

Functional Foods for Human Health and Management of Diseases -A Review

Dr. CHITHRA.V

Department of Biochemistry, NSS College, Pandalam

University of Kerala, Kerala, India

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Abstract: Functional foods are specialized foods having extra-nutritional functions. Functional foods are indeed specialized foods that provide health benefits beyond basic nutrition. They contain biologically active compounds, such as fiber, probiotics, antioxidants, and phytochemicals, that support optimal health and may reduce the risk of chronic diseases when consumed regularly as part of a varied diet. They can be natural (like blueberries or whole grains) or fortified/enriched (like iron-fortified cereal or yogurt with live cultures) and are consumed as part of a regular diet for specific physiological benefits. A food can be regarded as functional if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way which is relevant to either the state of well-being and health or the reduction of the risk of a disease. A food can be made functional by increasing the concentration, adding or improving the bioavailability of a particular component. Functional food science will serve to establish claims based either on enhanced function or disease risk reduction. Functional foods play an important role in maintaining a healthy lifestyle and reducing the risk factors of various diseases. Most foods have a functional element which is responsible for improving the healthy state. All food substances such as fruits, vegetables, cereals, meat, fish, dairy contain functional ingredients. A wide range of naturally occurring substances from plant and animal sources having active components which play a role in physiological actions deserve attention for their optimal use in maintaining health.

Keywords: Functional foods, biologically active compounds, bioavailability, antioxidants, healthy lifestyle.

I. INTRODUCTION

Functional foods are regarded as foods that have potential beneficial effect on health beyond their basic nutritional value. They promote good health and lower the risk of diseases. Functional foods have received widespread popularity across the globe, and they are commonly known as “nutraceuticals” and “designer food [1].

Functional foods are specialized foods having extra-nutritional functions. Developed countries are introducing newer functional foods in the market every year. Among functional foods, functional eggs are very popular and available in the Indian market also. They promote the overall health of the consumers besides supplying valuable nutrients. The technologies for developing functional eggs like omega-3 enriched eggs and meat are available. Functional foods refer to natural or processed food products that contain biologically active substances—whether currently identified or not—that, when consumed in appropriate, safe, and practical amounts, offer proven health advantages.³ Such foods may originate from either plant or animal sources and can also include processed foods enriched with beneficial compounds^[2]

These additions may include prebiotics, probiotics, symbiotic, polyunsaturated fatty acids (PUFAs), essential fatty acids (EFAs), vitamins, minerals, amino acids, and proteins. Moreover, many functional foods are rich in phytochemicals such as flavonoids, polyphenols, phenolic acids, phytosterols, and both nutrient and non-nutrient antioxidants. Depending on their active components, functional foods may support various physiological functions. They may help combat oxidative stress, lower inflammation, enhance insulin sensitivity, reduce glucose absorption, support insulin secretion, and improve lipid metabolism.^{5,6} These include whole grains, legumes, spices, vegetables, fruits, fermented foods, and food-derived bioactive compounds that can positively influence metabolic pathways. Their integration into daily diets—particularly in culturally appropriate ways—offers a sustainable, low-cost, and accessible means of supporting diabetes prevention and control.

II. FUNCTIONAL FOODS AND THEIR SOURCES

2.1 Plant origin

Plants are the rich source of natural oxidants and help to strengthen innate immunity and protects from the toxic effects of oxidants. Tomato contains a plethora of bioactive compounds such as lycopene, neoxanthin, violaxanthin, α -cryptoxanthin, zeaxanthin, lutein, β -cryptoxanthin, β -carotene, γ -carotene, ζ -carotene, α -carotene, phytoene, phytofluene, cyclo-lycopene-neurosporene, and β -carotene 5, 6-epoxide [3] (Burns et al. 2003).

Lycopene is the prominent bioactive compound in tomatoes and it has been widely studied over the past decade. Approximately 100 g of tomato contains 12 mg of lycopene. Chemically lycopene is acyclic carotene with 11 conjugated double bonds, these double bonds are contingent to isomerism and their isomers are reported to be found in blood plasma. The human body by itself is unable to synthesize carotenoids so the body is completely dependent on dietary sources. Studies have been reported that 85% of the lycopene in the human diet is obtained from tomato and tomato-based food products. Moreover, lycopene is a key intermediate in the biosynthesis of other essential carotenoids like β -carotene, and xanthophylls [4] (Ruiz-Sola and Rodríguez-Concepción 2012).

