in food as well as in medicinal

application. Fenugreek paste, locally termed as 'Cemen' is a popular food in Turkey [105], which is prepared from ground fenugreek seeds. Crushed fenugreek seed is used to make ball to make clarified butter. Fenugreek has strong spicy and seasoning type sweet flavour [106]. Aromatic and flavourful fenugreek is a popular spice and is widely used for well-known medicinal properties [107]. India is a major producer of fenugreek and also a major consumer of it for its medicinal application. It is used as a functional food, traditional food and nutraceuticals. Singhal et al. [108] demonstrated hypo-cholesterolemic activities of fenugreek seeds and Basch et al. [109] reported that fenugreek seeds lowered serum cholesterol, low-density lipoprotein (LDL) and triglyceride in hypercholesterolemic patients. According to Basch et al. [109] Fenugreek consumption in diet reduced triglyceride accumulation in the liver. Fenugreek also used as an antibacterial, anticancer, antiulcer, antioxidant, and antidiabetic agent. It helps to improve digestion. Fenugreek contains different alkaloids, flavonoids and saponins [110,111]. Grover et al. [112] reported that fenugreek seeds showed hypoglycaemic and anti-hyperglycaemic activity in diabetic mice. The aqueous extract of fenugreek showed significant positive effect on ulcer. It has soothing effect on gastric and gastritis ulcer [113]. Fenugreek possess various bioactive compounds, among them trigonelline, galactomannan, diosgenin, 4-hydroxyisoleucin, and soluble dietary fibre fraction are important [114,115]. Several study revealed anti-diabetic property of diosgenin in animal model [116-118]. Recently, Bahmani et al. [119] demonstrated that, trigonelline which is bioactive compound of fenugreek is responsible for anti-diabetic property of fenugreek and it decreases blood cholesterol too. Diaszhenin is one of the important bioactive compounds of fenugreek and it is used as contraceptive pills [119]. Dietary fibre of fenugreek seed is used for cooking [120,121] and it is very active to reduce postprandial hyperglycemia in preclinical model and decrease serum lipids [122,123]. Fenugreek provides natural food fibre and other nutrients required for human body [124]. Saponins are found to be in maximum concentration in the fenugreek [125] and Cholin content is very high in fenugreek [126]. Fenugreek seed is riched in multivitamin such as Vitamins-A (1040 IU per 100 g), B1 (0.41 mg per 100 g), B2 (0.36 mg per 100 g), C (12.0 mg per 100 g), nicotinic acid (1.1 mg per 100 g) and niacin (6.0 mg per 100 g) [127].

Cordyceps mushroom

Cordyceps militaris is widely distributed in China, Tibetan Plateau, Bhutan, Nepal and north east India at high altitude. In traditional Chinese medicine it is used as a tonic herb [128]. *C. militaris* has traditionally been used as a functional food and several bioactive compounds like adenosine, cordycepin, polysaccharides, mannitol, and ergosterol have been isolated from it [129,130]. It can be used to treat various inflammatory disorders and boosting the immune system [131]. Several researches demonstrated its promising activity in various inflammatory disease models like ovalbumin-induced asthma, dextran sodium sulphate (DSS)-induced colitis, and croton oil-induced ear oedema [132]. Humoral immune hyper-function was inhibited by cultivated Cordyceps and it improved liver function of post-hepatic cirrhosis patients by up regulate the level of the serum complement [133]. Recently, *C. militaris* cultivated on germinated soybean (GSC) extract and it was very effective against allergy and Type I hypersensitive animal model [132,134]. Cordycepin isolated from hot water extracts of C. Sinensis might be a good drug candidate against anticancer and antimetastatic [135]. 100 g of *Cordyceps militaris* contains 2.01 g manitol and 24.71 g trehalose free sugar. It is rich in polyunsaturated fatty acids (68.87%) than saturated fatty acids (23.40%). Various organic acids were found in this mushroom as oxalic, citric and fumaric acids (0.33, 7.97 and 0.13 g/100 g, respectively). Among the phenolic acids, only 0.02 mg p-Hydroxybenzoic acid was found in 100 g of this mushroom and d-tocopherol concentration was 55.86 lg/100 g [136]. This functional food has been used as drug and need further research by modern scientific approach for accurate phytochemical and bioactive compounds.