Broccoli are the flowers of *Brassica oleracea* var. *italica*. Its flowering head, leaves and stalk are consumed as vegetables across the globe. Broccoli is commonly regarded as the “Crown Jewel of Nutrition” because, it is immensely rich in variety of nutrients such as vitamins, minerals, fibres and secondary metabolites. In addition, it is rich in Vitamin K, B1, B2 [5] (Damon et al. 2005) and minerals like Na, K, Ca, Mg, Cl, P and S. Dietary consumption of cruciferous vegetables is highly beneficial in preventing stomach, colon, thyroid, skin and prostate cancers.

Soya beans (*Glycine max*) are a legume. The major bioactive fractions of soya beans include peptides, isoflavones, saponins, and protease inhibitors. soya beans are also rich in isoflavones which have potent estrogenic and anti-estrogenic properties and saponins which are proven to have significant anti-inflammatory, anti-carcinogenic and cardioprotective properties [6] (Guang et al. 2014).

Lycopene is a potent antioxidant, and can protect DNA from free radicals and thereby prevent mutations that lead to cancer [7]. A study had shown that lycopene can protect cells from chromosomal aberration [8]. Spinach is an abundant source of the carotenoid lutein, which is highly beneficial for patients with macular degeneration and cataracts [9]. Compared to other leafy vegetables spinach is rich in flavonoids which includes patuletin, spinacetin, spinatoside, jaceidin, and flavone [10]. These compounds are responsible for the potent antioxidant and anti-inflammatory properties of spinach.

Pomegranate (*Punica granatum* L) fruits are rich source of phytochemical such as polyphenols, anthocyanins, tannins, flavonoids, lignans, terpenoids, and sterols. Ellagitannin which is broken down to ellagic acid is the main active constituent of pomegranate which is responsible for its strong antioxidant activity [11]. (Akbar et al. 2015). Punicalagin and punicalin are the two other ellagitannins having antioxidant and anti-inflammatory activity [12].). Numerous studies have claimed health benefits of pomegranates in preventing chronic diseases such as hypertension, arthritis, cancer, hyperglycaemia, reducing oxidative stress and maintaining cholesterol levels [13].

Another study has revealed that pomegranate juice inhibits cell growth, induces pro-apoptotic proteins and downregulates anti-apoptotic proteins and suppresses the progression of prostate cancer and breast cancer as well as lung and colon cancer [14]

Mango (*Mangifera indica* L.) is rich in polyphenols and other micronutrients which exert several health benefits. Mangiferin, gallic acid, gallotannins, quercetin, isoquercetin, ellagic acid, and β -glucogallin are the polyphenols present in mango. Mango parts have been used in traditional system in the management of various diseases. Mango extracts counteract the oxidative damage induced by the excessive production of free radicals. Mango extract has beneficial effects in hypoglycaemia by inhibiting α -amylase and α -glucosidase activities [15],[16].

2.2 Nuts as a source of functional food

Almonds are the most popular nut consumed by humans. They have a high nutritional value and are rich in polyphenols, vitamins, carbohydrates and polyphenols. Almonds are also rich in monounsaturated fatty acids such as oleic, linoleic and palmitic acids. Intake of almonds reduce chronic disease such as diabetes, hypertension and help in weight maintenance [17].

Walnuts are one of the most nutritive nuts belonging to family Juglandaceae. They are rich in proteins, fats, vitamins, minerals, and polyphenols. The major triacylglycerols; free fatty acids found in the walnut kernel are oleic, linoleic, linolenic acids [18],[19] (Poulose et al. 2014). They also contain high quantity of omega-3 fat [alpha-linolenic acid] which has been linked with numerous health benefits. Walnuts also contain amino acids such as lysine and arginine which are converted to nitric oxide, which acts as a potent vasodilator, inhibiting platelet adhesion and aggregation, and reducing the progression of atherosclerosis. Ellagic acid present in the walnut reduces the risk of congestive heart disease and suppresses cancer progression. Melatonin present in walnut is a powerful antioxidant and regulates circadian rhythm. Dietary supplement of walnut improves memory consolidation and has been reported to delay the progression of neurological disorders.