Flaxseed:

Flax (*Linum usitassimum*) is a blue flowering annual herb comes to Linaceae family. It produces golden yellow to reddish brown coloured flat seed. It has been used for medicinal purposes for over 5000 years [137,138]. More than 50 countries cultivate flaxseed [138,139]. According to Oomah [140], World's largest producer and exporter of flaxseeds is Canada. Scientific research has focused on fibre-associated compounds known as lignans. The richest source of mammalian lignan precursors is flaxseed [141,142]. Flexseeds are very effective in several diseases like diabetes, arthritis, neurological disorders, osteoporosis, cardiovascular disease, cancer and various chronic non-communicable [143-145]. Consumption of flaxseed has also been shown to lower LDL cholesterol [146,147] and platelet aggregation [148]. Several researches supported the chemo protective activities of the omega-3s and lignan phytoestrogens of flaxseed in human and animals [149-171]. Estrogen-dependent cancers can be prevented by mammalian lignans. In rodents, flaxseed has been shown to decrease tumours of the colon and mammary gland [155,164,172-176] as well as of the lung [177]. Different studies demonstrated that, consumption of flaxseed reduce breast [168,178,179] and prostate cancer [180-182]. It has also been reported that the ingestion of 10 g of flaxseed daily elicited several hormonal changes associated with reduced breast cancer risk [183]. Recent study revealed the anti-hepatotoxicity property of flaxseed oil [184]. *In vivo*, *in vitro* and *in silico* study reported that, dietary flaxseed might be a good approach to treat muscle dystrophies [185].

Tomatoes (*Solanum lycopersicum*)

Tomato is an important vegetable because of lycopene which is the primary carotenoid found in this fruit [186]. Different products are obtained from tomato, such as ketchup, sauces, and soups [187,188]. The tomatoes are rich in various bioactive compounds such as lycopene, β-carotene, phenolic compounds, flavonoids, glycoalkaloids, tomatine pro-vitamin A and vitamins C and E [189-197]. A clinical study by Giovannucci et al. [198] demonstrated that, tomato can reduce developing advanced prostate cancer [198]. Recent study revealed dietary lycopene consumption protect from prostate cancer by ERG protein expression [199]. Other than prostate cancer, it also has positive effect on breast, digestive tract, cervix, bladder, and skin cancer [200,201]. Along with peroxyl radicals scavenging capacity lycopene can also scavenge nitrogen dioxide and hydrogen peroxide [202,203]. Lycopene is the most effective as singlet oxygen quencher in biological systems [204]. Several work demonstrated that lycopene bioavailability of processed tomato is more than unprocessed tomato [205-207]. Recent study showed the hypolipidemic activities of processed tomato juice in animal model [208]. Tomato drink can reduce about 42% DNA damage in lymphocyte caused by oxidative stress [209].

Pumpkin (*Cucurbita pepo*)

Cucurbita pepo (pumpkin) comes under the family Cucurbitaceae. Cultivation of pumpkin originated in central Africa on 5500 BC

[210-212]. Pumpkin is one of the well-known plants which have been used as functional food [213]. It is very rich source of fatty acids like palmitic (C 16:0), stearic (C 18:0), oleic (C 18:1) and linoleic (C 18:2), linolenic (C18:3), sterols, gamma aminobutyric acids, proteins and peptides, polysaccharides, para-aminobenzoic acid and fixed oils, essential fatty acid such as omega 6 and omega 9, phytosterols, and antioxidants such as tocopherols, carotenoids, vitamin A and vitamin E [214-222]. Various ethnopharmacological studies demonstrated that *Cucurbita pepo* is used as antiviral, analgesic urinary disorders, anti-microbial, anti-ulcer, antidiabetic, anti-cancer, and antioxidant in various diseases [212,223-230]. Low dose pumpkin showed hypoglycaemic activity by decreasing triglycerides, LDL and CRP (C-reactive protein) and high dose pumpkin decreased cholesterol [231]. Pumpkin is used as anti-diabetic traditionally medicine worldwide [232,213]. Several studies reported that pumpkin exhibits anti-diabetic activities in mice model [233-238]. Another research demonstrated anti-diabetic effect of tocopherol fraction of pumpkin seed oil in Wistar rats [239,240]. Pumpkin helps to improve pancreas β cells functionality by increasing the number of insulin positive cells [241]. It is also very effective against alcohol induced hepatic damage [242-244]. Recent research stated that, the pumpkin seeds are very useful to manage the benign prostatic hyperplasia [245].

Garlic

Garlic (*Allium sativum*) was originated in Central Asia [246] and is used universally as a flavouring agent as well as traditional medicine and a functional food to enhance physical and mental health [247]. The health benefits of garlic are numerous, including anti-diabetic, cholesterol-lowering properties, chronic inflammation, cancer chemopreventive anti-aging, antibiotic, and anti-hypertensive, increase blood circulation, anti-gastric cancer, antioxidant [246,248-254]. Garlic mixed with calcium hydroxide to form paste and applied to treat carbuncle [255]. Garlic has various medicinal values due to its oil-and water-soluble, sulphur-containing elements [256-262]. The whole garlic bulb contains alliin, a derivative of the amino acid cysteine. Alliin is converted to allicin by allinase [13]. Allicin is responsible for the pungent odour of fresh garlic [263,264]. Alliin was the first natural compound which has both carbon and sulfur-centered stereochemistry [265]. Allicin have been investigated for their chemo-preventive activity [7]. Water content is 65% of fresh weight of garlic and the bulk of the dry weight is composed of mainly fructans, a fructose-containing carbohydrates, followed by other compounds like fibre, sulfur compounds, free amino acids and protein [266]. Several work demonstrated that, garlic extract capable to reduce diet-induced hyper-cholesterolemia [267]. Garlic has also been used for the prevention of CVD. The cardio protective effects are more likely due to its cholesterol-lowering effect. A meta-analysis [268] demonstrated that, an average of 900 mg garlic/day can reduce 9% serum cholesterol. Some authors suggested that garlic can reduce total cholesterol levels by 12% [269,270]. Although another study reported that, 12 weeks of garlic treatment was ineffective to reduce cholesterol in hypercholesterolemia subject [271,272]. Anti-tumorigenesis activity of garlic has been demonstrated in several preclinical models [250]. Several epidemiological studies demonstrated that, stomach cancer risk can be reduced by increasing allium intake [273]. In a clinical study with more than 40,000 postmenopausal women showed that, garlic consumption can reduce nearly 50% risk of colon cancer [274]. Antimicrobial activity of garlic has been documented from long time and Mr. Louis Pasteur also demonstrated the same [247,275-285]. Several recent studies also reported the promising effect of aqueous garlic extracts against various bacteria as antibacterial agent [286-289]. Recent study demonstrated that, allicin and other organosulfur compounds from garlic showed promising antibacterial effect on methicillin-resistant *Staphylococcus aureus* (MRSA) which are now considered as a major hospital acquired pathogen all over the world [290]. It has been shown hepatoprotective activities of garlic in several studies also [291-293]. Due to hepatoprotective effect of garlic, it can be a very good supplementation with first line anti-TB drugs [294]. Antimicrobial activity of garlic against *Mycobacterium tuberculosis* was firstly documented in 1946 [295]. Another study reported that, being promising antimicrobial agent, aqueous extract of garlic can be useful for dental caries and periodontitis [296].