2.3 Functional foods of animal origin

Fish

The chief bioactive component present in fish products are polyunsaturated fatty acids. Eicosapentaenoic acid and docosahexaenoic acid (DHA) form the major components of polyunsaturated fatty acids. DHA forms an essential component of cellular membranes in brain and retina. DHA is critical for normal functioning and development of organs in children. Preclinical and clinical studies have shown the beneficial effects of fatty acids in inflammatory diseases such as arthritis, psoriasis, Crohn's disease, and chronic diseases such as cancer and cardiovascular diseases. DHA have also been found to provide protective effect in neurological diseases [20]

2.4 Microbial functional foods

Microbial-derived functional foods include four groups of foods viz., Probiotics, Prebiotics, Symbiotic, and Synbiotics. Recently, a new food has been included and that is Postbitics.

Probiotics: Probiotics are the mono or mixed culture of living microorganisms, which when ingested in certain amounts, has a positive impact on host health, beyond conventional nutritional effects. These stimulate the growth of certain other bacteria in the colon, thus improve health. Bacteria most often used as probiotics are Lactobacilli and Bifidobacteria which can be given along with the fermented foods e.g., yoghurt, fermented vegetables/ meat. . Probiotics are known for their anti-carcinogenic, hypocholesterolemic and antagonistic action against enteric pathogen in the intestines. Dairy products are the best source of calcium. Probiotics have been incorporated in milk products, mayonnaise, edible spreads [21]. Probiotics constitute around 65% of functional food market. Probiotics inhibit pathogen growth by synthesizing biochemical compounds which possess antimicrobial activity, altering the pH, receptor binding of pathogens, and initiating immune response. Probiotics have also been found to be useful in the management of neurological disorders.

Prebiotics: Prebiotics are ingredients/ compounds that have a beneficial effect on microflora in the large intestine of the host e.g., fibre, fructo oligosaccherides, lactulose, sugar alcohols. Generally, they are carbohydrate that may be fermented in the large bowel and stimulate growth of potentiality beneficial Bifidobacteria. The most prevalent forms of prebiotics are nutritionally classed as soluble fiber.

Symbiotic and Synbiotics: Symbiotics contain probiotics and prebiotics combined randomly while synbiotics contain specific probiotics and prebiotics mixed together to benefit one another. Because the word alludes

2.5 Natural Bioactive compounds

Natural bioactive molecules such as curcumin, resveratrol, quercetin, sulforphane, epigallocatechin, lycopene, and ellagic acid have been studied for their direct and indirect effects on various molecular pathways. Curcumin is the major bioactive constituent in *Curcuma longa* and is found in the spice turmeric as well as other sources. It has been studied for its antioxidant and anti-inflammatory properties [22]. Resveratrol (3,5,4-trihydroxystilbene) is found in grapes and pomegranates and studies have shown its benefits on vascular function, immunity and the gut microbiota[23] ,Apples are abundant in quercetin, which has shown potent neuroprotective properties in neurodegenerative diseases [24] . Cruciferous vegetables such as broccoli, cabbage and kale are abundant in sulforphane, which is a. potent activator of the Nrf2-ARE pathway and promoter of redox, thereby protecting from oxidative stress. In addition, sulforphane modulates Phase I and II xenobiotic-metabolizing enzymes and directly inhibits binding of carcinogens to DNA, preventing DNA adduct formation [25] .Epigallocatechin are a group of compounds found in in tea leaves which have been shown to have widespread pharmacological properties [26]

III. HEALTH BENEFITS OF FUNCTIONAL FOODS

3.1 Foods that can promote normal blood pressure levels and support overall health

Unsweetened yogurt. The high amounts of the minerals calcium, potassium, and magnesium—all thought to help regulate blood pressure.

Berries: Strawberries and blueberries are rich in antioxidant compounds called anthocyanins reduce blood pressure.

Beets: This root vegetable is high in nitrates, which the body converts into nitrous oxide, a molecule that's been shown to reduce systolic blood pressure.

Sweet potatoes: Loaded with magnesium, potassium, and fiber, this side dish superstar is a delicious way to lower blood pressure.