Cranberry (*Vaccinium macrocarpon*)

Cranberry belongs to the Ericaceae family and 90% of total production of it contributed by North America and Canada [297]. Intake of cranberry juice significantly increases plasma antioxidant level [298-300]. Cranberry juice has been recognized as efficacious in the treatment of urinary tract infections since 1914 [301]. Several investigations have exhibited the ability of proanthocyanidins of cranberry juice to inhibit the attachment of *Escherichia coli* to uroepithelial cells [302-305]. Cranberry is beneficial to various diseases like cardiovascular disease, lipoprotein oxidation, and atherosclerosis [299,306,307]. Several *in vitro* studies supported the anti-cancer property of cranberries [308-313].

Cocoa (*Theobroma cacao*)

Theobroma cacao is commonly known as cacao tree or cocoa tree. The cocoa tree originated from ancient Central America [314]. Cocoa and cocoa-rich chocolates are very popular and widely consumed food component [315-317]. Cocoa is beneficial on blood pressure, vascular, platelet function and insulin resistance [315]. Cocoa beans and their parts are important ingredients for making chocolate. Cocoa is among the richest sources of polyphenols [318] and the total polyphenol content of the cocoa bean is about 6-8% by dry weight. Flavonoids, polyphenols, and procyanidins are the most important bioactive compounds with disease preventive characteristics [314]. Cocoa and cocoa products are recognized for health benefits related to hypertension, diabetes, anaemia, cardiovascular diseases, atherosclerosis, obesity, tuberculosis, fever, gout, kidney stones, mental fatigue, poor sexual appetite, neurodegenerative diseases and cancer [314,319-324]. Recent metaanalysis study stated the blood pressure lowering property of cocoa rich food [325] and it has been found that, in addition to the hypotensive effects, cocoa flavonols reduce adipose tissue by stimulating thermo genesis and lipolysis [326]. Recent research demonstrated that, cacao osmotin and its derived peptides might be a good drug candidate against pathogenic fungi [327].

Peanut

Peanut is an important crop worldwide and by-products of peanut contain vitamins, proteins, antioxidants, fibers, polyphenols, and minerals. These ingredients are used in many processed foods. Some reports described that, peanuts are also source of flavonoids, phytosterols and phenolic acids which are able to block the absorption of cholesterol from diet. Peanut also contains 20 amino acids and known for its disease preventive properties [328].

Strawberry

Strawberries, a rich source of phytochemicals and vitamins are considered as functional food for their preventive and therapeutic health benefits. Strawberry is also known for its antioxidant capacity [329,330]. Many studies found its anti-inflammatory, antihyperlipidemic, antihypertensive, or antiproliferative effects principally via downregulation of NF-kB activity [331-336]. Strawberries are a significant source of flavonoids. Flavonoids have been shown to have direct antibacterial activity [337-339]. Different epidemiological studies support the protective effects of strawberries against cancer, inflammation, cardiovascular mortality and hypertension [335,340]. Some studies demonstrated that, strawberries can reduce oxidant stress [341,342]. Different epidemiological and clinical studies observed cardio-protective effects of strawberries. Pinto et al. [343] using *in vitro* models reported the role of strawberry phytochemicals in managing hyperglycemia and hypertension. Another report demonstrated berry polyphenols as a potential phytotherapy in obesity and hyperglycemia [344]. Strawberry has been shown to exert anticarcinogenic effects [331,345]. Stoner et al. [346,347] showed the effects of freeze-dried strawberries on the inhibition of tumors in rodents.

Tannins (a specific strawberry polyphenols) showed significant anticancer effects in human breast, cervix, and colon carcinoma cells [348,349]. Ellagic acid found in strawberries demonstrated anticarcinogenic effects in several human cancer cell models in some studies [350,351]. Several studies described the role of strawberries in curing age-related neurodegenerative disorders [352-354].

Table 4 showing examples of foods with higher content of specific nutraceutical substances.

Diosgenin	Fenugreek
Allyl sulfur compounds	Garlic
Isoflavones (e.g. genestein, daidzein)	Soybeans and other legumes
Quercetin	Citrus fruit
Capsaicinoids	Pepper fruit
EPA and DHA	Fish oils
Lycopene	Tomatoes and tomato products
Isothiocyanates	Cruciferous vegetables
β-Glucan	Oat bran
CLA Beef and dairy	Beef and dairy
Catechins	berries
Adenosine	Garlic
Curcumin	Tumeric
Ellagic acid	Strawberries
Cellulose	Most plants (component of cell walls)
Monounsaturated fatty acids	Tree nuts, olive oil
Inulin, Fructooligosaccharides (FOS)	Whole grains, garlic
Lactobacilli, Bifidobacteria	Yogurt and other dairy
Catechins	Cocoa
Lignans	Flax
Cyclic peptides, cordycepin, 10-membered macrolides, cepharosporolides C, E and F, pyridine-2,6-dicarboxylic acid and 2-carboxymethyl-4-(30-hydroxybutyl) furan, dipicolinic acid	*Cordyceps militaris*

Table 4: Examples of foods with higher content of specific nutraceutical substances.

Functional Foods from Animal Sources

Some animal products with potential beneficial effects on human health are considered as functional foods. Some examples are as follows:

Fish

Fish contain animal protein. Fish oils contain the omega-3 (n-3) polyunsaturated fatty acids, vitamins and minerals [355]. The omega-3 fatty acid is an essential class of polyunsaturated fatty acids (PUFAs). Omega-3 fatty acids can reduce the rate of cardiovascular diseases or CVD [356] and it can also lower triglyceride level [357]. Studies by Kris-Etherton et al. [358] reported the effects of omega-3 fatty acids to reduce the incidence of CVD. Some observational studies report a decrease in cardiovascular disease with higher fish oil intake [359]. Omega-3 fatty acids also decrease the risk of thrombosis [360].

Consumption of 35 g of fish per day has been shown to reduce the risk of total mortality by cardiovascular disease [361]. Fish oil also plays role in decreasing weight and waist circumference [362]. The evidence of fish oil supplements lowering triglycerides has been found in dialysis patients [363]. Saccone and Berghella reported that, fish oil supplements appeared to be associated with greater weight at birth of the child [364]. Another report demonstrated that, supplementation of fish oil improves the quality of life in patients with chronic heart failure [365]. Some studies reported that, patients with a higher consumption of fish are less likely to have type 2 diabetes as compared to patients with lower fish consumption [366]. Recent randomized, controlled clinical trial by Pase et al. [367] showed the effects of long-chain omega-3 fish oils on cognitive and cardiovascular function.

Dairy products

Dairy products are considered as functional foods as they are rich of calcium. Fermented dairy food products could prevent diseases such as hypertension. Calcium helps preventing osteoporosis and possibly colon cancer. Other than calcium, many other components in fermented dairy products are known as probiotics. Probiotics are microorganisms with health benefits to the host animal by improving its intestinal microorganisms. Probiotics are termed as functional foods which can alter and modify pre-existing intestinal flora [368,369].

Both beneficial (e.g. *Bifidobacterium* and *Lactobacillus*) and detrimental (e.g. Enterobacteriaceae and *Clostridium* spp.) bacteria inhabit the human gastrointestinal tract. Among these bacteria, lactic acid bacteria are used in food fermentation [370-372]. Probiotics are

known for their anti-carcinogenic, hypo-cholesterolemic and antagonistic actions against gut pathogens. Probiotics are used in colon cancer risk reduction [373,374]. This is because lactic acid cultures are able to alter the activity of faecal enzymes such as β-glucuronidase, azoreductase, nitroreductase which plays a role in the development of colon cancer [375,376].