Leafy greens: Cabbage, collard greens, spinach, kale, and other greens are high in nitrates, which have been found to offer blood pressure benefits.

Fatty fish: Salmon and mackerel are packed with heart-healthy omega-3 fatty acids and vitamin D, nutrients that can help lower and regular blood pressure.

Whole grains (especially oatmeal): Oats and other whole grains contain a type of fiber called beta-glucan, which may lower both systolic and diastolic blood pressure.

Pistachios: Eating pistachios may lower blood pressure and cholesterol.

Bananas: Potassium is an essential mineral that helps the body get rid of sodium, relaxes blood vessels, and lowers blood pressure

Kiwifruit: Eating two kiwi fruit daily may help lower blood pressure. [27]

3.2 Functional Foods and Brain Health

1. Fatty Fish: Fish like salmon, mackerel, and cod are rich in Omega-3 fatty acids, specifically EPA and DHA. These healthy fats lower blood levels of beta-amyloid, the protein responsible for damaging clumps in Alzheimer's disease. They enhance neuronal signalling and are vital for building brain and nerve cells, improving memory and learning [28]

2. Green Leafy Vegetables: Plant staples like spinach, kale, and broccoli are packed with brain-healthy nutrients, including vitamin K, lutein, folate, and beta-carotene. These antioxidants protect brain cells from free radical damage and are heavily linked to slowing down cognitive decline [29]

3. Blueberries: Blueberries are loaded with flavonoids and antioxidants. They improve blood flow to the brain and protect it from oxidative stress. They are known to preserve brain tissue and may even reverse memory-related brain shrinkage. [30]

4. Walnuts: Walnuts contain a high concentration of the Omega-3 fat alpha-linolenic acid (ALA), alongside vitamin E, these compounds fight chronic inflammation and oxidative stress, leading to better scores on cognitive function tests over time [31]

5. Eggs: Eggs act as a primary dietary source of choline, vitamin B6, B12, and folic acid. Choline is an essential nutrient for memory and communication between brain cells [32]

3.3 Functional Foods with Anti Neuroinflammatory Properties

Phytonutrients, also known as phytochemicals, are naturally occurring compounds found in a wide variety of plant-based foods, including vegetables, fruits, whole grains, legumes, nuts, seeds, and cereals [33] (Singh et al., 2023a). While they are not classified as essential nutrients like vitamins or minerals, phytonutrients play a significant role in promoting health and preventing disease [34],[35]. These bioactive compounds, such as flavonoids, carotenoids, and polyphenols, possess antioxidant, anti-inflammatory, and neuroprotective properties that are particularly beneficial for brain health [36],[37]; Some examples include:

Broccoli: Contains sulforaphane, which inhibits NF- κ B signaling, reduces inflammatory cytokines, and enhances memory consolidation [38]

Berries: Rich in anthocyanins, have anti-inflammatory effects and may prevent neuroinflammation associated with brain aging and degenerative diseases [39]

Whole Grains: Provide fiber, vitamins, and essential nutrients that support cognitive function and reduce inflammation [40]

Fermented Foods: Like yogurt and kefir, contain probiotics that can modulate gut health and potentially reduce systemic inflammation [41]

Unsalted Nuts: Offer omega-3 fatty acids and other beneficial compounds that can reduce inflammation and improve cognitive function [31]

IV. FUNCTIONAL FOODS IN THE MANAGEMENT OF LIFESTYLE DISEASES

Many functional foods have been found to be potentially beneficial in the prevention and treatment of cardiovascular disease, the leading cause of mortality in various countries especially United States. These foods include soybeans, oats, psyllium, flaxseed, garlic, tea, fish, grapes, nuts, and stanol- and sterol ester enhanced margarine. When eaten in adequate amounts on a consistent basis, these foods may aid in decreasing the risk of cardiovascular disease by several potential mechanisms: lowering blood lipid levels, improving arterial compliance, reducing low-density lipoprotein oxidation, decreasing plaque formation, scavenging free radicals, and inhibiting platelet aggregation. Functional foods, rich in fiber, omega-3s, polyphenols, and phytochemicals, help prevent cardiovascular disease (CVD) by lowering cholesterol, reducing inflammation, improving blood pressure, and combating oxidative stress, with examples including oats, soy, fatty fish, nuts, fruits, vegetables, tea, and garlic, supporting a heart-healthy diet [42]

Whole grains, such as brown rice, oats, millet, barley, and quinoa, are rich sources of fibre, antioxidants, vitamins, minerals, and bioactive phytochemicals like carotenoids and phenolic compounds. These constituents have been shown to play a pivotal role in modulating postprandial glycaemic responses and enhancing insulin action [43]. Studies suggest that a higher intake of whole grains is associated with a significantly reduced risk of developing type 2 diabetes mellitus (T2DM). Oats, in particular, contain β -glucan, a soluble fibre that lowers fasting blood glucose and glycosylated haemoglobin (HbA1c) levels in individuals with T2DM [44]. Regular consumption of oats improves insulin sensitivity and reduces markers of inflammation. In India, traditional grains like pearl millet and finger millet also hold promise. These grains are high in dietary fibre and resistant starch, which modulate glucose absorption, reduce glycaemic load, and support gut health [45]. Encouraging their use in daily diets—especially as a replacement for refined grains—can have a meaningful impact on glycaemic control at the population level [46]

Legumes—including lentils, chickpeas, kidney beans, black beans, and soybeans—are low-glycaemic foods packed with plant-based protein, fibre, and polyphenols. These bioactive compounds offer anti-diabetic, hypolipidemic, and anti-inflammatory benefits. Studies show that legumes reduce fasting blood glucose, improve insulin secretion, and lower cardiovascular risk. Peptides derived from legumes, such as aglycin and vglycin, are known to exert insulin mimetic effects, regulate key signalling pathways like PI3K/Akt, and support β -cell preservation [47]. For example, chickpeas have demonstrated the ability to lower postprandial glucose and suppress appetite, aiding in weight and glucose regulation [48]. Similarly, black bean peel extract has been found to alleviate oxidative stress and modulate lipid metabolism via hepatic gene regulation [49]. Incorporating legumes into traditional Indian meals, such as dals and curries, aligns with both cultural preferences and nutritional goals, making them an ideal functional component in diabetes dietary planning.

Garlic (*Allium sativum* L.), a widely used culinary spice, offers multiple health benefits owing to its rich content of bioactive compounds such as allicin, alliin, various organosulfur compounds (e.g., diallyl sulfide, trisulfide), saponins, and phenolics. Both raw and processed forms of garlic have been shown to help lower blood glucose levels and positively influence lipid profiles by reducing total cholesterol and Low-Density Lipoprotein (LDL) cholesterol while potentially improving High Density Lipoprotein (HDL) cholesterol levels [50]. Several plant-based foods also exhibit hypoglycaemic properties. Curry leaves (*Murraya koenigii*) are rich in polyphenols, alkaloids, and flavonoids like mahanine and girinimbine, contributing to their antidiabetic potential. Drumstick leaves (*Moringa oleifera*) contain potent antioxidants such as beta-carotene, chlorogenic acid, and epigallocatechin gallate, along with flavonoids and saponins that support glucose regulation [51]. Bael leaves (*Aegle marmelos*) offer additional benefits due to their alkaloids, terpenoids, and coumarins [52]. Mulberry leaf extract has shown promise in helping manage post-meal blood glucose in T2DM individuals [53].

Nuts like almonds, pistachios, walnuts, and hazelnuts are considered functional foods due to their dense nutrient profile. They are rich in high-quality proteins, unsaturated fatty acids, fibre, phytosterols, polyphenols, and antioxidant vitamins

such as tocopherols.[54] Their cardioprotective and anti-inflammatory effects are largely attributed to compounds like α - and γ tocopherol, ellagic acid, oleic acid, α -linolenic acid, and magnesium [55]

4.1 Functional foods for cardiovascular health

Functional foods, defined by their ability to confer physiological benefits beyond basic nutrition, represent a cornerstone to prevent and control CVD. Functional food with beneficial health properties includes fruit and vegetables, whole grains, legumes, nuts, fish, soya protein, tea, coffee, chocolate, and animal source-based functional food. Through an exploration of the diverse array of bioactive components present in functional foods, such as plant sterols, antioxidants, omega-3 fatty acids, and fiber-rich grains, readers develop a comprehensive understanding of the mechanisms through which these nutritional powerhouses exert their cardioprotective effects [56]