The prebiotics are defined as 'non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one or a few number of bacteria in the colon and thus improves host health' [377]. These include starches, dietary fibres, sugar alcohols, and oligosaccharides [378]. Among these prebiotics oligosaccharides found naturally in many fruits and vegetables and have received great attention for their health benefits [379]. Prebiotics as food additives are valuable for functional foods and also helps in preventing diet-related diseases [380]. The prebiotic concept has been further extended to understand the effect of the synbiotics which is a mixture of pro-and prebiotics [377]. Many such synbiotic products are currently on the market in different countries. Recently our group demonstrated the use of combination of probiotic microbial strains supplemented in food as possible therapeutic and prophylactic agent to fight against inflammation and degeneration in Inflammatory Bowel Diseases (IBD) [381].

Beef

Meat and meat products contain important source of protein, fat, and several functional compounds [382]. Thomas and others [383] described the importance of animal meat for the high quality proteins as well as for its contribution to food security in the rural livelihoods. In 1987, conjugated linoleic acid (CLA) was first isolated from beef. CLA is an anti-carcinogenic fatty acid and it is a mixture of isomers of linoleic acid. CLA consists mixture of two isomers, cis-9, trans-11 and trans-10, cis-12. Conjugated linoleic acid has been approved as GRAS (generally recognized as safe) in USA since 2008 [384]. CLA increases in cooked foods and it acts as a weight-reduction agent. Reports showed that, CLA acts as a protective agent in mammary carcinogenesis and aberrant colonic crypt foci in rats [385]. On the other hand, dairy cow milk contains conjugated linoleic acid by dietary modification [386]. Conjugated linoleic acid isomers also reported to block lipogenic genes expression in rats [387]. Meat processing and preservation technologies are essential for food security and also to supply good-quality and affordable meat products. Many authors have reported different methods and technologies to extend the shelf life of fresh meat [388].

Animal foods

Some animal foods such as vitamin-like substances, coenzyme Q10, α-lipoic acid and others are considered as physiologically active compounds. According to some reports carnitine is an essential nutrient in infancy [389]. Coenzyme Q10 is a vitamin-like substance and plays an important role in the generation of cellular energy in the human body. It also helps in healthy cardiovascular effects [390]. α-Lipoic acid has been known for its antioxidant activity [391].

Table 5 showing some examples of nutraceutical substances grouped by food source and Table 6 showing some of the food ingredients approved by Food Safety and Standards Authority of India (FSSAI) in India.

Plants	Animal	Microbial
α-Glucan,	Conjugated Linoleic Acid (CLA)	*Saccharomyces boulardii* (yeast)
Ascorbic acid	Coenzyme Q10	*Bifidobacterium bifidum*
γ-Tocotrienol	Eicosapentaenoic acid (EPA)	*B. longum*
Quercetin	Docosahexenoic acid (DHA)	*Lactobacillus acidophilus*(LC1)
Luteolin	Spingolipids	*L. acidophilus* (NCFB 1748)
Gallic acid	Choline	*Streptococcus salvarius* (subs.
Indole-3-carbonol	Calcium	Thermophilus)
Indole-3-carbonol	Selenium	
Pectin	Creatine	
Daidzein	Zinc	
Glutathione	Minerals	
Potassium		
Allicin		
δ-Limonene		
Genestein		
Lycopene		
Hemicellulose		
Lignin		
Capsaicin		
Geraniol		
β-Ionone		
α-Tocopherol		
β-Carotene		
Nordihydrocapsaicin		
Selenium		
Zeaxanthin		
Minerals		
MUFA		

Table 5: Examples of nutraceutical substances grouped by food source [10].

Impact of Urbanization on Health and Functional Food Market

The direct and indirect beneficial effects of functional food depend on environmental factors such as place and time of cultivation. The benefits and risks of functional foods to individuals and populations as a whole must be determined carefully.