4.2 Cardioprotective Bioactive Components and Mechanisms

Plant Sterols/Stanols (Phytosterols): These compounds, found in margarine and fortified foods, structurally resemble cholesterol, inhibiting its absorption in the intestine and reducing LDL cholesterol levels [57]. Omega-3 Fatty Acids (EPA/DHA): Derived from fish oils, these polyunsaturated fats reduce triglyceride levels, decrease blood pressure, improve endothelial function, and provide antiarrhythmic effects. They reduce platelet aggregation (thrombosis) and vascular inflammation. Antioxidants (Polyphenols/Flavonoids): Found in berries, cocoa, and tea, these agents neutralize free radicals, reduce oxidative stress (reducing LDL oxidation), and boost nitric oxide availability to improve vasodilation [59]. Fiber-rich Grains/Soluble Fiber: Soluble fibers like β -glucans in oats/barley form a gel in the gut, trapping bile acids and promoting excretion, forcing the liver to use blood cholesterol to create new bile acids, thus lowering LDL cholesterol [60]. Soy Proteins & Isoflavones: These components help lower total and LDL cholesterol and may improve vascular health by enhancing endothelial function [61].

4.3 Functional foods for the management of Diabetes Mellitus

Phenolic compounds in blackberries stimulate glucose uptake by HepG2 cells and increase cellular glycogen content [24]. Prebiotics are food supplements with non-digestible fibers that selectively enhance the actions and growth of gut bacteria [62].

There is a link between gut microbiota and diabetes; prebiotics and probiotics which control gut microbiota can therefore be employed in diabetes management due to their mechanisms of action which include: responses to inflammation and oxidative stress and modifying intestinal microbiota [63], [64]. Probiotics had a possible effect on glycemic index and significantly decreased blood glucose in diabetic individuals [65].

Sources of PUFAs include fish, cereals, fish oil, and oilseeds [66]. They are beneficial in their protective effects against inflammation, and it has been discovered that in Type 2 diabetes, PUFAs reduced the levels of inflammatory biomarkers like TNF- α , IL-6, and CRP [67]. Omega-3 fats are found in fish such as salmon, tuna, and a few plant oils while omega-6 fats are found in many plants' oils [68-69]. In children, omega-3 fatty acids (ω -3 FA) reduced the risk of beta cell islet autoimmunity at greater possibility of developing Type 1 diabetes because of its anti-inflammatory activity. Omega-3-fatty acids also improved mononeuropathy in patients. ω -3 FA regulated carbohydrate metabolism by upregulating the PPAR signalling pathway in the skeletal muscle thereby reducing gluconeogenesis and increasing glycolysis [70].

Curcumin, a purified compound from *Curcuma longa* L improved insulin signalling by upregulating the expressions of P13K, Akt, IRS-2, and (IGF)-1R and downregulating IRS-1 and IR [71].

Resveratrol, a polyphenol found in peanuts, grapes, and berries exerts anti-inflammatory properties by suppressing the activities of cytokines, and proinflammatory kinases, increasing the expression of sirtuin (SIRT1), and inhibiting nuclear factor- κ B. Resveratrol also has antioxidant capacities. In cellular and animal studies, resveratrol possesses glucose reducing effects and enhances insulin production from the β -cells in T2DM [72].

4.4 Functional foods for the management of Obesity

Obesity is a global problem and numbers are rising at a fast pace in developing countries and it becomes a major public health concern. Economic costs associated with obesity are high and increasing as the rate of obesity. Obesity leads to its co-morbidities; namely diabetes, hypertension, cardiovascular diseases, osteoarthritis, stroke and inflammatory diseases. Changes in life-style along with modifications to the diet are important in the management of obesity. Certain dietary components and foods have the ability to induce thermogenesis and modify the trafficking of nutrients in the body [73].

Legumes rich in protein also contain phenolic compounds such as flavonoids, isoflavones, phenolic acids and lignans. They play a critical role in metabolism [74]. Evidence has shown that diets rich in protein induces satiety, suppresses appetite and food intake [75]. Protein in general induces high satiety and thermogenic effects compared to its macronutrient counter parts carbohydrates and fats because of high demand of energy associated with catabolism, and protein synthesis [76].