Industrialization, globalization and urbanization, these three factors influences Indian life-styles and food habit. In India, incidence of lifestyle related health problems such as diabetes, cardiovascular diseases, hypertension and obesity increasing rapidly [392]. Day by day people are becoming disease prone due to the stressful work and less physical activity [393]. Work related stress leads to many diseases such as hypertension and cardiovascular diseases [392]. Choice of foods and diet structure such as fast food and added sugar in the diet gradually changing the human health quality [394]. In this current scenario functional food plays an important promising role in the healthy human life. Indian consumers' markets are increasing for a healthy food as well as demand of functional foods are increasing in Indian food industry.

Ingredient	Industry Usage	Health Claims
Omega 3 and 6	Functional foods (fortified foods): e.g. omega fortified malted beverages	Prevention from inflammatory and autoimmune diseases, also reducing cholesterol, and hence, various heart risks.
Probiotics	Functional foods: e.g. probiotic Yogurt/dahi improve intestinal microflora and aid better digestive health.	Improve intestinal microflora and aid better digestive health.
Beta glucan	Functional beverages: e.g. soya milk drinks	Soluble fibre that soaks up the cholesterol.
Phytoestrogens	Functional foods: e.g. rice bran fortifies oil	Reduce the risk of many kinds of cancers, cholesterol and risk of coronary heart disease.
Tocopherols	Functional foods: e.g. rice bran fortifies oil	Cholesterol lowering potential. Prevent or delay heart disease and related Complications, cataracts, macular degeneration, prostrate and other cancers.
Ginseng	Dietary supplements: e.g. Tonicsand stimulants	Cures lethargy, arthritis, impotence, senility, ani-aging properties.
Beta-carotene	Dietary supplements: e.g. Beta-carotene in antioxidants	Prevent night blindness, skin problem, enhance immunity, protect toxins and cancers

Table 6: Some of the food ingredients approved by food safety and standards authority of India (FSSAI) in India.

Indian Functional Food and Nutraceutical Market Size and Growth

Among the developing countries, India is the most potential market for nutraceuticals and dietary supplement products. Nutraceuticals market is growing rapidly in comparison to other sectors of Indian food market.

According to Ernst and Young study, Indian functional food market in 2008 was about INR 30 billion, apart from the dietary supplements and it has grown at a CAGR (compound annual growth rate) of 18% as compared to a world average of 7% [392]. Indian functional food market deals with products like fruits, vegetables, fortified juices, energy drinks, fresh dairy products, confectionary, breakfast cereals, and fibre rich foods which imparting the desired health benefits and physiological changes. Main ingredients of these products are probiotics, prebiotics, omega fatty acids fortified foods, tocopherols, phytoestrogens, xylitol, soy, gluten and whey proteins. In 2010, about 116 new functional food products were launched in India [395]. Out of these, 80 products were targeted at enhancing the cardio vascular functioning and the rest 36 at promoting the immunity.

Conclusion

Functional foods are an important part of healthy lifestyle that also includes a balanced diet and physical activity. Functional foods will be successful depending on several factors including their effectiveness, safety, and quality. Our understanding of functional foods by scientific research will enhance the knowledge on long-term health benefits. Some functional dairy products support healthy heart by lowering blood pressure. Epidemiological studies needed to cope with enormous amount of inquiries and demands for functional food all around the world. Probiotics supply necessary bacteria which act as commensals in the gut and form a biofilm by colonizing specific tissue locations. Through quorum sensing these heterogeneous food products provide additional physiological fortification as well as developmental signals. Phytochemicals, micronutrients in food and animal resources, microbes and their metabolic by-products directly or indirectly help mobilize the body's physiological network encompassing the neuro-immuno-endocrine cycles and help maintain optimum health. More future research on food items will expand the existing knowledge of functional food as well as developing specific strategy in the biodiversity management.

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