Conjugated linoleic acids are isomers of linoleic acid and found mainly in milk, meat and their products of ruminants. Short term consumption of a spread made with CLAs, induced the expression of lipid metabolizing genes and reduced inflammatory gene expression compared to other fatty acids [77]. Protective mechanisms of CLAs against obesity are increased energy expenditure, decreased energy intake, reduced lipogenesis and enhanced lipolysis, and reduced adipocyte proliferation and differentiation [78] - [81]. The primary mechanism of CLA in fat reduction is through the modulation of transcription factor PPAR γ , thereby inhibiting the downstream metabolic pathways involved in lipogenesis and adipocyte differentiation [82], [83]. Stearoyl-CoA desaturase-1 (SCD-1), a key enzyme in the regulation of lipid oxidation and hepatic lipogenesis, is one of the targets of obesity management. Administration of isomers of CLAs resulted in either reduced SCD-1 or inhibited the activity in a variety of cells [84].

Bilberries and sea buckthorn (whole, phenolic extract, oil) administered for 30 - 35 days, decreased waist circumference, weight, vascular cell adhesion molecule and intercellular adhesion molecule of overweight and obese women [85]. Bilberry anthocyanidin-enriched extracts inhibited adipocyte differentiation in 3T3L1 cells by inhibiting the adipocyte transcription factors peroxisome proliferator-activated receptor (PPAR) and Sterol regulatory element-binding protein 1c (SREBP1c) and tyrosine residues of IRS1 phosphorylation [86].

Hushbush blueberry powder at 2% reduced body fat, liver weight, body weight, triglycerides, fasting insulin, abdominal fat mass, but increased adipose and skeletal muscle PPAR activity and affected PPAR transcripts involved in fat and glucose metabolism in obese rats [87]. Blueberry polyphenols suppressed adipocyte differentiation, adipogenesis and cell proliferation [88].

Methanol mango peel extracts inhibited the accumulation of lipid droplets in 3T3L1 cells at a concentration of 50 - 100 $\mu\text{g/ml}$. Mango pulp extracts did not show any effect in inhibiting lipid content [89]. Administration of mulberry polyphenol water extracts for 12 weeks reduced obesity in hamsters via reducing hepatic fatty acid synthase, 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA) reductase, and dyslipidaemia [90].

4.5 Functional foods for the management of hypertension

In the management of hypertension, important aspects are balancing sodium levels, relaxing blood vessels, improving endothelial function, and reducing arterial stiffness [91].

Nitrate-Rich Vegetables: Beets and leafy greens (like spinach and Swiss chard) contain dietary nitrates that the body converts into nitric oxide. This naturally dilates blood vessels and lowers blood pressure [92].

Potassium & Magnesium Sources: Bananas, sweet potatoes, and avocados help balance sodium levels, offsetting its blood pressure-raising effects. **Fatty Fish:** Rich in omega-3 fatty acids, fish like salmon and mackerel reduce inflammation and support overall cardiovascular function [93].

Whole Grains & Fiber: Fermentable fibers from oats, buckwheat, and legumes promote a healthy gut microbiome, which recent studies link to reduced systemic blood pressure [94].

Probiotic Dairy: Low-fat yogurt and buttermilk provide calcium, probiotics, and bioactive peptides that have been shown to modulate blood pressure [95].

Berries & Spices: Berries are packed with anthocyanins, while spices like cinnamon, turmeric, and garlic contain active phytochemicals that provide antioxidant and anti-inflammatory properties to blood vessels [96].

These functional foods are the foundation of clinically proven heart-healthy eating plans:

The DASH Diet: The Dietary Approaches to Stop Hypertension limits sodium while emphasizing fruits, vegetables, whole grains, and lean proteins.

The Mediterranean Diet: Centers on functional foods like extra virgin olive oil, nuts, legumes, and fresh produce [97].

V. CONCLUSION

Functional foods have been receiving considerable global attention because of their nutritional value and the presence of constituents which are critical in regulation of physiological processes. Functional foods have all the ingredients necessary for a healthy diet and have been found to possess health benefits. Recommendation of functional foods is evolving and will be an essential strategy for maintenance of healthy state and delaying or preventing the onset of diseases.

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